SOPAC

Catastrophe Insurance Pilot Study, Port Vila, Vanuatu:

Developing Risk-Management Options for Disasters in the Pacific Region

by

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SOPAC JOINT CONTRIBUTION REPORT 147

December, 2003

Prepared for World Bank Office, Sydney, and AusAID, Canberra, Australia

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Exchange Rates Adopted:

AUD$1.00 = USD$0.65

AUD$1.00 = 75 Vatu

Abbreviations & Symbols:

AOSIS	Association of Small Island States
AusAID	Australian Agency for International Development
CBD	central business district
CDMP	Caribbean Disaster Mitigation Project
ECRi	Environmental & Community Risk International Pty Ltd
EQC	New Zealand Earthquake Commission Ltd
ESCAP (EPOC)	Economic and Social Commission for Asia and the Pacific
FEMM	Forum Economic Ministers Meeting
g	acceleration due to gravity
GDP	Gross Domestic Product
GEMS	Global & Environmental Modelling Systems Pty Ltd
GII	Geophysical Institute of Israel
GIS	geographic information systems
hPa	hectopascals
IRD	Institut de recherche pour le Développement
PIFS	Pacific Islands Forum Secretariat
SOPAC	South Pacific Applied Geoscience Commission
UK DFID	United Kingdom Department for International Development
UNFCCC	United Nations Framework Convention for Climate Change
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
USAID	United States Agency for International Development
USGS	United States Geological Survey
UTC	Universal Time

Acknowledgements

This study was generously funded and supported by AusAID, Canberra and the World Bank Office, Sydney, Australia.

The report was produced by an expert team headed by Graham Shorten, working with the SOPAC Community Risk Programme. The core technical team members and contributors are listed below:

- Graham Shorten, Environmental & Community Risk International (ECRi) Pty Ltd, Brisbane, Australia. Geotechnical Engineer/Risk Scientist: Developed, managed and coordinated all aspects of the study.
- Stanley Goosby, Pacific Disaster Center (PDC), Kihei, Hawaii, USA. Chief Scientist & Director Applications Development Division: Undertook risk-loss modelling of tsunamis in conjunction with tsunami impact models and animations of Vasily Titov.
- Ken Granger, Risk Science, Buderim, Australia. Risk-GIS Consultant/Geographer: Developed community surveys of Susanne Schmall into GIS and re-analysed data to develop measures of vulnerability and risk for peri-urban settlements.
- Kevin Lindsay, Risk Management International Consulting (Riskman) Pty Ltd, Port Vila, Vanuatu. Insurance Broker/Training & Development/Auditor: Instituted Government Risk Management System in Vanuatu and analysed the penetration of private insurance in households, businesses, and utilities of Vanuatu.
- Purnima Naidu, SOPAC, Suva, Fiji Islands. Graduate Scientist/Community Risk: Assisted in all aspects but particularly in GIS database development.
- Stephen Oliver, Global Environmental Modelling Systems (GEMS) Pty Ltd, Melbourne, Australia. Consulting Meteorologist/Oceanographic-Climate Modeller: Developed extreme wind, wave and storm surge climate models for Vanuatu and risk-loss calculations for meteorological hazards.
- Kerry Stewart, DunlopStewart Ltd, Auckland, New Zealand. Registered Valuer/Environmental Auditor: Analysed and calculated potential losses to infrastructure, services and utilities from extreme events in Vanuatu.
- Vasily Titov, Consultant, Seattle, USA. Research Scientist/Tsunami Modeller: Produced tsunami impact models and 3-D animations to inform lay audiences of the hazard.
- George Walker, Aon Re Australia Ltd, Sydney, Australia. Head of Strategic Development: Provided a full analysis of the various ways that a catastrophe insurance scheme might be implemented in the Pacific based on broad experience in the Asia-Pacific region.
- Susanne Schmall, Consulting Services, Ebergoetzen, Germany. Participatory Project Planning/Community Moderator/Facilitator: Conducted institutional appraisals and participatory community workshops, moderation and analysis in peri-urban settlements which were re-analysed for this report.

The authors wish to thank members of various Departments of the Vanuatu Government involved for their kind assistance including the Director of Geology, Mines and Water Resources and Esline Garaebiti for assistance in seismology matters; Job Esau, National Disaster Management Office; the Director of Lands & Survey, Mike Bakeo and Tony Kanas for assistance with setting up survey base-stations, Jotham Napat of the Vanuatu Meteorological Office; and Richie Nichols of PWD.

Others who contributed generously via discussion were the Commodore of the Vanuatu Marine Authority, Marie-Noelle Ferrieux-Patterson and Astrid Boulekone on risks to the harbour; Des Ross of Airports Vanuatu Ltd; John Chaniel of UNELCO power and water authority; and Patrick Pedica of Shell Pty Ltd.

We also thank Paul Dunk and Alastair Roger of Aon Risk Services and Kevin Lindsay of Riskman for their keen advice on the local insurance market. Thanks also go to David Middleton, General Manager NZ EQC and Rod Mead, General Manager Civic Assurance in Wellington for their lengthy discussions and advice on catastrophe insurance schemes, and to Sir Humphrey Maud, Robert Lyle and David Whiting for their advice on the Small States Insurance Scheme. Technical advice on hazards and risk was generously shared by New Zealand IGNS Ltd members Robin Falconer, Hugh Cowan, Mike Kozuch, Warwick Smith and Rafael Benites, Avi Shapira and team of the Geophysical Institute of Israel and by Marc Regnier of IRD.

Thanks are due for the input of the Forum Economic Ministers, and the Pacific Islands Forum Secretariat and Emma Ferguson. The assistance of the Government of the Republic of Vanuatu, the National Representatives of Vanuatu to SOPAC, Michael Mangawai and later Steven Tahi, and particularly Alf Simpson, Director of SOPAC, and their collective permission to publish this information, are all gratefully acknowledged.

Foreword

To many, the islands of the South Pacific are their idea of paradise. But those who live there know only too well the endemic perils. Nature, that formed the idyllic islands, and the sea that characterises them, can turn deadly. Pacific Islanders must find ways to cope with earthquakes, cyclones and tsunami.

A nation needs first to understand the hazards to which it is subject and the damage they can do. With this knowledge, a combination of land-use controls, building codes with compliance regimes and transferring of the financial risk can be implemented. Of course, no risk can be entirely eradicated and there will remain the need to plan and prepare in order to look after those whose lives or properties are affected by natural disaster.

Risk-transfer involves diversifying the financial burden of a disaster away from the affected economy. This is done through the financial or insurance systems of the world. The result of risk transfer, or insurance, is that part of the aftermath of a disastrous event is a contracted inflow of funds. Of course this protection must be paid for and what can be achieved is limited by the cost. For nations like the Pacific Island Forum countries, the funding of an insurance scheme is one of the foremost issues.

Designing the most cost effective scheme requires expertise, information and an understanding of the society which will benefit. This report contains a wealth of information about the hazards and the societies at risk. It proceeds to explore the possibilities with respect to disaster insurance schemes.

There is still some way to go but this report provides a very sound basis. From one of the most southerly of the South Sea islands, and one which has had a disaster insurance scheme in force for over half a century (and has been lucky enough not to need it), I bring you best wishes for a successful outcome and a pledge of assistance whenever this can be given.

David Middleton

General Manager

EQC

New Zealand Earthquake Commission

Executive Summary

Background: The Pacific Island Countries collectively face an immense, but largely undefined, risk from natural hazards. With extreme weather events apparently on the rise and many of the countries already experiencing economic difficulties, a series of extreme events or a single catastrophe has the potential to overwhelm an entire national economy. Risk transfer within the region or global risk-pooling arrangements, taken together with other mitigation options, can soften that blow. Drawing on the experience of catastrophe insurance in the Caribbean, the World Bank has set out a strategy to try to extend those lessons to the Pacific.

Pilot Area: Port Vila is representative of many aspects of the Pacific Island Countries as whole. Its choice as a pilot for this study was influenced by those similarities and by its advanced status in the SOPAC Pacific Cities hazard and risk-assessment programme. The pilot area is exposed to severe hazard from earthquakes, tsunamis, floods, cyclonic winds, storm surges and storm waves. Construction standards are poorly controlled, urban planning is severely limited by land ownership issues, and a burgeoning class of peri-urban settlers is crowding into the poorly serviced city fringes. Poverty here is defined less in terms of low income and more by issues arising from insecure land tenure such as inadequate access to clean water, sanitation, education, housing and health care. More than 36,000 people now live and work and worship in over 6,300 buildings in the pilot area having an estimated replacement value greater than AUD$900 M.

Major Hazards: In order to develop estimates of future damage, computer-modelling of cyclonic winds based on historic records back to 1950 was calibrated against the effects of Cyclone Uma in 1987 which caused over AUD$100 M damage in Port Vila alone – probably the largest single recorded disaster in Vanuatu to date. Storm surge and storm wave modelling based on Cyclone Beni in 2003 defined the potential damage from these hazards as limited. The worst-case cyclone and associated events might cause losses approaching AUD$640 M in Port Vila. An analysis of uplifted coral terraces in the pilot area and historical seismicity, taken together with seismic microzonation and the lessons of the M_w 7.1 Port Vila Earthquake of 2002, has helped define the probable future damage from earthquake. The worst case earthquake might cause losses of AUD$330 M. Modelling of tsunami hazard suggests a worst-case scenario of a 6-7 m wave impacting more than 200 buildings in the central business district of Port Vila for almost AUD$40 M damage as well as destroying some 1,500 buildings in peri-urban coastal settlements with potentially huge human losses.

Programmes in Place: Much of the reconstruction following recent major disasters in Vanuatu has been through external aid funding although the combined resources for the rehabilitation effort has generally has fallen short of fully covering losses. A Government Risk Management System instituted from 1991-4 which was to provide the basis for risk management for Government assets has largely been abandoned. Major components of infrastructure, including the international airport and telecommunications facilities, have been privatised. Utilities like water and power are under long-term contracts to a private organisation for operation and maintenance, while asset ownership is retained by the Government. It is not clear in some cases just how much risk is retained by the private operators and which risks are insured. A significant proportion of private residences and contents, together with the majority of commercial buildings, contents, stock and business interruption appear to be adequately covered for loss with private insurers. The insurance market has *de facto* policed cyclone construction standards since Cyclone Uma. While certain sectors of the economy appear to be well embedded in the private insurance culture, the remainder of the nation relies on post-disaster funding either from the Government current account or largely from charities and foreign aid or, ultimately, from Government borrowing from international agencies and shifting the burden to increased taxes. In 2000, for the first time, the Government made a specific budget allocation for disaster relief and, with SOPAC assistance, it has recently established a National Disaster Management Office.

Regional Perspective: Extrapolation of anticipated losses from the pilot area to the Pacific Region is not an exact science given the paucity of good historical information on hazards and their recurrence periods, and the lack of comparable and up-to-date census figures and building data. It is based on a number of assumptions the principal one being that the most likely grouping of nations for a regional scheme would be

Fiji Islands, Solomon Islands, Vanuatu, Samoa and Tonga. A regional scheme will need to consider estimates of loss scaled up from the pilot area. The combined population of these nations, the assets and their values - including more than 1.6 million people and 320,000 buildings - are 40-50 times larger than those of the pilot area. These countries all face comparable hazards, the level of which can be related to the pilot area, and the common greatest risk is a direct hit on the capital city. The combined population of the capital cities at 325,000 people is almost 10 times that of the pilot city and the equivalent value of assets at comparable risk is higher than Port Vila by a factor of about 7. The average capital city in this regional grouping is expected to suffer losses in the 100-year event of 30% of GDP for earthquake and 60% for cyclone. In the 500-year event, those losses climb to 70% for earthquake and 150% for cyclone. Cyclone and earthquake need to be considered as independent events, and a factor introduced to take into consideration the possibility of more than one capital city being impacted in the same time frame.

Risk Management Options: Catastrophe insurance, within the broader issue of comprehensive risk management in the Pacific, is a subject that cross-cuts many different areas in a complex web of interactions. The paths of international risk-financing and risk-transfer initiatives (including recent advances in catastrophe insurance in the Caribbean states, AOSIS initiatives in the UNFCCC, and the privatised Commonwealth Secretariat Small Island States Insurance debt-servicing scheme) appear to be converging. The fundamental issue to be acknowledged in the Pacific is that all forms of risk management are eventually linked, and all reach to the highest decision-making bodies in the country. SOPAC has demonstrated in a practical way in Pacific Island Countries that a holistic and comprehensive risk management approach to the issue - based largely on forward planning - is essential for success, and that solutions rest with the grass-roots level of community as well as at the top levels of government.

Scheme Design: Any scheme to cover the shortfall in expenditure by National Governments will need to be specifically adapted to Pacific conditions and should meet regional criteria for coverage; reconstruction funds; affordability of premiums; efficiency of administration; moral hazard with regard to any pool and claims-handling; technical soundness; and political acceptability, as well as being closely linked with other means of disaster mitigation and risk management in the region. Critically, the scheme needs to include any national initiatives as an integral part of a regional (or larger) scheme so that risk may be transferred to a larger pool. Drawing on international experience, a framework for the development of a regional system has been developed to this end, and design options have been laid out for consideration. If a replacement policy was to be adopted, premiums would no doubt exceed what is affordable in this region. Because the premiums are likely to be determined by issues of affordability and by the political process, the design objective for the scheme will be to determine a set of policy conditions that satisfies the limitations on premiums.

Conclusions: Port Vila is a representative starting point for analysing the risk of the five leading countries in the Pacific Region. The portfolio at risk and the extent of those risks have been defined. It is clear that the measures being undertaken by Vanuatu (as in most of the other countries) are insufficient to deal with the long-term threat of disasters. Under the current circumstances, and in the event of the first truly catastrophic event in the region, risk-transfer to aid donors will suddenly emerge as a major issue. The magnitude of this looming issue behoves careful planning to avoid such surprises. The first and crucial step in the path to developing a regional catastrophe insurance scheme is for the countries involved to demonstrate the political will to establish a realistic and truly comprehensive national and regional risk management regime. From this first step, it becomes a relatively less complex matter to gain financial backing, establish the knowledge of insurance portfolio conditions, undertake scientific risk-loss analysis and employ this data in economic and financial-risk analysis to ensure economic and social stability in the face of catastrophe.

Recommendations: A list of recommendations and actions to be taken begins with Pacific Leaders instigating action in key regional organisations that will eventually lead to a consensus view amongst PICs, risk-practitioners, insurance industry, and funding and support agencies on the most politically acceptable and effective scheme for risk financing in the Pacific region. Key steps in the process will be to expand hazard and risk-loss investigations in the region to provide the basic information for the scheme, and to use risk-financing modelling to enhance efficiencies in the approach. The development of the optimum catastrophe insurance scheme will depend greatly on the closeness of its links with a wide range of risk-management and disaster-mitigation initiatives already in place; in short, by developing a truly comprehensive risk-management regime in the Pacific.

Catastrophe Insurance Pilot Study, Port Vila, Vanuatu

Introduction

Background

The Commonwealth Secretariat/World Bank Joint Task Force on Small States characterises small states - including the Small Island Developing States (SIDS) of the Pacific region, and specifically the Pacific Island Countries (PICs) in the present context - as being especially vulnerable to natural disasters. Disasters are responsible for high volatility in national incomes at a time when many small states are already facing an uncertain and difficult transition to a changing world trade regime. As most adverse events affect the entire population of SIDS, risk-transfer at the national level is not feasible. Regional or global risk-pooling arrangements are seen to have much greater potential.

The real danger, though, lies in the long-term prognosis for the PICs: The record of disaster events in the Pacific region is too brief and sketchy to draw future lessons. Numerical modelling techniques must be relied upon to glimpse this future. The World Meteorological Organisation warned only recently that extreme meteorological events such as cyclones are on the rise. Seismic gaps often obscure the true potential risk from earthquakes. Given the long return-periods of extreme events, it is almost certain that the region will suffer more damaging events than hitherto experienced - in other words, the worst is yet to come.

Despite a growth in disaster mitigation programmes over the last decade, there is little sign yet that many PICs have the capacity to prepare any better for disasters or, indeed, to react to them any more effectively. Recent experiences have shown that even relatively small losses from disasters have not been compensated for by aid funds or national spending, so that over time, the infrastructure of many countries is sliding into decline.

The question of who will pick up the bill for catastrophes of yet-unrecorded proportions, if the PICs are unable to do so, remains a relevant one.

One of the main agenda items of the World Bank-Commonwealth Secretariat Task Force on Small States is to investigate, with its Pacific member countries, regional organizations and bilateral development partners, what relevance the Bank's work on catastrophe risk management in the Caribbean can have for the Pacific.

The World Bank's Pacific Regional Strategy report (World Bank 2000) sees the small Pacific Island Countries as more vulnerable than their larger developing country counterparts to external economic and environmental shocks. The PICs have limited or nonexistent access to global capital markets and relatively low resilience to withstand and recover from those exogenous shocks over which they have no control. In this regard, a vulnerability index designed by the Commonwealth Secretariat ranks the World Bank Pacific Island member countries amongst the 28 most vulnerable of 111 developing countries. Furthermore, the report sees the immense size of the region and the variety of cultures and political systems as limitations to regional cooperation.

Pacific Islanders are generally regarded as a group of highly-resilient peoples – the very survival of their societies for millennia in a challenging environment speaks for itself. However, the inordinate levels of natural hazards (particularly in the 'Ring of Fire' countries) coupled with the intrinsic poverty of resources, increasing urbanisation together with the emergence of a class of urban-poor, and the high levels of aid-dependency, all put the newly-independent, modern Pacific Island states at critical economic risk.

Probably no single Pacific Island state has the independent economic resources required to recover from a truly catastrophic event affecting that nation's capital city or main island. The frequency and potential impact of large cyclones or earthquakes is high and the capacity to pay for recovery is greatly limited by the relatively insecure economies of Pacific Island Countries.

The pressure on donor funds for the Pacific Island economies is enormous so that issues of risk receive relatively little attention. Compared to the urgent needs of health and education and the promotion of good governance and regional security, the prospect of future ruin must seem a remote chance to many.

Assumptions

The principal assumption adopted in this project is that Port Vila can be regarded as a microcosm of the Pacific: That the capital of Vanuatu can be taken as a model for other Pacific capital cities, and indeed for the Pacific Island Countries as a whole - the region to which any comprehensive scheme for financing risk from catastrophic events must be applied.

In view of the wide diversity of culture and economy and risk across the region (and for that matter, even within Port Vila and Vanuatu itself), this assumption is obviously a broad generalisation. Despite this, there are sufficient similarities within the Pacific region that do allow this pilot project to be viewed as a first glimpse of the risk faced by the peoples of the region, and to provide an indication of the ways in which it might be addressed.

Port Vila was chosen by SOPAC as a location likely to reflect a situation typical of the Pacific Island Countries. A critical pre-condition for the choice, however, was that this was one of the urban centres most advanced in a SOPAC hazard and risk-assessment programme called Pacific Cities. This programme had been started some 5 years earlier in Port Vila, Suva, Nuku'alofa, Honiara, and Apia. Pacific Cities has provided most of the base-line geographic and geotechnical information, the fundamental assessment of building and infrastructure assets, and the assessment of natural hazards for these cities. More importantly, the programme has captured all of this diverse information on a single, interactive, geographic Information systems (GIS) database to which the outcomes of this pilot project can easily be added and readily analysed.

History of Project Establishment

The pilot project was established following on from an examination of risk-transfer options for another group of developing island countries subject to natural disasters – the Caribbean nations. A study carried out there for the World Bank (Pollner 2001) had the advantages of starting with a much more established, well-defined and coordinated insurance market, and a situation where the hazard climate had been more closely studied and modelled for a number of years and where certain risk-loss analyses had been conducted. Some of these jump-off points had yet to be established for the Pacific region and the first steps to do so are taken in the current project.

The concept of a potential Pacific regional catastrophe insurance scheme (similar to that developed by the World Bank for the Caribbean region) was first aired at the FEMM3 (3rd

Pacific Islands Forum Economic Ministers Meeting) in Samoa in 1999.

After initial contacts from the World Bank and the Australian Treasury in mid-2000, SOPAC reviewed the methodology of the World Bank Caribbean project and identified the areas where extra work would be needed to complement ongoing investigations in the Pacific.

FEMM4 in 2000 opened the way for a pilot study by requesting SOPAC, the World Bank and Australia to progress work on catastrophe insurance through:

- Examining the effects that factors such as the non-homogeneity, cultural differences and variations in asset ownership of Pacific islands will have on a proposal for regional catastrophe insurance, within the broader context of disaster mitigation.

- Considering the appropriateness of a pilot study of one Pacific Island country for which hazard data is readily available, with a view to developing a regional proposal should the study findings warrant it.

The envisaged pilot study was to assemble and analyse data on hazard and disaster events pertinent to the requirements of the insurance industry. This work was to be essential in developing an understanding of the relevance of a catastrophe insurance model for the wider region.

Following an examination of progress on the original concept, a decision was taken at FEMM5 in Niue in 2001 as follows:

"In the context of considering the desirability of a comprehensive risk mitigation plan, including insurance cover against catastrophic natural events, Ministers:

- Requested SOPAC to report on the conclusions of the pilot study of Port Vila, Vanuatu to FEMM 2002; and

- In light of findings of the pilot study, requested SOPAC, the World Bank and Australia to report together to FEMM 2002 on the applicability of catastrophe insurance as a possible component of a broader, more comprehensive disaster management strategy in the Pacific."

Australia provided funding from July 2001 for SOPAC to initiate the 12-month pilot study in Port Vila in order to establish the feasibility of a Catastrophe Insurance scheme in the Pacific region. The specific projected outcomes of the original study were to:

- Engage ni-Vanuatu and regional stakeholders and raise awareness

- Produce a comprehensive risk-GIS database of Port Vila

- Complete multi-hazard risk and damage analyses

- Establish a basis for structural damage functions and losses

- Analyse the broad cultural and ownership issues involved

The SOPAC response efforts following the major earthquake that hit Port Vila on 3rd January 2002, and Cyclone Waka which devastated Vava'u in Tonga a few days earlier, impacted on the work being carried out for the project. A review of progress was undertaken between representatives of SOPAC and the World Bank in Sydney in February 2002, and the following points were noted:

- The interdependence and dispersed international character of the project participants and wide diversity in expertise required had given rise to some inevitable delays
- Certain aspects of hazard assessment needed to be extended, particularly the development of visualisation and animation displays designed for lay audiences
- The project should be extended to focus more closely on the economic effects of disasters and the mechanics of the preferred risk-transfer insurance models for the pilot area
- The local cultural and ownership context should be more closely defined and provision made for adaptation of the involved communities based on the outcomes of the project

The renewed focus on the local cultural and ownership context and adaptation provisions was addressed by linking the study closely to a concurrent DFID-funded SOPAC study on Disaster Risk Management in Marginal Communities of Port Vila summarised in Shorten & Schmall (2003).

An extension of the original project into a second phase was proposed in order to address most of these issues before the FEMM6 meeting due in Port Vila in July 2002. In this way, both the original and extended outcomes could be reported on at that meeting. The projected outcomes of the second phase were to:

- Quantify the factors in catastrophe risk, including the impact and frequency of hazards and the infrastructure elements at risk
- Evaluate various risk-transfer models following damage-cost assessment
- Identify appropriate risk-transfer models taking into account asset-ownership diversity and issues
- Raise stakeholder awareness further

A full report was made to the FEMM6 meeting in Port Vila and, in the same period, a comprehensive series of meetings and presentations were scheduled for the other ni-Vanuatu stakeholders in the project.

Work Programme

The objective of a regional insurance scheme is to increase the ability of Pacific island countries to address the financial impost of natural events domestically and to obviate the need to call on donors for emergency assistance. It is recognised, however, that catastrophe insurance is only one method of risk financing for catastrophes, and only one possible component of a broader, more comprehensive disaster management strategy. Catastrophe exposure can be incorporated into macroeconomic policy to generate a process of more sustainable economic growth and reduce the financial and economic volatility from periodic natural disasters.

The first step was to assemble and analyse data on hazard and disaster events, as a key input to developing full-scale risk modelling. Physical risk exposure was mapped to serve as input to actuarial, damage and pricing modules. The work was designed to supplement the existing information infrastructure developed under the SOPAC Pacific Cities programme in Port Vila. Augmentation included numerical modelling and risk and damage analysis of earthquakes, tsunamis and meteorological hazards associated with cyclones such as wind storm, storm surge and storm wave effects. An important part of the process was the engagement of national and regional stakeholders and funding agencies in the process.

A variety of international organisations and private consultants were involved in supporting the work of SOPAC. These included the World Bank, AusAID, Government of Vanuatu, Global Environmental Modelling Systems (Melbourne), Pacific Disaster Center (Hawaii), Vasily Titov (Seattle), Aon Re (Sydney), DunlopStewart (Auckland), and Riskman International (Port Vila), with important contributions from the New Zealand Earthquake Commission (Wellington) and Civic Assurance (Wellington).

This work complemented a variety of concurrent SOPAC programmes and projects including:

- Pacific Cities Programme - Port Vila component
- Comprehensive Hazard And Risk Management (CHARM), Vanuatu component
- Disaster Risk-Management in Marginal Communities of Port Vila
- Strengthening Community Resilience through Applied Community Risk and Vulnerability Analysis in the Mele Bay Area
- PACPOL Oil spill pollution contingency plans for Port Vila Harbour
- South Pacific Sea Level and Climate Monitoring Project, Phase III based on the Port Vila tide gauge component

The catastrophe insurance pilot study in Port Vila has involved a number of elements of scientific work including:

- Establishing a comprehensive, GIS-based information infrastructure for Port Vila
- Aerial photography and digital elevation modelling of Port Vila and Mele onshore areas
- Bathymetric and geophysical surveys of Port Vila Harbour and Mele Bay offshore areas
- Multi-hazard risk and damage analyses for Port Vila
- Extensive geographical database of the characteristics of building assets, structures and values in Port Vila and Mele including the potential for wind, flood, wave and earthquake damage
- Extensive hazard, physical, infrastructural and population information residing on a risk-GIS database
- Population database of Port Vila and Mele on the enumeration-area level of detail
- Computer animations and visualisations for a worst-case scenario tsunami wave impacting Port Vila Harbour and Mele Bay
- Tsunami modelling including tsunami risk scenarios, flood zonation maps and risk and damage analyses of Port Vila and Mele for the worst-case scenarios
- Structural damage functions for all categories of buildings in Port Vila, predicting

response during cyclonic wind storms

- Wind-storm modelling including wind storm risk scenarios, zonation maps and risk and damage analyses of Port Vila and Mele
- Earthquake risk microzonation map and risk and damage analyses of Port Vila
- Storm-surge modelling including storm-surge risk scenarios, and risk and damage analyses of Port Vila and Mele
- Storm-wave modelling including storm-wave risk scenarios, zonation maps and risk and damage analyses of Port Vila and Mele
- The basis for structural damage functions, damage indices, and probability distributions of losses for the Port Vila and Mele areas.

Some delays occurred due to the slow start-up of inter-related projects and the flow-on effects of the New York World Trade Center disaster in September 2001 but, significantly for a project of this nature, major interruptions to the work schedule were caused by the impact of Tropical Cyclone Paula which struck Port Vila in February-March 2001, and that of the major Port Vila Earthquake and tsunami of January 2002.

A summary of the conclusions of the study was tabled at FEMM6 (6th Pacific Islands Forum Economic Ministers Meeting) in Port Vila on 2-4th July 2002 in a Pacific Islands Forum meeting session document *PIFS(02)FEMV.12*.

As well, the conclusions were reported in a presentation: *Catastrophe Insurance Pilot Project – Extension to a Pacific Regional Scheme* at the Crowne Plaza Hotel, Port Vila, on Monday 1st July to an audience of around 50 delegates including Forum countries economic Ministers and aides attending the FEMM6 meeting.

Furthermore, the findings were also disseminated in a presentation: *Risk to Port Vila and Mele from Major Natural Disasters - Impacts on Infrastructure and the Environment* at Le Meridien Hotel, Port Vila on Tuesday 2nd July, to an invited local audience of over 60 including the Vanuatu National Disaster Management Committee, National Planning Committee and Port Users Committee, local village communities, Embassy staff, airport and utilities operators, local engineers and others.

The current report and a summary brochure (Shorten 2003b) complete the SOPAC requirements. Reports produced by the various consultants to the project are incorporated in full as appendices to the current document.

Elements at Risk

This section draws heavily on the Pacific Cities programme work carried out in Port Vila from 1996-2002. A report prepared for SOPAC by Mr Kerry Stewart of DunlopStewart Ltd, Auckland as part of the current investigations, details the risk to major infrastructure in Port Vila and the surrounding area. The full report is included as Appendix 1. Reference is also made to work carried out in a parallel, UK DFID-funded SOPAC project *Disaster Risk Management in Marginal Communities of Port Vila*, as well as a PIFS study, also funded by DFID, in adjacent peri-urban communities to the north of Port Vila. Mr Ken Granger was engaged by SOPAC to provide GIS analyses of the results of social surveys and participatory community analysis carried out for the related SOPAC-DFID project by Dr Susanne Schmall (Schmall 2002, 2003). The full report by Ken Granger can be found as Appendix 2.

The risk faced by a community depends on the impact of the hazard and the vulnerability of the elements at risk. Risk, then, is a function of the potential *impact* of hazards (cyclones, earthquakes, tsunamis) on the various *elements* at risk (buildings, infrastructure, people), and is modified by the *vulnerability* (structural integrity, shelter) of those elements or the *resilience* (coping measures) of the response. The potential impact depends on both the *frequency* of the hazard (number of times it is likely to occur in a given time-frame) and its *size* (Richter Magnitude, Cyclone Category, etc), as well as its *proximity* (shallow earthquake, direct-hit cyclone) to the elements at risk and the nature of the *interaction* (poor foundation conditions, unfavourable wind direction, landslides generated) with those elements.

Risk is an abstract concept, but it can be reduced to dollar terms. The full impacts of hazards should be measured in social or environmental, as well as financial, terms, so it is important to ultimately take into account the real costs of social change and environmental degradation. This report considers mainly the primary cost of physical loss and damage in the urban setting of Port Vila (Figure 1) and its peri-urban settlements.

Figure 1: Computer animation of Port Vila looking northwest across to Mele Bay

The Pilot Area

Port Vila, the capital city of Vanuatu is located at approximately 17.5°S latitude on the island of Efate in the Southwest Pacific – well within the cyclone belt. It lies only 50 km east of the

New Hebrides Trench, astride the tectonically active plate-subduction zone - a source of major earthquakes and tsunamis.

The topography of the whole southwestern quarter of Efate - including greater Port Vila - is an expression of a past major collapse of the volcanic edifice of the island (Figure 2). Up-thrown fault blocks within this mega-landslide have steep flanks prone to continued major slope failures - often triggered during large earthquakes or heavy rain.

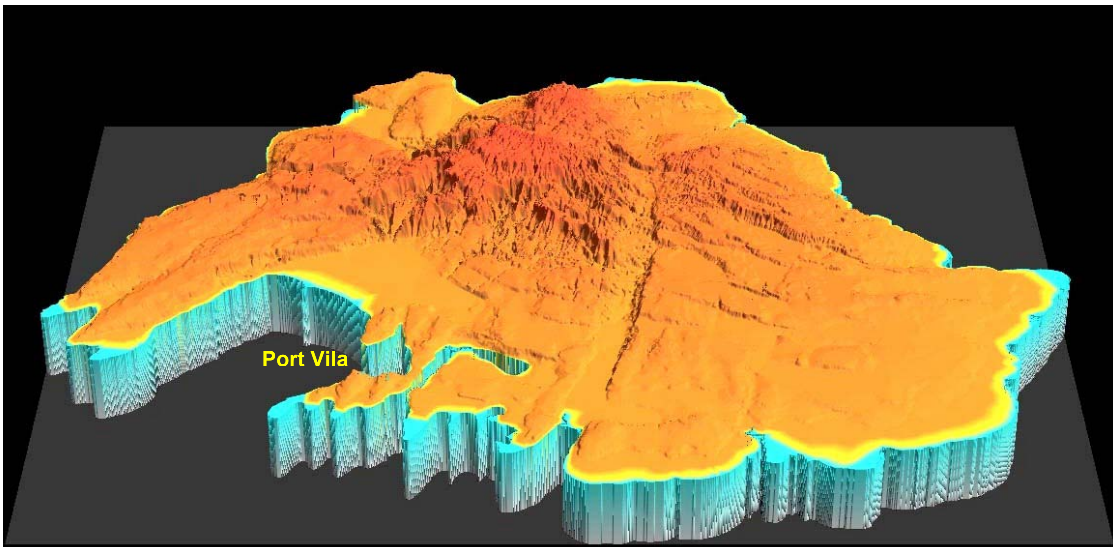

Figure 2: Island of Efate showing collapsed zone around Port Vila and Mele Bay in the foreground

Despite the limited protection afforded Port Vila Harbour by the restricted entrance from the more exposed Mele Bay, much of the central business district, the commercial and harbour facilities and some of the peri-urban villages and informal settlements lie less than 10 m above mean sea level and within several hundred metres of the shoreline. Those facilities are critically exposed to tsunamis, cyclonic winds, storm surges and storm waves. Many parts of the city built on reclamations over thick deposits of sediment, or atop high plateaus, will experience earthquake effects which are magnified up to several times. At least one active fault cuts through the city.

Construction codes and standards for buildings and foundations are largely uncontrolled, and many foreshore reclamations are badly sited and poorly compacted. Lack of sewage treatment for the city and oil-shipping facilities located in the restricted harbour bring their own potential hazards. Urban planning is limited by seemingly-insurmountable land ownership issues, lack of development finance and urban poverty. National disaster response programmes are limited in their capacity at best.

The contributing factors for catastrophe all exist - it is only a matter time before Vanuatu - together with many other developing Pacific Island Countries in similar situations - faces a disaster of a proportion that tests the very survival of the national economy.

GIS Information Database

Pacific Cities and Related Programmes

The Pacific Cities programme was initiated in 1996 to assess risk from natural and human-induced hazards to Pacific capital cities and, at the same time, provide a basis for the sustainable development of those cities. Much work has been carried out for Suva, Port Vila, Honiara, Apia and Nuku'alofa, while Lae, Nadi and Luganville are potential new starters. Port Vila is arguably the most advanced city in the programme. A summary of the programme and the related mitigation work can be found in Shorten (2002b).

Pacific Cities has developed a geographic information systems (GIS) database for each of the participating cities which includes physical data, cadastral information, assets and infrastructure data and population data as well as overlaying hazard assessment data (Figure 3). This information provides the basis for a quantitative assessment of risk from all sources; it provides a foundation for sociological studies leading to improvements for the inhabitants of the cities and surrounding settlements, and is an essential element in planning sustainable development of the capitals - and thus the nations themselves.

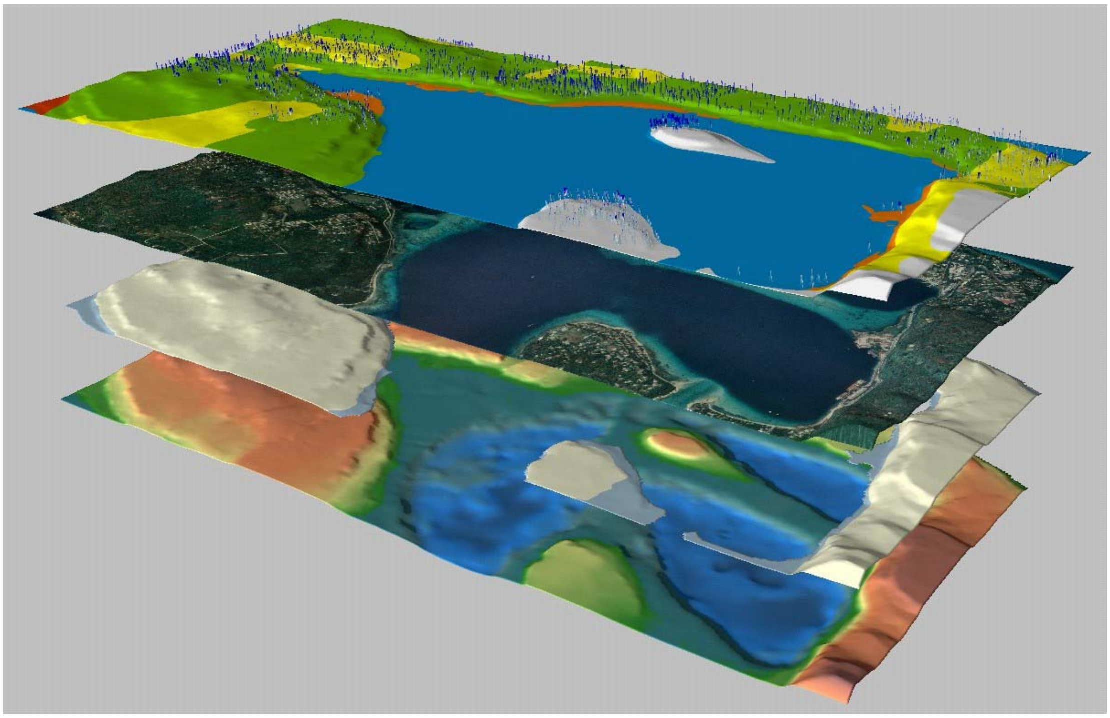

Figure 3: GIS database layers for Port Vila

Pacific Cities falls within the wider framework of the Community Risk Programme of SOPAC. This Programme has promoted a concept known as CHARM (Comprehensive Hazard And Risk Management), which seeks to advocate and implement best risk management practices, based on S.A.A. (1999) standards, though all levels of Pacific communities and governments. Also under the Community Risk Programme is the Environmental Vulnerability Index (EVI) project which combines a set of indices related to national development, based exclusively on environmental issues. In 2001 SOPAC and UNOCHA combined to organise a regional meeting and workshop (Barr 2001; Shorten 2001) aimed at developing a framework for building safer urban communities in the Pacific. The four main themes of the meeting:

- Creating an integrated approach to urban development planning,
- Legislation and enforcement to improve national building codes,
- Creating a model for the development of urban search and rescue capacity,
- Preparing for coordinated multi-agency emergency response operations,

define the essence of mitigation measures that need to be set in place alongside any potential catastrophe insurance scheme.

As well, SOPAC was engaged in a UK DFID-funded programme of work exploring risk and perceptions of risk in the marginal communities of Port Vila in connection with health and poverty issues. Concurrently, a joint DFID/ESCAP(EPOC)/Pacific Islands Forum Secretariat (PIFS) partnership in Port Vila was surveying and defining the plight of peri-urban dwellers. While adding dramatically to the growth of the city, many of these people are faced with inadequate water supply, sewerage and waste disposal services.

Port Vila has demonstrated substantial progress in developing all four dimensions of sustainability: economic, social, cultural and environmental. In pursuing this programme, SOPAC has developed good rapport with representatives from government, civil society, research schools, enterprise and finance institutions.

Arguably, one of the most pressing policy issues for Port Vila is the need to define the water and sanitation systems in relation to the other elements of the city through the use of a risk-GIS database (Granger 1998). This initiative would contribute to the sustainable exploitation of the city's harbour and groundwater supplies. There is a great deal to be gained for the future of Port Vila by integrating the privatised UNELCO water distribution information, the Pacific Cities urban-planning and risk-management data, and information on the special water and sanitation problems faced by the peri-urban settlements outside the city distribution system, together with the proposed septic and wastewater management plan by the municipal authorities.

Port Vila Database

With the assistance of the Department of Geology, Mines & Water Resources (DGMWR) and other departments such as the National Disaster Management Office (NDMO), SOPAC assembled a geographic information systems (GIS) database for Port Vila and some peri-urban areas between 1995 and 2001. This was augmented between 2001-2002 with data from outlying peri-urban settlements of Mele, Maat and Blacksands, and further, with infrastructural information for the conurbation in 2002.

As of 2001, the published Port Vila Pacific Cities dataset (Biukoto et al. 2001) included the layers of data shown in Table 1. This dataset is systematically named, where the first character 'V' refers to the city, Port Vila, and remaining 5 characters describe the nature of the data.

In the dataset related to the assessment of city buildings (Vasset), information is available for 4,803 buildings in the fields shown in Table 2. The information field *Main use of building* is displayed geographically in Figure 4 as an example.

Lying behind this basic dataset is a further wealth of as-yet unpublished information, including an extremely detailed airborne dataset of height and contour information at 10 m centres.

Table 1: Published GIS datasets from SOPAC Pacific Cities Project: Port Vila

GIS Data Layer	File Name	Principal Source of Data
1. Assessment of city buildings	Vasset	SOPAC field survey
2. Harbour bathymetry	Vbathy	SOPAC swath mapping survey
3. Borehole locations	Vbhpos	Geology & Mines
4. Geotechnical borehole data	Vbhcla Vbhstr Vbhsam	SOPAC assessment of borehole logs
5. Cadastral property lots	Vcadas	VANRIS database
6. Coastline including major rivers	Vcoast	VANRIS database
7. Drainage	Vdrain	VANRIS database
8. Geology	Vgeolo	SOPAC field notes
9. Roads	Vroads	VANRIS database
10. Seismic microzonation	Vseism	IRD-SOPAC-DGMWR
11. Micro-tremor recording sites	Vsites	IRD-SOPAC-DGMWR
12. Physiographic terrain model image	Vdtm12	SOPAC-Airesearch Pty Ltd
13. Orthophoto image (re-sampled)	Vortho	SOPAC-Airesearch Pty Ltd

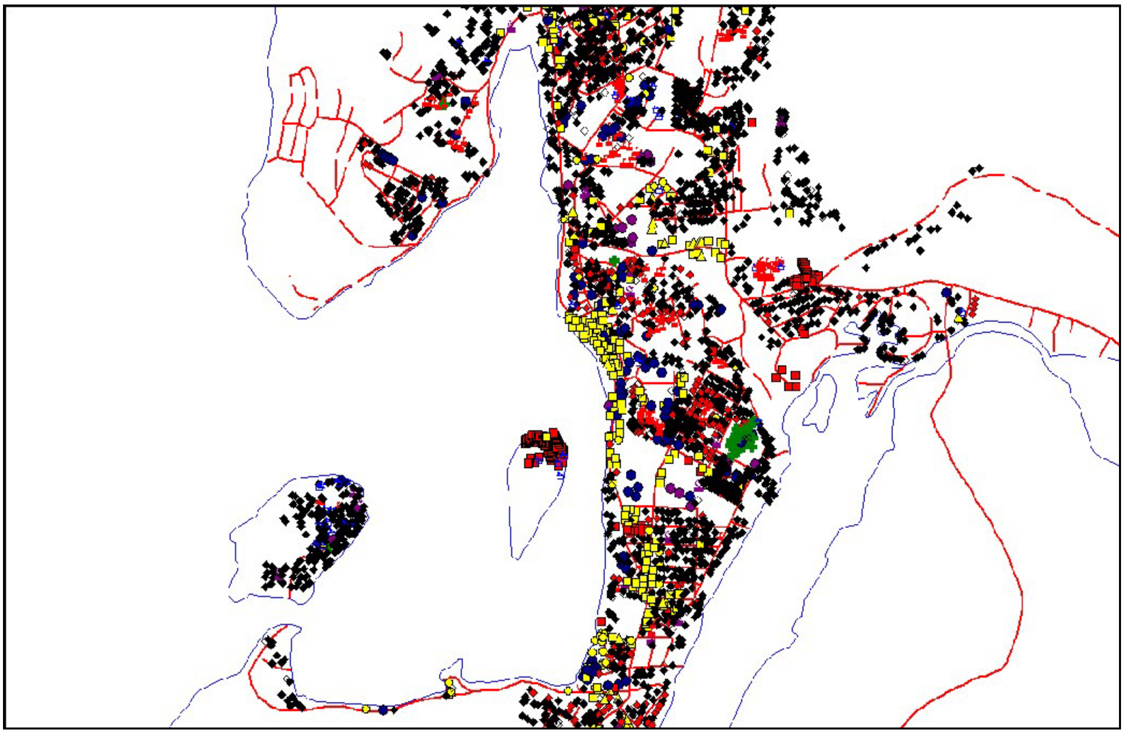

Figure 4: Port Vila building assets database - Main Use of Building field shown

Table 2: Information fields available for Port Vila building assets (Vasset)

Main use of building	Roof material type	Minimum floor height above ground
Subsidiary use	Roof shape	Maximum floor height above ground
Plan regularity	Roof pitch	Under-storey material type
Wall material type	No. of Stories	Under-storey structure
Window space distribution	Base floor area	Concrete cantilever width

This data enables the development of a digital terrain model with a vertical resolution of approximately 0.5 m (suitable for urban planning for road works, drainage, water supply and sewerage), and orthophotos with horizontal resolution down to 0.2 m pixels for the entire Port Vila city area, as well as for the Mele area. The assessment of the Port Vila city building asset database has been extended into the Mele area, where datasets on drainage, roads, vegetation and crops have also been added. Some of the aerial photography and derived digital elevation model products have restricted distribution due to a cost-sharing and licensing agreement with contractors Airesearch (now Fugro) Pty Ltd.

By digitising contour values of Efate from the VANRIS dataset, a coarse digital terrain model of the entire Efate island area with around 10 m vertical resolution has been produced by SOPAC. Very high-resolution swath mapping digital data is available too from SOPAC for Port Vila Harbour and for the northern half of Mele Bay. A much coarser dataset of deep ocean bathymetry to the west and south of Port Vila was obtained from a combination of the 1-minute satellite altimetry dataset and the ship-track dataset maintained by SOPAC.

Extensive control point surveying and reconciling was carried out by SOPAC in close cooperation with the Department of Lands & Survey to attempt to resolve issues of relative and absolute location that arise from the lack to date of accurate conversion parameters for translating fixed survey points from pre-satellite GPS surveys.

Population and Demographics

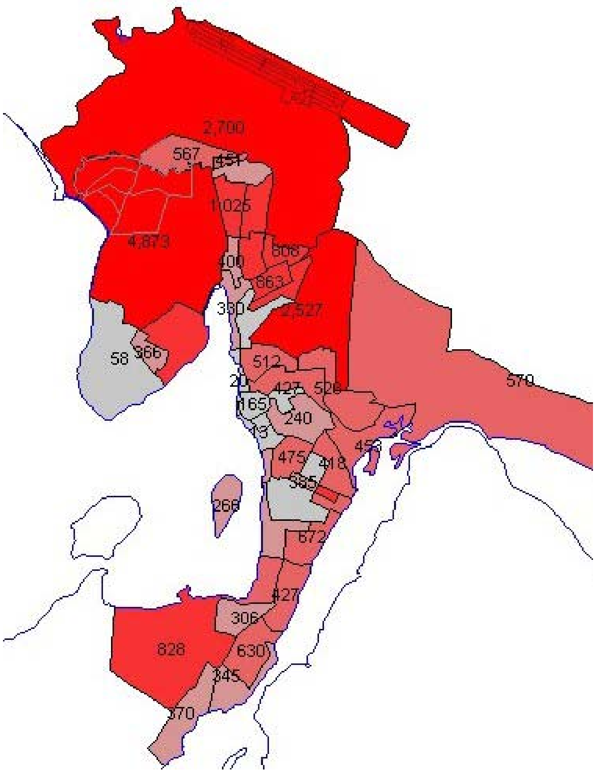

Figure 5: Port Vila enumeration areas showing total population for each area

Accurate official figures and the current census of population are difficult to obtain. The 1999 Vanuatu census counted 30,295 people in greater Port Vila, including peri-urban areas to the north, distributed in enumeration areas as shown in Figure 5. The map of individual enumeration areas of Port Vila was supplied by the Government and this has since been digitised by SOPAC and included in the Port Vila GIS database.

The 4,803 dwellings and commercial buildings surveyed in the same area by the SOPAC Pacific Cities programme (Biukoto et al 2001), are unlikely to be a complete sample because of the rapid growth of informal settlements. Of these buildings, 3,844 were classified as houses or other accommodation structures.

In the Mele-Maat-Blacksands peri-urban area to the northwest of Port Vila (Figure 6), most of the 1,541 buildings recorded (Shorten et al. in prep.) and the 173 surveyed (Schmall 2002) were houses. A total 7,650 residents were estimated from surveys and census data. At the average population density of around 6 per household determined from a recent peri-urban survey sample, and given an average annual growth rate in the period of 4.2% for Port Vila (Chung & Hill 2002), it could be expected that somewhere upwards of 36,000 people currently live in Port Vila and its peri-urban settlements.

That number is expected to grow in the foreseeable future. In 1999, the urban population of Vanuatu was 21% of the national total and around one-third larger than the figure ten years earlier. If the present rate of growth is to continue, then the urban population will double by the year 2016. Most of these urban dwellers would be concentrated in Port Vila.

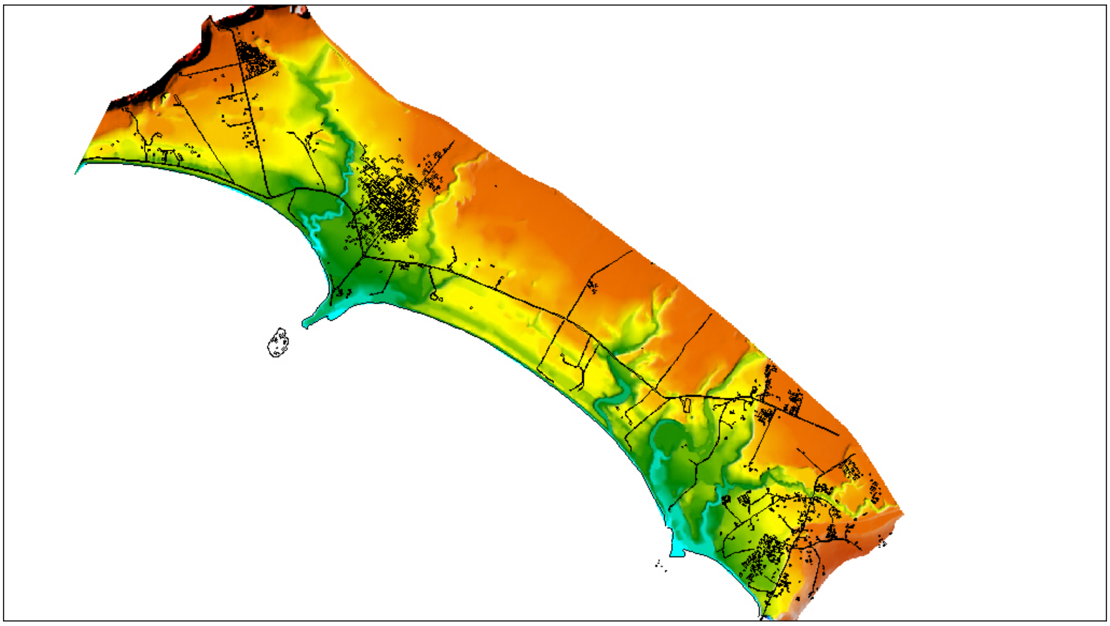

Figure 6: Mele, Maat and Blacksands buildings and roads overlay on a digital elevation model

Cultural, Social and Ownership Context

The context for the urban and peri-urban setting of Port Vila has been recently defined in a study that set out to assess the extent and nature of informal settlements in Vanuatu (Chung & Hill 2002). Vanuatu has a youthful and fast-growing population, undergoing rapid social change and mobilising increasingly from rural to urban areas. Urban development, especially in Melanesia and particularly in Vanuatu, is seen as confronting traditional and modern law, particularly in regard to land tenure. Urban poverty is already a pressing concern in Vanuatu with a large proportion of urban dwellers forced to live in sub-standard, unhealthy conditions with uncertain land tenure contributing to insecurity. There has been a general failure in the urban housing market to meet the expectations of the population due to the high cost of construction, lack of affordable credit, insufficient funds to implement services, land tenure restrictions on service provision, lack of affordable housing for low-income earners, and poor coordination of planning for urban infrastructure. The large increase in urban population revealed by census figures was not matched by officially approved new dwellings, suggesting that many households had been pushed into informal housing.

Poverty in Vanuatu has been demonstrated to be not only defined by low-income but also by inadequate access to clean water and sanitation, education, housing, health care and other basic services. Living in the informal urban settlements generally means living in poverty. Insecure land tenure underlies the poor living standards in the informal settlements: Government will not allow leases over Crown land until plots are adequately serviced with water, electricity, sewerage and drainage and yet local councils have insufficient resources to provide such services. As a result, legalisation of housing leases does not keep pace with demand, restricting people from investing in better housing. Added to this in some areas - Blacksands being one - is the problem that traditional landowners are unwilling to allow construction of permanent housing or even allow provision of water or electricity services for fear of losing control of their traditional lands.

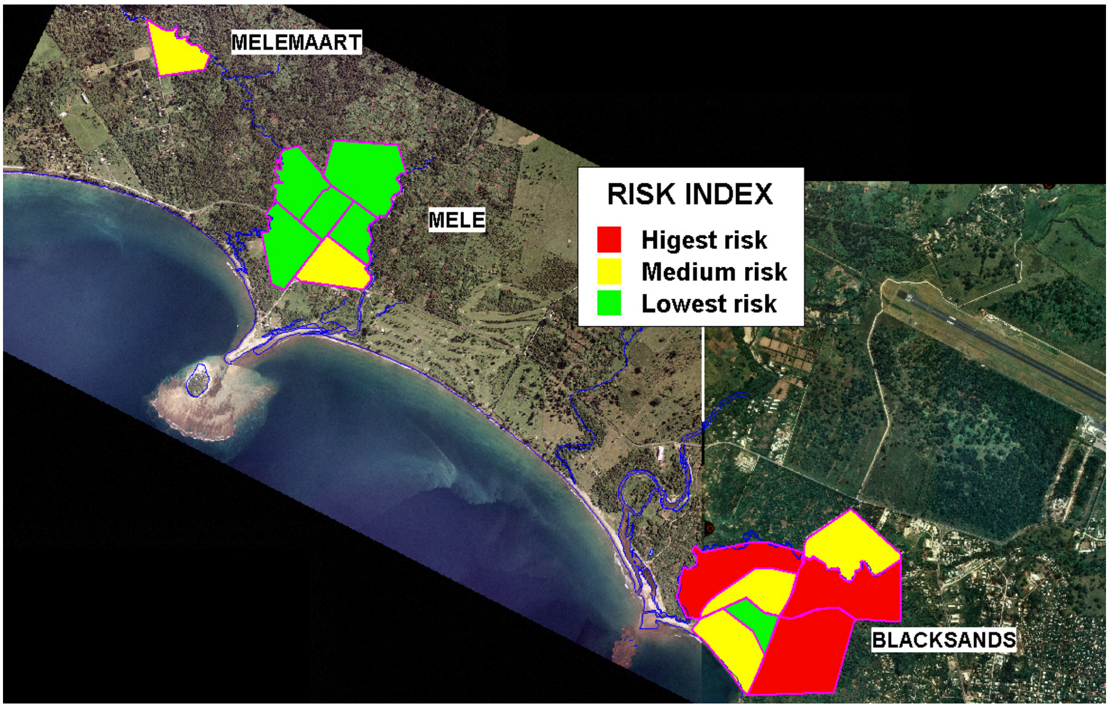

Figure 7: Comparative risk between 14 neighbourhoods of Mele, Maat and Blacksands

Chung & Hill noted that informal settlements often grow up in marginal land susceptible to regular flooding and solid and liquid pollution, poor sanitation and polluted groundwater and at high risk from natural disasters. A further complication is that, quite part from the variation in the local traditional landowning groups in the Port Vila area such as the Ifira and Mele groupings, there is a gradation from typical urban dwellers to traditional village dwellers in the peri-urban formal villages, to the typical informal settlements.

The peri-urban village of Mele, which operates in a traditional chiefly system, has already relocated on traditional land some distance inland of the original coastal village site of Mele Island following a health crisis and cyclone in the 1950s, and is even now considering a further relocation to high land. The nearby people of Maat sought refuge from an active volcano on Ambrym some decades ago. Blacksands by contrast is an informal peri-urban settlement of peoples from widespread locations in Vanuatu; many arriving as refugees from natural disasters and hardship elsewhere in the country. There are at least eight communities in Blacksands with different chiefly associations but no overall, cohesive organisational structure. These communities are tolerated by the traditional landowners, but are unable to install adequate water or electricity infrastructure because of the insecure land-rights.

The peri-urban dwellers alone makes up about over one-fifth of the population of greater Port Vila and live outside the formal system of water supply and sanitation provided for the capital. Situated on low-lying coastal land, they are arguably some of the world's most exposed communities to a number of hazards including river floods, cyclones, earthquakes, tsunamis and pollution.

A survey of 173 households (Schmall 2002) was carried out in the Mele, Maat and Blacksands settlements, adding important information in the fields shown in Table 3. A great deal of effort was made to standardise the questionnaire with that being used by the PIFS-ESCAP project in other peri-urban areas to the north of Port Vila city including Olen and Freswota (Chung & Hill 2002) so that results would be comparable.

Shorten et al. (2003) and Shorten et al. (in prep.) analysed the results of the survey by Schmall (2002) in the three villages and settlements. They explored the internal differences between fourteen 'neighbourhoods' developed on lines of geography and local ethnicity, and drew conclusions on risk for the settlements. Shorten et al. created indices of overall vulnerability, drawing from the survey data on shelter, sustenance, security and social vulnerabilities, and factored in exposure to disasters in order to calculate an overall risk index for the neighbourhoods. In this way they were able to compare and contrast overall risk amongst neighbourhoods (Figure 7), as well as internally, within each settlement. The informal settlement of Blacksands was seen to be at much higher risk from all causes, including disaster-related risk, than the traditional villages of Mele and Maat. A summary of the results was reported in Shorten & Schmall (2003).

a. Household
1. Male or female head of household
2. No. of household members > 16 years
3. No. of household members < 16 years
4. No. of children not going to school
5. Highest qualification of head of household
6. No. of people with a paid job
7. Sale of products from household
8. Weekly household income
9. No. of people attending primary school
10. No. of people attending secondary school
11. No. of people attending college/university
12. No. of people born in Mele
13. No. of people born in Efate
14. No. of people born on other islands
15. No. of people born in other country
16. No. of people emigrated from within Efate
17. No. of people emigrated from other island
18. Name of island of origin
19. No. of people emigrated from other country
20. Reason for emigration to Mele
21. Reason for leaving Mele
22. No. of people with malaria
23. No. of people with dengue
24. Other sicknesses recently contacted
25. Place treatment sought

b. Household_Conditions
1. Wall material type
2. No. of sleeping rooms
3. Need for house improvements
4. Any house improvements made
5. Who paid for house improvements
6. Electricity supply
7. Source of cooking fuel
8. Source of water supply
9. Type of drainage
10. No. of families to each toilet
11. Type of toilet

c. Land Tenure_Livelihood
1. No of household in building
2. House ownership
3. How was house obtained
4. Land ownership
5. Rent paid for land – amount
6. Rent paid for house – amount
7. Any problems with land owner
8. Any problems with house owner
9. Ever forced to move
10. Any land owned by household
11. Adequacy of food supply
12. Proportion of food grown in own garden
13. No. of cattle owned
14. No. of chickens owned
15. No. of pigs owned
16. Proportion of home-grown food traded
17. TV ownership
18. Radio ownership
19. Boat/Canoe/Speedboat ownership
20. Car/Truck/Motorbike ownership
21. Telephone/Mobile ownership
22. Bicycle ownership
23. Torch ownership

d. Hazard _Vulnerability
1. Hazard type perceived as major threat
2. Encroachment of flood-water in past
3. Any perceived future flood threat
4. Past storm damage
5. Past earthquake damage
6. Disaster Impact on health
7. Disaster impact on food
8. Any past evacuation or flight
9. Disaster mitigation measures adopted
10. Participation in current disaster activities
11. Source of information on disaster
12. Source of assistance received
13. Kind of help received

Table 3: Information areas on community conditions and vulnerabilities in Mele, Maat and Blacksands

Housing and Buildings

In order to estimate damage levels in monetary terms, it was first necessary to develop an economic model for the value of assets at risk in the study region. Individual replacement values have been computed for the 4,976 buildings actually surveyed in the Pacific Cities programme in the Port Vila and Mele Bay regions. These have been based on the wind-response building classes, floor areas surveyed for each building, and estimates of the range of unit-area replacement values across the four building classes (Table 4) provided by the local insurance industry (Riskman International and Aon Risk Services). The unit-area values included the cost of demolition of damaged buildings, and the mean of the range was generally taken to estimate the replacement values.

Table 4: Floor value (AUD$ per square metre) estimates for the four building classes applied in the study

Building Class	Brief Description of Structure	Lowest Estimate AUD$	Best Estimate AUD$	Highest Estimate AUD$
Class A	Well engineered structures: Schools, hospitals	935	1,200	1,470
Class B	Concrete or concrete block structures; Moderate quality construction, poor earthquake provisions	1,200	1,470	1,735
Class C	Wooden bungalows; poor wind, earthquake provisions	935	1,200	1,470
Class D	Poor quality: Shacks and sheds	400	670	800

The number of individual buildings (together with their combined value) assigned to each wind-response building class A-D in the Port Vila city area study is given in Table 5.

Table 5: Number of buildings assigned to each building class, and aggregated values

Building Class	Number of Buildings	Value (AUD$ M)
Class A	254	49.2
Class B	2,822	459.3
Class C	1,629	161.7
Class D	98	5.1
All	**4,803**	**675.3**

The replacement value of the 4,803 buildings in the Port Vila city area is calculated at AUD$675 M, with an estimated further AUD$145 M in contents. The additional 1,541 buildings (of which a sample of 173 were surveyed) and contents identified in the Mele-Maat-Blacksands peri-urban settlements are expected to add at least another AUD$80-100 M in value, totalling at least AUD$900 M for greater Port Vila. Notwithstanding, growth rates estimated at around 10% in the peri-urban areas of Mele-Blacksands and Olen-Freswota, although lacking definition through building control and regulation records, suggest that this value is growing rapidly.

Infrastructure and Services

SOPAC carried out a comprehensive survey to estimate the potential losses to Port Vila infrastructure from a variety of natural catastrophes (Table 6). The level of impact of each catastrophe was set at a level based on the scientific investigation and hazard modelling studies; generally at the 100-year event level. While it did not attempt to estimate the total value of the infrastructure, the report identified reinstatement costs, given the proscribed events, amounting to almost AUD$40M. Altogether, the value of building structures, contents, and the reinstatement values of infrastructure for Port Vila city and peri-urban areas approaches AUD$1 Billion. The full report can be found in Appendix 1.

The potential damage to infrastructure in the Port Vila and Mele areas due to natural catastrophe has been derived from interviews, research and anecdotal evidence and site inspections of the asset groups identified. The exercise has not included any allowance for consequential losses due to the failure of the infrastructure. The significance of quantitative estimates of risk to infrastructure should be considered in conjunction with the consequences of these losses, as some of the low value losses may have the greatest consequential impacts.

Table 6: Total anticipated re-instatement cost estimates for infrastructure following major disaster

Infrastructure Class	Cyclonic Winds	Earthquake	Severe Rainstorm	Storm Surge	Tsunami	Total Values in AUD$000's
Airport	310	2,500	200	-	-	3,010
Bridges	-	1,250	1,190	40	30	2,510
Communications	200	15,050	-	-	-	15,250
Oil & Gas	140	3,700	-	-	100	3,940
Power	120	120	-	-	-	240
Roads	90	320	150	40	20	620
Seawalls	1,060	690	50	50	240	2,090
Sewerage	-	-	-	-	-	-
Water	20	1,050	680	-	-	1,750
Wharf	1,340	7,210	-	1,340	30	9,920
Grand Total	**3,280**	**31,890**	**2,270**	**1,470**	**420**	**39,330**

The estimate of reinstatement seeks to restore the service to current standards i.e. providing the same service potential as currently provided by the existing infrastructural assets. With the data currently available we cannot accurately define the effects of the defined risks. As there has not been any natural disaster of the magnitude under consideration by this project recorded in Port Vila, and because of the uncertainties involved in predicting the damage caused by any such event, the quantification of loss can only be considered as order-of-magnitude estimates of potential loss.

These losses have been graphically represented in Figure 8 which provides the total estimated reinstatement costs for all infrastructure assets by catastrophe type, showing earthquake to be by far the expected largest potential contributor to the damage of infrastructure. This contrasts with the expected maximum damage in housing expected from cyclone. The figures can also be considered by asset type (Figure 9) which shows the total exposure per infrastructure asset type for all scenarios.

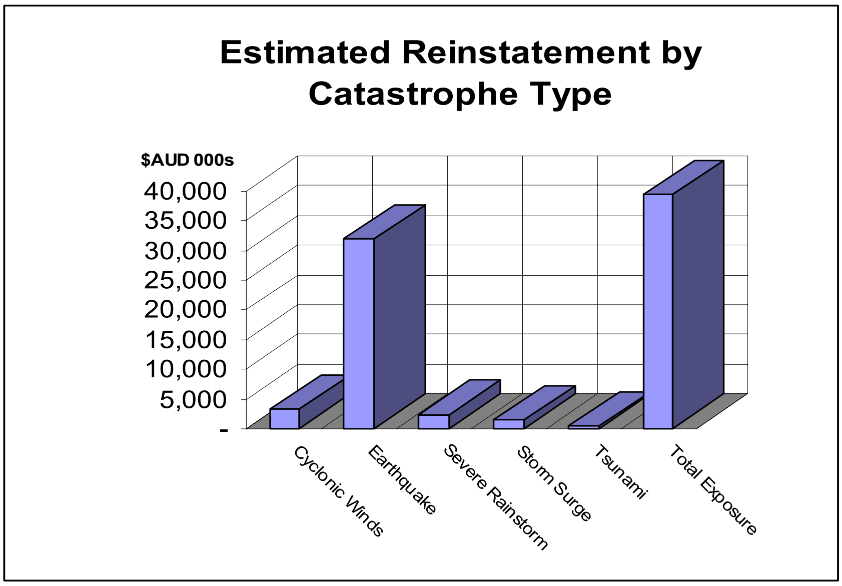

Figure 8: Estimated reinstatement by catastrophe type

The results show that the losses anticipated in a major earthquake are significantly more than the losses expected under all other natural disasters scenarios combined. While this is an expected outcome, the recent January 2002 earthquake in Port Vila highlights the reality of this scenario and indicates the exposure of particular sectors of the infrastructure.

The infrastructure asset with the greatest exposure to earthquake (in dollar terms) is communications, due to the potential loss of the main exchange (building and equipment) in Port Vila. The wharves, airport, oil, gas and petroleum supplies are also likely to suffer significantly loss. Despite less exposure in value terms, the infrastructure assets that are likely to have the most significant immediate effect on the local community relate to the loss of the bridges and water supply.

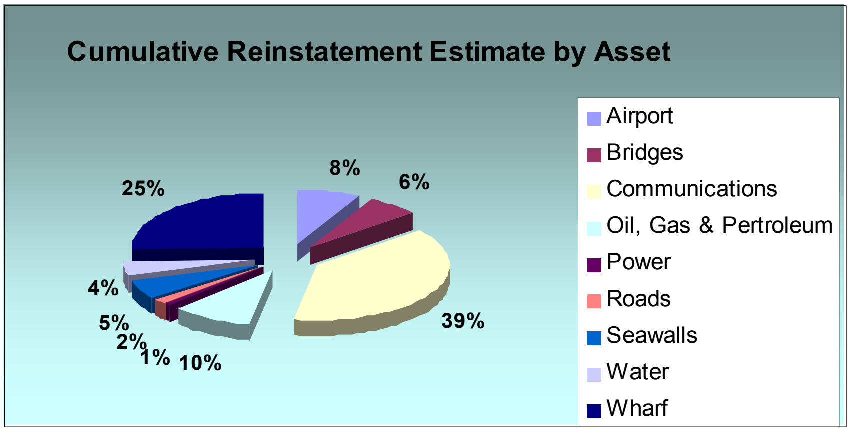

Figure 9: Cumulative reinstatement estimate by asset

Meteorological Hazards

SOPAC commissioned Mr Stephen Oliver of Global Environmental Modelling Systems Pty Ltd (GEMS) to develop a model for quantifying the risk presented to major Pacific cities by tropical cyclone wind storm, storm surge and storm wave action. SOPAC assisted by providing baseline information for the study. The full reports can be found in Appendix 3. The reports describe the components of the modelling and the results of applying the model to the island of Efate, with particular emphasis on the city of Port Vila.

Cyclone Hazard

Introduction

The Pacific cities are vulnerable to varying degrees to severe damage as a result of the extremes winds associated with tropical cyclones. A recent example is the damage caused to Vanuatu by tropical cyclone Uma in 1987. This was a severe storm, which passed close to the main island, Efate, causing an estimated AUD$100 M damage to Port Vila, and some AUD$230 M damage overall in Vanuatu according to official Government figures.

It is intended that the approach described in the current report should be extended to other Pacific cities in the future. The results of this study were developed in conjunction with a concurrent major study of cyclone-generated storm surge funded by AusAID.

The present study had the following primary requirements:

- Develop a general methodology for estimating the long term risk associated with wind storm events that can be applied to any of the Pacific Island Forum major cities impacted by tropical cyclones;
- Develop an adaptable damage model for building assets within the cities;
- Apply the methodology to the island of Efate, and
- Report the results of applying the model to Efate.

The methodology employed the following steps:

- Develop a statistical climatology of tropical cyclone events based on historic records;
- Develop a model for generating quasi-random cyclone events consistent with the storm climatology, where the storm event is described in terms of a set of standard parameters such as central pressure (intensity), speed and direction of storm movement;
- Apply an existing empirical model based on the set of cyclone parameters specifications to each storm event to define the temporal and spatial variation of the broad scale wind for that storm;
- Develop a topographically based wind model to convert the broad-scale cyclonic wind fields to location-specific wind gusts;
- Develop a regional vulnerability model to estimate rates of damage as a function of wind speed for each building asset (or group of assets) included in the study;
- Apply the wind and vulnerability models to a large number of cyclone events

representative of storm activity over many thousands of years, and

- Integrate the results to estimate levels of damage over Efate and the related frequency of occurrence of those damage levels.

Regional Cyclone Database

It became apparent during the study that storm central pressure data quoted for the Vanuatu region was inaccurate for the more intense storms as all pressures below 950 hPa were reported as 950 hPa. This problem was addressed by seeking access to a South Pacific cyclone track database developed by the New Zealand Meteorological Service. After 1950, the evolution of satellite-based remote sensing provided a more reliable basis for identifying and categorizing cyclone events.

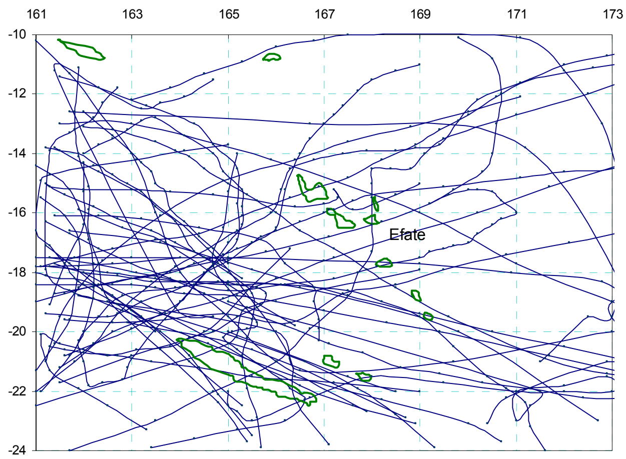

Figure 10: Tracks of cyclones included in the storm climatology

To assess the range of possible storms potentially impacting on Vanuatu, all storms occurring after 1950 and which crossed the region bounded by longitudes 161° and 173° E and latitudes 10° and 25° S were considered. The tracks of these storms are shown in Figure 10.

In order to specify a probability distribution for the location of storms relative to Efate, storms were initially classified by the longitude at which they crossed latitude of Efate (approximately 17.5° S). These crossing longitudes were tabulated and a probability distribution was fitted to the data. The results of this analysis are shown in Figure 11. The historical tracks are shown to be weighted to the west of the Vanuatu group.

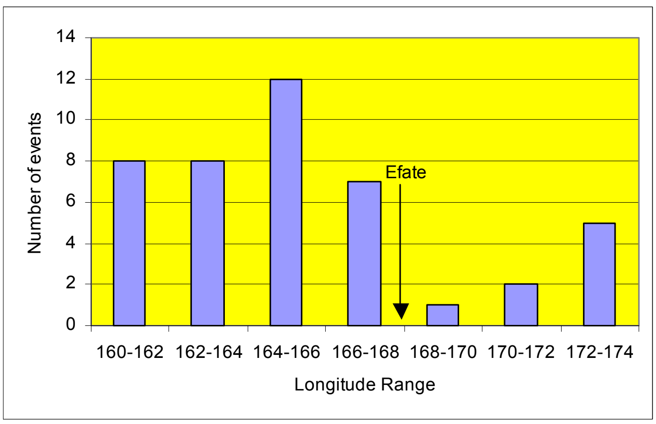

Figure 11: Observed crossing longitude for storms passing through latitude 17.5° S

In order to specify a storm track, a parabolic function was fitted to each storm track in the database. The idealised track is then used to specify the defining track parameters:

- The direction of movement at the point of crossing the latitude of Efate (Figure 12)
- The track curvature, ie. the rate of change in direction with latitude

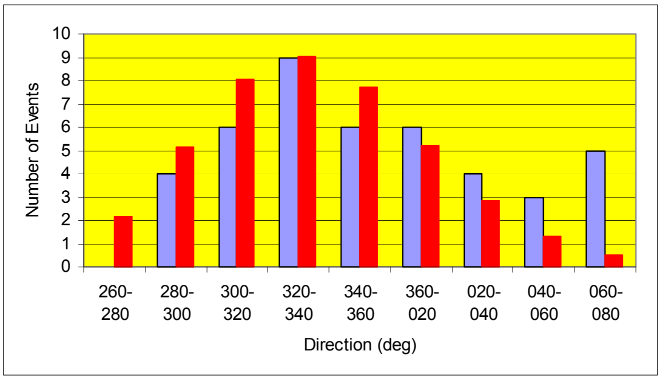

Figure 12: Observed *versus* Predicted cyclone direction based on analysis

The primary parameter for specifying storm intensity is its central pressure (wind speed will also depend to some degree on the storms speed of movement). The central pressure of each storm at the time that it crossed latitude of Efate was extracted from the database. The data shown in Figure 13 exhibit a bi-modal character; most storms were above 980 hPa but there was a secondary, more intense group of storms, with central pressures below 950 hPa.

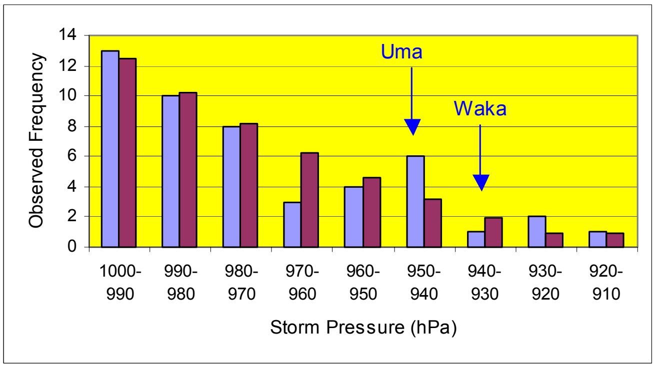

Figure 13: Distribution of storm central pressure: 24 year observations (blue) and fitted distribution (red)

Storm Surge and Storm Wave Hazard

Mr Stephen Oliver of GEMS was also engaged by SOPAC to establish a modelling system for assessing the impact of waves at Port Vila and the adjacent Mele Bay area, and to validate that impact by modelling the waves associated with an actual cyclone in the area. From this, he was to select a representative extreme wave/storm surge event, model waves in detail for such an event, assess their potential impact at selected locations, and comment on the potential risk to the local communities from extreme wave events associated with tropical cyclones. The full report can be found in Appendix 3b.

Tropical Cyclone Beni

For validation purposes, the study focussed on the impact of Tropical Cyclone Beni which occurred in January 2003. This storm was selected because it produced unusually large waves in and around Port Vila and there was access to good data for the event. In addition, the track of the storm appears to correspond directly with that expected to produce extreme wave events. In order to establish how extreme this event was (in terms of waves) relative to overall storm frequency, the intensity of Beni and its track was compared with historical records of storm tracks over a period of thirty years.

Modelling of Beni was undertaken at a high level of detail, firstly involving the modelling of open ocean waves associated with the storm, and then the detailed interaction of the waves with the shoreline at locations in Port Vila and near the Mele Bay villages. In particular, quantitative predictions of wave run-up and over-topping at these locations were made by applying a site-specific, one-dimensional, shoreline model.

Tropical Cyclone Beni formed some 240 nautical miles south of the Solomon Islands on 24th January, 2003. It initially tracked southwards and then deepened as it turned moves towards the southeast. The cyclone is estimated to have reached its maximum intensity of 920 hPa (Category 3) at or about 0600 UTC on 29th January. Beni's track is shown in Figure 14.

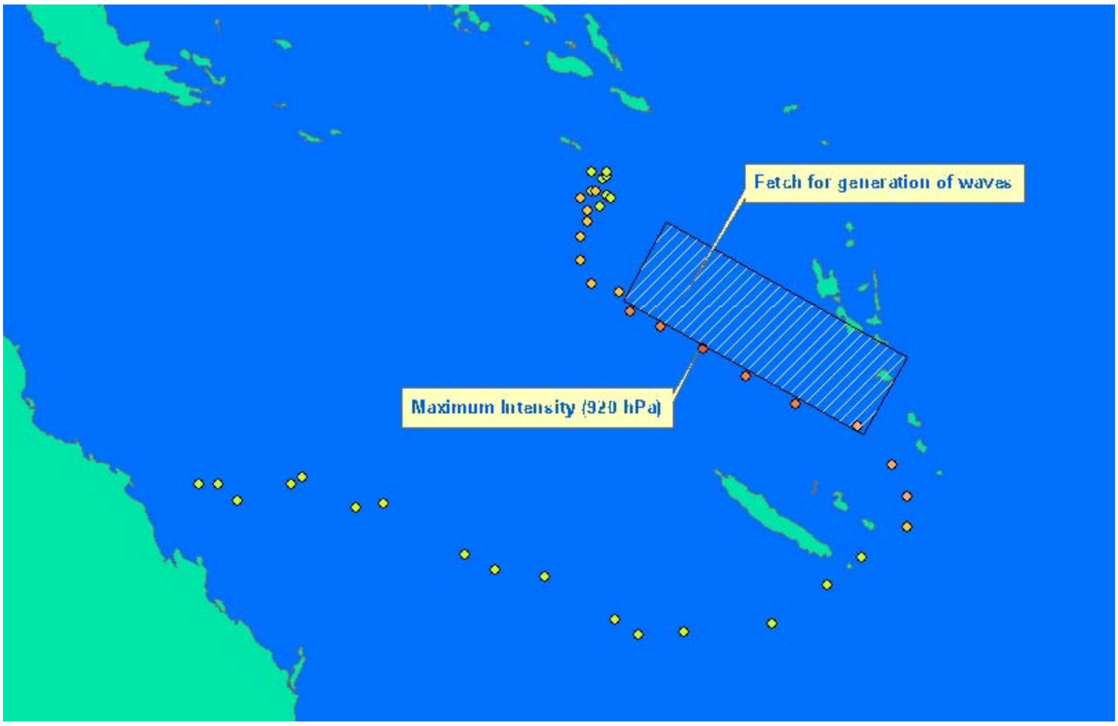

Figure 14: Track of Tropical Cyclone Beni, January 2003

Beni passed to well to the west of Efate, causing notable inundation of exposed coastlines on 30th January. Reporting of the effects of Beni referred to significant inundation that was consistently described as resulting from a storm surge. Impacts at Port Vila were quite pronounced as the photograph of debris thrown up by wave action in Figure 15 shows.

Closer examination of the event shows that any storm surge at Efate associated with Beni, is likely to have been minimal. The maximum (10 minute mean) winds over Mele Bay are estimated to have peaked at about 50 km/h earlier on 30th January. An examination of records form the tide gauge located at the port shows that the maximum sea-level residual was only of the order 0.3 m. Since the maximum steady-water sea level in the port was well below Highest Astronomical Tide, it is clear that storm surge was not the major cause of the inundation and it was, in fact, wave run-up and overtopping from large storm waves that had the major impact.

Figure 15: Debris from TC Beni storm waves in harbour-side parking area north of Port Vila CBD

This conclusion is supported by an examination of Beni's track. This shows that the radius of maximum winds would have been moving steadily south-eastwards with the storm, thereby maintaining extreme winds over waves propagating in the same direction; towards the southern islands of Vanuatu. The region of wave 'fetch' is apparent in Figure 14. Some of the wave energy from waves initially generated well to the north-west would have propagated into Mele Bay; these waves would then have been accentuated by waves generated by west to south-westerly winds on the rear flank of the storm as it passed southwards of Efate.

Extreme Event compared with TC Beni

The track of Beni appears to be ideal for maximising storm waves in Mele Bay; a more southerly track would cause the larger waves to propagate more southerly as well, with little chance of the waves entering Mele Bay, due to its orientation. Should the track have been shifted too much further to the east, the maximum winds and associated wave maximum would also shift eastwards and be able to enter Mele Bay. The latter case would be expected to result in much stronger, damaging winds impacting upon Port Vila, and may result in a larger storm surge effect.

A comparison was made of the relative impacts from waves associated with different cyclone tracks, and a model was run for TC Beni and for a storm of the same strength, on a track shifted approximately 2.5 degrees east to provide theoretical data for an extreme event. The tracks are shown in Figure 16 and the wave fields at a similar time in the storm evolution are shown in Figure 17.

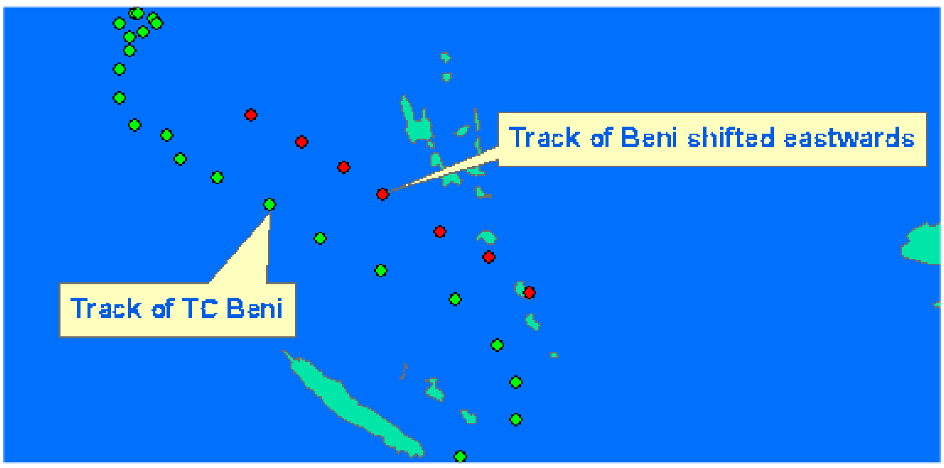

Figure 16: Tracks of TC Beni (green), and Beni shifted approximately 250 km to the east (red)

The wave field for Beni has a maximum of around 19.5 metres compared with 14.5 metres for the track shifted to the east – the main cause for the difference is the effect of northern islands of Vanuatu which reduce the effective fetch. The wave maximum is also shifted eastwards in accordance with the region maximum winds. Modelling was undertaken to assess the impacts from an extreme event, comparing two possible storm events:

- **Case 1:** TC Beni with still-water level set to 0.5 m
- **Case 2:** TC Beni track, but intensity 910 hPa (which is the approximate 100-year storm central pressure for the Vanuatu region) with still-water level set to 1.0m.

The case approach was adopted since accurate specification of wave heights in the Port Vila-Mele Bay region at a range of return periods would require undertaking many hundreds of wave model runs for a wide range of cyclone events – varying intensity, speed of movement, track, and a range of sea levels. Instead, a representative design storm was considered in order to establish wave heights and their potential impacts at the extreme end of cyclone events, and to compare those impacts with that of Cyclone Beni.

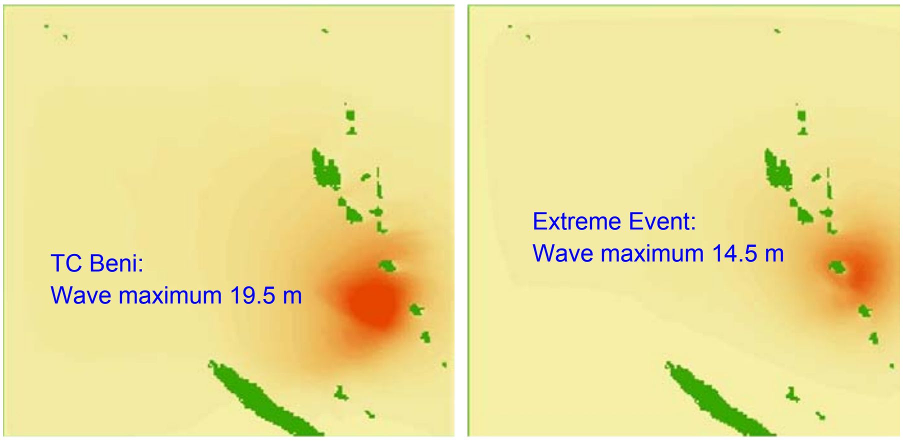

Figure 17: Wave height contours for locations of TC Beni and the extreme event nearest Efate

Wave Conditions

To this end, a cyclone of intensity 910 hPa (which is approaching the extreme cyclone intensity in the vicinity of Vanuatu) was set up to run on the same track as Beni. Still-water level at the time of maximum waves was set at 1.0 m above mean sea level – this is well above that coinciding with Cyclone Beni (a maximum of 0.2 to 0.3 m at the time of maximum waves). From a parallel study of storm surge risk, the 1000-year sea level is estimated at about 1.2 m above mean sea level – so that the selected event is extreme for both waves and sea level. Bathymetry and wave conditions were extracted form these grids along five selected cross-sections terminating shorewards from specific points of interest (Figure 18).

Wave conditions, calculated both for TC Beni and an extreme event (Figure 19 and 20), are estimated up to 9.5 m height at the offshore end of the cross sections. In general, the waves have long periods from 15 to 22 seconds. The resulting deep-water wavelength is 350 to 750 m, which determines that there will be strong wave-bed interaction from the shelf boundary.

Characteristics of the transition towards shore include shoaling, breaking and friction, with increasing effect for shallow water. The effect of shoaling and breaking is apparent at a number of sills and reef systems across the sections and there is significant damping of long-period waves as the wave approaches the shoreline.

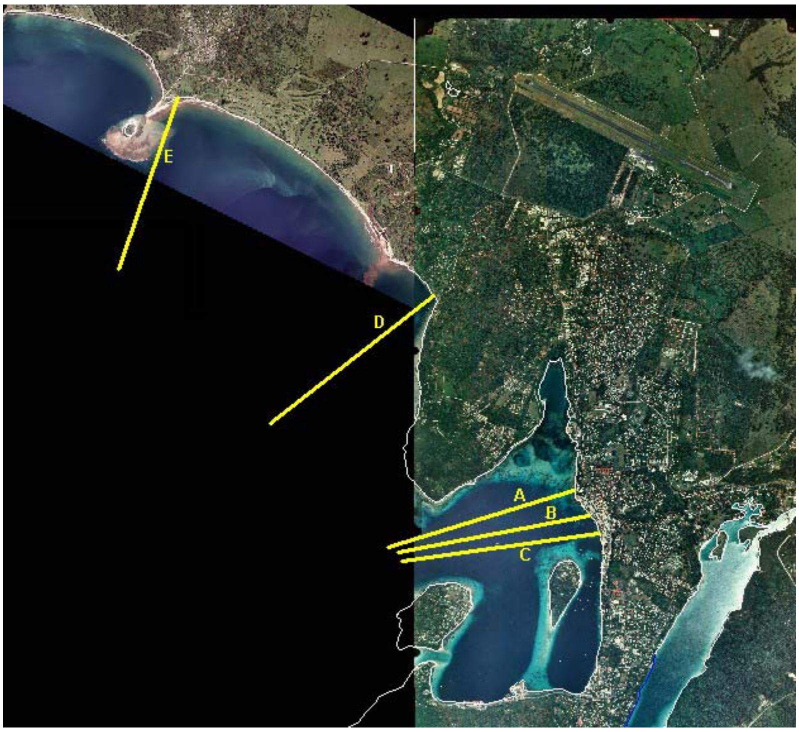

Figure 18: Sections A-E used for calculating storm wave heights, Port Vila Harbour-Mele Bay

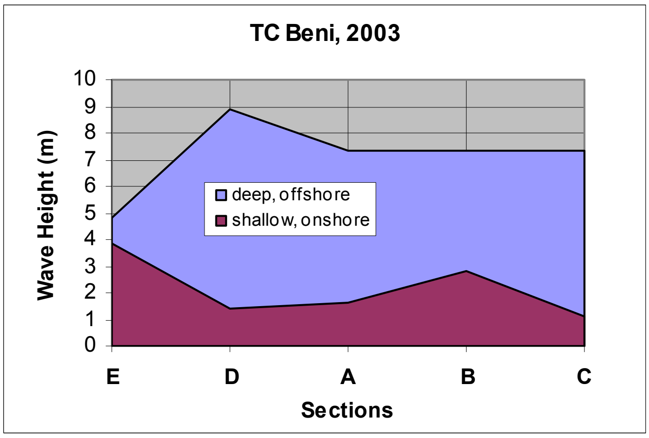

Figure 19: Wave heights experienced during TC Beni on Sections A-E

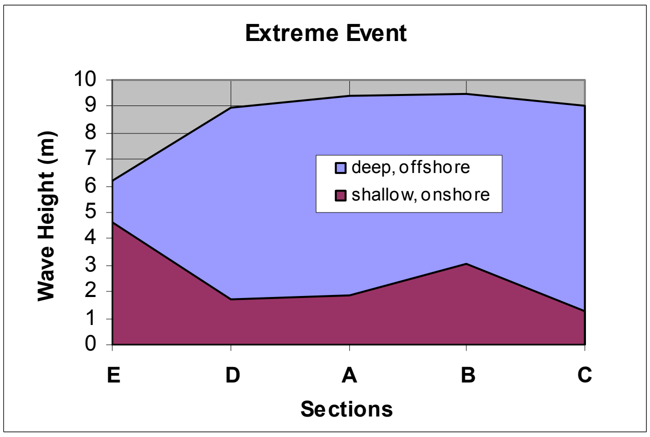

Figure 20: Wave heights predicted during an extreme event on Sections A-E

Geological Hazards

This section describes earthquake and tsunami hazards, drawing much of the information on earthquake from more than a decade of research carried out by the French organisation IRD, investigations by SOPAC, a joint USAID-funded SOPAC-GII-IRD seismic microzoning project with the Vanuatu Government, and the investigations carried out more recently in relation to the January 2002 Port Vila Earthquake and the accompanying tsunami jointly by the Vanuatu Department of Geology, Minerals and Water Resources, IRD and SOPAC. The modelling of tsunami hazard for Port Vila Harbour and Mele Bay was performed by Dr Vasily Titov in Seattle and used in a risk-loss assessment by Mr Stan Goosby of the Pacific Disaster Center in Hawaii with assistance from SOPAC in providing baseline information. Their full reports on tsunami hazard and loss are contained in Appendix 4 and 5. Animations of the tsunami impact on both Port Vila Harbour and Mele Bay are provided on the accompanying CD.

Earthquake Hazard

General Seismicity

Port Vila is situated on the south-western corner of a single, large extinct volcano which is the island of Efate. Efate itself lies about 50 km east of the New Hebrides Trench, the surface expression of an active subduction zone which dips at a steep angle eastwards beneath Efate.

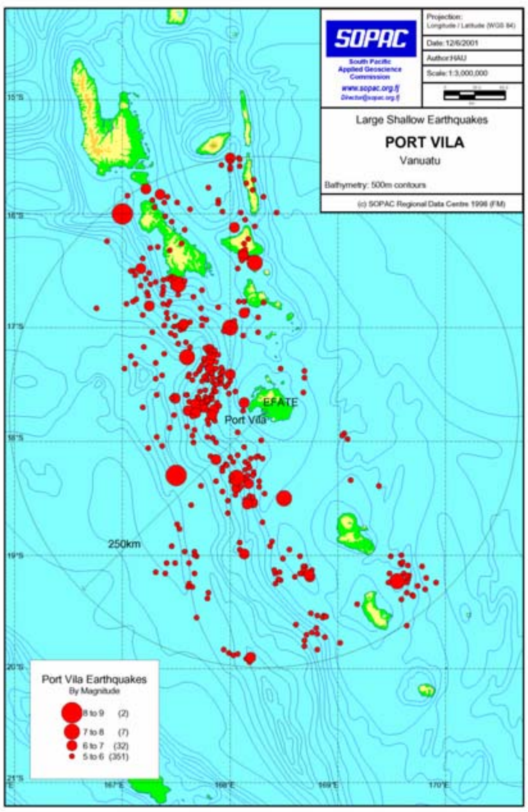

Figure 21: Historical seismicity within 250 km of Port Vila

Very high levels of seismic activity are associated with this subduction zone and, while the zone is modelled as the most likely source of a large earthquake, smaller (though closer) earthquakes can, and do, occur in the seafloor around Efate, and less frequently on the island platform itself. The seismic risk is taken as a probabilistic combination of all of these sources over time. Although the estimated maximum likely earthquake, governed by energy-release and seismic characteristics of the seafloor in that particular region is taken as M_w 8.1 in the vicinity of the trench, earthquake energy output diminishes as the square of distance from the source, so there is no guarantee that a closer and smaller earthquake could not do as much, or more, damage to Port Vila. A map of the general seismicity of the immediate region is shown in Figure 21.

The frequency-magnitude characteristics of earthquakes in the area were described by Hofstetter et al. (2000)

Historical Events

Port Vila has a history of being affected by earthquakes, most of which over the past 100 years have fortunately caused relatively little damage (Louat & Baldassari 1989), the last and most damaging occurring as recently as 2nd January, 2002. The length of the scientific seismological record, and even of the traditional oral record of the inhabitants, is worryingly short.

1880: The event of 1880 generated a seiche in Port Vila Harbour that inundated extensive areas of the harbour islands and stranded large number of fish in the vegetated areas well above sea level.

1927: Eyewitness accounts from Port Vila suggest that the largest tsunami experienced there was as a result of the 24th January 1927 event of Ms 7.1 located on South Malekula. The tsunami entered the harbour and apparently caused seiching and flooding of the shoreline up to several metres above the normal tide levels. Its origin and magnitude are uncertain.

1950: An event with a magnitude near 7 occurred about 100 km southwest of Efate.

Between 1961 and 1978, a series of large earthquakes (Ms > 5.5) recorded in the vicinity of Efate ranged up to magnitude 6.0 with an isolated example of Ms 6.5.

1961: A small tsunami was recorded in Port Vila harbour after the 23rd July 1961 (Ms 6.0) event 100 km south of Port Vila.

1965: On 12th August 1965, an Ms 6.3 earthquake in the north of the group was felt with intensity MM7 in Efate.

1974: The 30th June 1974 a Ms 5.7 earthquake occurred about 25 km south of Port Vila, resulted in cracks in newly constructed multi-storey buildings and rock-falls from cliffs in the city.

The ORSTOM-Cornell network began operating in 1978. According to Prevot & Chatelain (1984), only four earthquakes of large magnitude had been recorded in the archipelago since the inception of the network. The largest one was the Mere Lava event near Santo.

1979: Three events occurred to the west of Efate. The first on the 17th August (Ms 6.1) occurred 35 km off Efate. It was followed nine days later by a second shock (Ms

6.0), some 20 km to the north of the first one.

1980: The largest, 12th May 1980 (Ms 6.1), was the Mere Lava event near Santo that caused relatively major damage but no casualties.

1981: The earthquake of 15th July 1981 (Ms 7.0) occurred approximately 85 km northwest of Efate and was reported to have caused damage in Port Vila. This earthquake is notable for having occurred in an area that had not experienced any large earthquakes in the preceding 75 years.

According to Prevot & Chatelain each of the earthquakes was preceded by swarms around the zone where the aftershocks occurred, in areas of characteristically low seismicity, and even to the rear of the arc, east of Efate. The swarms occurred up to eight hours before the main shock, and the aftershock zone expanded quickly over the following days to cover areas 5 to 10 times greater than normal earthquakes of such magnitude. Thus, even though an earthquake of 7th July 1981 was centred some distance offshore of Efate, the region of aftershocks spread onto the island itself.

1999: The 26th November, Mw 7.5 earthquake occurred between the northern tip of Ambrym Island and the south of Pentecost. It was the largest known earthquake to be recorded in that area. Located at the depth of 18 km, it induced a maximum uplift of over 1.2 m at the easternmost tip of the island near Pamal and Ulei. This earthquake caused felt intensities of MM6 to 7 on the Mercalli scale, and was the origin of a tsunami which struck Baie Martelli in South Pentecost and causing much damage, ten deaths, two lost and several injuries in both Pentecost and Ambrym islands.

Palaeo-seismicity

Work by Howorth (1983; 1985) recognised at least seven raised Holocene reef terraces reaching up to 12.5 m above the highest living corals on the western side of Mele Bay, some 10 km west of Port Vila. He considered the uplift of each terrace to be co-seismic and associated with earthquakes of large magnitude, probably greater than magnitude 7.5.

The five youngest terraces, ranging in height between 1-2 m each, and reaching up to about 6.5 m above current sea level, yielded radiocarbon dates back to around 5,000 years BP suggesting that, as a rule, large earthquakes have occurred in the near vicinity during that period at least every 1,000 years on average. Prior to 4,500-5,000 years BP there are indications of an earlier tectonic event that resulted in a catastrophic uplift of the western margin of Mele Bay relative to the bay itself. This event may well have been the initiation of a massive palaeo-landslide which can be seen to have affected fully one-third of south-western Efate including all of Mele Bay and Port Vila harbour and peninsula, and which apparently coincided with the rise in post-glacial sea level to around its current height.

Using the magnitude-recurrence relationship above, and estimates of seismicity from USGS data together with more recent data from the local IRD network (Prevot & Chatelain 1984), an approximate relationship was developed for earthquake magnitude-return periods in the Efate-New Hebrides Trench vicinity (Figure 22).

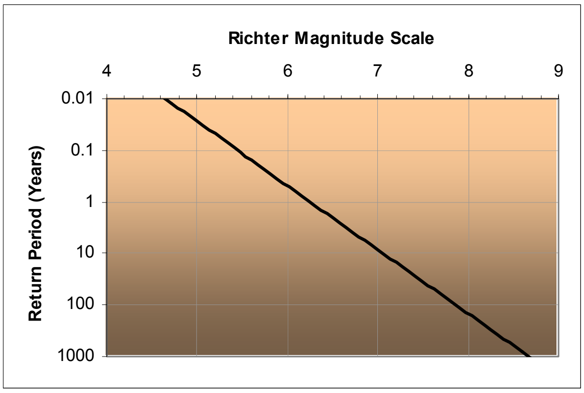

Figure 22: Approximate earthquake magnitude-return periods in the vicinity of Efate

By comparing the results of historical earthquakes sourced in the New Hebrides Subduction Zone and the record of felt intensities in Port Vila (Modified Mercalli scale), an approximate relationship has been developed between the two in Figure 23. In the long term, earthquake intensities between MM9-10 are possible in Port Vila; and the effects at these intensities are described in Table 7.

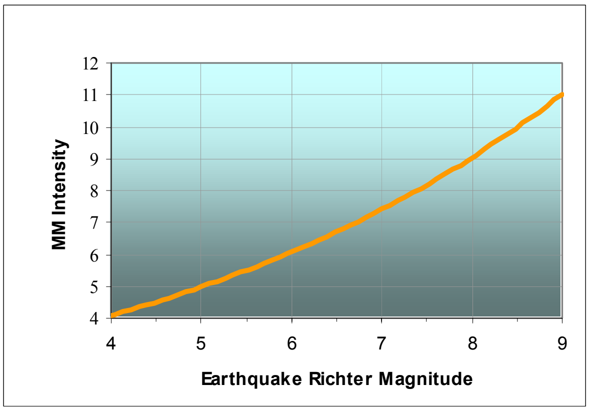

Figure 23: Approximate relationship between earthquake magnitudes in the New Hebrides Subduction Zone and Modified Mercalli (MM) intensities felt in Port Vila

A combination of the relationships developed in Figures 22 and 23 gives approximate recurrence periods for felt intensities in Port Vila shown in Figure 24. When read in conjunction with Table 7, this provides a more readily understood measure of potential damage specifically to Port Vila from regional earthquakes sourced in the New Hebrides Subduction Zone in the vicinity of Efate.

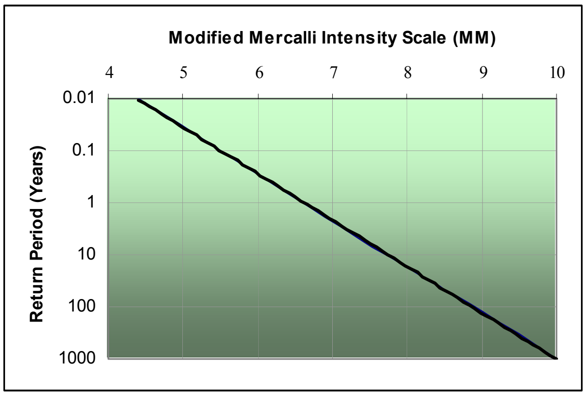

Figure 24: Approximate Modified Mercalli felt-intensity return periods for Port Vila

Table 7: Modified Mercalli intensity scale (1956 version)

I. (MM 1) Not felt except by a very few under especially favourable conditions.

II. (MM 2) Felt only by a few persons at rest, especially on upper floors of buildings.

III. (MM 3) Felt by persons indoors. Many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibrations similar to the passing of a truck. Duration could be estimated.

IV. (MM 4) Felt indoors by many, outdoors by few during the day. At night, some awakened. Hanging objects swing. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. Wooden walls and beams could sometimes crack.

V. (MM 5) Felt by nearly everyone; many awakened. Direction of the arrival waves could be estimated. Liquids resonate, some overflow. Some dishes, windows are broken. Unstable objects overturned. Pendulum clocks may stop, restart, and change their rhythm. Curtains may flap, paintings move.

VI. (MM 6) Felt by all, many frightened and run outside. Pedestrians stagger. Glasses dishes are broken. Books are drawn out from their shelves. Paintings are pulled out from walls. Some heavy furniture moved; a few instances of fallen plaster. Masonry of type D split. Small bells started to ring. Trees and bushes shake or vibrate. Damage slight.

VII. (MM 7) It is hard to stand. Drivers feel the earthquake. Hanging objects tremble. Furniture is broken. Type D masonry is damaged or cracked. Less solid chimneys are destroyed at the roof level. Loose plasters, bricks, stones, tiles, cornices, and parapets fall off. Some fissures in type C masonry. Waves in the lakes, the water becomes muddy. Small slips on embankments, sands and gravel. Large bells began to ring. Irrigation trenches are damaged.

VIII. (MM 8) Driving is disturbed. Damage in type C masonry: partial collapses. Few damages in type B masonry, and nothing to type A. Plasters and some walls in masonry could fall. Fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned. Unbolted house frames jump out of their foundations. Branches are broken. Cracks appear on humid soils and on high slope areas. *(Damage slight in specially designed structures. Considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures).*

IX. (MM 9) General panic. type D masonry destroyed; type C masonry damaged with sometimes complete collapse and type B seriously damaged. Damage to all foundations. If the frames are not anchored, they shift off their foundations and are damaged. Considerable damage to water tanks, underground pipes are broken. Clear visible cracks on the ground surface. In alluvial zones, outbursts of saturated sands, splashing of water and mud. *(Damage considerable in specially designed structures. Well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations).*

X. (MM 10) Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. Serious damage on dams, breakwater and embankment. Large land sliding. Water overflows the riverbanks, canals, lakes. Sands and mud move horizontally on flat land.

XI. (MM 11) Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. (MM 12) Damage total. Lines of sight and level are distorted. Objects thrown into the air.

PS:

Masonry A, B, C, D: To avoid imprecision of language, the masonry quality, bricks or others, is specified by the use of the following letters:

Type A masonry: *Serious workmanship, mortar and conception of high quality. Reinforced, conceived to resist lateral forces.*

Type B masonry: *Serious workmanship and good mortar. Reinforced but not conceived to resist lateral forces.*

Type C masonry: *Workmanship and mortar of average quality. Not reinforced, not conceived to resist lateral forces.*

Type D masonry: *Weak materials, workmanship of bad quality, little or no horizontal resistance.*

The maximum recorded Modified Mercalli effect in Port Vila (see Table 7 for a description of the 12 levels of the Modified Mercalli scale:1956 version) from past earthquakes has previously been as high as MM7 and, in the recent January 2002 event, up to MM8 and even higher. It has been estimated (Prevot & Chatelain) that a maximum likely predicted intensity might be about MM9.

Comparison with the style and intensity of earthquakes occurring in similar tectonic settings in New Zealand (Dowrick & Rhoades 1999) indicates a strong parallel with attenuation characteristics there. If the New Zealand attenuation curves can, in fact, be adopted, it suggests that maximum effects in Port Vila might reach MM10 (at which stage most masonry and frame structures are destroyed) given a maximum predicted earthquake of M_w 8.1 at shallow depth with an epicentre close to the 2002 event.

Seismic Microzonation

The effects of earthquakes can, in many situations, be exacerbated by ground resonance. The phenomenon of resonance is dependent on specific ground conditions, and these are known to vary widely across the Port Vila area.

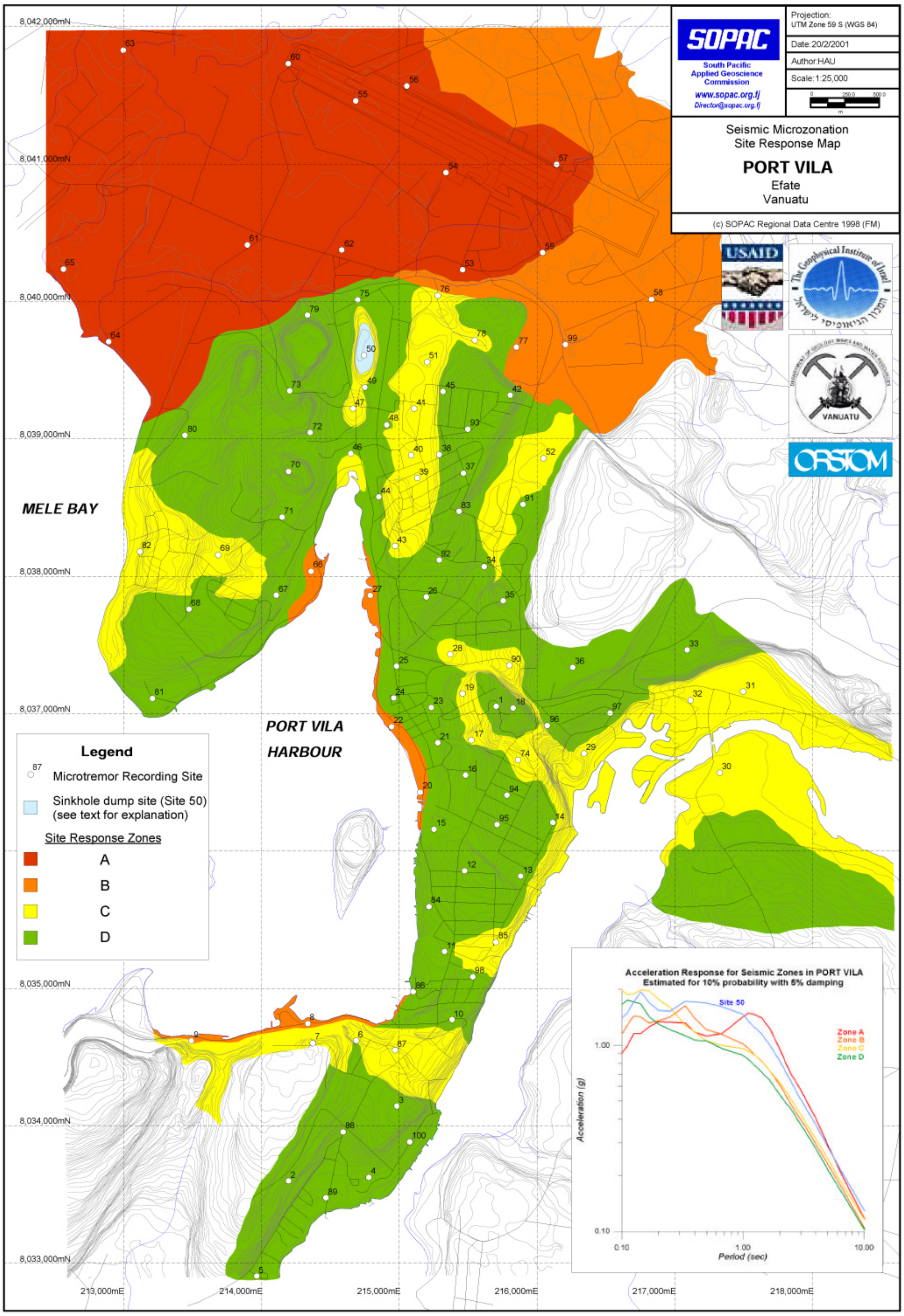

Figure 25: Seismic microzonation of Port Vila

Microzonation studies employing the Nakamura micro-tremor technique and based on developments by Shapira & van Eck (1993) were carried out across the area (Shapira 1999; Shorten et al. 1999; Regnier et al. 2000; Shorten et al. 2001) to identify those areas where ground resonance might occur. Ideally, basins containing deep sediment or artificial fill and areas of steep relief or abrupt change of slope are more prone to ground resonance effects, increasing peak ground accelerations up to 2.5 times. The most unfavourable situations occur where the resonant frequency of a building (generally a function of building height and stiffness) matches that of the ground upon which it is constructed.

The results of the seismic microzonation study (Figure 25) predicted that the area of thick sediments in the Mele Bay-Bauerfield Airport district (red) would be particularly susceptible to the amplification of earthquake effects, followed progressively by marginal reclaimed lands around the harbour (orange), and then deeply weathered and low-lying areas (yellow). Most of the high bedrock areas of the peninsula (green) were considered unlikely to be susceptible to amplified earthquake effects. The inset to Figure 25 shows the expected acceleration response of the various seismic microzones, adopting a probability of 10% in 50 years (about 1 in 450 years). The figures obtained by considering all sources large and small, near and far, gives very high (over 1 *g*) accelerations because Efate itself has been included as part of the source area. At these high levels of acceleration, particularly for the weak soils of zones A and B, the graphs show that foundation failure theoretically occurs before resonance can take effect.

More recent work (D. Novakov pers comm.) suggests that the modelled earthquake accelerations for Port Vila from Shorten et al. (2001) are probably too high, being a factor of 1.5 more than the estimates in the current National Building Code of Vanuatu.

This microzonation assessment was put to the test by the technical/damage assessment (Shorten 2002a) and post-event intensity survey (Garaebiti et al. 2002) following the 2nd January, 2002 Port Vila Earthquake.

2nd January, 2002 Port Vila Earthquake

The largest earthquake recorded to date in Port Vila occurred at 17:22 hours on 2nd January, 2002 (4:22 am on 3rd January, local time). The shock measured M_s 7.3 (M_w 7.1) on the Richter Scale and the focus was located by the local IRD network in Vanuatu at 17.763°S and 167.850°E, about 45 km west of Port Vila at a depth of 18 km below the sea floor.

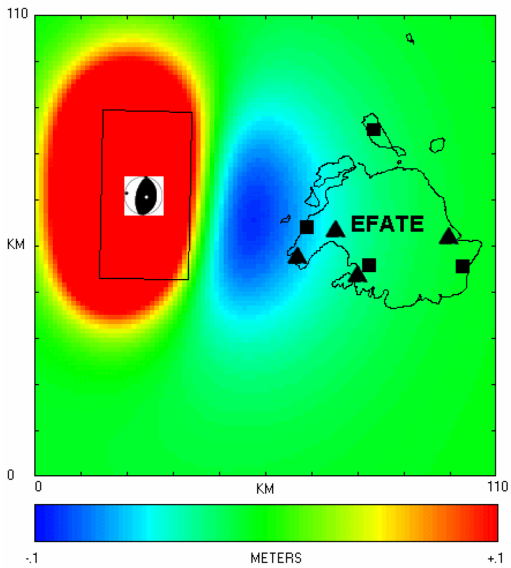

Figure 26: Elastic deformation of the sea-floor as a result of 2nd January 2002 Port Vila Earthquake

IRD modelling (Figure 26) indicates the likely area of sea floor deformed by the earthquake mechanism. The shock was followed 15 minutes later by a moderate-sized tsunami in Port Vila Harbour. Later that same evening, at 9:17 pm, Port Vila was rocked by an M_s 6.4 aftershock in the same epicentral region. Figure 27 shows the differences between the IRD local network and the USGS NEIC epicentral locations of the main shock and the larger aftershocks.

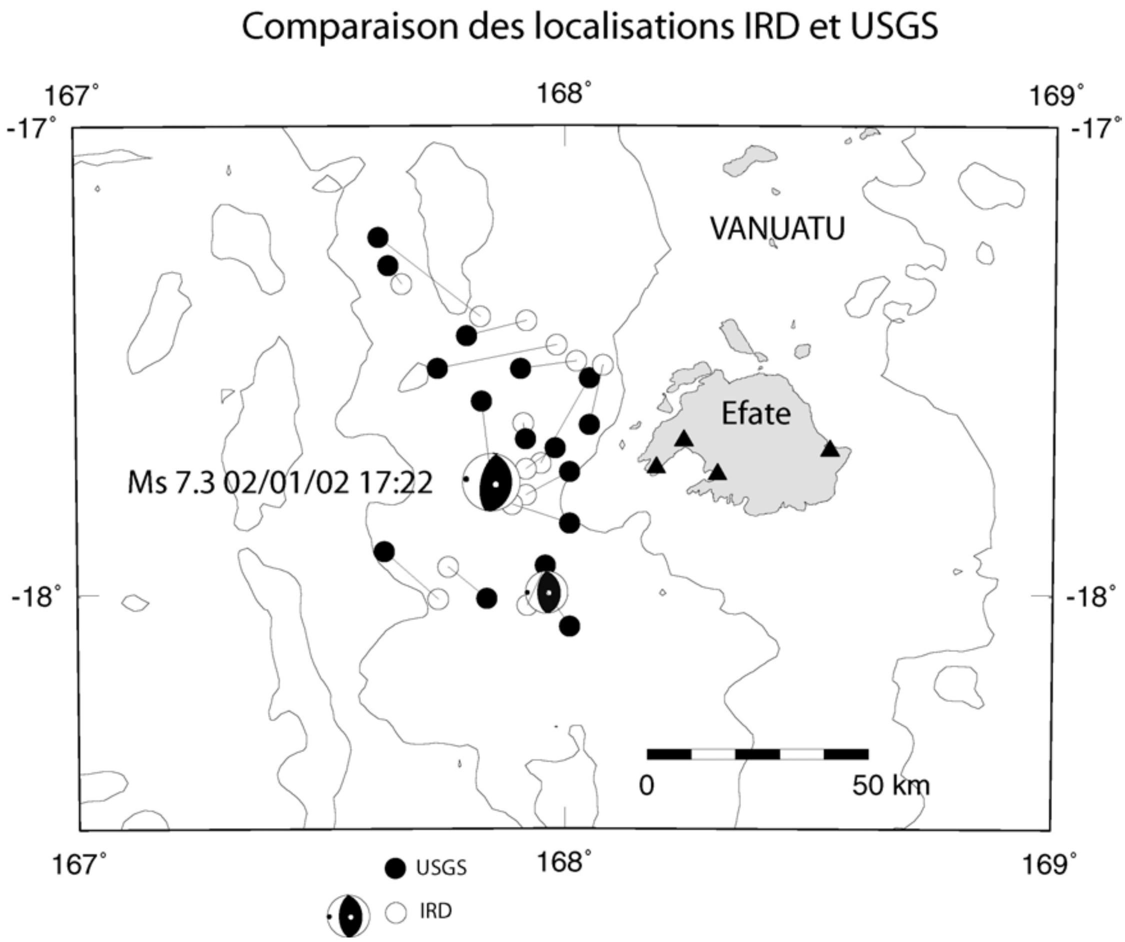

Figure 27: Location of 2nd January 2002 Port Vila Earthquake and major aftershocks. Comparison between USGS and IRD epicentre locations *(Courtesy IRD, Noumea)*

Much of the damage to Port Vila was related to inadequate building construction practices or came about either indirectly as a result of ground failure (liquefaction, settlement, or landslide).

In the fortnight following the earthquake, a general survey of felt intensities was carried out across the whole of Efate while a special, more concentrated survey of almost 200 eyewitness accounts was carried out specifically in the Port Vila area and reported by Garaebiti et al. (2002). The Modified Mercalli effects across Efate are shown in Figure 28, indicating the general level of intensity around Port Vila as lying between MM7 and MM8.

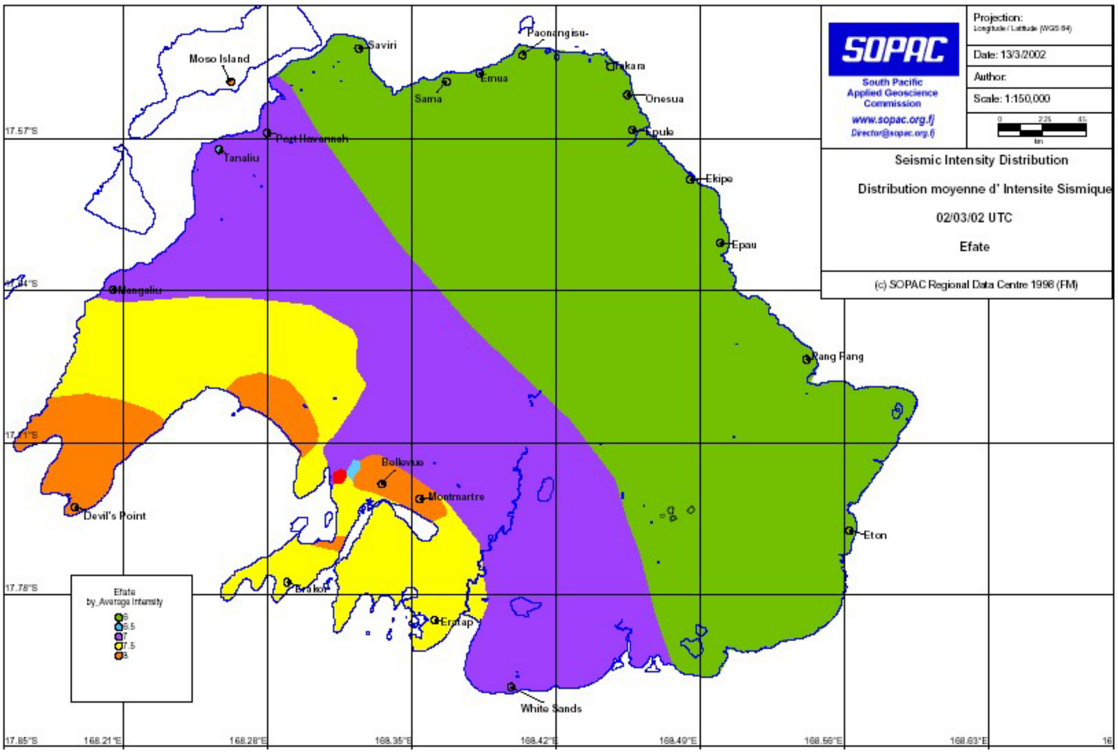

Figure 28: Modified Mercalli effects across Efate as a result of the January 2002 Port Vila Earthquake

The results of the concentrated survey around Port Vila are shown in Figure 29 against the backdrop of the earlier predictive microzonation map. Considering that the whole of the relatively small area of Port Vila can be viewed as equidistant from the earthquake 45 km distant to the west, the general background level of felt intensity in the city can be assumed to be just above MM7.

This information is further summarised in Figure 30 which highlights the zones in which at least some degree of amplification of earthquake intensities might be expected (red zones), and those zones in which no amplification is expected (green zones), according to the predictions of the earlier microzonation survey.

Superimposed on this background is a series of dots representing the Modified Mercalli values derived from the post-event intensity survey, colour-keyed to indicate whether the observed value was above, below or equal to the general background value. Reports of anomalously high intensity (MM8-10; red dots), anomalously low intensity (MM6; yellow dots, and background-level intensity (MM7; green dots) can then be compared directly with predicted values through the scheme:

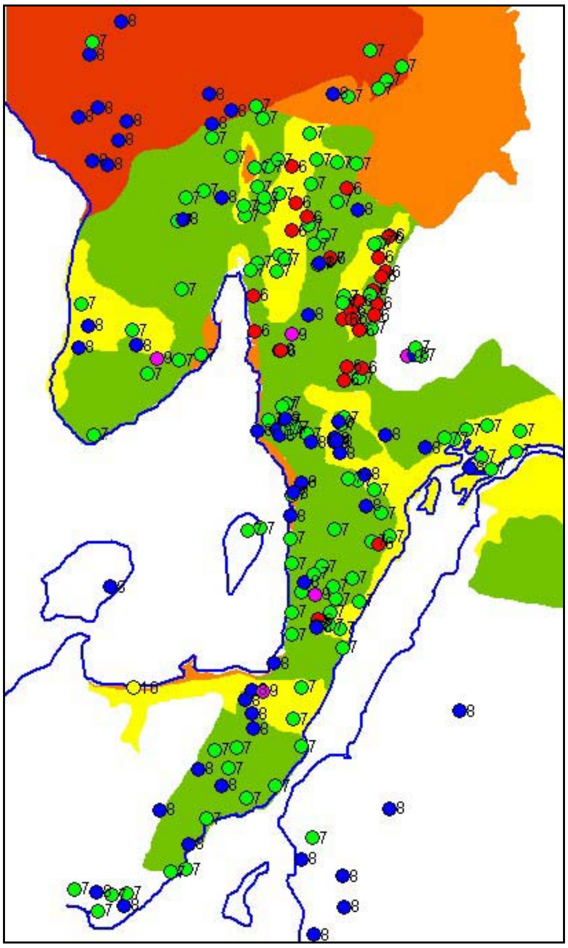

Figure 29: Modified Mercalli (MM) intensities surveyed after January 2002 Port Vila Earthquake compared with microzoning results

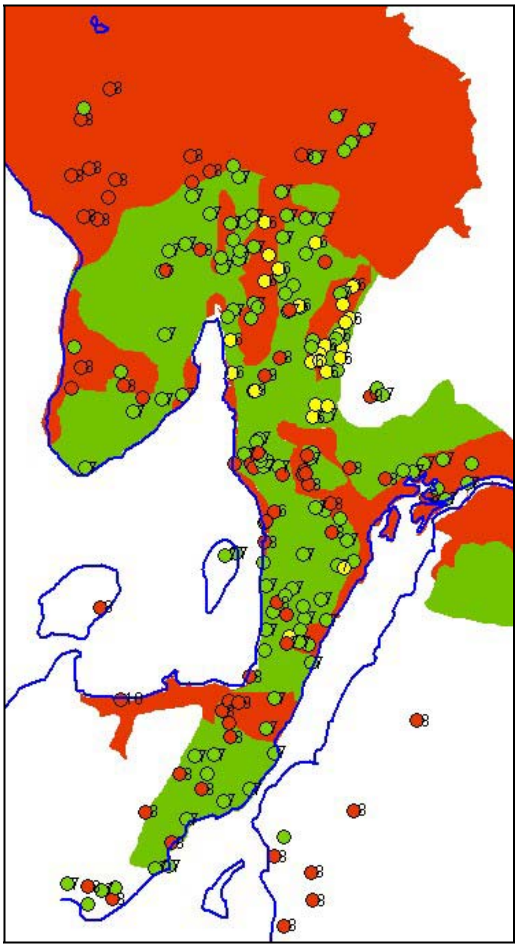

Figure 30: Predicted zones of amplification (red) compared with MM intensity results of January 2002 Port Vila Earthquake (see Table 8 for colour key)

Table 8: Explanation of colour key for Figure 30

Red dots on Green zones	Microzoning results tend to **under-predict** as judged by recent earthquake effects
Red dots on Red zones	Microzoning results tend to **predict correctly** as judged by recent earthquake effects
Green dots on Green zones	Microzoning results tend to **predict correctly** as judged by recent earthquake effects
Green dots on Red zones:	Microzoning results tend to **over-predict** as judged by recent earthquake effects
Yellow dots on Green or Red zones	Microzoning results tend to **over-predict** as judged by recent earthquake effects

The intensity levels above or below intensity MM7 are grouped in Figure 31 as anomalously-high and anomalously-low areas respectively, set against a general background of intensity MM7. These areas are draped over a digital terrain model to demonstrate their relationship to the physiography of Port Vila.

Only two anomalously-low (MM6; green) areas have been delineated and these lie in the northern part of the city, both matching closely with deeply weathered physiographic troughs developed on grabens in the limestone bedrock. The areas were expected from microzonation tests to provide some amplification of intensity. Post-event results, however, suggest that ground conditions in these particular zones and like areas might, by contrast, de-amplify earthquake intensities.

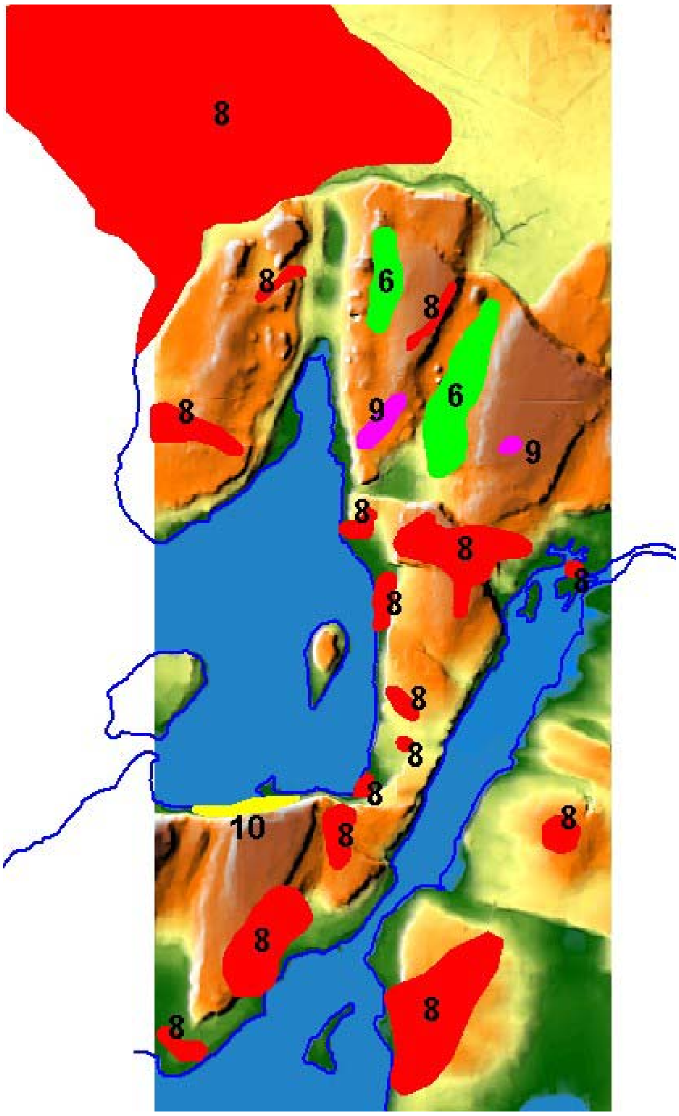

Figure 31: Generalised areas of intensity above and below background level of MM7

A large, anomalously-high (MM8; red) area lies, as expected from earlier investigations, north of the city in the Bauerfield-Mele plain. The area of the predicted high has been reduced somewhat though due to the more favourable results from the intensity surveys in the vicinity of the airport. Other MM8 highs lie, also as expected, over low-lying reclaimed areas and deeply weathered fault zones throughout the city.

Less expected perhaps are the MM8 high anomalies observed on steep topography and plateau-tops throughout the city which were not anticipated from the results derived from the earlier microzoning study, even though topographic effects have been long-recognised as influencing the resonant amplification of earthquake effects. Two small MM9 highs also lie on the high plateau tops between the MM6 lows discussed above.

Landslide and Ground Failure Hazard

The landslide and ground failure hazards are discussed briefly as one issue here although they have been mentioned elsewhere. Although some of the damage in past earthquakes has been due to structural failure resulting directly from poor building standards, most of the effects noted have been as a result of subsidence, liquefaction or landslide.

Efate island is basically a single large volcano. The weak tuffaceous rock making up the majority of the island is capped by a younger limestone, uplifted in the Port Vila area. The topography of the region surrounding Port Vila is the result of a mega-landslide where about one-third of the island of Efate has collapsed in the past – perhaps around 4,000 years ago. Part of the main escarpment is evident around Klem's Hill to the northwest of the city where large-scale slope failure has continued episodically.

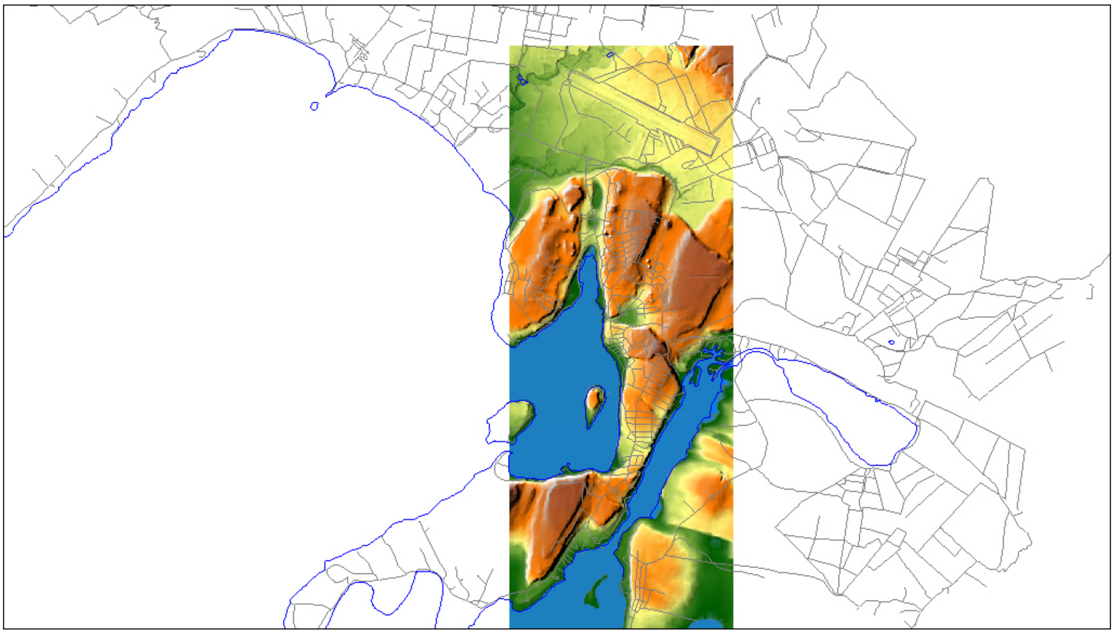

Figure 32: Steep-sided fault blocks in Port Vila prone to landslide

Elsewhere through the city area, large jumbled blocks of bedrock with faulted margins (Figure 32) form steep cliffs which are prone to collapse, occasionally during heavy rainfall, but particularly during large earthquakes when a multitude of landslides occur along the escarpments (Figure 33).

Figure 33: Roadway failure at the Klem's Hill escarpment on the western access to Port Vila

The most susceptible areas are those where the blocks are tilted or uplifted differentially so that the underlying tuff is exposed in the cliff face – the high cliff line immediately south of the harbour at the back of the main wharf and port area is the prime example in the city.

Figure 34: Slope failure in weak tuffaceous rock, blocking the main wharf access road - a limestone capping forms the cliff-line at the top of the slope

The weaker, fractured tuffs are particularly prone to slope failure (Figure 34), bringing down fragments of the overlying limestone capping in large rock falls as well (Figure 35, 36).

Figure 35: Limestone rock-fall on the main wharf access road

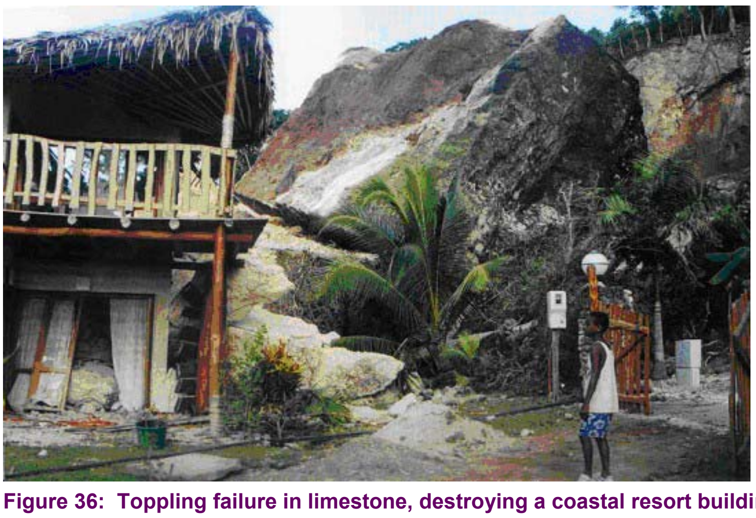

Figure 36: Toppling failure in limestone, destroying a coastal resort building

Apart from the uplifted fault blocks, some areas – particularly the harbour itself and the low-lying region immediately north of the city at the head of Mele Bay - are depressed areas, filled with later sediments. It's in these areas, including part of the main airport runway, that liquefaction and foundation failure often takes place, especially in areas where, for example, approach fills are raised by several metres to maintain bridge abutments above river flood levels, imposing extra loads on the saturated foundation soils.

Figure 37: Areas of damaging settlement (yellow lines) during the 2002 earthquake in reclamations over deep harbour areas (dark blue lines)

The third area of concern is the reclaimed areas on the margins of Port Vila Harbour, where poorly engineered fill for wharves or building foundations over soft sediments and deep marginal areas of the harbour (Figure 37, 38), and harbour-side roadways (Figure 39) are prone to consolidation and collapse during severe earthquake shocks.

Figure 38: Settlement and fissuring of harbour-side fill at main city markets during 2002 earthquake

Figure 39: Fissuring and slumping of harbour-side roadway

Tsunami Hazard

The report describes tsunami modelling for preliminary analysis of tsunami hazard for Port Vila Harbour. This study includes modelling of tsunami generation for several source scenarios, tsunami propagation and inundation in Port Vila Harbour, carried out by Dr Vasily Titov in Seattle and Mr Stan Goosby of the Pacific Disaster Center in Hawaii with assistance from SOPAC in providing baseline information. Their full reports on tsunami hazard and loss are contained in Appendix 4 and 5.

Computer animations of the tsunami impact on both Port Vila Harbour and Mele Bay are provided on the accompanying CD.

The initial plan for this pilot project had been limited to just one worst-case scenario simulation of tsunami inundation in Port Vila. The 2nd January, 2002 Port Vila earthquake and consequent tsunami presented an unexpected and early opportunity to test the developed tsunami model against the field data collected after the event by the SOPAC team (Shorten 2002a). Hence, a tsunami with the same earthquake source scenario was simulated using the same numerical model and the same numerical grids as for the worst-case model. The comparison of the model results with the field data showed general agreement with eyewitness observations and amplitude measurements, increasing the level of confidence in the worst-case modelling. Nevertheless, the modelling results of this study should be considered only as preliminary and should be used for the tsunami risk-loss analysis of Port Vila with caution. There are several factors that make this research a preliminary estimate, rather than a complete tsunami hazard mitigation study:

- the quality of the bathymetry data used for the tsunami computations is very good in the Port Vila Harbour itself, but is very poor outside the harbour and in the immediate vicinity of the Efate Island, which can affect the model predictions (Figure 40);
- one source scenario alone is not sufficient to estimate the tsunami potential – this may require the modelling of several different source mechanisms and source locations.

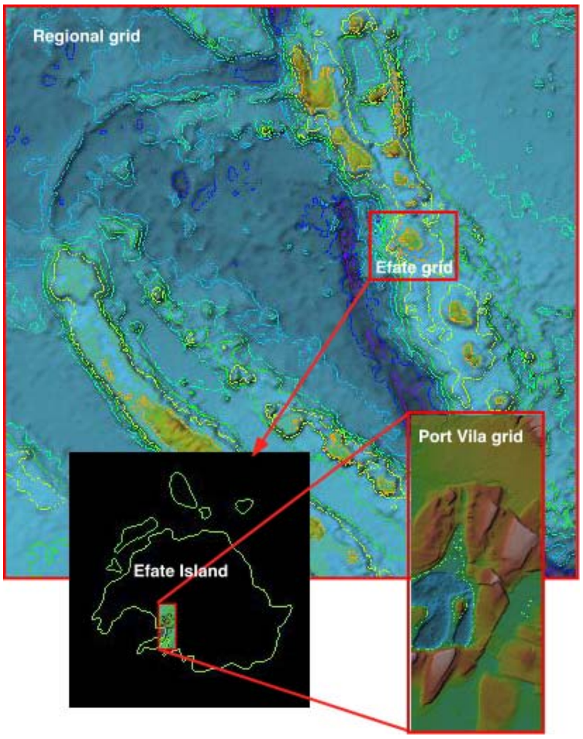

Figure 40: Numerical bathymetry grids used for modelling tsunami paths

Efate Island is located just east of the New Hebrides subduction zone, which is a part of a tectonically active system known to produce large earthquakes. The worst-case scenario is assumed to be an inter-plate reverse thrust event with the rupture under the continental slope in front of the Efate Island. The fault plane is placed at the interface between the subducting Australian plate and North Fiji Basin. The fault parameters are conformed to the inferred interface geometry (Jarrard, 1986;Pacheco et al., 1993) namely a NNW-SSE plane dipping at a moderate angle to the east (36°/073°). The magnitude of the earthquake scenario is specified to be the same as the strongest historical event, M_w = 8.1 with a rupture area of 120 x 40 km^2.

Worst-Case Tsunami

The wave heights computed over the regional grid demonstrate the propagation pattern of the tsunami along the New Hebrides Arc (Figure 41).

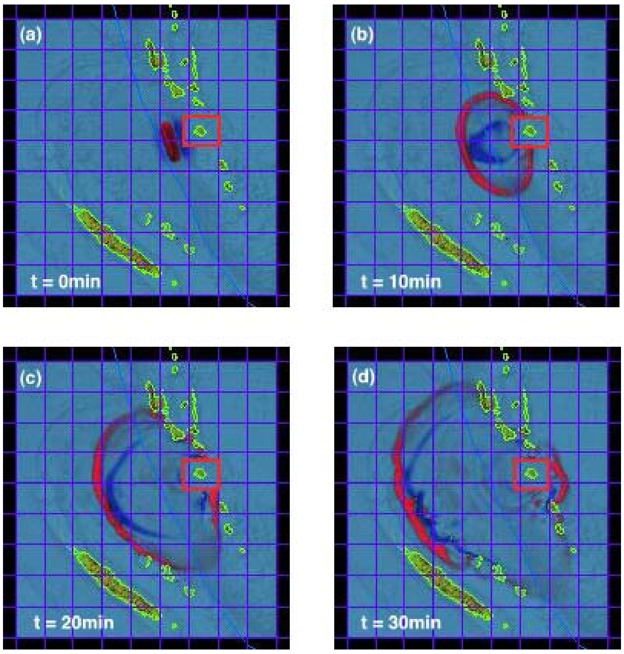

Figure 41: Location of tsunami maximum with time – Regional setting

The computed sea-floor deformation has a typical pattern for the subduction zone earthquake with the subsidence near the coast and a larger uplift offshore. Maximum computed uplift is 3.2 m, maximum subsidence is –0.3 m.

The wave reaches Efate island, closest to the source, about 10 minutes after the earthquake. In 20 minutes the wave arrives at Loyalty Islands and after 30 minutes it is near New Caledonia. The first wave to reach the Port Vila Harbour is a small negative wave, originating from the subsidence of the tsunami source. This is typical for earthquakes in subduction zones. As a result, the effect of the tsunami starts at Port Vila as a withdrawal of water from the harbour through a relatively narrow harbour entrance. The first positive wave enters the Port Vila Harbour 14-15 minutes after the tsunami generation (Figure 42).

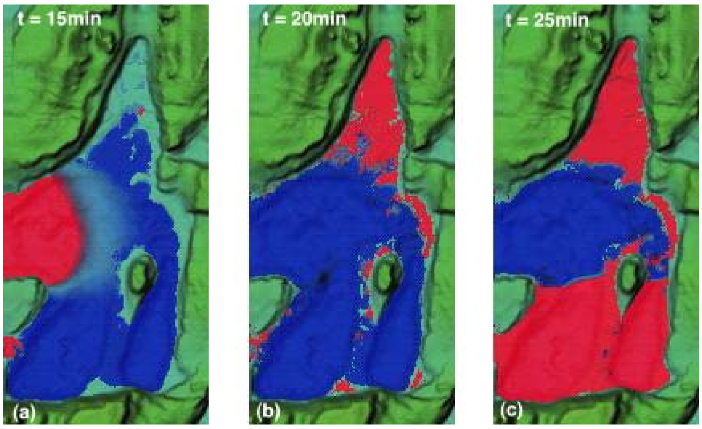

Figure 42: Location of the tsunami maximum with time inside Port Vila Harbour

A computer animation has been created to illustrate computed tsunami evolution in Port Vila Harbour from this moment on: 14 minutes through 25 minutes after generation. The simulation shows very strong currents at both entrances around Ifira island while the water flows into Port Vila Harbour. The main water flux occurs through the northern entrance; therefore the opposite waterfront on the east shore of the harbour is struck with the highest amplitude waves. The inundation of this shoreline starts 17 minutes after the earthquake. At the same time the simulation shows violent flooding of the shallow northern part of the Harbour, where extensive inundations are also computed. Another area of substantial flooding is at the Navy Base location on the south-eastern part of the harbour, where the inundation occurs 2 minutes later. The maximum computed inundation line is shown in Figure 43.

Figure 43: Maximum computed tsunami inundation line

After the first tsunami wave, which produces the largest inundation, the model shows continuous complex wave dynamics inside Port Vila Harbour. The later tsunami waves continue to enter the harbour causing repeated floods of already inundated areas. Water masses in different parts of the Harbour separated by shallow bars interact with each other in a complicated resonant pattern creating strong currents over the shallow areas and whirlpool structures around the deeper parts of the Harbour (Figure 44).

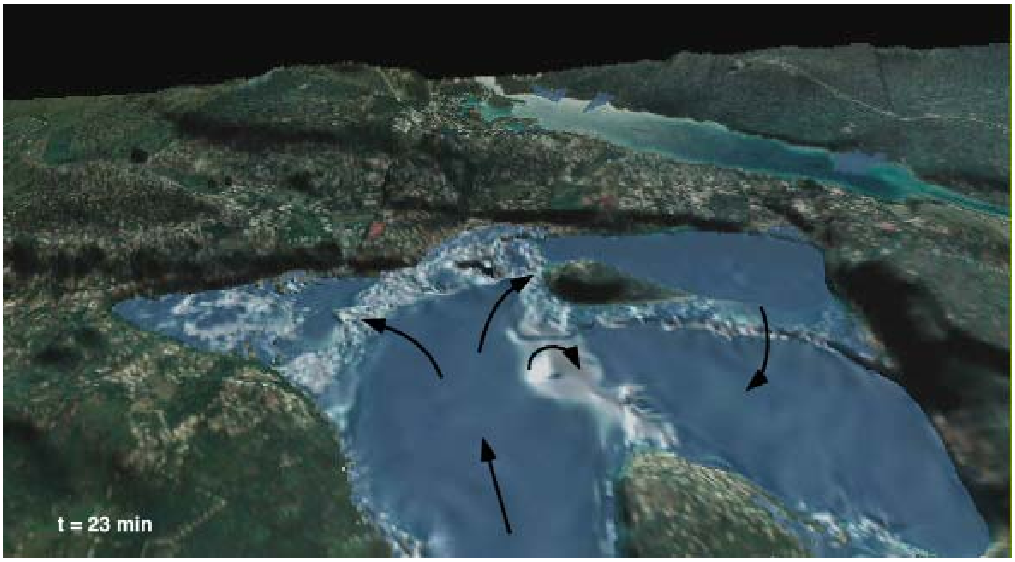

Figure 44: Tsunami-driven interactions between the water masses in Port Vila Harbour

The model computed up to 9 m maximum vertical inundation in Port Vila Harbour and maximum water penetration of about 200 m beyond the shoreline.

2nd January, 2002 Tsunami

At 17:22:49 h on the 2nd January 2002 (UTC) an earthquake of magnitude M_w 7.1 shook the area near Port Vila in Vanuatu. The epicentre of the earthquake was located in the same general area adopted for the source in the worst-case scenario Port Vila tsunami study described earlier.

Several minutes after the earthquake a small tsunami was observed in Port Vila by numerous eyewitnesses and was recorded on the National Tidal Facility tide gauge. The tsunami did not produce any damage but was significant enough to create visible effects throughout Port Vila Harbour. The eyewitness accounts recorded and quantified by the SOPAC survey team (Shorten 2002a, Garaebiti 2002) have yielded important observation data to calibrate the tsunami model for Port Vila Harbour.

The epicentre of this shallow earthquake was located directly offshore Vanuatu Island on the continental slope of the New Hebrides Trench at 17.590 S, 167.829 E. The associated tsunami could have been generated by either a co-seismic elastic deformation of the ocean bottom, or an aseismic ground failure (landslide or slump) on the ocean floor. The correlation between the earthquake magnitude and the observed size of the tsunami in the Port Vila Harbour suggests that the co-seismic deformation was the most probable source of this wave. The elastic bottom deformation depends on the earthquake magnitude and the geometry of the fault. Both of these parameters are determined by the centroid moment tensor (CMT) solution for the seismic data. CMT solutions for this event published by USGS and Harvard are substantially different; therefore both solutions have been tested for the tsunami modelling. Each CMT solution produces two double-couple fault models of the source that are not distinguishable from the seismic records alone. Other considerations – including, sometimes, tsunami evidence – have to be applied to choose the right fault geometry. Hence, both double-couples were considered for tsunami modelling for completeness.

Consequently, the following four double-couple source parameters in Table 9 have been used for the tsunami simulations:

Table 9: Tsunami source parameters

Nodal Planes	Strike	Dip	Orientation	Slip
USGS: NP1	001°	32°	32°/091°	81°
USGS: NP2	192°	59°	59°/282°	96°
HRV: NP1	298°	14°	14°/028°	20°
HRV: NP2	189°	85°	85°/279°	104°

All model faults have been assigned the same spatial dimensions (80 x 40 km) and the same slip amount of 0.9 m. The epicentre of each fault plane is the same. Assuming rigidity value of 3 x 10^{11} N/m^2, all these sources correspond to a M_w = 7.2 earthquake (Harvard estimate of this event).

Each set of parameters was used as input for the elastic deformation model to produce the static earth crust deformation due to the corresponding fault rupture (Okada 1985). The bottom deformations corresponding to these fault models are shown in Figure 45 (uplift in red, subsidence in dark blue).

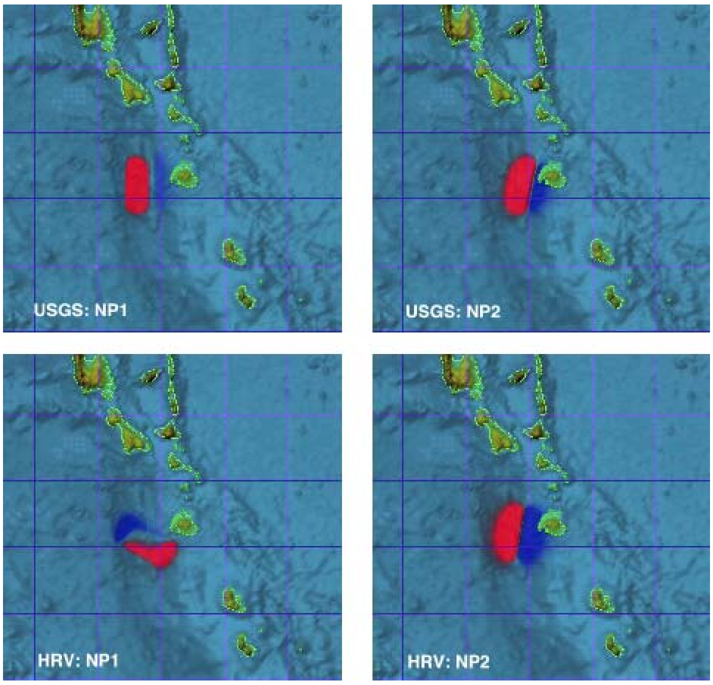

Figure 45: Sea-floor deformations for different rupture scenarios

Results

The MOST model was used to compute tsunami propagation from each model source and wave evolution inside the Port Vila Harbour. The model uses the same computational grids as for the "worst-case" scenario simulation. For three of the computed source scenarios, the first wave that arrives at Port Vila is a negative wave. The Harvard NP1 scenario – the only CMT solution with substantial strike-slip component – produces an initial positive wave at the Harbour with much smaller amplitudes than the rest of the sources.

The computed arrival time of the first positive wave in the Harbour varies from 9 to 14 minutes after the earthquake for the different sources. The wave dynamics after the first positive arrival is fairly similar for the three non strike-slip scenarios (HRV:NP2, USGS:NP1, NP2).

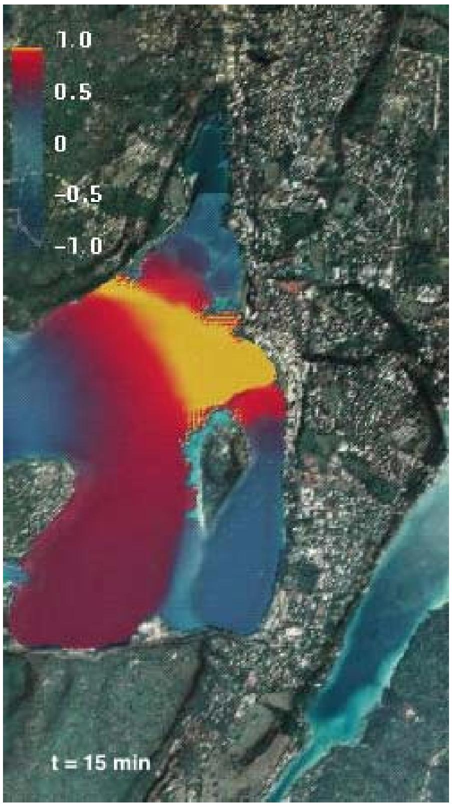

Figure 46: Positive wave in Port Vila Harbour 15 minutes after the earthquake

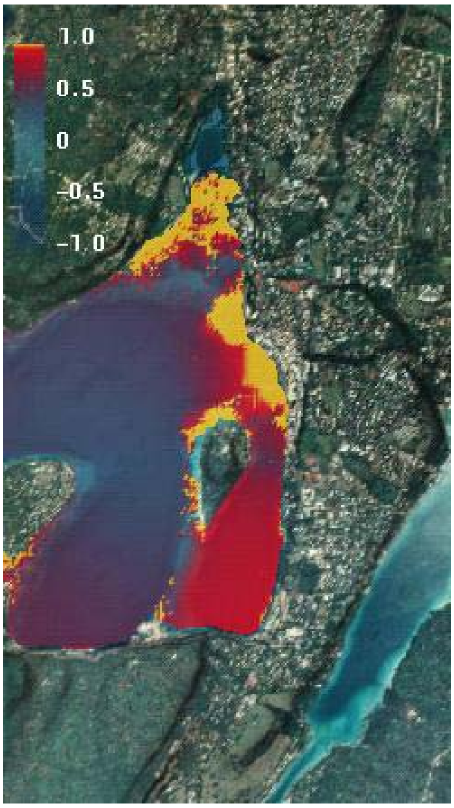

Figure 47: Positive wave in Port Vila Harbour 18 minutes after the earthquake

The wave reaches at the waterfront of the eastern shoreline of Port Vila Harbour and the NTF tide gauge at approximately the same time (Figure 46); the shore of the Navy Base is reached about 2-3 minutes later (Figure 47). The model did not compute substantial inundation for any of the simulated source dislocations. The maximum computed wave heights along the Port Vila coasts do not exceed 1.5 m, which is consistent with the eyewitness accounts.

Model Results vs. Observations

The observations for this event consist of the instrumental record of the tsunami at the NTF tide-gauge (Figure 48) and eyewitness accounts collected by the SOPAC team (Shorten 2002a).

When the model is compared with the tide gauge record, the computed waves for all sources have substantially shorter periods than the recorded signal. The computed waves show 6 to 7-minute period of water oscillation at gauge location, while the record indicates 15 to 20-minute period. Interestingly, all the eyewitness accounts indicate much higher frequency oscillations (periods of 3-5 minute) in the Harbour than recorded at the tide-gauge. Several explanations can be put forth to explain the observation discrepancy:

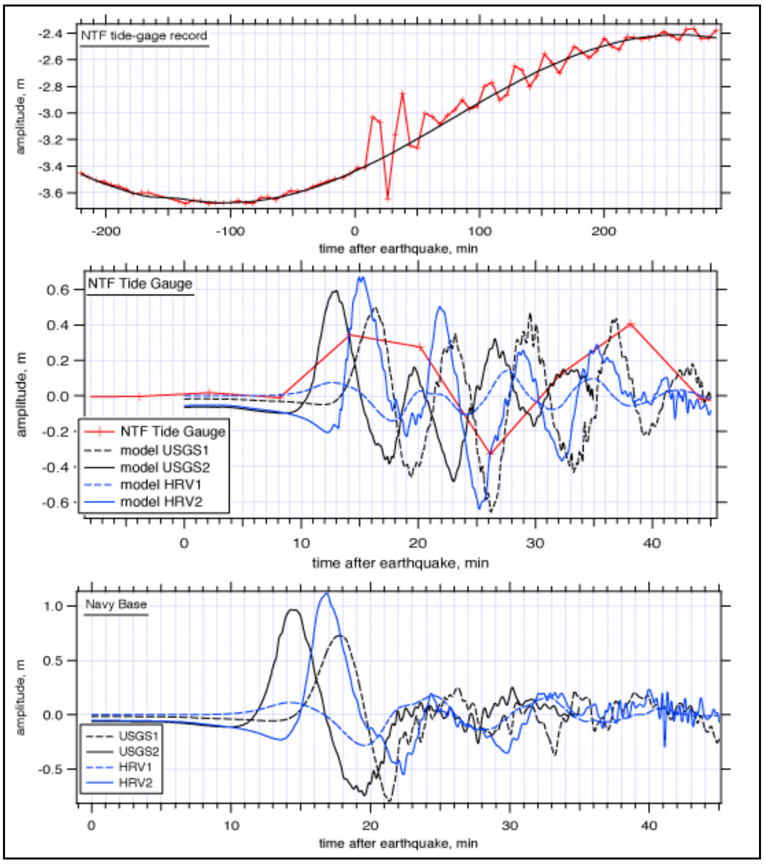

Figure 48: Recorded and modelled details of the tsunami wave

1. The tide gauge record is highly aliased due to the low-sampling rate (~6 minutes), does not catch all the peaks of actual water oscillations, therefore distorts the period of the tsunami.
2. The tide gauge construction can induce distortion of high frequency waves (compared with tide periods) if the intake pipes have small diameter. This problem of tide-gauge tsunami records is well known and has been addressed in the literature (Satake et al. 1988; Noyem 1976).
3. All the eyewitnesses exaggerated the frequency of water level oscillations, since none of them had actually timed the period.

This study favours the combination of (1) and (2) to explain the long periods of recorded tsunami. The model predictions combined with the eyewitness accounts provide strong evidence suggesting 3 to 7-minute periods of the tsunami inside the harbour. However, since the model prediction can be affected by less-than-perfect bathymetry outside Port Vila Harbour, the final answer can be obtain only after inspecting the tide gauge frequency response characteristics.

The computed amplitudes correspond well to the recorded signal for the three no-strike-slip sources and are much smaller for the HRV:NP1 strike-slip source. The computed maximum amplitudes for these three sources are similar and qualitatively agree with eyewitness observations around the harbour.

Source Mechanism

The four considered-potential fault plane solutions in Figure 45 produce four different initial deformations, and therefore would cause different tsunamis in Port Vila Harbour. Figure 48 shows modelled tsunamis for all computed fault solutions. While all three dip-slip sources have similar signals at the gauge, the observations seem to favour the normal fault mechanism with steeper dipping fault plane (HRV and USGS: NP2): it produces the wave with earlier arrival time, first withdrawal with relatively larger amplitude and higher positive amplitudes. All these are consistent with eyewitness observations. This mechanism appears to suggest an intra-plate earthquake within the North Fiji basin. The thrust mechanism with shallower dipping plane (NP1) would suggest an inter-plate event at the subducting Australian plate interface. That mechanism (inter-plate event) is assumed for the worst-case scenario simulation (but for a larger magnitude earthquake). Tsunami observations suggest that the January, 2002 earthquake did not rupture the plate interface and, therefore, did not release accumulating stress there, leaving the potential for large inter-plate event in the future.

Conclusions

This study has performed numerical modelling of tsunami inundation inside Port Vila Harbour for the purpose of evaluating tsunami risk. Several source scenarios have been simulated. The worst-case tsunami simulation provided estimates of maximum tsunami inundation possible inside the Port Vila Harbour. The simulation of the 2nd January, 2002 tsunami tested the tsunami model predictions against tsunami observations in Port Vila. The comparison confirmed the credibility of the MOST model estimates for Port Vila. The results of this project lay ground for a full-scale tsunami risk assessment study for Port Vila and other Vanuatu sites.

Risk-Loss Analysis

The reports on cyclone hazards by Mr Stephen Oliver of Global Environmental Modelling Systems Pty Ltd (GEMS) and tsunami hazard by Dr Vasily Titov of Seattle and Mr Stan Goosby of Pacific Disaster Center (PDC), Hawaii, all contain analyses of disaster risk-loss. Full details of the cyclone-related risk-loss studies carried out for Port Vila by GEMS can be found in Appendix 3, while the tsunami risk-loss studies are principally covered in the reports by PDC in Appendix 5, and supported by the modelling of studies in Appendix 4.

Cyclonic Wind Risk-Loss

Port Vila is particularly susceptible to cyclonic wind damage because of the large stock of buildings constructed on cliff edges and high plateaus around the harbour where wind speeds are undiminished or even accelerated by the topography (Figure 49).

Figure 49: Complete destruction of house overlooking Port Vila Harbour during TC Nigel in 1985

Vulnerability Model

The derivation of damage vulnerability curves for tropical cyclones affecting Efate such as Cyclone Uma in 1987 (Figure 50) are described in this section. The relationships between damage and wind speed developed in the current study are integrated with probabilistic models of tropical cyclones as part of an overall project to assess potential tropical cyclone damage in several cities in the South Pacific.

Vulnerability curves, as used in this report, are relationships between damage index and wind gust speed. The damage index is defined for a building structure, as follows:

Damage index (D) = (repair cost) / (value of building)

Although, theoretically, D could exceed 1.0, according to the above definition, it is assumed that repair will not take place if D exceeds 1.0, and an upper limit of 1.0 can be assumed.

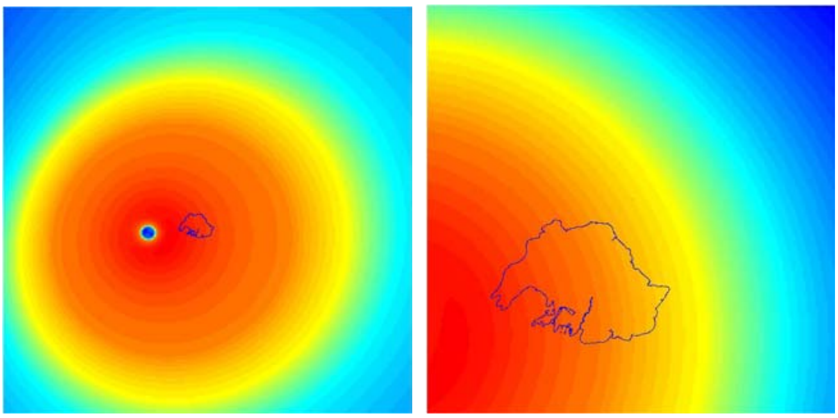

Figure 50: Modelled field of wind speed associated with TC Uma at its closest point of approach to Efate

Data was provided by SOPAC on 4,803 buildings in Port Vila and another sample of 173 buildings in the Mele Bay area. These data provided information on the usage, position, wall and roof materials, roof shape and pitch, number of storeys, plan area, and foundations of each building. Answers to additional questions on construction practices in Fiji and Vanuatu, were provided by SOPAC.

Another source of useful information for calibration purposes was a report on the damage caused by Cyclone Isaac in Tonga in 1982 (Reardon & Oliver 1982). This report indicated an overall damage index of 0.3 to 0.35, in the main island of Tongatapu, where a maximum gust of 47 m/s was recorded. However only 30% of concrete block houses suffered significant structural damage, whereas 55% of timber framed house received significant damage.

Classes of Building Strength

Previous studies of building damage following severe tropical cyclones and hurricanes, have indicated that inadequate structural connections are the main cause of structural failure. It is difficult to assess the strength of connections in individual buildings when they are not exposed. However, the Tonga experience (Reardon & Oliver 1982) is that concrete block houses are likely to have roof structures that are more securely anchored. Thus wall material can be taken as a good indicator of overall building strength.

Another good indicator of building strength is the building use and function. The more prestigious buildings have generally been engineered by professional structural engineers to resist cyclonic wind forces. In Tonga, 85% of industrial and commercial buildings in the main city of Nuku'alofa had only slight or no damage in Cyclone Isaac according to Reardon & Oliver.

Table 10 indicates the weightings given to various building characteristics in order to classify the buildings for their potential resistance to cyclone wind forces. Within each characteristic, points were assigned on a scale of ten. For example the system used within *Wall Material* characteristic is listed in Table 11. Only building characteristics listed in Table 10 were used in the assessment of strength.

Points for each characteristic were skewed according to the weightings in Table 10, and added together to give an overall score for each building. The scores were then grouped into four groups: A, B, C and D. The number of buildings in Port Vila within each class is shown in Table 12.

Class A included 5.3% of all buildings; primarily commercial and industrial buildings, public safety and health services buildings. Class B buildings (58.8%) included nearly all houses with concrete block walls, as well as commercial buildings not included under A. Class C (33.9%) incorporates most houses with other wall materials. Class D, with the buildings assessed as weakest, only included 2% of the total, and largely consisted of sheds and open shelters.

Table 10: Building characteristics used to assess cyclone resistance and their weightings

Characteristic	Weighting
Main use	0.25
Wall material	0.20
Windows	0.20
Roof material	0.15
Roof shape	0.10
Roof pitch	0.10

Table 11: Points assigned to the Wall Material characteristic

Wall material	Points
Concrete	8
Metal	7
Bricks	6
Timber	5
Fibre-cement sheets	3

Table 12: Strength classifications for Port Vila buildings

Classification	Number of buildings	Percentage of numbers	Percentage of value	Scale factor (m/s)
Class A	254	5.3	20	70
Class B	2,822	58.8	52	65
Class C	1,629	33.9	27	60
Class D	98	2.0	1	50
Total	**4,803**	**100**	**100**	**-**

Derivation of Vulnerability Curves – By Strength Class

The derivation of vulnerability curves for wind storms has been discussed by Leicester et al. (1979), Holmes (1996), and Walker (1995). A vulnerability curve describes the relationship between fractional damage i.e. the fraction of the value of the building, as a function of the peak wind gust at the site, or in the vicinity of the building.

Leicester *et al* proposed a vulnerability curve consisting of straight line segments with break points corresponding to the initial onset of minor damage, and the onset of major damage (damage index of 0.2). Walker proposed vulnerability relationships for Queensland buildings consisting of two power law functions added together. However, these curves do not smoothly transition to full damage (damage index of 1.0) at the high wind speed end.

The vulnerability curves derived for this study are continuous functions of wind speed, and smoothly transition from 0 to 1 with increasing gust wind speed. They are based on the

Weibul function, usually used for probability distribution functions for the strength of structural elements. This has two parameters : a shape factor, k, which determines the general shape of the curve, and a scale parameter, c, with units of wind speed, which determines the position of the curve on the wind speed axis. A shape factor of 8 was used for all the curves proposed for this study. This value gives a curve which has a generally similar shape to that proposed by Leicester *et al*.

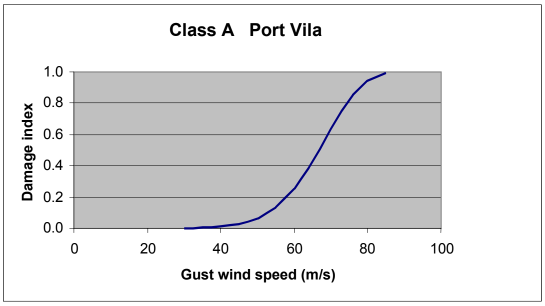

Figure 51: Vulnerability curve for Class A buildings.

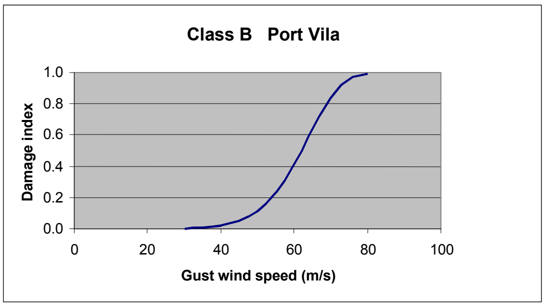

Figure 52: Vulnerability curve for Class B buildings

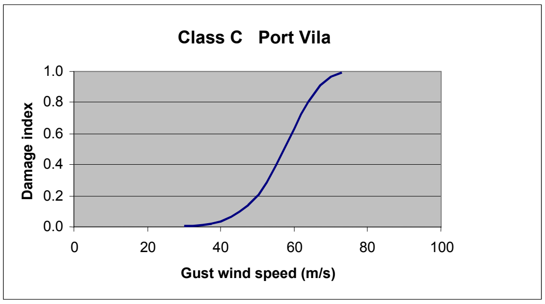

Figure 53: Vulnerability curve for Class C buildings

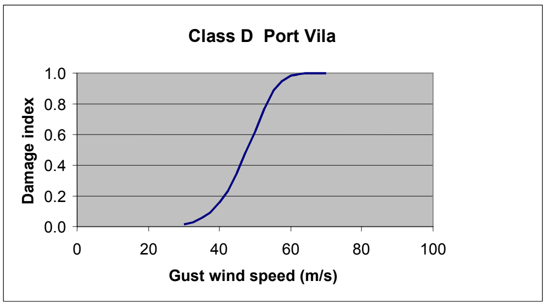

Figure 54: Vulnerability curve for Class D buildings

At the wind speeds corresponding to the scale factor, a damage index of 0.63 is obtained. The scale factors are based on the performance of buildings in Tonga in Cyclone Isaac in 1982, but with a reduction in the expected damage for Classes B and C, based on the descriptions of building practices in Fiji and Port Vila supplied to JDH Consulting. Figures 51-54 show the damage curves for the four building classes.

Topographic Wind Model

The risk model developed for wind damage at Port Vila, Vanuatu gives estimates of the damage to be expected in the city as a function of the local gust wind speed at each site. If the city were located in flat uniform terrain, this damage could be related directly to recorded gust wind speeds at the airport anemometer. The latter can be related directly to the simulated gradient (mean) wind speeds generated by the GEMS Cyclone model. However topography will affect the situation in two ways:

- Large scale topography of the order of the height of the atmospheric boundary layer, and with a width exceeding that of the city area, may affect the overall level of wind speeds in the city, and
- Local topography may affect local gust speeds on a site by site basis, and differently for different wind directions.

Both these aspects are considered for Port Vila and Vanuatu in this report, although the second aspect is treated in more detail.

Large-scale Topographic Effects

The large-scale effects of the approximately 600 m peaks of the volcanoes of Efate island (Figure 55) on winds from tropical cyclones are quite difficult to estimate. Clearly there will be some shielding of Port Vila by this topography. Peaks of this height exceed the height of the over-ocean boundary layer at the centre of a tropical cyclone, and it is likely that topography of this height will change the dynamics of the cyclone itself.

The aerodynamic effects of the large-scale topography of Efate island could be investigated successfully by means of wind-tunnel testing. This technique has been used for Hong Kong Island for example. Some examples of this type of wind tunnel testing is described in Leicester et al. (1979).

A rough indication of the effect of topography on cyclonic winds can be indicated by the measurements carried out in Hong Kong during Typhoon York in 1999. Measurements at Central Plaza, which is sheltered from southerly winds by The Peak, showed about a 14% reduction in mean wind speed compared with those at the exposed Waglan Island (Holmes 1996). However it is not clear that measurements were at equivalent heights above the ground.

A reasonable estimate of the effect of the high topography of Efate Island on northerly winds would be a 15% reduction. This can be taken as applicable to the quadrant from north-west to north-east. Figure 55 also shows overall directional reduction factors applied for wind direction between 270 through 360 to 110 degrees.

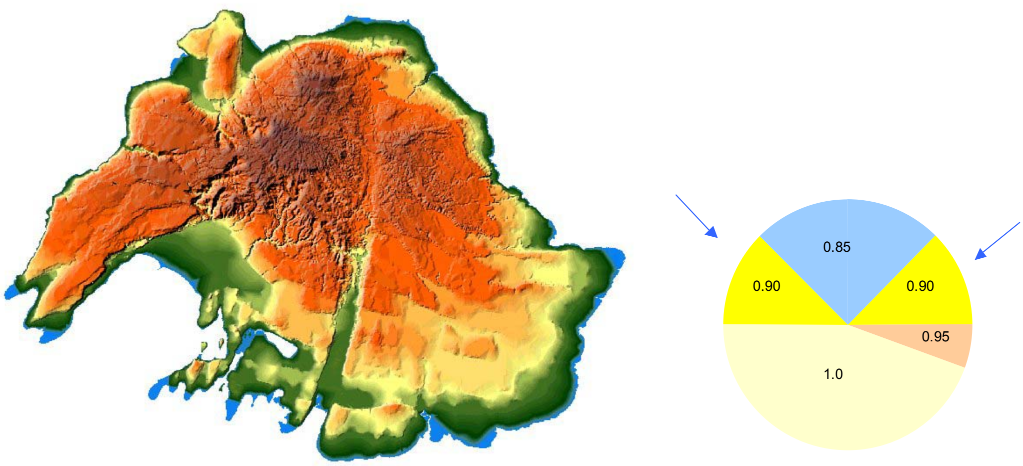

Figure 55: Topographic shielding reduction factors as a function of wind direction

Small-scale Topographic Effects

The land elevations in Port Vila range between a few metres to about 100 m, above sea level. In the north part of the city, some of the slopes can be quite steep, apparently rising 50 m in a distance of 100 to 200 m. The slope of the land upwind of a site is a major factor in determining the speed-up effects on wind speeds. The maximum speed-up is achieved for an upwind slope of about 0.3. Above that slope, the flow separates and the magnitude of the speed-up is limited (Kumar 1987).

The following procedure was used to assess the small-scale topographic effects in Port Vila and Mele Bay:

- The matrix of 1 kilometre squares of the city and its environs were labelled A to D running from west to east, and 1 to 10 from north to south (Figure 56). A smaller matrix labelled E-F/1-2 was created for the Mele Bay assets.
- An average Topographic Multiplier, defined according to the Australian Standard for Wind Loads (Kumar 1987), was estimated for each designated square and for each of four principal wind directions. The technique relates the gust wind speed at a typical building height of 4 metres to that at the airport, representing flat, open terrain.
- The average gust speed in each square was related to the gust speed at the standard meteorological height of 10 m at the airport, through a simple conversion factor for the height change. This also incorporated terrain roughness effects.
- The average gust wind speed within each kilometre square was related to the mean (time-averaged) gradient wind speed at an elevation of 100 m, or greater.

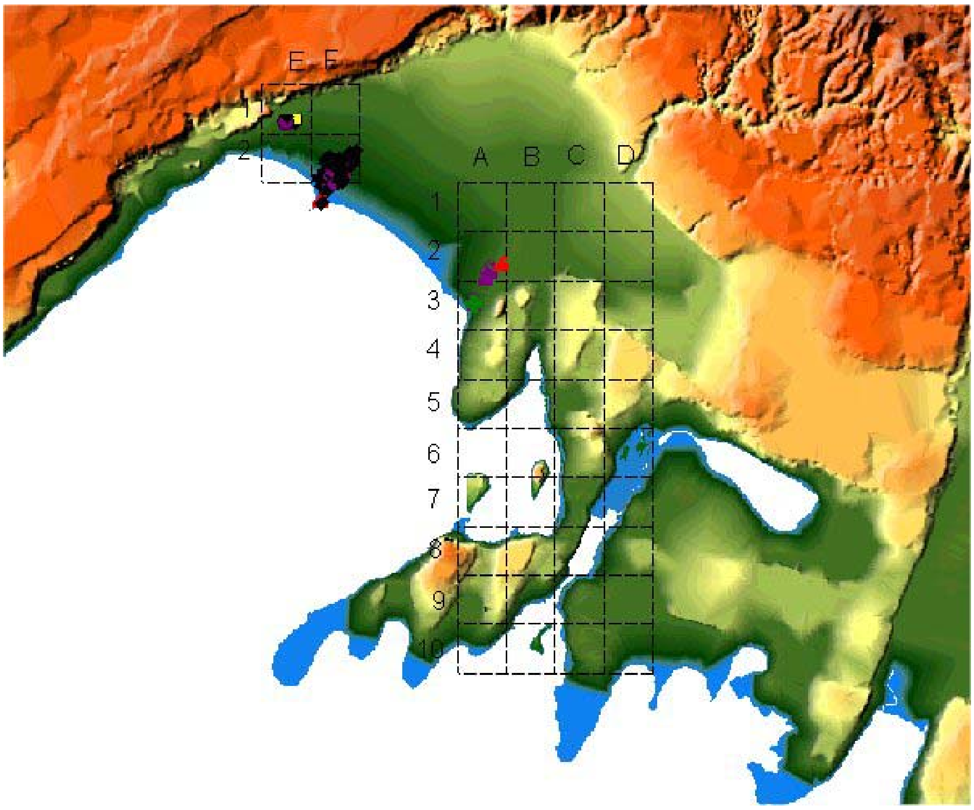

Figure 56: Topography of Port Vila and designation of one-kilometre squares

Topographic Multipliers have been developed for the Port Vila grid, relating average gust speeds within each square at 4 m height to that at the same height at the airport. It should be noted that, for any given wind direction, the wind speeds can vary considerably within any given square. For example, it will be highest near the crest of a hill or at the edge of a cliff or escarpment, and fall away both upwind and downwind. These represent no more than estimated average values, with higher and lower values expected within any given square.

It should be noted that the non-dimensional multipliers for topography and height change are not sensitive to the general level of wind speed, and are applicable in all stages during the passage of a cyclone.

Correction For Terrain Roughness Effects

For the squares with the greatest building density within Port Vila, there will be a reduction in the expected peak gust due to the modification of the cyclonic boundary layer by the roughness of the terrain, i.e. the upwind buildings. This effect is greater the longer the 'fetch' length of rough terrain. In this case, there is a significant reduction due to this effect for north and south winds for squares C3 to C8 in Figure 56. Smaller effects have been assessed for other squares and wind directions.

The reduction is determined as follows. Interpolation of the terrain-height multipliers in the Australian Standard for Wind Loads (Kumar 1987) for Terrain Categories 2 and 3 at 4 m according to distance was carried out according to an exponential adjustment with a distance constant of 2 km. This adjustment rule was derived from wind-tunnel tests at Monash University and is reported in the Commentary to the appropriate Australian Standard. The resulting multipliers for terrain effects are tabulated and are given as 2-second gust multipliers at 4 m within each square as a ratio to the 10 m gust multiplier in Terrain Category 2 - assumed to be the appropriate one for the airport. The default value in this table for no terrain roughness effects is: 0.93.

Correction For Height Of Airport Gust

In Table 12, the ratios of the average 2-second gust speeds in each kilometre square, incorporating both topographic and terrain effects, to the gust wind speed at 10 metres height at the airport have been calculated. These ratios are derived from the corresponding values in Table 10, simply by multiplying by the values in Table 11. For squares not affected by terrain roughness effects, the factor is 0.93 (Kumar 1987). For squares and wind directions affected by terrain roughness effects, the multiplying factors are lower in Table 9.

Gradient Wind Multipliers For Cyclones

To determine the multiplier to convert the gradient (mean) wind as calculated from numerical models of tropical cyclones, to airport wind speeds, it is first necessary to calculate the conversion factor for mean wind speeds over flat terrain at the surface. An average value of 1.60 for the gust factor, at 10 metres in standard flat terrain (airport), was used for the present calculations.

Conclusions

The effects of the small-scale topography of Port Vila on cyclonic wind speeds for four directions has been investigated, in order to estimate multipliers to convert the gust wind speed at the airport, to equivalent conditions at each site within the city.

Multipliers to convert the gradient wind speed in tropical cyclones to the gust wind speeds at the airport, and at each site within the city of Port Vila have also been derived

The large-scale effects of the volcanic peaks to the north of Port Vila on cyclonic winds have been estimated approximately. More accurate determination of these effects can be achieved with small-scale wind tunnel tests, as has been done with Hong Kong and Hawaii, for example.

Economic Model – Asset Values

In order to estimate damage levels in monetary terms, it was necessary to develop an economic model for the value of assets in the study region. At this stage, the economic model is limited to the replacement value of buildings in the asset list supplied by SOPAC.

Replacement values have been computed for the 4,976 buildings listed in the Port Vila and Mele Bay regions. These are shown earlier as Table 4, and have been based on estimates of floor area for each building and estimates of the unit area replacement value for across the four building classes. In most cases, the floor area was provided as an estimated range and the mean value of the range was taken to estimate the replacement values.

Replacement cost estimates were provided by Risk Management Pty limited and Aon Insurance. The Risk Management estimates included the cost of demolition of damaged buildings; these values, expressed as cost per square metre for each of the four building classes were used as benchmarks for the modelling.

The number of individual buildings assigned to each Class A-D, and the computed total value of all buildings included in the study is shown earlier in Table 5.

Scenario Modelling

The economic modelling, though relatively simple, included a process to estimate the effectiveness of insurance. This was achieved by considering the behaviour of an “insurance” pool under varying scenarios and averaging over random samples of one hundred year periods.

The pool algorithm was defined as:

$$\text{Pool} = \text{Pool} + \text{ROI} - \text{CapCost} - \text{DamLoss}$$

were ROI, Return on Investment is based on a designated investment rate,

Cap Cost, Capital Cost based on an interest rate on any capital borrowed to cover damage losses and DamLoss is the loss due to wind storm. This algorithm was computed in annual increments, based on random cyclone behaviour over 100-year periods.

The model allows for variations in premium rates (expressed as a percentage of replacement value), variation in capital cost (also expressed as a rate of interest); it also allows for changes to the vulnerability of assets through the vulnerability curves to allow for building upgrade or replacement.

Model Integration - Overview

The physical and economic models were integrated so as to provide estimates of damage (in percentage and dollar terms) for each building asset for any specified storm. The individual damage levels can also be integrated to provide total damage estimates.

The integrated model can be applied to actual storm events or for storms generated synthetically to represent the long term cyclone climatology of the region.

Verification – Tropical Cyclone Uma

The integrated wind storm damage system was tested against Tropical Cyclone Uma which impacted Efate in February 1987.

The track of TC Uma is shown in Figure 57. The storm passed just to the west of Efate, so that its region of maximum winds directly affected the island. Maximum wind gusts for the storm there were estimated at 120 knots (60 m/s).

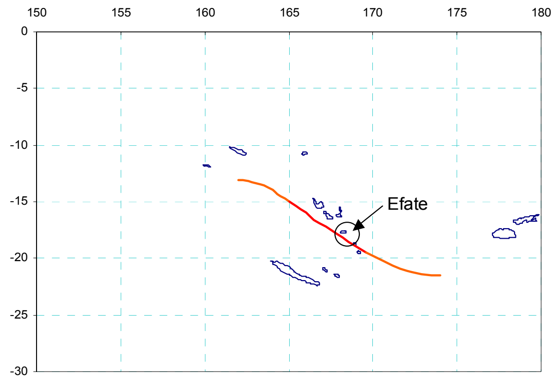

Figure 57: Track of Tropical Cyclone Uma

The lowest pressure recorded at Port Vila was 957 hPa and the maximum sustained wind was estimated at 75 knots - the anemometer at Port Vila was destroyed by the cyclone winds.

The GEMS cyclone model was run based on the track details supplied with a radius of maximum winds set to 30 nautical miles. The 'B' parameter was adjusted so that minimum pressure obtained at Efate was close to the observed value of 957 hPa. The wind field around the storm as it passed Efate was illustrated earlier in Figure 50. Figure 58 shows the spatial variation of modelled peak wind gust speed.

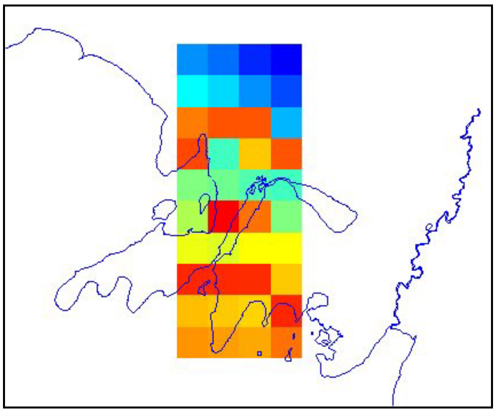

Figure 58: Spatial variation of peak wind gust speed in TC Uma

Table 13 gives the damage levels for Uma across the four building classes and in total in percentage and absolute dollar terms. The total estimate for the buildings included in the study, around AUD$115 M, compares with the actual total damage.

Table 13: Model damage estimates for Efate – TC Uma

Building Class	Damage (%)	Damage (AUD$M)
Class A	8.8	6.2
Class B	13.5	63.9
Class C	23.7	41.2
Class D	70.2	3.5
All	15.2	114.8

The model was also tested against Tropical Cyclone Prema which passed close to Efate in 1993. This storm was more intense than Uma but appears to have been a much smaller cyclone, with a relatively small radius of maximum wind. The model predicts damage of the order of five per cent, but there was little observational (wind) data so that modelling the storm itself was somewhat problematic.

Results – Damage Frequency

A statistical climatology of tropical cyclone events based on historic records back to 1950 was used to generate random events in a cyclone modelling system run for storms equivalent to 5,000 years. A topography-wind model was set up and a damage-loss analysis was carried out, using wind speed-damage vulnerability models developed specifically for building classes in Port Vila. The loss analysis was calibrated using Cyclone Uma.

The results for each storm expressed in terms of both absolute dollars and percentage of total value were aggregated in terms of return periods. It should be noted that these results are subject to the accuracy of the estimates made for floor areas and relative replacement values.

By applying the wind and vulnerability models over a large number of cyclone events, the results could be integrated to estimate the levels of damage expected for Port Vila in the future and the relative frequency of occurrence of those damage levels. Table 14 gives the overall estimates for the Port Vila building data set included in the study. The model was re-run to measure the potential benefit of upgrading and retrofitting Class B and Class C buildings with the results also shown for comparison.

Table 14: Overall Efate damage estimates for current state of building assets and for upgraded assets

Recurrence Interval (Years)	Damage (%) Current	Damage (%) Upgraded
10	< 0.1	< 0.1
25	1.1	0.7
50	8.2	5.9
75	18.0	15.0
100	28.5	21.6
450	65.0	55.0
1000	81.8	72.5

Damage levels were also computed for each of the topographic 42 wind zones imposed over Port Vila. Damage levels are calculated for each building class for recurrence intervals of 50, 100, 450 and 1,000 years. The relative differences between the cells largely reflect the topographic/terrain differences between locations. The model was also used to estimate the frequency (recurrence interval) of levels of damage, expressed as percentage of buildings damaged to a particular damage level. For example, 10% of Class A buildings would be impacted to a level of 50% damage once every 455 years but, in contrast, Class C buildings would experience the same level of damage more frequently - every 88 years - underlining the importance of raising building standards.

The total of expected losses to buildings and infrastructure combined might be more than AUD$260 M in the 100-year event cyclone. The 100-year event has about a 50:50 chance of occurring in a 70-year lifetime.

Storm Wave Risk-Loss

Cyclone Beni, a Category 4 event with central pressure down to 920 hPa, struck Port Vila a glancing blow on 30th January 2003, causing damage to buildings and installations on the Port Vila foreshore, particularly in the northern part of the central business district. The damage was widely attributed to storm surge although studies carried out by GEMS for SOPAC showed the surge effect was minimal compared to the impact of waves generated by the tracking of the storm towards Port Vila. An extreme scenario developed from Cyclone Beni and shifted eastwards to pass closer to the city was used to examine the potential for surge and wave damage. Storm surge was found to have minimal effect partly because of the steeply shelving island margins. Storm waves however are predicted to cause overtopping of sea walls and minor flooding and damage to harbour-side hotels, restaurants and buildings as foreshadowed in Beni. This finding highlights the need for better urban planning and setback provisions in the city. Minimal flooding is expected in the peri-urban settlements at the head of Mele Bay during extreme wave events generated by tropical cyclones.

Wave Run-Up

From the modelling of inshore wave heights described in the hazards section, wave run-up height above mean sea level (Figure 59) has been estimated for each of the modelled cyclone conditions by applying the formulae for run-up to the various upper beach-face grades in the five areas under consideration (see Figure 18). This run-up will occur on top of the notional still-water level (SWL) that includes both tide and storm surge components.

The effect of beach-face grade upon wave run-up is significant, and a relatively small flattening of the beach profile will result in a decline in the run-up level. This is a natural response of a beach system, where the beach face changes conditions from reflective during low-energy, to dissipative during high-energy.

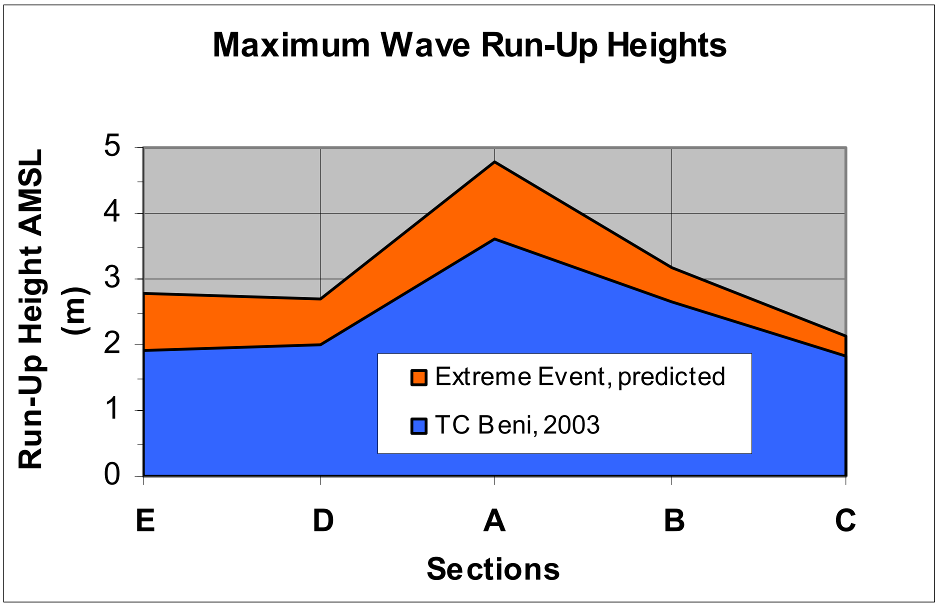

Figure 59: Maximum wave run-up heights above msl from TC Beni and predicted during an extreme event

For Sections B and C in the CBD waterfront area, wave-overtopping formulae were applied to the situation there (vertical walls) for the modelled wave conditions. Permissible levels for overtopping depend upon the level of access and use, and are defined for situations where there are pedestrians, vehicles or buildings involved. Methods to estimate a safe distance behind the vertical wall are not well established, and can only be inferred from wave transmission tests. Applying these methods to Section B, a 15-m setback is estimated for the level of a TC Beni event, and a 25-m setback for the case of the extreme event. However, it is necessary to recognise the uncertainty associated with these estimates, and for practical purposes, setback distances should potentially be doubled. The requirement for volume overtopping on structural stability of the seawall is 50 l/s per m if the promenade is unpaved, and 200 l/s per m if the promenade is paved. Given the relatively narrow nature of the bituminous paving at the back of Port Vila Harbour seawall, it is likely that mild damage may be experienced in the event of the extreme event for Section B where the unpaved limit would be exceeded. Damage is anticipated to include scour behind the bitumen and some potholing across the pavement.

Applying the wave run-up formulae to Section D at Blacksands, total run-up levels are estimated as 2.0 m and 2.7 m above msl for the TC Beni and extreme cases respectively. The upper level of the beach face is estimated to be 1.7 m above msl with the roadway at 2.0 m above msl. Consequently, the roadway at the northeast corner of Mele Bay is expected to be safe under TC Beni conditions, although possibly washed by several individual waves. Under extreme conditions, the scarp would be flattened, extending at the same grade as the beach towards the roadway. For a 1 in 40 grade, a 0.4 m height difference would extend the beach crest 15 m shorewards.

At Section E near Hideaway Island, total run-up levels are estimated at 1.9 m and 2.8 m above msl for the Beni and extreme cases. Ground levels corresponding to this section are estimated to be roughly 1.0 m above msl, indicating that it will be heavily washed during the TC Beni case, and inundated during the extreme event. This will tend to scour the upper part of the beach face, causing a flattening of the profile.

It must be stressed that these theoretical erosion condition requires sustained wave and water levels, which is unlikely during a cyclone event. For a short-duration event, the observed retreat of the beach crest will be unaffected by the land level behind the crest. Observed erosion will also include a significant component due to long-shore transport, as noted previously. As the still-water level under extreme conditions is the same as the estimated land level, the tombola will be fully inundated.

The modelled results for specific locations around the Mele Bay-Port Vila Harbour area show that the low-level inundation that occurred during TC Beni was almost certainly associated with very large waves rather than storm surge as such. Wave run-up was found to have significant impact on beaches at the Mele sites and these results can probably be reasonably extrapolated along the Mele Bay shoreline.

Potential Damage

The extreme event case showed that higher levels of run-up and potential for beach erosion; and some low-level inundation could be expected to impact on buildings or other assets close to the shoreline. The results suggest that such wave events do not of themselves present a major safety danger to the village communities. The results for Mele indicate that an impact line be established to at 3.0 m above mean sea level, and that some further buffer for error, may be applied.

At Port Vila, the impact of Beni was to cause inundation of the shore front to the north of the CBD and over-topping of the main sea wall. Further southwards, towards the port, wave action is attenuated by the protective influence of Ifira island.

For the more extreme event, both run-up and beach erosion and overtopping are likely to cause some problems, and would probably result in at least minor structural damage to the wall itself. More importantly, over-topping rates for the extreme event suggest the need for set-back constraints for buildings in this area. Reported incidences of impacts to the Hotel Rossi and the Chantilly development during TC Beni would seem to confirm these calculations. A setback of between 25 m and 50 m along the shore line in northern Port Vila has been suggested for extreme events.

In an earlier section, asset losses during an extreme storm surge (and storm wave) event to infrastructure including seawalls, wharves, bridges and roads were estimated as almost AUD$1.5 M. However, the vast majority of these losses were anticipated as damage to goods potentially stored at the main wharf. Overall, the risk of loss from storm surge or storm wave remains insignificant.

Earthquake Risk-Loss

Figure 60: Structural damage to reinforced concrete Museum building during 2002 earthquake

A large proportion of the structural damage that occurred in the 2002 Port Vila Earthquake (Figure 60) was due directly to design inadequate for the situation of Port Vila. Lessons from the 2002 earthquake also show that buildings on thick alluvial deposits, reclaimed land, or high ridges and plateaus can be expected to experience even higher intensities than on sites with rock foundations.

Using the experience of past earthquakes, the Mean Damage Ratio (MDR) experienced for Port Vila appears to coincide approximately with the curves developed on the basis of reported MM intensities for buildings generally designed to about 0.12 *g* (12 %) base shear (Tiedemann 1992; pp. 483-486) for moderately irregular buildings founded on medium-hard alluvium. This is, of course, an average across a wide variety of structural types in Port Vila. This relationship is similar to the Percent Damage-MM Intensity curve developed by Blong (1992) for (mainly reinforced concrete) buildings in Port Vila other than timber and un-reinforced brick.

On the basis of this assumption and given the assessment of the total value of buildings in Port Vila the Annual Probability-Loss relationship curve has been developed (Figure 61). Blong concludes that it would be prudent to regard the Port Vila area as having the potential for large, infrequent but damaging earthquakes.

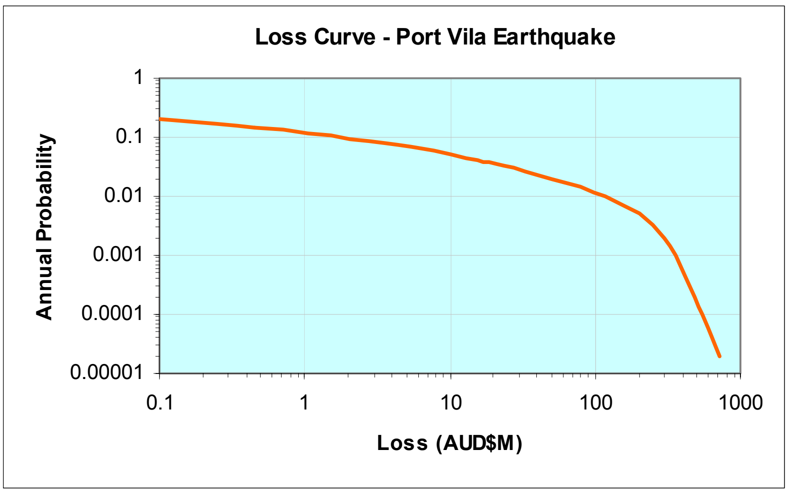

Figure 61: Loss curve for Port Vila city and peri-urban area showing the annual probability of exceedance

The maximum anticipated earthquake for the Vanuatu archipelago is M_w 8.1 and shocks of this size occur in the wider Vanuatu region, usually along the New Hebrides Trench to the west of the Group, with a return period of less than 100 years. Closer to home, a series of uplifted coral terraces on the western side of Mele Bay indicate there has been a Richter Magnitude 7.5-8 event in the near vicinity of Port Vila every 1,000 years on average, lifting the area by 1-2 m each time. The 1000-year event has about a 5% probability of occurring within a 50-year time-frame.

The earthquake that hit Port Vila on 2nd January 2002 - the largest since 1927 - caused great consternation and around AUD$15 M in losses to the city including widespread minor structural damage to buildings and the destruction of a 3-storey secondary school (Figure 62) and Government office block, and a vital highway bridge, as well as blocking the port access road by major landslides for several weeks.

Figure 62: Structural failure of the lower floor of a 3-storey school classroom building during 2002 earthquake

The Teouma Bridge (Figure 63) was destroyed as a result of a rotational failure of the abutment fill and foundation which in turn disrupted the bridge abutment and the deck.

Figure 63: Failure of Teouma Bridge on the eastern access to Port Vila during 2002 earthquake

There are several key bridges (Figure 64) on the two main roads into Port Vila, a hillside pass and the main port road adjacent to unstable land that have high likelihood of failure in a future catastrophic event, effectively limiting access to Port Vila to inter island shipping only.

Figure 64: Failure of bridge approach embankment on western access to Port Vila during 2002 earthquake

The stability of part of the main airport runway is also in question in the case of very large earthquake. This threat to major infrastructure from landslide and ground failure is seen not only as a potential major cost item in future catastrophic earthquakes, but also as severe restriction to rapid post-event recovery (see Appendix 1 for details).

The loss curve of Figure 61 predicts that the 100-year earthquake would cause some AUD$117 M damage to buildings in Port Vila and its peri-urban settlements, while infrastructure losses are expected to add another AUD$32 M, for a total of AUD$150 M losses. The 500-year event (10% probability in 50 years) might result in damage of AUD$330 M. On this scale, it's obvious that the 2002 Port Vila earthquake was a relatively small event - causing losses of only 1.3% of all assets - that can be expected to recur frequently.

Tsunami Risk-Loss

The Pacific Disaster Center (PDC), Hawaii collaborated with SOPAC to demonstrate a methodology for assessing flood losses to selected buildings in the Port Vila and Mele areas from an earthquake-generated tsunami. PDC engaged an expert in tsunami modelling for the task and carried out a risk-loss analysis using the modelled scenario. The full reports can be found in Appendix 4 and 5.

Animations of the tsunami impact on both Port Vila Harbour and Mele Bay are provided on the accompanying CD.

Introduction

In order to anticipate the impact of the tsunami hazard, the PDC team implemented a Risk and Vulnerability Assessment (RVA) methodology, which is applicable to a variety of natural and human-induced hazards for providing quantitative assessments of potential impacts of disasters. This methodology can contribute significantly to mitigation and response planning thereby avoiding and/or offsetting the effects of potential disasters. In order for this methodology to be successful:

- A comprehensive understanding of the risk is required.
- Knowledge of appropriate physical models must be applied.
- Robust and applicable data and information resources appropriate to predictive models and analytical methods must be acquired.

Applications of predictive modelling, high performance computing, geographic information system (GIS) resources, scientific visualisation and animation provide a very powerful capability for assessing the potential impact of hazards on built environments.

The Method of Splitting Tsunami, Mofjeld (MOST) model was used to simulate tsunami evolution in both the Port Vila Harbour, and Mele Bay, and to estimate the maximum inundation based upon a hypothetical earthquake event. The model uses the shallow water wave formulation, as well as three nested grids of different resolutions (ie 10 km, 4 km, and 5 m) to simulate the tsunami evolution from the deep-water tsunami source area to the shallow water depths of Port Vila Harbour and Mele Bay. The narrative that follows describes tsunami wave behaviour for Port Vila Harbour only, and summarises the detailed explanation under *Tsunami Hazard*.

Based on the analysis of the model output, the tsunami begins to evolve shortly after the earthquake and reaches Port Vila Harbour about 10 minutes later. The first wave to reach the harbour is a small negative wave, originating from the subsidence of the tsunami source. This is typical for earthquakes in subduction zones. As a result, the tsunami starts at Port Vila as a withdrawal of water from the harbour through a relatively narrow entrance. The first positive wave enters the Port Vila Harbour approximately 14 minutes after the generation of tsunami. A computer animation created for this project illustrates the computed tsunami evolution in Port Vila Harbour. The simulation shows very strong currents at both entrances around the island of Ifira while the water is flowing into Port Vila Harbour. The inundation of this shoreline starts 17 minutes after the earthquake. At the same time, the simulation shows violent flooding of the shallow northern part of the harbour. The maximum computed inundation is about 200 m beyond the shoreline. The model described earlier shows continuous complex wave dynamics inside Port Vila Harbour with a series of waves continuing to enter the harbour to cause repeated flooding of already inundated areas.

Tsunami Flood-Loss Analysis

The flood loss analysis utilized the model-generated inundation results, SOPAC supplied building inventory data and the building replacement cost to determine the numbers of selected building classes (A, B, C, and D) within the Port Vila and Mele inundation zones, and to estimate the flood losses and flood states for those building classes. Table 4 provides a brief description of the building-class classifications used.

Flood states represent the level of flooding (eg. low, medium, and high) and are specified for each selected building within the inundation zone. The low flood state represents water heights of 0.25-2.75 m, the medium flood state represents water heights of 2.75-4.25 m, and the high flood state represents water heights in excess of 4.25 m (Table 15).

Table 15: Flood states representing the level of tsunami flooding above natural ground level

Flood State	Minimum Water Depth (m)	Maximum Water Depth (m)
Low	0.25	2.75
Medium	2.75	4.25
High	4.25	-

Additionally, the analysis makes three assumptions:

- Any class A, B, C, or D buildings within the inundation zone are destroyed (probably and extreme assumption in the case of multi-storey reinforced concrete buildings).
- The building replacement cost includes the cost of demolition and debris removal.
- Replacement cost is based on the building class and floor area, shown in Table 4.

Port Vila Inundation Zone

Much of the central business district of Port Vila lies less than 10 m above sea level and there is much in the way of high value commercial and business investment at street level and up to first-floor level where a maximum tsunami is expected to impact (Figure 65).

Figure 65: Parts of the Port Vila central business district in the potential inundation zone

The class A, B, C, and D buildings identified within the Port Vila inundation zone are shown in Figure 66. The dark blue line in that figure denotes the maximum tsunami run-up, which extends up to 200 m beyond the shoreline. Water height is predicted to rise up to 6 m above mean sea level.

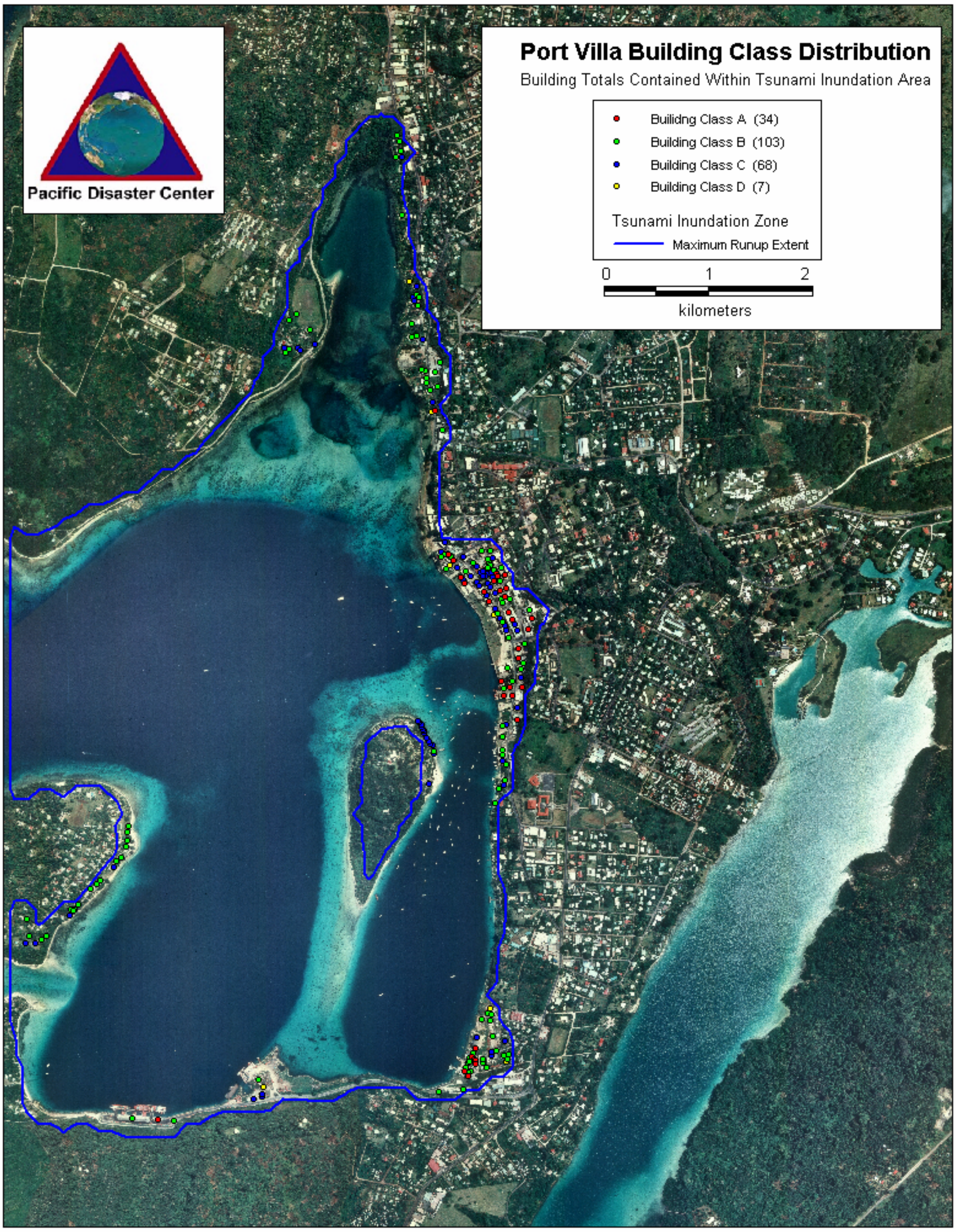

Figure 66: Distribution of inundated building classes in Port Vila

Tables 16-18 display the building count information, building floor area, and loss estimates for the Port Vila area. Tables 19-21 show the same information for the Mele area.

Table 16 shows the number of A, B, C, and D buildings located within the Port Vila tsunami inundation zone in each of the three flood states. In addition, this table shows the percentage of A, B, C, and D building classes for each flood state. Based on the table, there are a total of 212 buildings within the inundation zone of which 34 (16%) are A buildings, 103 (49%) are B buildings, 68 (32%) are C buildings, and 7 (3%) are D buildings. The B and C buildings account for 81% of the total buildings.

Table 16: Port Vila flood state by building class

Building Class	Low Flood State		Medium Flood State		High Flood State		
	Count	%	Count	%	Count	%	Total Count
A	6	8.2	19	20.0	9	20.5	**34**
B	44	60.3	47	49.5	12	27.3	**103**
C	19	26.0	26	27.4	23	52.3	**68**
D	4	5.5	3	3.2	0	0	**7**
Total	**73**	100.0	**95**	100.0	**44**	100.0	**212**

Table 17 shows the number and flood area of class A, B, C, and D buildings located within the tsunami inundation zone by flood state. In addition, this table provides the total area for each building class in square meters. According to the table, the 212 buildings occupy a total floor area of 27,750 m^2 of which 5,700 m^2 (21%) are class A buildings, 13,125 m^2 (47%) are class B buildings, 8,450 m^2 (30%) are class C buildings, and 475 m^2 (2%) are class D buildings. The class B and C buildings account for 77% of the total floor area.

Table 17: Port Vila flooded area by building class

Building Class	Low Flood State		Medium Flood State		High Flood State		
	Count	Area	Count	Area	Count	Area	Total Area m^2
A	6	1,650	19	3,100	9	950	**5,700**
B	44	5,300	47	6,200	12	1,625	**13,125**
C	19	1,775	26	4,075	23	2,600	**8,450**
D	4	275	3	200	0	0	**475**
Total	**73**	**9,000**	**95**	**13,575**	**44**	**5,175**	**27,750**

Table 18 shows the flood losses in AUD$ by building class, count and expected losses. The loss values were calculated by simply multiplying the respective areas listed in Table 17, by the replacement cost estimates in Table 4. From the table, losses total AUD$36,592,000 and, of those losses, 19% are building class A, 53% are building class B, 27% are building class C, and 1% are building class D. The class B and C buildings account for 80% of the losses.

Table 18: Port Vila flood losses in AUD$ by building class

Building Class	Building Count	Losses AUD$
A	34	6,840,000
B	103	19,293,750
C	68	10,140,000
D	7	318,250
Total	**212**	**36,592,000**

Port Vila Tsunami Losses - Summary

Port Vila was struck by a significant tsunami 15 minutes after the M_w 7.1 earthquake of

January 2002. The observed effect at the shoreline varied across the harbour (Figure 67), reaching a maximum peak-trough height of 3 m near Ifira island according to eyewitness reports (Figure 68). The tsunami fortunately occurred almost coincident with a spring-low tide so that flooding of the city area was narrowly averted by a matter of hours. If at the time there had been a spring-high tide, the height observed at the Waterfront Bar close to the city indicates that the central business district would have been flooded with more than 1 m of water, moving with considerable force.

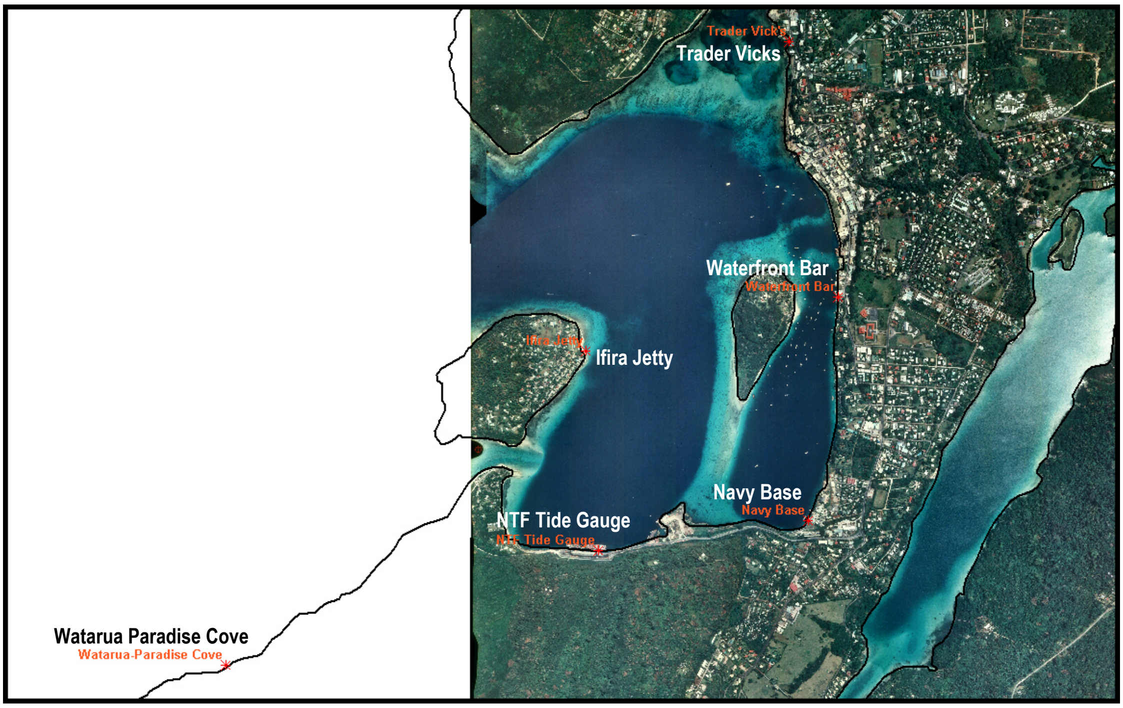

Figure 67: Observation localities for January 2002 tsunami, Port Vila Harbour

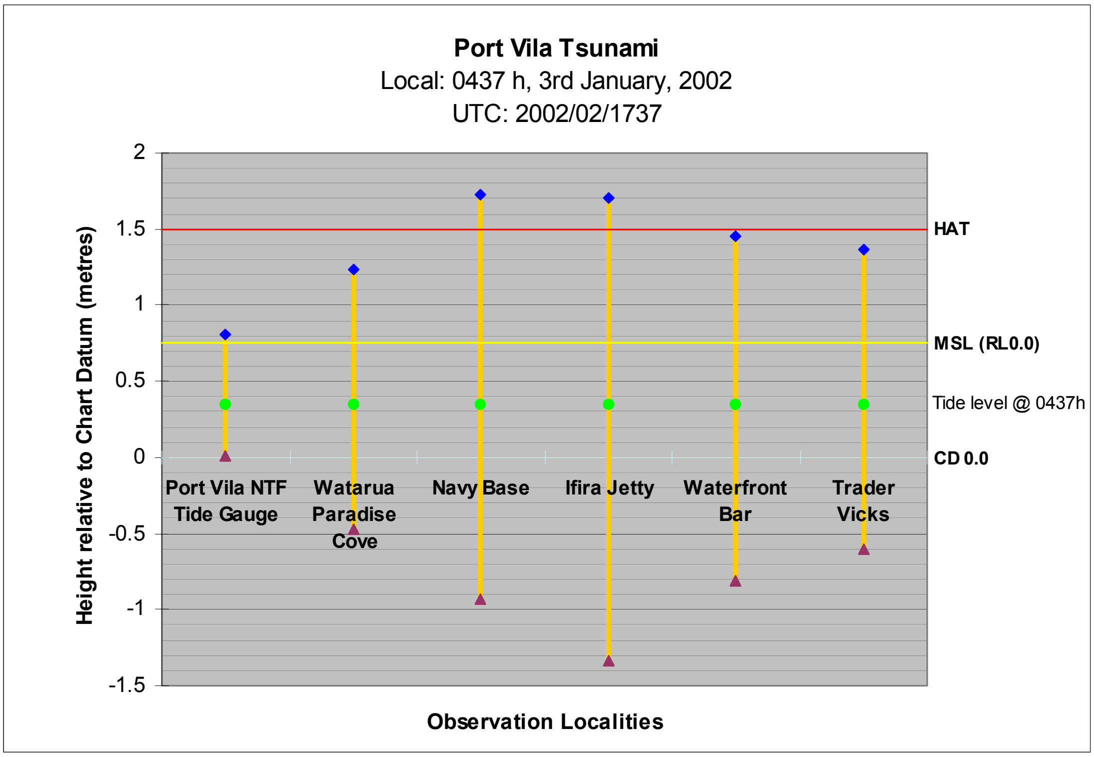

Figure 68: Eyewitness observation accounts of peak-trough wave heights in the January 2002 tsunami

A maximum-likely tsunami scenario was developed for Port Vila generated from a hypothetical M_w 8.1 earthquake in the same location as the January 2002 event, 50 km west of the capital, and equivalent in magnitude to the largest earthquakes recorded in the region to date. The probability of occurrence of the tsunami event has not been calculated but it is arbitrarily assumed to be an order of magnitude lower than the return period of the M_w 8.1 earthquake in the region. The location of the hypocentre of such an earthquake and its proximity to Port Vila, the actual mechanism, orientation and rupture area of the tsunamigenic fault, and the tsunami travel-path are all critical variables that introduce such uncertainty.

In this worst-case scenario, it's anticipated that 212 buildings would be inundated around Port Vila Harbour, and flood states representing the level of flooding have been specified for each building within the inundation zone. The tsunami is expected to cause at least 8 m vertical inundation in places. Altogether some 28,000 m^2 of mainly commercial floor space would be impacted and inundated to some degree, causing anticipated losses of more than AUD$37 M, including losses to infrastructure.

Mele Bay Inundation Zone

A similar analysis was carried out by PDC for inundation by the same event at the head of Mele Bay, but with the important distinction that, in this case, a limited sample only of the buildings was considered. A sample of the styles of buildings to be found in the Mele Bay inundation zone is illustrated in Figure 69.

Figure 69: Styles of buildings in the potential Mele Bay inundation zone

Figure 70 shows the class A, B, and C buildings which were actually sampled within the Mele Bay inundation zone (there were no class D buildings sampled in Mele). The dark blue line denotes the maximum tsunami run-up, which extends up to 2 km beyond the shoreline.

Tables 19-21 display the building count information, building floor area, and loss estimates for the Mele Bay area. Table 19 shows the number of sampled A, B, C, and D buildings located within the Mele Bay tsunami inundation zone in each of the three flood states. As for Port Vila, the low flood state is set at water heights of 0.25 m to 2.75 m, the medium flood state denotes water heights of 2.75 m to 4.25 m, and the high flood state represents water heights in excess of 4.25 m. This table also shows the percentage of sampled A, B, C, and D building classes in each flood state.

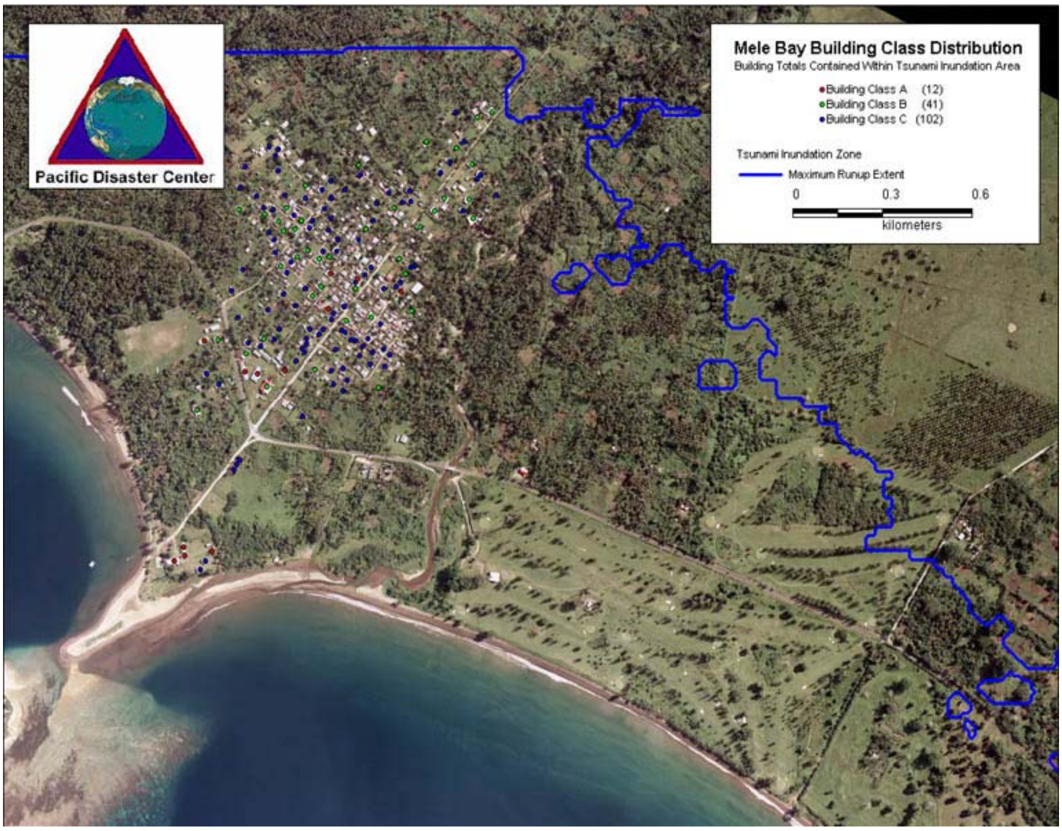

Figure 70: Distribution of inundated building classes in Mele (surveyed buildings only)

As indicated in the table, a total of 155 buildings were sampled within the Mele inundation zone, 12 (8%) of which are building class A, 41 (26%) are building class B, 102 (66%) are building class C, and 0 (0%) are building class D. Class B and C buildings account for 92% of all buildings.

As there are some 1,540 buildings in the Mele, Maat and Blacksands settlements, the sample of 155 buildings can be considered as representing a 10% sample of the area.

Table 19: Mele Bay flood state by building class

Building Type	Low Flood State		Medium Flood State		High Flood State		
	Count	%	Count	%	Count	%	Total Count
A	0	0	4	4.2	8	25.0	**12**
B	13	48.1	23	24.0	5	15.6	**41**
C	14	51.9	69	71.8	19	59.4	**102**
D	0	0	0	0	0	0	**0**
Total	**27**	100.0	**96**	100.0	**32**	100.0	**155**

Table 20 shows the number and flooded area of class A, B, C, and D buildings located within the Mele tsunami inundation zone by flood state. In addition, this table provides the total area for each building class, calculated from the original survey database. The table shows that 155 buildings occupy a total area of 21,672 m^2, of which 13% are class A buildings, 32% are class B buildings, and 55% are class C buildings. No class D buildings were surveyed here. Class B and C buildings account for 87% of the total floor area.

Table 20: Mele Bay flooded area by building class

Building Class	Low Flood State		Medium Flood State		High Flood State		
	Count	Area	Count	Area	Count	Area	Total Area m^2
A	0	0	4	662	8	2,126	**2,788**
B	13	2,078	23	3,392	5	1,447	**6,917**
C	14	1,568	69	8,366	0	2,033	**11,967**
D	0	0	0	0	0	0	**0**
Total	**27**	**3,646**	**96**	**12,420**	**32**	**5,606**	**21,672**

Table 21 shows the Mele Bay flood losses in AUD$ by building class and flood level. The loss values were calculated by multiplying the respective areas listed in Table 20, by the replacement cost estimates for the Port Vila area shown in Table 4. As indicated in Table 21, total calculated losses are almost AUD$28 M, of which 12% losses are building class A, 36% are class B, 52% are class C, and while none are recorded here for class D. The class B and C buildings account for 88% of the losses.

Table 21: Mele Bay flood losses in AUD$ by building class

Building Class	Building Count	Losses AUD$
A	12	3,345,600
B	41	10,167,990
C	102	14,360,400
D	0	0
Total	**155**	**27,873,990**

A surveyed sample of 172 buildings (including Class D buildings) suggests that the comparative percentage distribution of building classes in both the Port Vila and Mele area is represented by the distribution shown in Table 22.

Table 22: Comparative distribution of building classes in the Mele Bay and Port Vila area

Building Class	Mele Bay % Assets	Port Vila % Assets
A	12	5
B	22	59
C	52	34
D	14	2
Total	100	100

Mele Bay Tsunami Losses- Summary

According to PDC, more than 1,500 buildings - almost all in the peri-urban area fringing Mele Bay - are prone to inundation by the maximum-likely tsunami. As the buildings considered in Table 22 represent only a 10% sample, and given that almost every building at the head of Mele Bay is inundated by the scenario event, the implication is that expected losses for this area might be approximately 10 times that shown, or around AUD$280 M.

However, a closer re-assessment of the size of building footprints using the Port Vila Pacific Cities GIS database indicated that the floor areas for the Mele Bay buildings were, on average, only 50-60% of the figures provided to PDC in the original survey database. In that survey, building floor area was calculated by the surveyor on the ground from estimated building dimensions and placed in one of several standard size ranges. Later calculations required averaging of these ranges, leading to inaccuracies in the final calculations.

Furthermore, while the per square metre replacement values determined for Port Vila might serve adequately for the main city area, it is difficult to justify those same building costs in the informal peri-urban settlements. It was estimated that the true Mele Bay replacement values are probably only around 60-65% of the Port Vila values. As a result, the total replacement costs calculated above should in fact be reduced to around 30-40% of those shown in Table 21. The total expected losses for the area would probably then be no more than AUD$80-100 M.

In this worst-case scenario, it’s anticipated that the several entire villages and settlements at the head of Mele Bay would be destroyed with potentially staggering loss of life.

Local Vanuatu Insurance Perspective

A local insurance and reinsurance expert, Mr Kevin Lindsay of Auckland and Port Vila-based Riskman International Pty Ltd was engaged to summarise the state of development of insurance and related risk management efforts within the Government sector in Vanuatu, especially with regard to the Government Risk Management System (GRMS) which this particular company was instrumental in developing. The full report can be found in Appendix 6.

Outline

The brief of Riskman was to provide a local perspective on the current insurance position in Vanuatu, and particularly the degree to which private and Government risks were covered under existing insurance arrangements and provisions of all sorts. The expected outputs of this study were as follows:

- **Contents and Business Interruption Costs:** In addition to the table of building replacement costs already provided by Riskman, develop a complementary table of the relative value of typical loss of contents and business interruption costs in the context of Port Vila-Mele
- **Consequential Losses:** Prediction of the relative levels of loss to Vanuatu due to consequential risks following on from catastrophes such as temporary loss of tourism opportunities and damage to seaport or airport facilities in the Port Vila-Mele area, based on the current economic figures for Vanuatu
- **Contribution of the Peri-Urban Economy:** Assessment of the extent to which people living in peri-urban communities such as Mele, Blacksands, Ifira and Malapoa are engaged in the Port Vila city economy, and the extent to which a disaster that affects these communities is reflected in the national economy
- **Losses from Cyclone Uma, 1987:** Actual and relative figures for losses of all kinds, particularly in housing, public buildings and infrastructure, associated with TC Uma in February 1987
- **Losses from Port Vila Earthquake, 2002:** Actual and relative figures for losses of all kinds, particularly in housing, public buildings and infrastructure, associated with the Port Vila earthquake of January 2002
- **Cyclone Readiness and Engineering Compliance Provisions:** Summary of the current requirements of the Vanuatu insurance industry for cyclone-readiness inspections and engineering certificates to be issued for private housing and public buildings
- **Private Householders and Business Insurance:** Tabulation of the degree to which people from various communities and levels of society carry their own private/business insurance cover, and the amounts of cover adopted for various insured areas
- **Infrastructure, Utilities and Services Insurance:** Summary of the degree to which Vanuatu has privatised its utilities and essential services and an assessment of the insurance provisions made by those organisations against risk from major disasters.
- **Government Self Insurance:** Assessment of the value of Government assets that are at risk in the Port Vila-Mele area given that a significant proportion of infrastructure

is now in the hands of private organisations, and typical losses that might be faced in the event of catastrophic earthquake or cyclone events

- **Government Risk Management System:** Short history of the development of the Government Risk Management System (GRMS) together with a description of its importance in developing and instituting any national catastrophe insurance scheme, as well as an assessment of the success of the GRMS to date, and the factors affecting that success or otherwise
- **Capacity to Institute Disaster Insurance:** Analysis of the capacity of the Vanuatu Government to institute and support any catastrophe insurance scheme through either an insurance pool or a national disaster fund, or a combination of both

Contents and Business Interruption Costs

In addition to the table of building replacement costs already discussed, Riskman also developed a complementary table of the relative value of typical loss of contents and business interruption costs in the context of Port Vila-Mele as shown in Table 23.

Riskman also provided typical values for commercial rentals, stock values and business interruption losses insured in Port Vila in Table 24. The data from these two tables are summarised in Table 25. A summary of self-insurance provisions for a sample of 98 confidential business clients is shown in Table 26.

Table 23: Profile of building cost, rental income and the value of the contents (tenants) and tenants revenue/business interruption insurance in Port Vila (Values in Vatu: 75 Vt=1AUD$)

	Calculate per Square metre				
	1	2	3	4	5
Class A.	**Repl**	**Rent**	**Contents**	**Stock**	**BI/Revenues**
Lower limit	60,000	1,050	17,636	25,337	30,903
Best estimate	80,000	1,200	22,045	31,671	38,628
Upper limit	100,000	1,500	26,455	38,005	46,354
Class B.					
Lower limit	80,000	8,727	36,000	Domestic	
Best estimate	100,000	9,500	47,500	modelling only	
Upper limit	120,000	10,000	50,000		
Class C.					
Lower limit	60,000	8,727	36,000	0	
Best estimate	80,000	9,500	47,500	0	
Upper limit	100,000	10,000	50,000	0	
Class D.					
Lower limit	20,000				
Best estimate	40,000				
Upper limit	50,000				

Class A - the cost is about right for 1 or 2 storey buildings (no air con) but add 20% for commercial 3 storeys plus (no air-con).

All based on gross floor area.

1. Replacement cost including all professional fees such as Architects & Engineers
2. Estimated revenue from rent including insurance claim preparation fees
3.1 Estimated replacement value of all commercial contents including additional costs
3.2 Estimated replacement value of all domestic contents including additional accommodation
4. Estimated commercial stock
5. Estimated revenue stream earned by the occupier business

Table 24: Typical values for commercial rentals, stock values and business interruption losses insured in Port Vila (Values in Vatu: 75 Vt=1AUD$)

Class A **Notes**		
Commercial rent calculation assumptions upper average		
		P/sq m
On the main street		2,000 ground floor
On the main street over looking bay		1,500 second floor
Second street		1,500 ground floor
Second street no view of bay		1,000 second floor
		1,500 Upper average
Estimated replacement value of all commercial contents		
Based on a typical office business -		
real estate, accountant, solicitor, insurance, small business		
Contents - ffe, computers etc.	4,409,097	
	200	sq. meters average area
	22,045	
Stock	6,334,146	
	200	sq. meters average area
	31,671	
Business Interruption		
Average sum insured	7,725,688	
	200	sq. meters average area
	38,628	
Not included in the above modelling		
Special higher values for commercial businesses		
Estimated replacement value of all commercial contents		
Contents - ffe, computers etc.	48,798,667	
	500	sq. meters average area
	97,597	
Based on a typical business -		
Merchandising, duty free		
Stock	42,750,000	
	500	sq. meters average area
	85,500	
Business Interruption		
Average sum insured	76,608,729	
	500	sq. meters average area
	153,217	
Not included in the above modelling		
Big ticket items such as Government, Unelco, Telecom		

The data from Table 23 and 24 are summarised in terms of AUD$ in Table 25 below.

Table 25: Values of commercial property, contents and revenues in Port Vila (Values in AUD$: 1AUD$=75 Vt)

Business Premises Values ($AUD)	Replacement Value Per m²	Rent Per m²	Contents Per m²	Stock Per m²	Business Interruption Per m²	Total Value Per m²	Total Value 200 m² Premises	Total Value 500 m² Premises
Best Estimate Small Professional Office Business	1,067	16	294	422	515	**2,314**	**462,784**	
Best Estimate Large Commercial Firm	1,067	27	1,301	1,140	2,043	**5,578**		**2,788,760**

Riskman also provided a summary of self-insurance provisions for a sample of 98 business clients in Table 26.

Table 26: Summary of self-insurance provisions for a sample of 98 business insurers

Strictly confidential source

SAMPLE 98 insured business clients

CLASS Buildings, Contents, Stock, Business Interruption

CURRENCY Vatu

RANGE		NO OF CLIENTS	TOTAL SUM INSURED	AVERAGE SUM INSURED
0	5,000,000	**10**	25,576,964	2,557,696
5,000,001	10,000,000	**6**	48,300,000	8,050,000
10,000,001	15,000,000	**15**	119,517,000	7,967,800
15,000,001	20,000,000	**10**	168,953,000	16,895,300
20,000,001	30,000,000	**13**	328,799,000	25,292,231
30,000,001	45,000,000	**13**	475,918,000	36,609,077
45,000,001	80,000,000	**14**	796,480,000	56,891,429
80,000,001	100,000,000	**6**	539,860,000	89,976,667
100,000,001	200,000,000	**6**	850,122,200	141,687,033
OVER	200,000,001	**5**	2,234,210,000	446,842,000
		98	5,587,736,164	
Comments				
Clients including business Interruption		**31**	**32%**	
Clients including building cover		**69**	**70%**	
Clients excluding buildings		**21**	**21%**	

The data from Table 26 are represented in graphic form in terms of AUD$ in Figure 71 below.

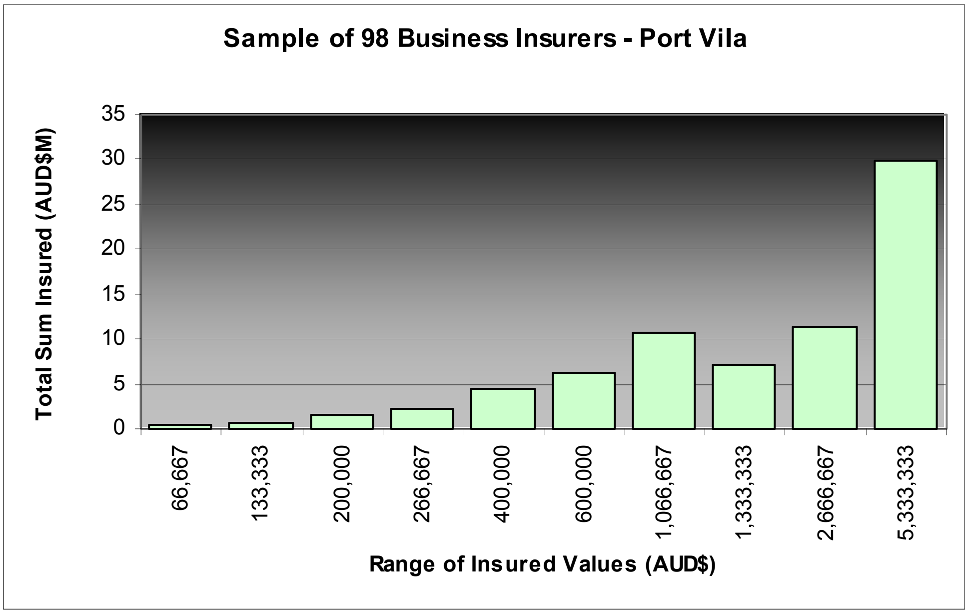

Figure 71: Total Sum Insured: Sample of 98 business insurers in Port Vila

Consequential Losses

Riskman provided a prediction of the relative levels of loss to Vanuatu due to consequential risks following on from catastrophes such as temporary loss of tourism opportunities and damage to seaport or airport facilities in the Port Vila-Mele area, based on the current economic figures for Vanuatu

The most representative example to study that may give a clue to such losses is Cyclone Uma which hit Tafea, Shepherds and Efate in February, 1987. The recent earthquake in January 2002 also provides a glimpse into what could be a devastating outcome.

Cyclone Uma had a destructive effect on agricultural crops and infrastructure. In the Port Vila-Mele area certain sectors, for example Government infrastructure and tourism, suffered major physical and business interruption loss.

In the context of insurance, business interruption (BI) responds to reduction in turnover plus increased costs of working (*eg.* alternative premises), less any savings in standard charges (*eg.* electricity, wages) arising out of a claim under the property insurance policy. Some BI is not usually insured e.g. tourist reduction. Therefore while it can be assumed that insurance will make a major contribution there are uninsured losses to be taken into account. For some 12 months after Uma, tourist arrivals were down. In other sectors such as construction and some professional sectors like accountants, activities increased significantly.

Cyclone Uma had a severe impact on the Government's finances in the form of lower revenue and higher expenditure. There were immediate supply shortages following Uma and prices increased by 17.5%. The fiscal deficit in 1987 increased to Vt797 million (AUD$10.6 M) from Vt635 million (AUD$8.5 M) in 1986. A Vanuatu Reserve Bank report in 2000 reported that the trade deficit had widened to as much as Vt279 million (AUD$3.7 M), due to the high number of imports to accommodate the reconstruction following Uma.

Real economic growth in the 1987/88 period stagnated around 0.6-0.7% see chart below (Figure 72). However, in terms of GDP, the economy in Vanuatu did not show a decline. On the contrary, it grew moderately. The year 1989 saw a recovery of income from tourism and copra with increases of 37% and 35% respectively.

Figure 72: Real percentage growth in Vanuatu GDP in period 1980-1999 in relation to effects of TC Uma, 1987

With respect to temporary loss of tourism opportunities and damage to seaport or airport it may be useful to use Cyclone Uma as a guide. In the event of another such disaster:

- There would be a sudden dip in National balance of trade.
- Property loss and consequential loss would be high. The period of interruption would range from 3 months to 18 months. In some cases business would not survive.

Some uninsured losses are what could be described as "sleeping" since they are dictated by insurers by way of deductibles or specifically excluded property. This is a sensitive area that deserves closer examination in the future through the Department of Statistics and the Department of Economics and Finance and with major infrastructure organisations such as Telecom and UNELCO.

Riskman has developed a matrix of describing insured and uninsured losses and this, or something similar must be developed with the sectors and ideally coordinated through the Government Risk Management Committee.

Contribution of the Peri-Urban Economy

Riskman also provided and assessment of the extent to which people living in peri-urban communities such as Mele, Blacksands, Ifira and Malapoa are engaged in the Port Vila city economy, and the extent to which a disaster that affects these communities is reflected in the national economy

Discussions with the Government Statistician indicated that contributions from these areas to the Port Vila economy can be viewed on two main levels:

- "Subsidence contribution" up to approximately 22% of agriculture: Supply of fresh vegetables and fruit to the hospitality sector and the main market.
- Buses, taxis, labour to the service and industry and manufacturing sectors.

The Department of Statistics provided statistics on the populations in the peri-urban areas around Port Vila (see *Population and Demographics*). Although an assessment of the extent to which disasters that affect these communities might be reflected in the national economy was sought from the Department of Economics and General Finance, none was forthcoming.

Losses from Cyclone Uma, 1987

Riskman, in cooperation with Cunnighams of Brisbane, provided actual and relative figures for losses of all kinds, particularly in housing, public buildings and infrastructure, associated with TC Uma in February 1987 (Table 27). After Cyclone Uma hit there were approximately 12 loss adjusters engaged in a variety of insurance assessing for a period of 3 months. Cunninghams was involved with about 70% of the insured losses assessed.

A preliminary discussion puts the insured losses of the private sector due to Uma at around AUD$25 M. It is unknown what sums were born by the private sector but estimates placed this somewhere in the vicinity of AUD$5 M or higher. Unfortunately much of this detail is based on memory and is not completely accurate. After 15 years, all records of claims have been destroyed. The excesses applicable, or even the exact number of claims are now uncertain, but it is believed there were more than 700.

It was also estimate that Government infrastructure was damaged to about AUD$25 M. Recollections were that Public Works buildings were severely damaged and it was over 4 years before PWD had proper accommodation again. It was generally considered that the demise of Public Works had quite a negative impact on the economy. It is essential for PWD to be able to operate effectively immediately after a devastating loss. It was considered ironic that even after such an experience a new PWD administration building was built without cyclone shutters.

While there is no doubt the insurance market coped with the loss there was significant loss of cyclone insurance capacity immediately following the cyclone. For example QBE Insurance, at the same time as discharging their liability under their policy, also cancelled all further cyclone cover.

Many insurance companies withdrew from the market *eg.* Vanuatu General, Sun Alliance, National Pacific, and American Home. The world's largest broker, Marsh also withdrew. Although the cyclone had some influence on their decision, other commercial considerations were also a major factor. Immediately following Uma the only insurance market available to local business was the London market. Most of the domestic properties remained uninsured against cyclone for several months. This had the effect of increasing the exposure of the banks that had loans over the properties. Local insurance intermediaries placed policies into the London market.

Within 12 months local insurers regrouped and subject to new cyclone criteria agreed to insure buildings, contents and business interruption against cyclone.

Table 27: Insurance claims related to TC Uma, Vanuatu, 1987

Cyclone "Uma", Vanuatu 1987					
Summary		Total	Number	2 largest commercial claims	
	AUD$	claims	of claims		
Commercial		$15,000,000	214	Buildings	$1,000,000
Domestic		$5,785,714	500	Contents	$400,000
Marine		$7,142,857	50	Stock	$100,000
Government		$25,000,000	0	BI	$500,000
Total		**$52,928,571**	**764**	**Total**	**$2,000,000**
Commercial					
Buildings		$8,571,429			
Contents		$2,857,143			
Stock		$714,286			
BI		$2,857,143			
Total		**$15,000,000**	**214**		
Domestic/Rentals		Total	Number	2 largest domestic claims	
		claims	of claims		
Buildings		$4,285,714		Buildings	$150,000
Loss Rents		$714,286		Loss Rents	$10,000
Contents		$714,286		Contents	$50,000
Temporary Acc		$71,429		Temporary Acc	$0
Total		**$5,785,714**	**500**	**Total**	**$210,000**
Marine		Total	Number	2 largest marine claims	
		claims	of claims		
Ships		$5,714,286		Ships	$250,000
Cargo		$714,286		Cargo	$100,000
Pleasure boats		$285,714		Pleasure boats	$50,000
Other		$428,571		Other	$0
Total		**$7,142,857**	**50**	**Total**	**$400,000**

Losses from Port Vila Earthquake, 2002

Riskman was also asked to search out actual and relative figures for losses of all kinds, particularly in housing, public buildings and infrastructure, associated with the Port Vila earthquake of January 2002

Two loss-adjusting firms, Cunninghams of Brisbane, Australia and McLarens of Fiji have been engaged in the assessing and adjusting. McLarens have been involved with about 80% of the insured losses assessed. The remedial work, under the supervision of McLarens has been more or less continuous through to December 2002. Table 28 shows their estimates of losses and damage.

Table 28: Estimates of insured and uninsured damage from January 2002 Port Vila Earthquake

Estimated Damage	AUD$
Total insured commercial claims	6,010,735
Total insured domestic claims	2,355,798
Insured damage	***8,366,533***
Total uninsured public buildings	1,000,000
Total uninsured infrastructure	1,000,000
Uninsured damage	***2,000,000***
Total damage	**10,366,533**

The response from QBE Vanuatu indicated that for reasons of commercial competition, it was prepared only to provide global costs of the earthquake claims on QBE, the amount being Vt300 million (AUD$4.0 M): As at the end of May 2002 the total was Vt326 million (AUD$4.3 M). However, as the repairs to premises are completed, they expect this may reduce slightly. QBD was not prepared to provide the splits requested between commercial material damage and business interruption plus uninsured losses and the domestic material damage and loss of rents.

Notwithstanding the above analysis, the generally accepted total damage figure at the time of writing approaches AUD$15 M.

Cyclone Readiness and Engineering Compliance Provisions

Riskman provided a summary of the current requirements of the Vanuatu insurance industry for cyclone-readiness inspections and engineering certificates to be issued for private housing and public buildings. In recognition of the highly damaging effect that cyclones can have, the Government of Vanuatu takes a high profile in its endeavours to educate and instruct the population on protective measures. There is extensive coverage in the local telephone book and there is an excellent warning procedure through the country's media. Radio New Zealand International (SW service) also includes cyclone-warning bulletins.

In 1990 the Vanuatu Government introduced a draft building code, which not only deals with cyclone standards (based on Australian Standard AS1170) but also earthquakes (based on the New Zealand standard). For commercial-occupation risk, insurers require the issuing of a compliance cyclone certificate by a local engineer and/or architect. This procedure is one that has evolved through the insurance market and has worked very well since. Legislation was to be passed in 2003 to take the draft code into law. In reality, the insurance market has policed the cyclone construction standards since Cyclone Uma.

There is a requirement for commercial buildings to have all ground and first floor glass shutter protected. Complying roller shutters are becoming more popular as they both look attractive and also provide security features. For residential properties, including private dwellings and rented premises in domestic occupation, local insurers have, as an interim procedure, adopted a questionnaire specifying construction methods (Figure 73). With the insurance market becoming increasingly selective, it is probable that Vanuatu domestic property owners will eventually have no option but to comply through an independent Engineers Report.

Cyclone questionnaire – complete one form for each House

Name: ______________________________

Address of property: ______________________________

Policy number: ________________

If the answer to any question is "No", cyclone insurance cannot be provided.

If the walls of your home are of Fibro, Iron or Timber, an Engineer's certificate must be attached stating the building meets AS 1170 standards.

Attached:

Yes/No

If the walls are concrete block, have they been reinforced with concrete and iron rods?

Yes/No

Are cyclone screws and washers, (No. 14, Type 17) used to secure the roofing material?

Yes/No

Are the screws used to secure the roofing material at no greater spacing than 550 mm?

Yes/No

Does the building have Shutters on all Windows and external Glass Doors? If of external plywood, are they at least 15 mm thick?

Yes/No

If of battens, are they at least 25 mm thick and no more than 25 mm apart?

Yes/No

Signed ________________________ Date ________________

Figure 73: Questionnaire on housing construction methods in Vanuatu

Private Householders and Business Insurance

Riskman was also requested to provide a tabulation of the degree to which people from various communities and levels of society carry their own private/business insurance cover, and the amounts of cover adopted for various insured areas

The following tables (Tables 29 and 30) together with Figure 74 will be useful in developing models for the main city area of Port Vila. The sample taken by Riskman was of 254 policies in the Port Vila area including ni-Vanuatu and expatriate clients. Details are provided by value-band in the tables below.

Losses in Port Vila due to Cyclone Uma in February 1987 were poorly recorded and furthermore information held by the insurance industry was largely treated as proprietary. Records indicate that a minimum of AUD$53 M of insured and uninsured losses (including uninsured Government losses of AUD$25 M) were experienced in Port Vila although some estimates put the figure over AUD$100 M.

While the insurance market coped with this event, there was significant loss of cyclone insurance capacity immediately following the cyclone. QBE Insurance cancelled all further cyclone cover, four other smaller companies withdrew from the market and the world's largest broker, Marsh, also withdrew. Within 12 months, though, local insurers regrouped and, subject to new cyclone criteria, agreed to insure buildings, contents and business interruption against cyclone.

Currently, building owners in Port Vila are insuring business premises for loss of rental revenue as well as for building losses. The tenant businesses are insuring for loss of contents, commercial stock and business interruption to revenues at an average level slightly greater than the actual building property values. The typical small business and 200 m^2 premise has a total insured value around AUD$0.5 M, while a larger, commercial business and 500 m^2 premise would be insured for an average value around AUD$2.8 M.

A sample of almost 100 Port Vila businesses carrying over AUD$74 M against loss of buildings, contents, stock and business interruption, at an average cover of AUD$760,000, indicates that self-insurance provisions are generally adequate (see Figure 71). It is estimated that 80% of CBD businesses carry property insurance, and of those, about 40% would carry business interruption insurance. Most major business houses are well insured.

A recent sample of 220 residential insurers in Port Vila carried over AUD$35 M in home and contents with cyclone provisions covered for an average value of AUD$160,000 across the range shown earlier in Figure 75. A further sample of 34 residential insurers - but with no cyclone provisions - carried over AUD$3 M in home and contents insured for an average value of AUD$90,000.

While such samples are available to give an indication of the levels of insurance, it is difficult to grasp the full picture of private insurance due to client confidentiality and the reluctance of the insurance industry to divulge full details.

The actual terms and conditions provided by insurers vary widely. Discussion here relates to the situation at the time of writing. It’s important to note that the major insurer in Vanuatu, QBE Insurance, does not cover tsunami or flood events under their standard Domestic Specified Perils Policy. The standard Commercial Property and Business Interruption policy of QBE excludes physical loss, destruction or damage occasioned by or happening through flood or water from or action by the sea, tidal wave or high water unless there is an earthquake or seismological disturbance. This implies that tsunami in isolation is not insured unless it is able to be proved that a seismic event was in fact both responsible and recorded.

Cover granted by the QBE Hurricane, Cyclone, Storm & Water Tempest extension for both domestic and commercial policies specifically excludes any loss or damage caused by sea, tidal wave, high-water, flood, erosion, subsidence or landslip. Policies offered by Caillard Kaddour Insurance (CKI) Agents, through their London insurance market facilities, do include tsunami cover and do not have the exclusion noted above. It is estimated that CKI have about 25% of the property market insured.

It was estimated by Riskman that areas such as Mele would have less than 20% of buildings and contents insured, while noting that specific properties which qualify for a bank loan would be insured. It appears in general that the amounts of cover adopted by insurance buyers in Port Vila, though, is adequate, as evidenced by the reaction to the recent earthquake and the experience of Riskman over a significant time in Port Vila.

Table 29: Sample of 220 Home and Contents policy insurers *with* cyclone provisions in Port Vila

Strictly confidential source

Sample	220 insurance policies sampled
Location	Port Vila area
Class	Home & Contents with cyclone
Currency	Australian dollars

VALUE BANDS OF SUMS INSURED		NO OF POLICIES	TOTAL SUM INSURED	AVERAGE SUM INSURED	TOTAL PREMIUM	AVERAGE RATE
$10,001	$20,000	17	$269,135	$15,831	$2,613	0.971%
$20,001	$30,000	15	$394,120	$26,275	$2,453	0.623%
$30,001	$50,000	24	$926,664	$38,611	$6,203	0.669%
$50,001	$75,000	21	$1,355,067	$64,527	$7,515	0.555%
$75,001	$100,000	23	$1,941,513	$84,414	$11,252	0.580%
$100,001	$150,000	35	$4,451,448	$127,184	$26,334	0.592%
$150,001	$200,000	31	$5,570,467	$179,692	$32,508	0.584%
$200,001	$300,000	28	$6,872,267	$245,438	$40,586	0.591%
$300,001	$500,000	19	$7,334,160	$386,008	$42,672	0.582%
$500,001	$1,000,000	6	$3,603,314	$600,552	$21,011	0.583%
OVER	$1,000,000	1	$2,460,000	$2,460,000	$13,801	0.561%
		220	**$35,178,154**	**$159,901**	**$206,949**	**0.588%**

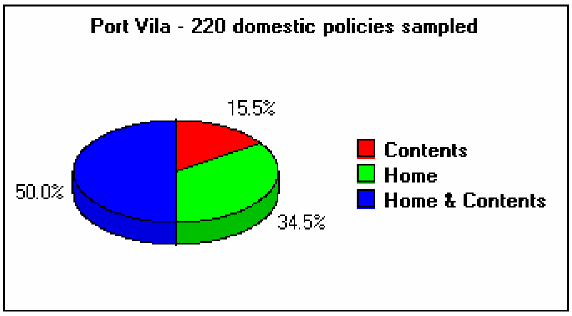

Figure 74: Pie chart showing distribution for the sample of 220 insurance policies in Port Vila

Table 30: Sample of 34 Home and Contents policy insurers *without* cyclone provisions in Port Vila

Strictly confidential source

Sample	34 insurance policies sampled
Location	Port Vila area
Class	Home & Contents without cyclone
Currency	Australian dollars

VALUE BANDS OF SUMS INSURED		NO OF POLICIES	TOTAL SUM INSURED	AVERAGE SUM INSURED	TOTAL PREMIUM	AVERAGE RATE
$0	$10,000	0	$0	$0	$0	
$10,001	$20,000	5	$77,227	$15,445	$533	0.691%
$20,001	$30,000	2	$48,000	$24,000	$227	0.472%
$30,001	$50,000	4	$135,818	$33,954	$641	0.472%
$50,001	$75,000	7	$376,800	$53,829	$1,556	0.413%
$75,001	$100,000	7	$599,533	$85,648	$2,716	0.453%
$100,001	$150,000	3	$386,667	$128,889	$1,110	0.287%
$150,001	$200,000	3	$506,733	$168,911	$2,008	0.396%
$200,001	$300,000	1	$249,333	$249,333	$587	0.235%
$300,001	$500,000	2	$680,000	$340,000	$2,824	0.415%
$500,001	$1,000,000	0	$0	$0	$0	
OVER	$1,000,000	0	$0	$0	$0	
		34	**$3,060,111**	**$90,003**	**$11,669**	**0.381%**

The data in Table 29 and 30 are summarised in graphical form in Figure 75 below.

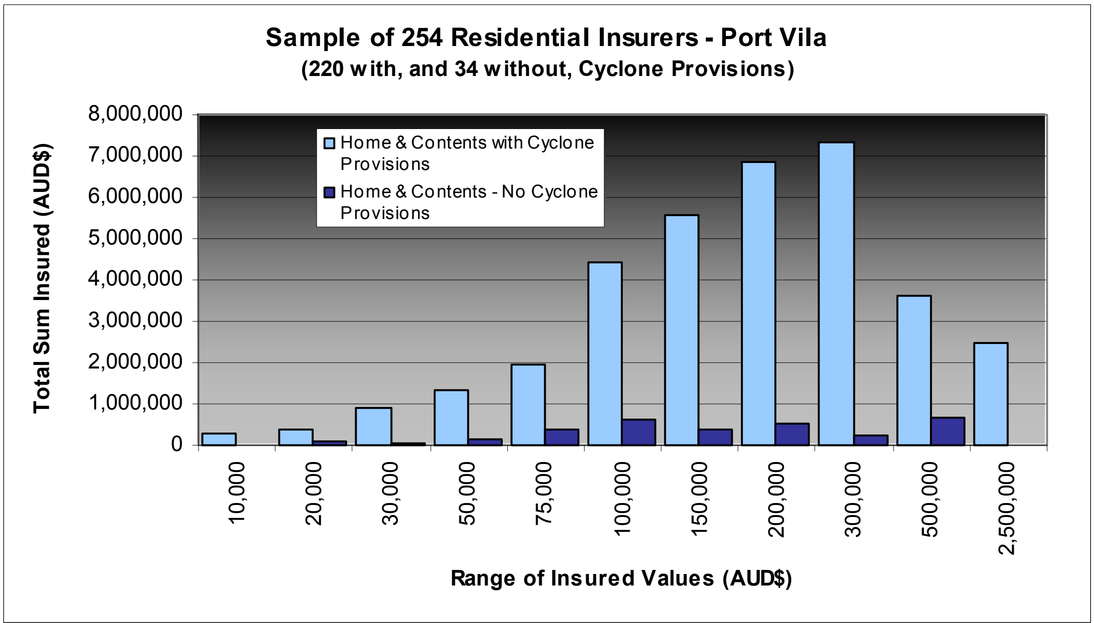

Figure 75: Total Sum Insured: Sample of 254 insurers in Port Vila, both with and without Cyclone Provisions

Infrastructure, Utilities and Services Insurance

The lessons of Cyclone Uma, and more recently the January 2002 earthquake, provide a glimpse of a possibly devastating outcome for Vanuatu in the future. Uma had a destructive effect on agricultural crops, while in Port Vila the Government infrastructure and tourism sectors suffered major physical and business interruption loss. Some business interruption such as tourist reduction is not usually insured. Therefore while it can be assumed that insurance will make a major contribution there are uninsured losses to be taken into account. For some 12 months after Uma, tourist arrivals were down, while activity in other sectors such as construction and some professional areas increased significantly.

Cyclone Uma had a severe impact on the Government's finances in the form of lower revenue and higher expenditure. According to the Vanuatu Reserve Bank, there were immediate supply shortages following Uma and prices increased by 17.5%. The fiscal deficit in 1987 increased to AUD$10.6 M from AUD$8.5 M in 1986. The trade balance deficit widened to AUD$3.7 M, due to the high number of imports to accommodate reconstruction. Real economic growth in the 1987/88 period stagnated around 0.6-0.7%. However, in terms of GDP, the economy in Vanuatu did not show a decline, but on the contrary, grew moderately.

Some uninsured losses are what could be described as "sleeping" since they are dictated by insurers by way of deductibles or specifically excluded property. This is a sensitive area that deserves closer examination in the future through the Department of Statistics and the Department of Economics and Finance and with major infrastructure organisations such as Telecom and UNELCO.

There is an imperative to develop a matrix describing all insured and uninsured losses through the various sectors and ideally a response coordinated through a Government Risk Management Committee.

Telecom Vanuatu Ltd (TVL) is reported to have an excellent insurance programme, and it appears that TVL could rely on insurance funding in the event of the catastrophic perils under discussion. In addition they have an impressive contingency plan with a containerised exchange that can be shipped in relatively quickly in emergencies.

Details of the insurance carried by UNELCO – the major suppliers of water and power – were not readily available. It appears that the main buildings, plant, and equipment including pump station are insured against cyclone and earthquake risks, although there may be some shortcomings in insurance of the water infrastructure area including storage tanks and reticulation. Although this fact in itself is not critical, it is important to know what the contingency plans are if these elements are destroyed and whether funds are available for their repair. It is not clear if tsunami risk is insured. UNELCO insurance is placed in the French insurance market where major perils are often excluded from policies.

The insurance arrangements for Air Ports Vanuatu Ltd (APVL) appear well intentioned but the risk financing strategy of APVL may be short of comprehensive. They reportedly have, relative to their cash flow and capital base, high amounts of retained risk both from choice, and as dictated to by the insurance market. Of the total amount at risk in airport assets and business interruption losses, APVL holds about two-thirds insured. The airport runway and associated business interruption costs, valued at a greater amount again, are uninsured.

The main concern should be that the quality and reliability of insurance carried by critical utilities like UNELCO or APVL does not impact negatively on Port Vila and its inhabitants in the event of a catastrophe. The answer may lie in a form of auditing; developing a database spread-sheet, conducting interviews, and viewing of insurance policies as well as assessing the financial strength of the insurers. Such a model could identify gaps in post-loss risk financing for essential services. The findings could be used in a database model to answer questions as to whether a catastrophe insurance fund should be made available to critical organisations in the same category as UNELCO or APVL if shortcomings cannot be solved by conventional insurance.

Government Self-Insurance

Riskman was further requested to provide an assessment of the value of Government assets that are at risk in the Port Vila-Mele area, given that a significant proportion of infrastructure is now in the hands of private organisations, and to estimate typical losses that might be faced in the event of catastrophic earthquake or cyclone events

The question is often posed as to the value of Government assets at risk from catastrophic earthquake or cyclone events in the Port Vila area given that a significant proportion of infrastructure is now in the hands of private utilities. Apart from the main wharf which is reportedly insured for replacement value (estimated at AUD$4.2 M), and the main Government computer system, the Government of the Republic of Vanuatu carries no conventional insurance: Revenues are not insured.

The Vanuatu Government Risk Management Committee, led by the Directors-General of Economics and Finance and Public Works, has the responsibility for ensuring that the community is not put at serious risk from a major catastrophe. The Committee members are required to develop a basic understanding of the hazard situation and provide input into risk management of the nation's assets to ward off concerns of havoc following a catastrophe.

Earlier work by Riskman International in Port Vila developed a matrix describing insured and uninsured losses as a precursor to the model that must be developed within the various Government sectors. This work needs to be coordinated through the Government Risk

Management Committee, because the crux of the risk issue can only be addressed once the Government actually identifies their assets and the corresponding values.

An indication of the recovery time to be expected following damage to major Government assets is given by the four years it took to re-establish the Public Works Department building after Cyclone Uma. Fifteen years on, damage to the main wharf storage shed as a result of Uma remains. Damage to the connections between the wharf access decks and the wharf platform proper, and settlement of the access areas during the January 2002 earthquake has not yet been repaired. Loss of the wharf access road remains a serious threat in view of the failures experienced in and above the roadway during that earthquake.

Government Risk Management System

Development of the Vanuatu Government Risk Management System (GRMS) concept occurred in the period 1991-4 in response to a conviction from some quarters that such a mechanism is an absolutely essential prerequisite for risk transfer – either on a large or small scale, and for either conventional or catastrophe insurance. It is just as relevant today and, in fact, critical to the mind-set needed to develop and institute any national catastrophe insurance scheme. The model adopted at that time envisaged that the Government should have complete knowledge of its own assets and fully understand the risks facing them. In the interim, the concept has largely fallen by the wayside. The GRMS is home-grown and based on first principles, including a grass-roots approach to understanding and managing risk in all its forms. It has the potential to succeed with good leadership and the funding for an independent arbiter to keep the project and leadership focussed. The success of a scheme of this nature would provide the underpinning for a catastrophe insurance scheme in Vanuatu and regionally. The background to the development and instigation of the GRMS in Vanuatu in the 1990s is summarised below in Table 31.

Table 31: Summary background to the development of the Vanuatu Government Risk Management System

- **Risk-Management Practice Awareness:** During 1991-94 the first Government Risk Management Committee became aware of the need to improve risk management practice relating to assets, revenues, liability and personnel
- **Anecdotal Evidence:** There were alarming examples of issues and losses of which the Committee was aware but was powerless to do anything about them
- **Localisation:** With the emphasis for localisation of Government posts, many of the experienced line managers within Government Departments left Vanuatu and were replaced by inexperienced staff
- **Disaster Management:** Without practising day-to-day risk management, it is almost impossible to effectively put into place disaster management practices as there is a lack of knowledge and skills in the Government management culture
- **Government as its Own Insurer:** Although the Government took out some insurance the majority of its risks were not insured. Given that the Government carried the majority of its own risks. it was imperative that it establish best risk-management practice
- **Risk Management Project Development:** The project development model involved collaboration with all Departments commencing with the design of a dual-language, comprehensive, 12-page, in-house risk audit/survey to be carried out across all Departments and Ministries in the understanding that Government risks are in the areas of assets, revenues, personnel, and liabilities.
- **Risk Management Project Implementation:** Tailored documentation was developed stating risk management policy and procedures. The outcome of the project was the Vanuatu Government Risk Management System – known as GRMS

The steps to development of a Government Risk Management System and the criteria for performance of such a scheme are summarised in Table 32.

Table 32: Government Risk Management System development and performance criteria

- Establish Risk Management **Policy**
- Establish a formal Government Risk Management **Committee**
- Facilitate all Departments and Ministries to identify **areas of potential loss** that can be incurred from a variety of risk sources, which may vary in frequency and severity
- Set Management **Performance Standards** to enable Management and supervising staff to measure Government employee performance to stated risk management standards
- The Government Audit Unit to **audit** its these standards
- Enable **co-ordination** of risk management between: Departments and Ministries; the Disaster Management Office; Police and VMF; Others as may be determined by the committee
- Provide a **framework** to enable Government staff to be trained in knowledge and skills that enable risk management to be practised at all levels in their Department or Ministry.

The advantages arising from a scheme such as GRMS for the national government in terms of Government financial management and interfaces with the wider disaster management community and the private insurance industry are summarised in Table 33.

Table 33: Outcomes and advantages of a National Government Risk Management System

- **Flexibility:** Provides a flexible framework for Departments to practice risk management, and to co-ordinate with similar activities across the entire Government
- **Leadership Empowerment:** Establishes leadership functions and empowers all Government employees with the knowledge and skills to successfully reduce potential exposures to a wide variety of losses, subject to appropriate training and follow through by the Directors-General
- **Efficiency:** Emphasises practical prevention and reinforces one of the key goals to improve efficiency. Emphasises that waste, and many of the embarrassing situations that Government officers find themselves in, can be avoided through best risk-management practice
- **Disciplines:** Brings together a range of disciplines that are universally practised at various levels and degrees of sophistication by every successful organisation, and links risk management with Government budgeting or legal processes
- **Interface:** Provides the interface with disaster management as well as providing for and explaining the interface with insurance.
- **Partnership:** GRMS pre-requisite is to address asset registers and post-loss objectives; address risk financing; address risk control; with the working layer retained by Government (self-insured), including a mix of conventional insurance together with a catastrophe insurance scheme

Capacity to Institute Disaster Insurance

Riskman was asked to provide an opinion on the capacity of the Vanuatu Government to institute and support any catastrophe insurance scheme through either an insurance pool or a national disaster fund, or a combination of both.

The view of Riskman was that, while in theory such a scheme could be developed, the evidence is that without a very big budget and fresh input of suitably experienced and qualified expatriate personnel such a pool would not be workable. A more likely approach to success would be sub-contracting out the fund to a private organisation to manage just as Riskman might do for its captive clients. Under this approach, settling of claims would follow the normal insurance industry model.

The conclusion is that without some major improvement in commitment from the stakeholders, it is difficult to see the vision of a successful Government Risk Management System, or pooled fund against catastrophes, coming to pass in the near future in Vanuatu.

Parallel Initiatives

Catastrophe insurance, and the broader issue of comprehensive risk management in the Pacific context is a subject that cross-cuts many different areas in a complex web of interactions. By dent of the fact that all risk management issues are eventually linked, many related initiatives in the Pacific, and internationally, are converging. A number of existing international projects already encompass a Pacific catastrophe insurance concept in their scope. The initiative by the Association of Small Island States (AOSIS) to develop through the United Nations Framework Convention on Climate Change (UNFCCC), very similar risk transfer and financing options, but specifically for climate-related disasters, is a case in point.

Typically, though, the web is so tangled that the involved government departments from the each country are drawn in different directions by various agencies promoting their own particular risk management initiatives in different sectors. Government departments in the Pacific Island Countries are poorly funded and manned and generally find it difficult to cope with the demands being made on them.

The fundamental issue is that both funding agencies and Pacific Island Governments alike need to recognise and act on the fact that all forms of risk management are linked, and all reach eventually to the highest decision-making bodies in the country.

To this end SOPAC has forged a path, demonstrating in practice within Vanuatu, as well as many other Pacific Island Countries, that there is indeed a comprehensive way of approaching the problem. The solutions rests not only with practical steps to reduce vulnerability such as the Pacific Cities project (Shorten 2002b), applications of earthquake engineering (Shorten 2003a) and urban preparedness and response initiatives (Barr 2001), but also with efforts of the SOPAC Community Risk Programme (SOPAC 2002; 2003) to take the issue to the highest levels of government. In addition, SOPAC has worked with UK DFID and the Vanuatu Red Cross Society in participatory community projects at the grass-roots level (Shorten & Schmall 2003) to develop concrete solutions to risk in marginal peri-urban communities of Port Vila, acknowledging that civil society organisations also have a critical part to play. Through its work, SOPAC has been able to provide key inputs to the directions of the United Nations International Strategy for Disaster Reduction (ISDR).

Three of the most significant international projects that relate closely to the catastrophe insurance initiative deserve special mention and are outlined briefly below.

Caribbean Disaster Mitigation Project (CDMP)

The present pilot project in Port Vila arises directly from the strategy of the World Bank to investigate the potential relevance of catastrophe risk management initiatives in the Caribbean to the Pacific region. The following description of the Caribbean project is largely extracted from (Vermeiren 2000).

The purpose of the five-year Caribbean Disaster Mitigation Project (CDMP) was to establish sustainable public/private disaster mitigation mechanisms that measurably lessen loss of life, reduce potential damage, and shorten the disaster recovery period. The project was completed in December 1999, but many of the activities and institutional arrangements that were pilot-tested and established under the project remain firmly in place.

One of the objectives of the CDMP was to promote natural hazard damage mitigation and the use of loss-reduction incentives in the Caribbean property insurance industry. Soon after its inception in 1993 the project assisted national insurance associations in several of the Caribbean states in organizing meetings and technical conferences to address issues facing the industry, and to explore how the industry could play a more effective role in reducing property risk in the region. Surprisingly little headway was made in mounting these joint efforts to improve the quality of risk assessment and underwriting until it was ascertained that the local insurance companies and agencies retain little of the risk.

The Caribbean property insurance industry is characterised by a proliferation of general agency units representing foreign companies sharing the market with a relatively small number of Caribbean-owned companies. Industry experts agree that the number of agencies and companies is disproportionately large for the small volume of property risk underwriting in the region. In addition, the portion of the catastrophe risk retained by the companies in the region is small, estimated at approximately 15 percent, with the remainder being ceded to re-insurers outside the region. As a consequence, competition for agency fees and reinsurance commissions tends to drive the underwriting practice, often at the expense of a sound appreciation of the underlying risk.

Rates for property insurance in the Caribbean started creeping up in 1989, triggered by reinsurance losses caused by several hurricanes and finally Hurricane Andrew in 1992 followed by winter storms in Europe. These events created an extremely tight reinsurance market in 1993 through 1994. Prices reached levels of 200-300% above those of 1989 and prior years. Several companies refused to extend coverage to the Caribbean, and those that did imposed a 2 percent deductible on the insured value. Primary insurers and agencies in the region, highly dependent on the re-insurers, had no option but to pass on the increases to property owners.

The dramatic increase in the cost of primary insurance generated widespread complaints from the housing and commercial sectors throughout the region. It also put a temporary hold on several large tourism and commercial projects under development. Responding to the concerns from key sectors, CARICOM heads of government first addressed the regional catastrophe insurance crisis in July 1993. A multidisciplinary Working Party on Insurance and Reinsurance was established in 1994 to explore potential actions by government and private sector to address the issues involved in maintaining adequate catastrophe insurance coverage in the Caribbean.

Late in 1994 the Organization of American States (OAS), as executing agency for the CDMP, on request from the CARICOM Working Party prepared a working paper on Catastrophe Protection in the Caribbean. The paper addresses industry performance, retention of risk at a regional level, and opportunities for reducing risk. The World Bank joined in this effort, specifically to study mechanisms to establish a regional catastrophe risk fund.

In 1996, the CARICOM ministers of finance endorsed the recommendations of the report which included:

- Improving financial management in the insurance industry, including increasing the minimum capital requirements.
- Strengthening insurance regulation and requiring companies to provide more timely, detailed, and accurate financial reports.
- Creating a regional reinsurance mechanism to increase risk retention, including arrangements to establish pre-event catastrophe reserves.
- Reducing risk exposure through disaster mitigation and vulnerability reduction programmes aimed at public infrastructure and residential properties.

By that time, however, new capital had entered the reinsurance market, and rates had come down somewhat, so that the political will to effect a stronger regulatory framework and more effective financial management and reporting faded away.

Nevertheless, one promising development subsequent to the completion of the Working Party report was the establishment of a Caribbean Association of Insurance Regulators, an institutional framework that could play a critical role in rationalizing the Caribbean insurance industry in the future. The CARICOM Secretariat called on the World Bank and the OAS to provide the technical assistance to implement the recommendations on establishing a regional reinsurance programme mechanism and strengthening disaster mitigation, and vulnerability reduction programmes.

The World Bank obtained internal funding to study the feasibility of a Caribbean Catastrophe Reinsurance Fund, using as a model the private-sector-financed funds in California and Hawaii. In carrying out the study, the Bank held regular consultations with Caribbean regional institutions and governments, in particular those of the Organization of Eastern Caribbean States (OECS).

A report produced for the World Bank by Pollner (2001) concluded that a number of configurations and options for managing catastrophe risk exist. It found that these options can exploit risk-transfer instruments as well as different capital structures for managing and holding sufficient catastrophe reserves. It warns, however, that in the process of developing a risk-management framework for a regional grouping of countries, that pricing characteristics may vary once higher resolution data is incorporated. These may well eventually indicate that alternative structures and funding mechanisms need to be considered as additional choices for assets at risk. The report confirms that using a package of policy and financial instruments can lead to improved long-term development prospects for nations which periodically suffer the devastating effects of natural disasters.

On completing its study, the Bank prepared an initial proposal for a loan programme for the OECS states that combined the establishment of a regional risk management and financing mechanism with investment in mitigation and emergency preparedness measures. The mitigation-financing component was substantially expanded to include financing reconstruction for the countries affected by the hurricane and strengthening lifeline infrastructure and emergency response capacity. As part of this adjustment, the risk management component was changed to a contingency line of credit available to participating countries should a severe natural hazard strike them during the programme period. In parallel the Bank is continuing to prepare a separate programme covering the risk management and insurance component at the regional level.

Key elements of the disaster mitigation methods and institutional capacity building techniques that were pilot-tested under the CDMP have been included in the World Bank's OECS Emergency Reconstruction and Disaster Mitigation loan and credit programme. In addition the Office of Foreign Disaster Assistance of USAID, the agency that financed the CDMP, is providing grant funding for several projects designed to build on the experience gained under CDMP. The goals are to strengthen institutional capacity for disaster mitigation and vulnerability reduction at national and regional levels in the Caribbean.

Vermeiren (2000) believes that the standard product currently offered by the insurance industry to the average property owner in the Caribbean is expensive; more than half of the premium paid by the insured is allotted to commissions, profit, marketing, and administrative expenses. The underwriter pays little attention to catastrophe risk, and the industry does not offer the insured any incentive to reduce that risk. A substantial part of society is uninsured, and this applies not only to the lower income sectors but also to a large majority of government-owned properties.

Yet, other aspects of property insurance in the Caribbean demonstrate the industry's capacity to increase the awareness of risk and contribute to risk reduction. The homeowners' comprehensive group plan in St. Lucia and the use of technical inspection services by French property insurers in St. Martin exemplify a more proactive role for and by the industry. These two programmes as well as the highly protected risk programmes have in common the fact that insurance is used to introduce a critical element of control over the quality of the design and construction, the strongest determinant of a property's catastrophe risk.

The agencies that finance infrastructure projects in the region, be they national development banks, private sector banks, or multilateral financing agencies, are in a position to change the face of the property insurance industry in the Caribbean. If the beneficiary countries are to maintain positive growth in the face of increased losses from natural disasters, a concerted effort is needed to minimize failure of infrastructure due to the effects of natural hazards. In almost every case such failures have economic and financial consequences to national economies that far exceed the cost of repairs and reconstruction.

As a minimum, for the explicit purpose of protecting the client and themselves from catastrophic risk, lenders should require that infrastructure projects be insured as a condition for the loan. To protect their assets, underwriters of this risk should want a certification that the structure is designed and built in accordance with appropriate standards and good practice. The certification would be issued by an independent technical inspection service.

Vermeiren holds that only through a loss-prevention partnership of the owner, lender, and insurer will the value of the insurance industry as a potential contributor to loss reduction be realised.

UNFCCC-AOSIS Initiative

The following description of insurance-related actions and risk assessment in the context of the UNFCCC is summarised from Linnerooth-Bayer et al. (2003).

During the negotiations of the United Nations Framework Convention on Climate Change (UNFCCC), developing country parties stressed the need to find ways to meet the challenge of damage resulting from the impacts of climate change. The Association of Small Island States (AOSIS) originally suggested that a fund should be established to cover additional expenses where insurance was not available for damage arising from climate change. Various triggers to payment and financial mechanisms that might compensate developing countries were discussed, but in essence the insurance mechanism proposed by AOSIS was not aimed at establishing private sector insurance, but rather a compensation fund to address direct damage from sea-level rise. What remain from these earlier discussions in the UNFCCC, and in the Kyoto Protocol, calls for the consideration of the establishment of 'insurance', although the term does not refer to any specific kind of risk transfer or collective loss-sharing instrument.

Based on this, the Parties to the Convention decided, amongst other initiatives, to organise two workshops on insurance and risk assessment in the context of climate change and extreme weather events, and on insurance-related actions to address the specific needs and concerns of developing countries arising from the adverse effects of climate change and the impact of response measures. Submissions on the terms of reference for the workshops included a proposal for a specific international insurance fund. Others stressed the limitations of existing risk assessment models for estimating the future scale of risk from climate-change related weather events. The need for technical cooperation between insurance companies and climate scientists was also emphasised, as was the need for cooperation between the climate science and disaster-relief communities and the various UN bodies involved in disaster relief and prevention. It was also stressed here that insurance is only one possible mechanism to cope with climate change risks and that particular attention should be given to broader risk-management measures, including adaptation and prevention of losses, in addition to risk transfer.

Under consideration are specific ways in which the international community might assist developing countries to transfer their risks from weather extremes, including the supporting of public-private partnerships in insurance; providing alternative risk-transfer instruments to Governments to help in the insurance of public infrastructure; acting as a re-insurer to micro-insurers; supporting data collection and analytical capacity-building in country to provide the requisite data for financial risk analysis; or by supporting innovative risk-hedging instruments.

The Parties to this initiative are also currently exploring ways in which the international community could assist the developing countries to respond to disasters through insurance-related activities and collective loss-sharing mechanisms. In recognition that risk-transfer mechanisms are not always the most effective way to complement the national risk-management provisions, the group is re-considering the setting up of a compensatory fund for climate-related damage. Although not appropriate in the case of slow-onset impacts such as sea-level rise, relief from such a fund might in other circumstances be made dependent on precautionary measures or insurance cover being taken out.

The issues of the institutional set-up of such a fund are also under consideration; there are suggestions that it could be managed by an intergovernmental organisation of Member States, or operated through existing financial institutions such as the World Bank or the Inter-American Development Bank or similar institutions. As well as the development banks, other international institutions which are considered potential partners in the process are the UNEP Financial Initiatives (FI) Climate Change Working Group (CCWG), the International Strategy for Disaster Reduction (ISDR), the ProVention Consortium and the International Federation of the Red Cross and Red Crescent Societies.

Small States Insurance Scheme – CDMA

The information on the Small States Insurance Scheme is extracted from a Marsh-CDMA brochure.

Following on from Commonwealth Secretariat advice in 1997 for small states to investigate and encourage innovative approaches to disaster insurance, and repeated calls made by small states to the Joint Task Force of the World Bank and the Commonwealth Secretariat to small states in 1999-2000, a new debt-servicing scheme was conceived by the Commonwealth Disaster Management Agency Ltd which was subsequently jointly promoted with major risk and insurance brokers, Marsh & McLennan Companies.

The product was designed specifically for Commonwealth small states to provide financial support after a natural disaster of a size or magnitude defined by a loss trigger agreed between the state and the insurer and confirmed by independent experts. The trigger will establish the threshold of severity of a natural disaster causing economic loss greater than the claim against it. The policy will pay the existing debt servicing obligations of the small state for an agreed period with the aim of enhancing the country's ability to borrow money or direct available funds towards addressing recovery priorities. The demonstrated ability of a country to continue to fulfil debt-servicing following a natural disaster is seen as critical to its ability to maintain a favourable credit rating and so reduce interest rates on borrowings.

As in the attempts to institute the Vanuatu Government Risk Management System, the Small States Insurance Scheme would create, as a first step, a risk management matrix for government entities. This matrix is seen as one branch of a potentially larger risk management mechanism which is essential to the state adequately addressing its protection against natural disaster and creating a means for economic recovery.

The developers of the insurance scheme acknowledge that a key precursor to any such scheme would be the need to apply risk management principles and, as part of this effort, to analyse the meteorological/geological historic data; the concentration of property and economic assets to the possible hazards; the availability of monitoring information; the ability to establish an independent international event-review panel; and to predict the prospective nature of the losses.

Cover would be made available at the same premium rate for different event triggers, based on risk assessment and the development of indices for potential triggers. A flat rate of 1% per annum applied to the sums insured for each peril group is proposed. Debt-servicing cover would be provided for not less than 3 years and not exceeding 5 years.

Framework for a Regional Catastrophe Insurance Scheme

Dr George Walker of Aon Re Australia Ltd, Sydney examined the role of disaster insurance and the requirements and design of a national system of disaster insurance in the context of a developing country such as Vanuatu, taking into account the Pacific Regional context, and drawing on experiences elsewhere in the Asia-Pacific region. The full report can be found in Appendix 7.

The Role of Disaster Insurance

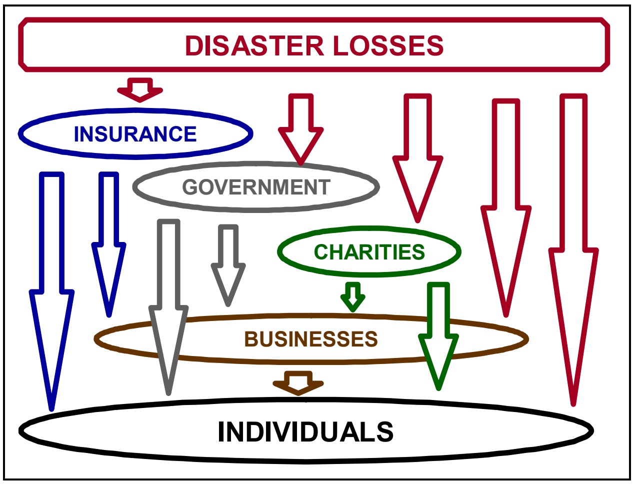

Figure 76: Distribution of catastrophe losses

When disasters strike, the resulting financial losses, whether or not they are initially met by government, charities, insurance or business, ultimately have to be paid for or absorbed by individuals, as shown somewhat simplistically in Figure 76.

How these losses are ultimately distributed among individuals is one of the main issues of disaster management.

Disasters are generally measured by both their social impact – ie by the lives lost, injuries sustained and numbers made homeless - and their economic impact - ie the financial losses caused by the disaster. However the real tragedy of disasters is the subsequent individual hardship endured by those affected by them. This hardship generally has a strong financial component arising from the loss of family income due to death or injuries to the main income earner, loss of jobs or loss of business income, the cost of repair or reconstruction of damaged homes and/or renting of alternative accommodation, or increased taxes to cover losses assumed by government authorities. Mitigation of this financial aspect of hardship is generally the primary objective of national disaster insurance schemes.

Government aid, charities and insurance are the main mechanisms by which this hardship can be reduced. Each of these spreads the financial losses beyond those directly affected, so reducing the maximum individual impact. Government aid does it by using money collected by taxation to assist those deemed most in need. This spreads the loss across the whole population in proportion to the contribution to taxes. Charities do it by seeking voluntary donations from those who have not suffered loss and passing these on to those seen to be most in need. Generally these two forms of aid complement each other, with government aid focussing on infrastructure and assistance in the form of low interest loans and special grants to both industry and individuals, and charities focusing on individual cases of extreme need.

Both these forms of mitigation tend to be reactive in that the funds used have to either come from the current account in the case of government, or be raised by special appeal in the case of charities. In the case of governments this may mean borrowing money from international agencies such as the World Bank and increasing taxes to pay this back over time.

Insurance, by contrast, is a proactive form of mitigation of hardship whereby an individual or organisation is able to transfer all or part of the financial risk of loss in advance of a disaster for a fee. If a disaster strikes and loss is suffered then the relevant financial compensation is made. The insured individual or organisation is assured of the compensation and not dependent on an assessment of need by government agencies or charities, and can get on with the recovery process less fettered by bureaucratic restraints. Government and charities are relieved of a portion of the financial and administrative burdens of recovering from disasters. And because of the internal international transfer of risk that occurs within the insurance industry through reinsurance the losses can be widely spread around the world, which means that the national economy will be subjected to a lesser financial shock.

For these reasons many governments in relatively developed countries, where insurance tends to be embedded in the culture, have made special provision for insurance against disasters. In some cases, where the risks are perceived as relatively low, this may be limited to a requirement that losses from disasters be covered by standard household policies. In other cases it has led to separate government organised and managed schemes. A review of these schemes shows that almost all of these schemes differ in some way from each other. This is because they depend on many factors.

Requirements of a National System of Disaster Insurance

Ideally a national system for disaster insurance scheme should meet the following criteria:

- Provide wide coverage
- Provide adequate funds for reconstruction and repair of damaged structures
- Be affordable
- Have an efficient administrative system including response to claims
- Be free of moral hazard
- Be technically sound
- Be politically acceptable
- Be linked with mitigation activities

Width of coverage

The primary purposes of national disaster insurance is to reduce the personal financial and associated emotional distress on persons affected by a disaster, and the drain on public funds in trying to alleviate the distress and restore community services. Ideally a national system should ensure cover of the whole population for all classes of losses from all hazards. In practice this is generally not achievable.

Consider the different classes of losses: A typical major disaster will involve damage to dwellings, businesses, and agriculture and government infrastructure. It will also involve loss of life and injuries which also have a financial cost associated with them. From an insurance perspective these are different classes of insurance which each have their own characteristics.

Dwellings involve buildings, which may contain one or more dwellings, which in turn may be owner occupied or rented, and contents, which are usually owned by the occupier. The primary characteristics of dwellings are their large number, relatively small individual value, and relative uniformity, which make them ideal for relatively standard insurance policies. In total they account for about one third of the total asset value of constructed facilities of a country and are generally the subject of the lowest level of building control in terms of design and construction.

Businesses are very diverse in terms of both their size and the nature of the risk. In general business losses can be divided into three main categories – buildings, contents including stock, and business interruption. Whereas with dwellings the building damage losses are dominant, this is not necessarily the case for businesses. Business interruption losses can be much larger than the losses due to building damage, particularly if the cause is infrastructure damage*, eg.* loss of power or water. In the case of warehouses, the contents losses can also heavily outweigh the associated structural damage, particularly where water damage is involved. Small, medium sized, large and global businesses also each have their own characteristics. Because of this diversity, businesses need to be divided into sub-classes that get smaller with increase in size and specialisation of the business. In total, commercial and industrial buildings also account for about one third of the total asset value of constructed facilities in a country. The level of building control exercised over their design and construction tends to increase with size, with that associated with small businesses being the least, and generally similar to that of dwellings.

Infrastructure losses include those arising from damage to railways, roads, dams, power stations, telecommunication systems, ports, airports, etc. In many countries these are mostly government owned facilities. They account for the other third of total asset value of constructed facilities in a country. Apart from the direct cost of repair and reconstruction, they are also a major cause of business interruption losses. Generally infrastructure has the highest level of control over its design and construction.

Agricultural losses from disasters can be very large. They can also be difficult to quantify. Whereas dwelling, businesses and infrastructure losses tend to be strongly correlated with each other, agricultural losses are often uncorrelated with these other forms of loss. Even the nature of the disasters giving rise to them is different, with droughts, pests and diseases playing a major role.

Losses due to death and injury are generally in the domain of life and health insurance. If they occur while persons are at work then they are in the domain of workers compensation.

As a result of these differences it is unusual to have a single national disaster insurance scheme covering all classes of loss. Most government backed schemes are concerned only with dwellings, some are concerned with all private property losses (but normally excluding business interruption), most schemes covering agriculture are for agricultural losses only, and most schemes covering government infrastructure losses are restricted to these.

In respect of hazards covered this also varies significantly. A number of government backed schemes cover all perils, but others are focussed on specific perils. The latter usually occur where the normal insurance industry provides cover for most hazards, but regards the specific perils as uninsurable.

The other factor that affects the width of cover within the community is the level of compulsion associated with the scheme. A number of schemes, mainly in the US, are purely voluntary, but most are in the form of compulsory additional cover to normal fire insurance policies. Where it is voluntary the take up appears to be generally less than fifty percent. Where it is compulsory as an addition to fire insurance, then the proportion of the community covered will be equal to the proportion covered for fire insurance. In Western countries this tends to be high, but in many other countries it is relatively low, particularly in regard to dwellings and small businesses.

Adequacy of Cover

Unlike normal insurance, a national disaster insurance scheme primarily provides a social service, not a commodity. As such it is not necessary that the scheme restore property to its previous situation in terms of either indemnity value or replacement value, which is the basis of most normal insurance.

Many schemes are limited in what they provide. Some have large deductibles. Some put upper limits to the cover provided. Others do both by providing a fixed amount of cover subject to a specified level of damage.

What is essential is that it makes a significant contribution to the reduction of hardship. In relation to dwellings this may mean providing sufficient funds to cover most of the cost of a basic dwelling. In the case of business or agriculture it may be to provide sufficient to keep the business or farm going. In the case of governments it may be to avoid severe increases in taxation. If it does not achieve this then it may be not serve its purpose.

Affordability

Affordability is primarily a function of the premiums and their value in relation to the financial circumstances of the owners.

The necessary premiums to be charged can be analysed using the following factors:

- The risk of damage
- The level of cover to be provided
- How the premiums are to be levied
- The approach adopted for financing the risk
- The administrative costs of the scheme

Determining what is an affordable premium however is not a scientific exercise. It is a socio-economic issue. It will depend on income after basic expenses on items such as food, health and accommodation have been paid. Affordability can limit the premiums, resulting in the level of cover provided being tailored to fit the premiums, not the reverse, which is the way normal insurance generally works.

The manner in which premiums are levied can also be important in respect of affordability. In normal insurance systems the premium is proportional to the cover. For full indemnity or replacement value cover this is fair and equitable. However if only restricted cover is provided questions of social equity arise. If the cover is the same then under the normal insurance approach premiums would be the same – meaning that rich and poor alike pay the same. However if this is associated with a first loss replacement cover it can result in the poor subsidising the rich. For what is essentially a social service, this is not a desirable outcome.

Administrative costs

An affordable scheme needs a practical and efficient system of administration. This includes the system for collecting the premiums, managing the accumulated funds, providing a timely and equitable response to claims following a disaster, and providing overall management of the system.

There are essentially two basic ways of administering a natural disaster insurance scheme. One way is to do it through normal insurance channels, with individual companies being responsible for the collection of premiums and payment of claims and the accumulated funds being placed in a joint pool, which is often underwritten to some extent by Government, and which is managed by representatives of industry and government. The other approach is for Governments to establish a separate government system with its own fund independent of the industry.

In countries where normal property insurance for fire and theft is almost universal, the insurance industry provides an efficient channel for administering a pool-based system, or at least collecting the premiums for a government based fund. Most existing schemes around the world operate in this environment. Where this is not the case the issue of width of cover becomes an issue. Should the scheme be restricted to property covered by normal insurance, or should it be universal with all property owners being levied for the requisite premium? If the latter approach is adopted then an efficient scheme for collection of the premiums and payment of the claims needs to be implemented. This may be undertaken through the insurance industry, but could be done through other channels such as those used for land tax. Means of enforcement is an issue that would also need to be addressed.

Claims handling poses special problems for separate disaster fund schemes. This is because during normal operations they have no claims or very few of them. Yet when a disaster strikes they are expected to be able to cope with large numbers of claims at very short notice. If claims handling costs are to be kept within reasonable bounds, or the scheme is not to be discredited due to public reaction to poor claims handling ability, it is necessary to have a sound and tested system in place at an agreed cost. The costs of this also have to be reflected in the premiums.

Part of the cost of administering the system is the cost of monitoring the risk and managing this risk. Increasingly this is being undertaken using sophisticated computer based tools.

The financial risk from damage to property is a complex interaction between the occurrence-risk of events causing the damage, topographical and geological factors such as soil characteristics, terrain and valley shapes, the geographical distribution of dwellings, the vulnerability of the dwellings to the hazard, and the cost of repairs and reconstruction. For some of the larger events like earthquake shaking damage, wind damage, and river floods, complex GIS-based models are the best way of ascertaining this risk, but their development is expensive. For other hazards like landslides and local severe storms the risk must generally be estimated by extrapolation from historical records. The problem is made more complex where a single event can produce several different hazards*, eg.* a cyclone can produce wind damage, flood damage and landslide damage.

Computer based catastrophe loss models can be developed to produce statistical information on the risk of loss from different types of hazards. This can be input into financial risk management systems that simulate the operations of the disaster insurance scheme over time including the premium income, the risk transfer mechanisms, the administrative costs, and the investment income from the accumulated funds. This allows analysis of the sustainability of different options.

Moral hazard

Another important need relates to moral hazard. Schemes need to be robust without too many opportunities for exploitation – especially in the aftermath of a disaster. Moral hazard is not just concerned with claims. The premium income and, if allowed to accumulate, the reserves, also need to be protected from exploitation.

Loss adjusters are familiar with the problems of moral hazard in the aftermath of disasters. A common example in respect of flood is the placing of old stock or household goods on the floor when a flood is threatening in the expectation of having them replaced by insurance. Where this has become a problem some insurance companies have countered it by inserting a clause in the policy conditions that moveable contents will only be covered if the flood level in the building exceeds a specified height that is less than the usual table or bench height. Shingle roofs are common in some parts of the world. As they age the timber cracks and they deteriorate. Hailstorms provide an opportunity to get them replaced, as it is difficult for insurance companies to distinguish between natural cracking and cracking caused by hail.

A more serious problem can occur where payment of claims is in cash on the basis of a builder's quotation without any checking by a loss adjuster. In the rush of claims following a major disaster it is not unknown for this situation to arise to be soon followed by enterprising entrepreneurs offering to provide inflated quotations for a fee. This is a hazard that can be avoided by having a rigorous claims system in place before the disaster.

Some forms of insurance can also encourage moral hazard. One example is a franchise system whereby if a claim is less than a certain amount no payment is made, but if above the amount full payment is made. This can encourage the inflation of many small claims, which may be not worth spending a lot of time checking, above the franchise limit. Deductibles based on actual cost of repair provide a much better deterrent to this moral hazard.

The problem of large reserves is a different type of problem. It is a political or commercial form of moral hazard. Large sums of money set aside in government funds or industry pools as long term reserves can become very tempting for politicians and economic advisers seeking to overcome some more pressing immediate financial problem, or unscrupulous people in business. One of the purposes of legislation is to provide protection against this hazard.

Technical soundness

Any scheme, to be effective and sustainable in the event of a major disaster, must be technically sound. It must be able to cover the prescribed risks without becoming insolvent. Income must balance or exceed expenditure.

The risks to a disaster insurance scheme are generally covered by a combination of

- Pool funds
- Risk transfer, *eg.* reinsurance
- Risk financing, *eg.* contingency loans
- Government guarantee
- Insurance industry contributions

The costs of doing this may include

- Costs of risk transfer
- Costs of risk financing
- Cost of government guarantee

Other costs apart from irregular major claims include

- Costs of administering the scheme including managing claims
- Costs of attrition losses – ie regular small claims
- Taxation
- Costs of measures to mitigate risks

The regular annual income to cover these costs comes from a combination of

- Premiums
- Investment income
- Industry levies
- Government grants

In the simplest system all the risk would be transferred except for a small retention to cover annual attrition losses. The premium income required to maintain this system will be equal to the market value of the risk as expressed in the cost of the reinsurance plus administrative costs and attrition losses. Premiums based on producing this level of premium income can be described as Market Value Based Premiums as in this case the policyholders in aggregate pay the true market value of the risk covered. Market Value Based Premiums will vary from year to year, being higher in so-called hard markets and lower in soft markets.

To provide protection from the fluctuations of the market, many schemes aim to build up a pool or fund. This can only be done by either charging higher premiums than the Market Value Based Premiums, or by industry or government underwriting a portion of the risk without passing the costs on through premiums. The latter approach is based on an assumption that major disasters are rare and hence there is a high probability that the scheme may run for many years without having to face a major loss. During this period the fund will build up in an exponential manner as a result of the increasing investment income it generates as it grows. As it grows it lessens the unfunded component of the risk, and provides an opportunity through the increasing investment income to eventually either reduce premiums or provide additional cover.

The Norwegian national disaster insurance system is an example of a system based on the Market Value Based Premiums approach. The New Zealand earthquake insurance scheme is an example of system based on building up a fund, which, because the Government carried the full risk for almost all of the first 40 years and no major loss has occurred in its 60-year history, is now in a very healthy position. Both systems are now technically sound because the risks are balanced against the income.

During recent years the development of powerful computer based tools that can simulate the risks and the financial operations of a scheme have made a big contribution towards ensuring technical soundness.

Political acceptance

Political acceptance is fundamental to both the establishment and the sustainability of national disaster insurance schemes. Political acceptance will largely depend on the affordability and perceived need for the scheme by the community. Apart from risk factors that cannot be changed in a short time frame, major factors determining this will be the level of cover to be provided, and how the premium is to be levied.

The minimalist approach is to cover all property owners for the same amount, irrespective of the value of the existing property, and pay the same premium. However the wealthier section of the community may be willing to pay higher premiums for greater cover, raising the question of whether this should be provided as an option under the scheme to increase the premium income, or, in the case of a separate national fund, left to the private sector in order to limit the probable maximum loss to the fund.

Other factors affecting political acceptance are the existing level of property insurance in the community and how the new scheme relates to any existing schemes.

Mitigation

A key factor affecting affordability is the vulnerability of buildings, facilities, their contents, and business operations, to the hazards. Nothing much can be done to change this at the start other than exclude the most vulnerable risks from the scheme – which to some extent can defeat the objective of the scheme, and may also be politically unacceptable. However the initial situation can be improved over time by incorporating incentives or regulations that will over time reduce the overall vulnerability. Indeed without them an insurance scheme can be a disincentive to mitigation and result in increased vulnerability over time.

The most effective means of doing this are the imposition of relevant building standards and land planning requirements for all new construction. There is often a relatively long period of time between major disasters, and during this period significant reductions in the overall vulnerability can be achieved by these measures. A good example of this is in Queensland, Australia, where changes in building requirements introduced in 1982 have resulted in a significant overall reduction in vulnerability to tropical cyclone winds during a period when there has been no major event. However there are significant costs associated with such measures in terms of added costs of construction, loss of amenity in terms of land use, and the cost of regulatory control measures to ensure compliance. These costs need to be balanced against the benefits if a politically acceptable solution is to be found to this issue.

Risk based premiums which recognise reduced vulnerability due to new construction satisfying specified minimum standards or retrofitting older construction can also be used, although experience to date suggests that this is limited in its effectiveness as owners prefer to pay a relatively small amount of extra premium in preference to a much larger up front single payment to cover the additional construction costs.

For mitigation activities to be effective it is generally necessary to maintain a high level of pubic awareness of the possible consequences of major disasters and the need to mitigate them. Most disaster insurance schemes include within their terms of reference the funding of public education and research activities in relation to disaster mitigation.

In a number of cases the provision of the insurance cover to new properties is subject to prescribed mitigation measures being in place. These options, however, are only available if the purchase of the insurance is voluntary.

Design Options

There is a wide range of options available for providing disaster insurance. The issues that need to be taken into account in selecting the appropriate option were discussed, with political and cultural issues identified as being as important as technical issues. In this section the principal options are discussed.

Classes to be covered

The range of classes of loss arising from a major disaster is summarised as follows:

- Dwellings – Building, Contents
- Small Business – Building, Contents, Business Interruption
- Medium and Large Business – Building, Contents, Business Interruption
- Agriculture – Crops, Livestock
- Government Owned Risks – Buildings, Utilities, Infrastructure, Emergency Services
- Health – Death, Accident Cover, Workers Compensation

A completely universal scheme would provide cover against all these classes. The most comprehensive scheme existing scheme appears to be the Consorcio de Compensacion de Seguros in Spain that covers everything except death and injury.

Normally agricultural losses are the subject of separate disaster insurance schemes. The reason for this is that the nature of agricultural losses is very different from that of losses arising from building damage. Also there is a range of hazards coming under the general description of pestilence and disease that have no equivalent in terms of building damage. Even in Spain where agricultural losses are covered by the overall scheme, they are handled separately within the scheme.

Historically governments have not insured their own losses. This appears to be due to an economic argument that owing to their size and their sovereign position in the national economy, there is no long-term advantage to governments in insuring their own losses. However the wisdom of this approach for smaller economies in a global economic society is now being challenged. In Australia, for instance, the Federal Government and several of the State Governments have centrally managed insurance schemes to cover major losses to their own assets.

Government relief schemes are an alternative to national disaster insurance schemes. This approach of a protected national disaster relief fund is a fundamentally different option to the disaster insurance approach. It is the traditional approach, but has two inherent weaknesses. The relief it provides tends to be ad hoc, and the subject of a great deal of bureaucratic procedures designed to prevent its exploitation, with the relief funds often taking a long time to reach those in need. It also tends to act as a disincentive to mitigation, with owners having little self interest in reducing risks. Insurance systems are much more compatible with the principles of modern risk management than relief. Indeed this is one of the primary reason why in Australia Governments have opted for their own internal insurance schemes, despite the traditional economic arguments about their economy efficiency – arguments which ignored the benefits of modern risk management.

Hazards to be covered

Disaster insurance is intended to cover catastrophic events, which can involve several coincident hazards. The range of events and associated hazards that could be included are:

- Earthquake – Shaking, Fire, Landslide, Tsunami, Subsidence (Liquefaction)
- Tropical Cyclone – Wind, Rain, Flash Flood, Stream Flood, Landslide, Storm Surge
- Thunderstorm – Wind, Hail, Rain, Flash Flood, Lightning,
- Other Weather Events – Rain, Flash Flood, Riverine Flood, Bush Fire, Wind
- Volcanic Eruption – Shaking, Debris Flow, Ash Fall, Lava Flow, Fire
- Man Made Hazards – Explosion, Major Fire, War, Terrorism, Riot
- Other – Pestilence, Disease

Only the Spanish scheme appears to cover all these hazards. Most government backed schemes are only concerned with natural hazards, and most restrict their cover to one or more specific hazards. There are generally historical reasons for the range of hazards covered, with most schemes appearing to have been initiated in the aftermath of a major disaster, the losses from which have either been poorly covered, or were not covered at all by insurance, or would not be covered following the disaster. A current example of the latter is the reluctance of the insurance industry to insure for terrorism following the terrorist attack on New York and Washington on 11 September 2001, which is leading to demands in some countries for national insurance pools to specifically cover acts of terrorism.

Type of scheme

The types of scheme can be classified as follow:

- Industry only, either as part of normal insurance, or collaboratively through an Industry Pool.
- Government Fund, providing either insurance direct to consumers, or providing reinsurance to insurance companies enabling them to provide disaster insurance cover.
- Joint Industry/Government Pool, through which industry provides the insurance, but which is protected in part by a Government guarantee and/or a co-insurance arrangement between the Government and industry.

In most countries some hazards like wind damage are covered by normal insurance, and in some countries like the United Kingdoms and Australia almost all hazards to buildings are covered this way. In some cases where the risks are considered too much for individual companies to handle on their own in a competitive environment, disaster insurance pools to which the different companies belong have been formed. The schemes in Norway and Switzerland are of this type, as is the scheme in Florida for windstorm damage to dwellings. Government's only role in these is to provide a supportive regulatory environment for the pool's operation, which ensures that all participating companies follow the same rules in regard to premiums and cover.

There are two types of purely government schemes. One type is where the government runs its own special insurance company. These schemes may be backed up by a special Fund or operated as part of normal Government income and expenditure. The schemes in New

Zealand and Iceland are examples of this type using a Fund, and Spain an example of this type incorporated into normal Government operations. The other type is where the government operates a reinsurance scheme with the cover being provided through insurance companies in the normal way. This is the system used in France and in Japan.

Joint industry government pools generally operate as industry pools, with policies being sold and claims being handled by individual companies, generally in conjunction with their own more general policies, but with some of the risk being carried by the government. The government may do this by guaranteeing to cover losses within a specified range or above a specified limit, or by accepting a proportion of the losses on a coinsurance basis. The recently introduced Taiwan Residential Earthquake Insurance Programme is of this type. The California Earthquake Authority's scheme is also a joint scheme, but in this case the government's role has been to organise it and run it, but not to carry any of the risk.

Universality of Cover

A major issue that needs to be resolved in relation to disaster insurance is how universal the cover is to be. The options are:

- Voluntary, either as an addition to a normal policy, or as a separate policy
- Compulsory, either in conjunction with normal insurance, or as a separate universal policy

A voluntary system normally only works where the level of ordinary insurance is high and awareness of the hazard covered is also high. The cover may be provided as an addition to an ordinary insurance policy, or as a separate insurance policy. All the disaster insurance schemes operated in the United States are voluntary ones. A significant problem with voluntary schemes is adverse selection due to them being more attractive to those at high risk than those at low risk.

Outside of the United States most of the government disaster insurance schemes have a compulsory element. In many cases the requirement is that it is compulsory to provide disaster insurance in conjunction with a normal insurance policy. In Norway, Iceland, Spain, France, Switzerland and New Zealand this is the situation in respect of property insurance. This works well where the level of insurance is high.

The other option is to require it to be compulsory for everyone having assets covered by the scheme. The system recently introduced in Turkey is of this type. If this approach is adopted then the question arises as to how premiums will be collected and claims handled. A number of options are available.

a) The cover is provided through insurance companies who also manage the claims, with owners being required to show evidence of payment at the time of paying taxes.

b) Insurance companies collect the premiums and pass them on to a special purpose government insurance organisation that handles the claims.

c) A levy is charged in conjunction with property tax, which goes to a special purpose government insurance organisation.

d) A combination of (a) and (c), or (b) and (c). If the former the scheme might allow owners to insure directly with insurance companies, and not be part of the scheme. However this could lead to a problem of adverse selection with the insurance companies only accepting the good risks and the scheme being left with a preponderance of bad risks.

Extent of Cover

Another critical issue is the extent of cover to be provided to policyholders. The options are:.

- Replacement value generally in conjunction with a deductible or franchise, and possibly a level of coinsurance or first loss limit.
- Indemnity value generally in conjunction with a deductible or franchise, and possibly a level of coinsurance or first loss limit.
- Limited amount of cover in conjunction with claim conditions such as a specified minimum amount of damage.

The choice depends a great deal on the level of premiums that can be charged and the level of risk that the government may be prepared to assume.

The most complete cover is unlimited full replacement cover with a minimal deductible. This is the type of cover provided through normal insurance in countries such as the United Kingdom and Australia. However it is only practical where the overall risks are low.

The level of risk to the scheme can be reduced by limiting claims to indemnity values and/or imposing significant deductibles and/or limits. Significant deductibles are the most effective but they would need to be large. Most disaster insurance schemes outside the United States and New Zealand appear to be based on indemnity cover. New Zealand uses a first loss limit approach but this is not regarded as a good system, as it effectively means the poor subsidise the rich. Co-insurance would be better than this.

Where the cover is for a limited amount it may be a percentage of the replacement or indemnity value, or an absolute amount. This system is used in Japan with specified percentages of the total indemnity value being covered subject to different specified levels of damage. It is also used by the Taiwan Residential Earthquake Insurance Programme, in which the cover provided is for a fixed amount subject to a specified level of damage occurring. A problem with this system is the specification of the level of damage, which is often in such terms as 'total loss', or 'half total loss', and the assessment of this when damage occurs. A considerable risk of moral hazard appears to exist unless there are firm guidelines and a rigorous system of control.

A fixed level of cover is appropriate if the primary objective is seen as social – ie ensuring everyone gets a basic amount to start again without any frills. In most cases it will be less than is needed, but it assumes there is a correlation between the value of property and the wealth of the owner. Thus the needs of the poorest may be almost fully met, while those of the rich may be only marginally met. It is assumed that the latter will be able to insure for the gap through normal insurance channels outside of the scheme.

If premium levels are essentially determined by affordability and not by the overall risk, as is often the case in high risk and less wealthy countries, then the selection of the appropriate option on the cover will be a critical decision.

Form of Premiums

There are essentially three forms of premium:

- Fixed Premium
- Fixed Premium Rate
- Variable Premium Rate

The form of the premium will to a considerable extent depend on the form of cover – and vice-versa.

If the cover is for a fixed amount subject to a specified level of damage then a fixed premium is appropriate. A significant limitation of this approach is that the premium level needs to be matched with the ability of the poorer section of the community to pay. It also treats all risks the same, which can be a disincentive to mitigation.

A fixed premium rate based on the indemnity or replacement value is the most common approach. Its advantage is simplicity of administration. Its weakness is that it treats all risks the same, so that good risks subsidise the bad risks. There is also a moral hazard in regard to the determination of indemnity or replacement value that can result in significant underinsurance. This can be a particular problem where insurance is related to mortgages, and the temptation exists to just insure for the amount of the mortgage.

A variable premium rate that is risk related in terms of hazard risk and vulnerability is a fairer system in many respects, and provides a much greater encouragement to mitigation. However it requires a more complex system of administration backed up by computer based systems, and would probably favour the rich, as there is also a tendency for the dwellings of the poor to be more vulnerable than those of the rich.

Upper Limit

One of the issues associated with disaster insurance schemes is the nature of the upper limit of the scheme. There are in essence three options

- No upper limits and no government guarantee
- No upper limits with a government guarantee
- A fixed upper limit with proportional cover above this.

Schemes backed by industry pools without government participation tend to have no upper limits – just as normal insurance companies offering disaster cover have unlimited exposure. The Norwegian scheme is an example of such a system. It is accepted in these systems that if an extremely rare extremely large loss occurs then some companies may become insolvent. Hurricane Andrew was an example of an event that had this effect. The losses sustained by the insurance industry as a result of the terrorist attack on the World Trade Centre are also expected to cause some insolvency. Experience indicates that when insolvency occurs, governments are under great pressure to meet any consequent unmet insured liabilities.

Where governments are involved it is more common for the system to be guaranteed by the government if losses exceed the capacity of the scheme. The New Zealand, French, and Iceland schemes are examples of this approach, and it happens automatically with the Spanish scheme.

In some cases an upper limit to the liability of the scheme for a single event is specified. The Japanese scheme and Taiwan Residential Earthquake Insurance Programme are examples of this approach. If a loss exceeds the upper limit then all claims are reduced in proportion to the amount by which the limit is exceeded. Such a system has not been tested, and it is not clear how such a system will work in practice, as in general the total loss will not known for a considerable time after the event, and early estimates often underestimate the loss.

Claims Handling

Claims handling is generally a function of the type of scheme. If it is a scheme operated through insurance companies in conjunction with their own general policies then the insurance companies generally handle the claims. If it is a government scheme with its own organisation then the organisation handles them. An example of the latter is New Zealand.

Since major losses are relatively rare and a separate disaster insurance scheme has few regular occurring claims, special arrangements with outside organisations have to be made, and plans need to be in place to ensure that the system works when needed. The New Zealand Earthquake Commission has invested a significant amount in claims management. This includes pre-existing contracts with off-shore loss adjusters, and sophisticated software systems that can simulate the expected number of claims given notification of the magnitude and location of a an earthquake, and then work out the number of assessors needed, the resources they will require, and their allocation in terms of time period and location until the claims have all been handled.

Financial Risk Management

An important aspect of any disaster insurance scheme is the way the financial risk to the scheme is managed. Reinsurance generally plays a significant role in this. Some of the options are:

1. No reinsurance, and government absorbs risk above level of accumulated funds.
2. Risk completely reinsured up to a specified probable maximum loss (PML) apart from a small retention for small attrition losses.
3. Reinsure a layer of risk above a retention to cover attrition losses and rely on accumulated funds and government guarantee to meet risks above this level.
4. Reinsure gap between level of accumulated funds and PML

Modelling the behaviour of disaster insurance funds shows that if the objective is the accumulate a Fund or Pool of sufficient size to ensure a sustainable system then the quickest way to do this is the first option – ie buy no reinsurance and let the government take all the risk above the level of accumulated funds, until the latter have reached a stage that some of the income they generate can be used for reinsurance. Because major losses are rare there is a reasonably high probability of this approach working. The New Zealand residential earthquake scheme is a successful example of this approach being used until the Fund had reached a significant level.

To achieve a sustainable system from the start, without external support, the only option is to fully reinsure the risk up to the PML – generally taken to be approximately the 200 year return period – apart from a small retention to meet annual attrition losses, and have a government guarantee to cover extreme losses above the PML unless an upper limit to the scheme is specified. The Norwegian system comes closest to this system – it provides no safety net above the PML. From a rationalist economic point of view this is an ideal user pays system with the user paying the market cost of the risk. The disadvantage is that the system is at the complete the mercy of the reinsurance industry and in a hard market may find it difficult to purchase the full reinsurance required and encounter consumer resistance passing on the higher premiums.

Most schemes aim to build up a fund to make the scheme more independent of fluctuations in the cost of risk transfer, but most governments are hesitant to initially assume all the risk. The premium income must first fund the administrative costs and the annual attrition losses. What is left over is available for buying reinsurance and growing the fund. If the Fund has to start from scratch, unless premiums much higher than the Market Level Based Premiums are charged – and this raises serious questions of fiscal responsibility – then there needs to be a sharing between reinsurance and government with a proportion of the premium income after meeting administration costs and attrition losses being used for reinsurance and the remainder used to grow the Fund. Modelling shows that if this approach is adopted the most effective use of the reinsurance is to adopt Option 3) above of purchasing it just above the attrition level. Option 4) only becomes an option when the accumulated Fund size reaches a level that with the income from premiums and investments is sufficient to reinsure the difference between the fund size and the PML at a level providing significant protection to the Fund and enable the Fund to continue to grow with the growth of exposure. When this situation is reached the scheme will have effectively reached a sustainable level of operation.

Management

Disaster insurance schemes are generally managed by boards of commissioners or directors.

If it is an industry only scheme then the board will be formed from representatives of the participating companies in accordance with an agreed constitution of the scheme.

A joint industry/government scheme will be formed by a combination of government and industry representatives. Such schemes will usually be subject to government legislation that prescribes how the representatives are to be elected or selected, and their terms of reference.

If it is to be a separate scheme run by a government organisation, a government appointed board, representative of all the stakeholders, would normally manage it. In addition to government and insurance industry representatives this could include technical experts and representatives of policyholders. Again the method of appointment of representatives and their terms of reference would need to be embodied in the legislation establishing and governing the organisation.

If the scheme is operated as a government departmental function then presumably departmental officers would run it with the assistance of an advisory committee which might be similar in structure to the government appointed board for the specialist government insurance organisation described above.

Administration

There are four options for administering a disaster insurance scheme. These are

- Outsourcing it to an insurance company or reinsurance company.
- Creating a separate unit to administer it, either an independent unit owned by participating companies in the case of a pure industry pool, or a separate government or semi-government unit in the case of a joint industry/government pool or specialist government insurance organisation.
- Administering it within a government department as part of its normal functions.

This would be the case if it was a departmental run scheme, but it is also an option for a specialist government insurance organisation.

- If the government has an existing insurance organisation such as a government reinsurance company, it could be made responsible for the administration of the system. It is understood this is how the interim earthquake insurance scheme is to be administered.

Mitigation

Most schemes around the world embody some degree of mitigation, mostly of the indirect form. This generally takes the form of setting aside a specified percentage of the premium income for public education and research that fosters mitigation. This often extends to encouraging the development of appropriate building codes and land use guidelines, and lobbying government for their incorporation in legislation and implementation. The New Zealand scheme is a good example of this.

A few schemes directly address the mitigation issue. In Fiji for example the provision of insurance for wind damage is subject to a certification that the building design meets a certain level or has been upgraded to this level. Flood insurance is also generally offered subject to moveable items being only covered if above a certain level of inundation of the building. In the United States the national flood insurance scheme is only available in areas where the local authority has embodied their flood plain requirements in their local byelaws. In Texas there is a government backed scheme of insurance for wind damage to dwellings in coastal areas which, for construction built since it was introduced, is only available for construction certified as meeting its own building code requirements.

The problem with direct schemes is that that non-complying construction may be excluded from the scheme. Alternatively all can be covered but the premiums and cover for complying buildings can be much better than those for non-complying buildings, with incentives offered to the owners of non-complying buildings to upgrade. The national flood insurance scheme in the United States uses the latter approach for non-complying buildings in approved local authority areas.

Design Tools

Background

Among the many important decisions to be made in establishing a sustainable disaster insurance system, the following are among the most important.

- Which risks should be covered and with what limits and/or deductibles.
- What is the appropriate technical price for each type of risk exposure (residential, commercial, agriculture etc.) and therefore the premium to be charged, based on premium volumes likely to be written at different rates, and how this impacts on the overall profitability of the company.
- What is the probability of ruin of the scheme (generally linked to the probability of the level of solvency for the entity falling below a given point) and is this acceptable?
- How much capital does the scheme require to be sustainable?
- How much reinsurance should be purchased, recognising the value of reinsurance as a

form of capital and a key financial management tool? (Another benefit is to provide a specific management focus on the risk retention policy, reinsurance leverage, credit risk and administrative cost.)

- How should the assets of a company be invested? What asset mix should the company employ, and how should this change to ensure optimal returns in both the short and long terms.

Each of these questions is obviously dependent upon the others. One cannot answer how much capital is required until one knows what coverage will be offered, the premium volume, the overall insurance exposure risks, and how the assets will be invested and the associated risks. Similarly, one cannot determine the optimal asset mix until one knows the premium volume, its volatility and the amount of capital available. And the premium depends as much on the policy conditions and the insured risk, as well as being restrained by affordability.

These various factors can be described as the system variables, with the object of the system design being to determine the appropriate combination of values of them. However doing this in a rational way has only become possible very recently.

Most of the current schemes were probably designed in a somewhat ad hoc manner as a result of particular political imperatives at the time. A major problem with disaster insurance schemes is that they are concerned with risks for which the level of loss is very high and the associated risk of occurrence is very low. As a consequence it is very difficult to derive reliable information on the risks by extrapolation of past losses. Factors contributing to this unreliability are:

- Major losses in a particular area from a particular type of hazard generally occur on average less than once in an average human lifetime.
- Detailed record keeping on losses is generally only available for periods much less than an average human lifetime.
- During an average human lifetime exposure and vulnerability in a particular locality can change by an order of magnitude.
- Although major losses occur somewhere more frequently differences in exposure and vulnerability from one region to another varies greatly.
- There are large differences in the value of money in time and space due to inflation and fluctuations in currency exchange values which make relating losses over time and between different countries very difficult.

Prior to the advent of sophisticated computer based information technology systems it was almost impossible to undertake rational analysis of the financial risks associated with disaster insurance systems, and consequently to design them in a rational manner. However powerful tools are now available which have changed this situation. These tools enable the simulation of the losses based on the physical characteristics of the hazards and their occurrence, and their effects on the built environment, about which there is generally much more scientific knowledge than there is on financial losses. They also enable the risk characteristics of different types of losses to be combined with each other, with the financial risks associated with fund management, and with the operational costs and system variables such as premiums, insurance cover, and reinsurance, to simulate the performance of disaster insurance systems into the future. This enables the effect of different combinations and values of the system variables on sustainability in terms of Fund growth and solvency to be studied and the most satisfactory system in terms of both technical requirements and social and political restraints established.

There are two separate types of tools used for this process:

- Catastrophe loss models
- Financial risk management models

The primary design tools are the financial risk management models, but the primary input to these models is the output from the catastrophe loss models.

Catastrophe Loss Models

When discussing risk assessment it is first necessary to define the risk. In the case of insurance it is the risk of insurance loss. This is a function of a number of factors:

a) The risk of occurrence of the physical event causing the loss.

b) The risk of the physical event impacting on populated areas.

c) The risk of damage given the occurrence of a hazard, which will be a function of the vulnerability of the buildings, facilities, infrastructure and crops to damage.

d) The insurable losses arising from the damage

The result is generally expressed in terms of the return period in years of a specified loss. Unfortunately the term 'return period' is often misunderstood. It is used as a descriptor of probability because to most people it is more understandable to say, for example, that a loss of $100 billion has a return period of 120 years than to say it has a probability of exceedance during the next 12 months of 0.00830, which would be the case if the loss occurred purely randomly with time. Strictly it means is that if current conditions were to remain unchanged for thousands of years, the average time between losses exceeding $100 million would be 120 years, which puts it into a context that enables the risk to be compared with other human timeframes, and hence provide a basis for decision making. However for use in analytical calculations it is the value 0.00830 that is generally more useful.

It will be noted that the reciprocal of 120 is 0.00833, which is very close to 0.00830. This is not a coincidence. For large return periods, and assuming purely random occurrence, the probability of exceedance is so close to the reciprocal of the return period that it is generally assumed to be the case. The approximation gets less accurate as the return period gets less. For example a return period of 10 years corresponds to a probability of exceedance of 0. 0952 compared with the reciprocal value of 0.1, and a return period of 1 year corresponds to a probability of exceedance of 0.6321 compared with a reciprocal value of 1.

The qualification of the occurrence being random is significant. Most assessment of insurance risk is based on this assumption, but it is only an approximation in practice. Typhoons do not occur purely randomly in time. Tropical cyclone occurrence is a function of large scale climatic conditions that vary with time. One cause of this variation is the well known oscillation in climatic conditions that produces the periodic El Nino phenomena. During El Nino periods the risk of tropical cyclones increases in the central Pacific and decreases in the western Pacific- and vice-versa during La Nina periods. If a tropical cyclone occurs then the probability of getting another one within the same region within a few weeks is higher than average because of a weather characteristic known by meteorologists as persistence, which means that if a certain weather pattern becomes established it tends to persist for a while. Earthquakes likewise do not actually occur randomly with time. They are the result of a build up of stress within the earth. When they occur they release stress, and transfer it to other places, so decreasing the risk in some places and increasing it in others.

The assumption of randomness of occurrence is typical of many of the assumptions and approximations that are made in insurance risk assessment. In time as knowledge of the time dependency of typhoons and earthquakes increases, it will be taken into account, but for now it is just one of the reasons why insurance risk assessment even at its best is still only an approximation, and needs to be used in a prudent manner.

However unless some assessment of the risk of insurance losses can be undertaken, they will be uninsurable. That has always been the case. In respect of disaster losses the difficulties of this assessment have often been the reason for government systems being developed – the insurance industry being unwilling to accept risks they could not assess. In recent years techniques have been developed that have led to large improvements in assessing these risks. Uncertainties remain, but providing they are recognised, sufficient information can now be generated on which to base a rational approach to disaster insurance.

With the information on insurance loss in probabilistic form decisions can be made on the levels of risk to be transferred and retained, estimates of average annual losses can be derived as a basis for premium setting, and dynamic financial analysis (DFA) tools can be utilised for managing the scheme and optimising it in terms of sustainability and costs.

Two main forms of risk assessment are used for disaster insurance loss assessment.

- Statistical analysis of past losses.
- Geographical information system (GIS) based simulation of hazards and losses.

In general statistical analysis of past losses is the most reliable approach for more frequent loss events of small to moderate magnitude, while GIS models are more suitable for modelling extreme events with low probability of occurrence. To obtain the overall characteristics of the loss it is generally necessary to combine results from different types of analyses.

Statistical Techniques

Statistical techniques are based on analysing past losses using extreme value probability distributions of one form or another. The technique assumes that future losses will have the same statistical characteristics as past losses. Normally losses are assembled in ascending order of magnitude and cumulative probabilities assigned to each loss as a function of its position in the order. Various forms of extreme value probability distributions are then fitted to this data. These fits are generally of the form of the loss or logarithm of the loss versus the logarithm or double logarithm of the exceedance probability.

There is no reason why in general any set of losses should fit any particular probability distribution since they are the result of a complex set of variables incorporating uncertainties of many different types, but different practitioners often favour one over another, while others just fit the best curve. Those with a background in insurance often use the Pareto distribution, which corresponds to a straight line fitting the logarithm of the loss plotted against the logarithm of the exceedance probability. Those with an engineering background often use either the loss plotted against the double logarithm of the exceedance probability (corresponding to Fisher-Tippett Type I extreme value distribution or Gumbel distribution), or the logarithm of the loss plotted against the double logarithm of the exceedance probability (corresponding to Fisher-Tippett Type II and III extreme value distributions such as the Weibul distribution).

The basic output of this analysis is the average number of events per year, and probabilities of different levels of loss being exceeded if an event occurs. This information can then be used to simulate randomly the event losses over long time periods and obtain statistical information on the annual aggregate losses and annual maximum event loss, on which premiums and reinsurance respectively are based.

For return periods less than the length of time of the record of the losses, this method can be reasonably reliable, and is certainly more reliable than any alternative. Unfortunately reliable data on losses over long periods of time is generally not available. There are a number of reasons for this.

- In the aftermath of disasters collating information on losses has had a low priority, particularly before computers dispensed with the need for collation to be undertaken manually using paper based records – a tedious and costly exercise.
- As a result of inflation and portfolio growth past losses can only be meaningfully used if they are indexed in some way to give the estimated loss that would occur with the current portfolio and current monetary values.
- If policy conditions have changed over time such as a change from indemnity to replacement cost as the basis of insured value, this needs to also be taken into account.

The limitations imposed by these conditions generally mean that only short records of useful loss data are available. Generally better information is kept on large losses than on small losses over longer periods, but then a problem arises over the allocation of the cumulative probabilities to these in view of the missing data. A further problem arises if one or two losses are very large and clearly not representative of the duration of the record. In this case an estimate has to be made of its return period to avoid the results being biased by this event.

The application of statistical techniques to insurance risk assessment is therefore as much an art as a science, despite being based on sophisticated mathematical analysis. But it is necessary if a reasonable indication of short-term losses and their variation are to be obtained.

GIS Loss Simulation Techniques

During the 1970's civil and structural engineers, concerned about design criteria for earthquakes and tropical cyclones began to use the computer to simulate the hazards because basic occurrence information such as the magnitude and location of earthquakes, and the central pressures and tracks of tropical cyclones, seemed more reliable than the occurrence information on the resultant hazards such as earthquake intensity and wind speed. About the same time in the insurance world a technique started to be developed for estimating disaster insurance losses by superimposing the geographical pattern of maximum wind speeds or maximum earthquake intensities from an event, real or imaginary, on populated areas and, using information on individual loss as a function of these hazards, integrating the loss over the affected areas to determine the total expected loss from the event.

These two developments coalesced during the 1980's and by the beginning of the 1990's commercial GIS insurance loss models for earthquake and tropical cyclones were available in limited regions of the world. During the 1990's there was continual expansion of the geographical scope of the models, which now embrace most major insured areas of the world at significant risk from earthquakes and tropical cyclones, and also extension in some regions to other hazards such as flood, hail and wild fire. Their use has now become a standard feature of property PML analysis for excess of loss treaty reinsurance for most major insurance companies, and underpins the growing use of alternative risk transfer and financing approaches such as catastrophe bonds. They have also become widely used as a basis for setting premiums in a regulatory environment where premium rates have to be justified.

GIS loss models are very complex computer software systems that integrate a number of different types of models as follows.

- A hazard model that simulates geographically the intensity of the hazard causing damage resulting for a specified event. In the case of an earthquake loss model, the hazard model is known as the attenuation model, and maps the estimated earthquake intensities arising from an earthquake of specified magnitude and depth occurring on a specified fault, and taking into account local amplification due to soft soil conditions.
- A vulnerability model that simulates the insured loss attributable to a particular building for different hazard intensities taking into account various building characteristics which affect its vulnerability to damage such as building type, construction materials, and age of construction, as well as its value and policy conditions such as deductibles, limits, etc.
- A portfolio model which is a database of all the buildings covered by the insurance programme containing information on location, value, building type, construction materials, age of construction and any other factors affecting their vulnerability to the hazard, together with policy information on the insurance cover.
- An occurrence model which simulates in a probabilistic manner the occurrence of the events giving rise to the hazard. In the case of earthquake loss, these models are based on a combination of known information about active faults plus historic records of earthquakes. For tropical cyclone loss, these models are generally based on historic records of tracks, central pressures and eye diameters (if available).
- An integration model which simulates the occurrence of events in accordance with the occurrence model, maps the maximum intensities of the hazard for each simulated event in accordance with the hazard model, superimposes this over a map of the portfolio information, calculates the individual losses according to the vulnerability model and aggregates these in the form required, and outputs the results in the desired form.

The basic output of GIS loss models are tables of loss versus the average number of exceedances of this loss per year (or its inverse the return period of the loss) in which form it can be used to randomly simulate the losses over many years which is the information needed for financial risk management models. This information can be produced for the total portfolio loss, or for any sub-set of these losses in terms of regional areas, subsidiary companies, building types, location category in terms of say soil type for earthquake loss, or terrain type for wind loss for use for risk rating purposes or internal allocation of costs.

The three major independent international commercial providers of GIS loss simulation models are Risk Management Solutions (RMS), EQE International (EQECAT), and Applied Insurance Research (AIR), which are all based in the United States. Some of the major reinsurance broking firms such as Aon have also developed their own models for internal use, and a number of smaller consultants have also developed models appropriate to their expertise and the regions in which they work.

Although the most sophisticated of these models are very complex, and embody considerable precise calculations, none can be described as accurate, as they depend on a considerable number of assumptions for which detailed knowledge is lacking. The assumptions used in the different models are based on the opinion of experts retained by the individual companies that produce the models. These opinions differ, reflecting the differences of opinion among experts on matters for which detailed knowledge is poor. As a consequence different models can produce widely differing results for the same portfolio. It is not unusual for results to differ by a factor of two or more. If the difference is less than 20 percent it is regarded as very small, but the results may be no more accurate than those that differ by a factor two. Output from these models should be regarded as best estimates based on expert opinion, and indicative of the order of magnitude of the risks of large losses, rather than accurate estimates of them.

By and large where uncertainties exist, the models are more likely to err on the conservative side. Consequently most models probably give relatively conservative results, and generally – but not always – the gradual refinement of models leads to a reduction in the estimated risks over time.

Undertaking detailed studies using these models is generally time consuming and expensive, unless undertaken at a relatively coarse level of portfolio accumulation such as Cresta Zones. They are also very demanding on the quality of the portfolio information required. Undertaking a study using them consequently becomes a major project in its own right.

Financial Risk Management Models

To determine the best set of values for the various design variables of a disaster insurance system such as premiums, cover conditions, reinsurance programme, investment strategy, etc, it is necessary to model the performance of the fund and financial operation of the system as a whole into the future. This type of analysis is commonly known as asset/liability modelling (ALM). When undertaken in terms of risk, a technique known in the insurance industry as dynamic financial analysis (DFA) is incorporated in the analysis to produce a financial risk management system. An understanding of the range of answers from such systems, the interactions between the answers, and the quantification of the effect of changes in policy decisions provides a framework for establishing an optimal design for the disaster insurance scheme and maintaining it. .

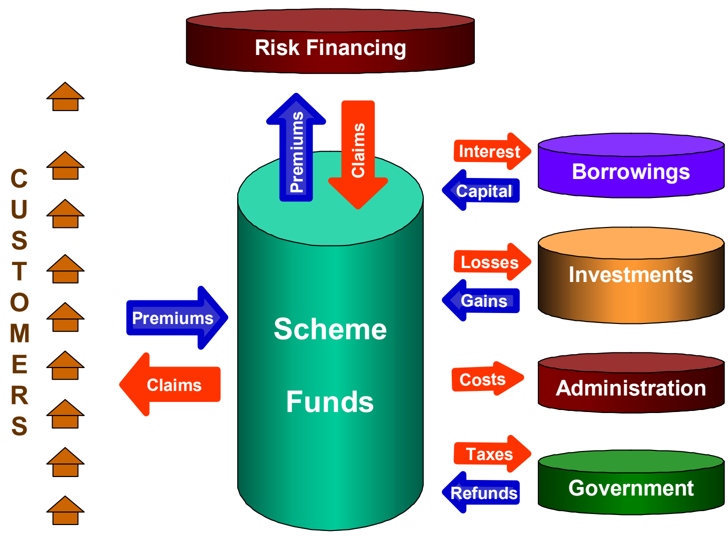

Figure 77: Financial structure of fund-based property insurance scheme

The basic financial structure of a fund-based property insurance scheme is shown Figure 77.

The basic purpose is to collect premiums from customers and pay out claims to them when they suffer a loss. However, administrative costs, investment gains and losses, reinsurance premiums and recoveries, borrowings if needed, and government taxes and refunds, eg. arising from a government guarantee – also affect the performance of the scheme.

The objective of financial risk modelling is to simulate this structure on a computer, input the uncertainties and proposed policies in regard to premiums, policy conditions and financial risk management strategy, and observe the resulting performance in terms of various balance sheet and profit and loss variables, and other performance indices.

Figure 78 shows the structure of a typical financial risk management software system designed to simulate the financial performance of a disaster insurance scheme. This takes as its input the projected variability in the amount and the timing of premiums, claims, expenses, growth in asset values and settlement patterns as represented by statistical distributions, together with the output of the analysis of insurance risk.

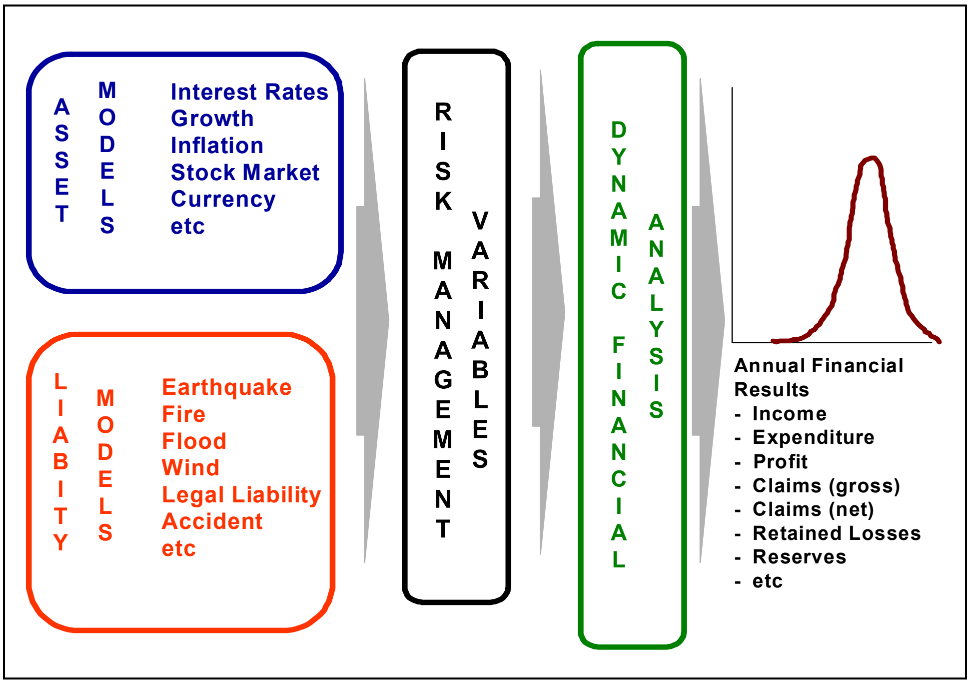

Figure 78: Structure of financial risk-management system

The system is normally constructed to simulate several years of operation into the future in order to observe how the system will behave over time. By changing the various risk management variables such as premiums, policy conditions and reinsurance proposals, a user can determine the combinations which give the most satisfactory outcome in terms of such factors as the sustainability of the scheme, affordability of premiums, and tolerance for risk.

Output from such models enables managers and administrators to get an understanding of the risks associated with different strategies, and not to have to rely only on subjective opinion.

The Minerva system recently developed for the New Zealand Earthquake Commission by Aon is an example of such a system. Minerva is designed to simulate the performance of the EQC's Natural Disaster Fund for 10 years into the future, allowing for portfolio growth and inflation. It includes a full probabilistic GIS earthquake loss model covering all dwellings in New Zealand, information on which is input on an individual basis describing location, type of building, age, estimated replacement cost, and the nature of the foundation soils. For estimating the exposure risks in future years new dwellings are created in accordance with input information on expected growth in dwellings, and increases in value are made in accordance with input information on inflation and improvements to existing buildings. The loss model includes several options for attenuation modelling, source modelling and vulnerability modelling, so that users can gain an understanding of the range of results due to different assumptions. The financial behaviour of the fund itself is modelled using two different asset models, one a simple traditional model and one a more complex state-of-art model. The system allows for both deductibles and first loss caps as policy conditions, and for both traditional CatXL reinsurance and alternatives such as Cat bonds and contingency loans. The system outputs in statistical form over 60 different factors describing the financial performance and position, cash flows and contingent liabilities for different investment strategies or returns, and various reinsurance or fund protection arrangements.

Regional Perspective

Summary - Risk Management Options

Catastrophe Insurance is one of a collection of options that can be drawn upon to manage risk in the Pacific.

Disasters have both a social impact and economic impact. The real tragedy of disasters is the individual hardship endured by those affected by them. Mitigation of the financial aspect of hardship is usually the main objective of national disaster insurance schemes.

Mechanisms by which this hardship can be reduced include government aid, charities and insurance. Each spreads the financial losses beyond those directly affected to reduce the impact on the individual. Generally, government aid focuses on infrastructure and assistance in the form of low interest loans and special grants to both industry and individuals, while charities focus on individual cases of extreme need. Both these forms of mitigation tend to be reactive in that the funds used have to either come from the current account in the case of government, or be raised by special appeal in the case of charities. In the case of governments, this often entails borrowing money from international funding agencies and increasing taxes to pay this back over time.

By contrast, insurance is a proactive form of mitigation of hardship whereby an individual or organisation is able, for a fee, to transfer financial risk of loss in advance of a disaster. If a disaster strikes and loss is suffered then the relevant financial compensation is made. Because of the internal international transfer of risk that occurs within the insurance industry through reinsurance the losses can be widely spread around the world, which means that the national economy will be subjected to a lesser financial shock.

Many governments in developed countries, where insurance tends to be embedded in the culture, have made special provision for insurance against disasters. In some cases, where the risks are perceived as relatively low, this may be limited to a requirement that losses from disasters be covered by standard household policies. In other cases it has led to separate government-organised and managed schemes. All of these schemes differ in some way from each other, depending as they do on many factors.

Cyclone and earthquake need to be considered as independent events, and a factor introduced to take into consideration the possibility of more than one capital city being impacted in the same time frame. If a replacement policy was to be adopted, premiums would no doubt exceed what is affordable in the region. According to Walker (2003), because the premiums are likely to be determined by issues of affordability and as a result of a political process, the design objective for the scheme will be to determine a set of policy conditions that satisfies the limitations on premiums.

Ideally any national or regional system for disaster insurance scheme should meet the following criteria summarised in Table 34:

Table 34: Requirements of a Pacific National or Regional system of disaster insurance

- Provide **wide coverage**: Cover uninsurable perils for dwellings and infrastructure
- Provide **adequate funds** for reconstruction and repair of damaged structures: Social service to make significant contribution to the reduction of hardship
- Be **affordable**: Level of cover to fit the premiums; address social equity issues
- Have an **efficient** administrative system including response to claims: Use insurance industry or Government body; premiums cover cost of claims-handling, monitoring and managing the risk
- Be free of **moral hazard**: Controls on claims-handling; large reserves
- Be technically and **financially sound**: Income must balance expenditure; build a pool or fund as protection
- Be politically **acceptable**: Fundamental to establishment and sustainability of scheme; acceptability depends mainly on the level of cover to be provided and how the premium is to be levied
- Be linked with **mitigation** activities: Incorporate incentives or regulations that will over time reduce the overall vulnerability eg. building standards, land planning; funding of public education and research activities in relation to disaster mitigation

To provide protection from the fluctuations of the market, many schemes aim to build up a pool or fund. In its simplest form, the financial risks to a disaster insurance scheme are generally covered by a balancing a combination of the following financial measures (Table 35):

Table 35: Technical soundness in financing a Pacific disaster insurance scheme

The risks to a disaster insurance scheme are generally covered by a combination of:

- Pool funds:
- Risk transfer, *eg.* re-insurance
- Risk financing, *eg.* contingency loans
- Government guarantee
- Insurance industry contributions

Costs of setting these up may include:

- Costs of risk transfer
- Costs of risk financing
- Cost of government guarantee

Other costs, apart from irregular major claims, include:

- Costs of administering the scheme, including managing claims
- Costs of attrition losses – *ie* regular small claims
- Taxation
- Costs of measures to mitigate risks

Regular annual income to cover these costs comes from a combination of:

- Premiums
- Investment income
- Industry levies
- Government grants

There are a number of critical considerations to be taken into account before launching into a regional scheme, so that a conceptual framework would need to be developed (Table 36). For example, the current level of household and business private insurance in Port Vila may well be already adequate, but this must be ascertained for each country involved in a regional scheme. If infrastructure and utilities have been privatised and are insured to a level commensurate with the national good, then these would not need to be covered further. Setting limits to premiums (and thus coverage), the necessity for developing a pool, and the form of management and administration are all important considerations.

Table 36: Summary framework for the development of a Pacific Regional system of catastrophe insurance

FRAMEWORK FOR THE DEVELOPMENT OF A REGIONAL SYSTEM
1. What is the current level of disaster insurance in the region?
In the less wealthy countries of the Pacific region, the average householder and small business is not covered because of expense or conditions applied. Need to determine which sections of the community towards which a national disaster scheme will be directed
2. What will it cover?
Dwellings only, for damage from natural hazards: extreme weather events and geological hazards - Government assets should be insured as part of a general insurance programme of Government property and not part of a special disaster scheme
3. What is the maximum limit to premiums in terms of affordability?
Premiums will be determined by affordability – these are likely to be low or provided through specific Government taxation. The risk will then determine not the premiums, but the level of cover that will be provided
4. What is the affordable risk?
Need to develop Risk-Loss modelling specifically for the Pacific Islands Region using the SOPAC community of expertise (hazard and property databases well underway) to determine policy conditions and the level of cover that can be provided – Need to develop priorities for different countries and institute the scheme sequentially
5. How will the system be structured?
Need to develop a specific Financial Risk-Management model to define a common Regional scheme or pool arrangement
6. How will it be managed and administered?
Need to consider how premiums will be collected, how claims will be assessed and paid, how will board members be appointed, and who will administer the scheme
7. What about loss control?
Need a firm control on claims-handing, and a clear link to building and planning regulations

Following these considerations, a series of choices might be presented (Table 37) which would involve decisions on the hazards and classes of assets to be covered, what ties would be developed with other forms of pro-active and reactive disaster mitigation, and whether Government would take advantage of the skills inherent in the private insurance industry. These skills might be especially important in questions of how to best administer the scheme, cover claims-handing in the event of a disaster, and in deciding what proportion of premiums might be used for either buying re-insurance or attempting to develop a regional pool over time.

Table 37: Options for a Pacific Regional catastrophe insurance scheme - possible choices highlighted

CATASTROPHE INSURANCE SCHEME - DESIGN OPTIONS			
1	**Classes to be Covered**		
	A	Dwelling - Building, Contents	√
	B	Small Business - Building, Contents, Business Interruption	
	C	Medium and Large Business - Building, Contents, Business Interruption	
	D	Agriculture - Crops, Livestock	
	E	Government Owned Risks - Buildings, Utilities, Infrastructure, Emergency Services	√
	F	Health - Death, Accident Cover, Worker's Compensation	
2	**Hazards to be Covered**		
	A	Earthquake - Shaking, Fire, Landslide, Tsunami, Subsidence, Liquefaction	√
	B	Tropical Cyclone - Wind, Rain, Flash Flood, Stream Flood, Landslide, Storm Surge	√
	C	Thunderstorm - Wind, Hail, Rain, Flash Flood, Lightning	
	D	Other Weather Events - Rain, Flash Flood, Riverine Flood, Bush Fire, Wind	
	E	Volcanic Eruption - Shaking, Debris Flow, Ash Fall, Lava Flow, Fire	√
	F	Human-Induced Hazards - Explosion, Major Fire, War, Terrorism, Riot	
	G	Other - Pestilence, Disease	
3	**Type of Scheme**		
	A	Industry only, either as part of normal insurance, or collaboratively through an Industry Pool	
	B	Government Fund, Providing either insurance direct to consumers, or providing reinsurance to insurance companies enabling them to provide disaster insurance cover	
	C	Joint Industry/Government Pool, through which industry provides the insurance, but which is protected in part by a Government guarantee and /or a co-insurance arrangement between the government and Industry	√
4	**Universality of Cover**		
	A	Voluntary, either as an addition to a normal policy, or as a separate policy	
	B	Compulsory, either in conjunction with normal insurance, or as a separate universal policy	√
5	**Extent of Cover**		
	A	Replacement value generally with a deductible or franchise, and possibly a level of coinsurance or first loss limit	
	B	Indemnity value generally in conjunction with a deductible or franchise, and a level of coinsurance or first loss limit	
	C	Limited amount of cover in conjunction with claim conditions such as a specified minimum amount of damage	√
6	**Form of Premiums**		
	A	Fixed Premiums	√
	B	Fixed Premium Rate	
	C	Variable Premium Rate	
7	**Upper Limit**		
	A	No upper limits and no Government guarantee	
	B	No upper limits with a Government guarantee	
	C	A fixed upper limit with proportional cover above this	√
8	**Claims Handling**		
	A	Insurance Industry	√
	B	Government	√
	C	Offshore Assessors	
9	**Financial Risk Management**		
	A	No reinsurance, and Government absorbs risk above level of accumulated funds	
	B	Risk completely reinsured up to specific probable maximum loss (PML) apart from a retention for small attrition losses	
	C	Reinsure a layer of risk above a retention to cover attrition losses and rely on accumulated funds and government guarantee to meet risks above this level	√
	D	Reinsure gap between level of accumulated funds and PML	
10	**Fund Management**		
	A	Industry board of participating companies	
	B	Joint Industry/Government scheme	√
	C	Government organisation and appointed board	
11	**Fund Administration**		
	A	Outsourcing to an insurance or reinsurance company	
	B	Creating a separate unit	√
	C	Administering within a Government department	
	D	Government reinsurance company	
12	**Mitigation**		
	A	Indirect - specified funds for public education, development of appropriate building codes and land-use guidelines	√
	B	Direct - certification that building design meets a certain level or has been upgraded to this level	√
	C	Incentive – incentives offered to the owners of non-complying buildings to upgrade	√

From Pilot Area to Wider Region

The losses to Port Vila (relative to the 2001 Vanuatu national expenditure) from the largest recorded past disasters (January 2002 Port Vila Earthquake and Cyclone Uma in 1987) appear small compared with the potential losses predicted from the 100-year and 500-year events (Figure 79). The Gross Domestic Product (GDP) for Vanuatu in 2001 is also shown for comparison.

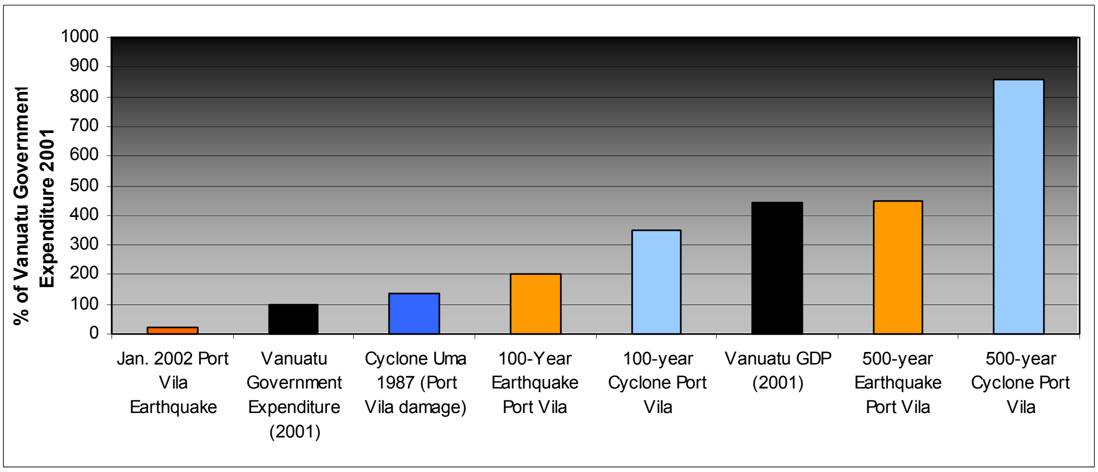

Figure 79: Losses from major disasters in Port Vila and predicted losses relative to Government expenditure

Extrapolation of anticipated losses from the pilot area to the Pacific Region is not an exact science given the paucity of good historical information on hazards and their recurrence periods, and the lack of comparable and up-to-date census figures and building data. It is based, then, on a number of assumptions. The primary assumption is that the most likely and most significant grouping of island nations in any catastrophe insurance scheme would be Fiji Islands, Solomon Islands, Vanuatu, Samoa and Tonga. These five largest, and most at-risk, countries are taken in this context to represent the Pacific region.

These five Pacific region countries, at the beginning of the new millennium, had a total population and assets at risk which exceeded 1.6 million people and 320,000 buildings, with an asset value estimated at over AUD$52 B; figures which are 40-50 times larger than those of the pilot area. In the interim there has been over 5% growth in the region, most of it in the urban areas. These countries face comparable hazard levels to the pilot area, but of course the incremental chances of more than one country in the region experiencing a 100-year event in the same time frame become more remote the more countries are considered as being affected.

The combined population of the capital cities of those five nations at almost 326,000 people is almost 10 times that of the pilot area. Given assumptions of hazard levels relative to Port Vila, the combined, equivalent values of assets at comparable risk in the regional capitals approaches AUD$8 B, which is about 7 times that of Port Vila alone.

Port Vila stands to experience losses in the 100-year event (40% probability in 50 years) of AUD$150 M from earthquake and tsunami and AUD$260 M from cyclone. The 500-year event (10% probability in 50 years) threatens Port Vila with losses of AUD$330 M from earthquake and tsunami and AUD$635 M from cyclone.

Given the GDP in 2002 for Vanuatu was AUD$327 M, these levels of loss in the pilot area equate in the 100-year event to about 50% from earthquake of the national GDP, and 80% of

GDP from cyclone (Figure 80). In the 500-year event, the predicted losses from earthquake are approximately equal to the GDP, and from cyclone are almost twice the GDP. This level of predicted loss is largely reflected throughout the region as shown in the same figure and tabulated in Table 38.

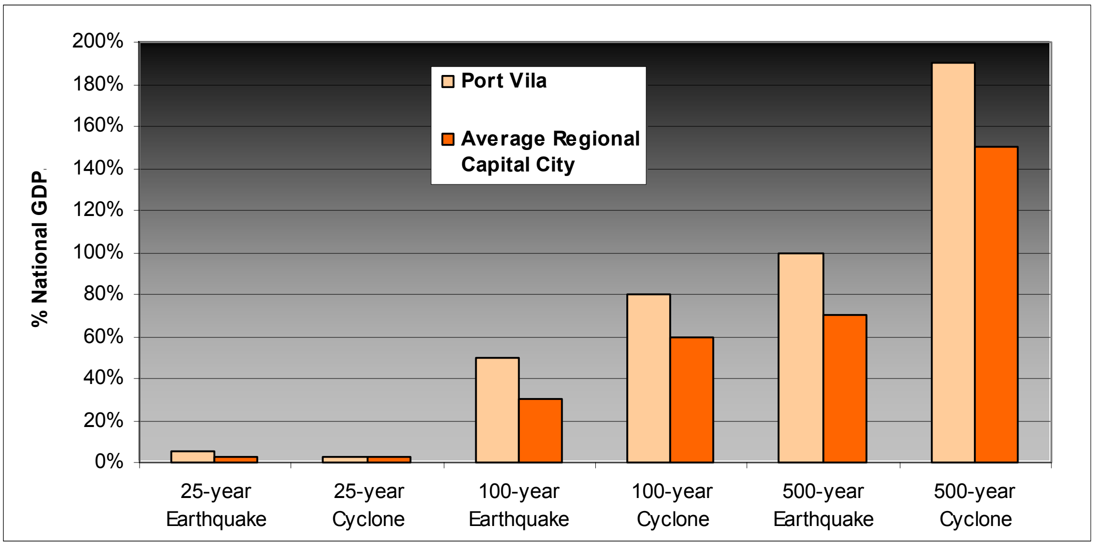

Figure 80: Predicted losses from earthquake and cyclone in regional cities, compared with Port Vila

On the assumption that more than one of the capitals might be affected by high-level earthquake or cyclone events in the same period, anticipated regional losses might be 2-3 times more than those calculated for the Port Vila pilot area. Historical events like Cyclone Bebe in 1972 which struck Tuvalu, Fiji and Tonga in turn, clearly demonstrate that multi-country events are possible.

Table 38: Predicted losses over various terms relative to national GDP

Hazard Event	Pilot Area Port Vila Predicted Losses AUD$ M	Pilot Area Port Vila Predicted Losses % Vanuatu GDP	Pacific Region Average National Capital City Predicted Losses % National GDP (Fiji, Solomon Islands, Samoa, Tonga, Vanuatu)
25-Year Return-Period (86% probability in 50 years)			
Earthquake:	$15 M	5%	3%
Cyclone:	$11 M	3%	3%
100-Year Return-Period (40% probability in 50 years)			
Earthquake:	$150 M	46%	30%
Cyclone:	$260 M	79%	60%
500-Year Return-Period (10% probability in 50 years)			
Earthquake:	$330 M	101%	70%
Cyclone:	$635 M	194%	150%

Conclusions

The major risk facing the pilot city is from earthquake and cyclone catastrophes. The 100-year return-period catastrophes have a 50:50 chance of happening within the span of a human lifetime, so they are not remote events to be ignored. Their financial impacts can be measured in terms of at least several times the gross national annual expenditure, imposing severe financial burdens on already weak systems. Meanwhile, lower-level disasters and damaging events sap continually at nation-building efforts to the detriment of sustainable development.

The Vanuatu case is representative of at least the five largest countries in the Pacific region, and is a valid starting point for analysing the regional risk. In other words there are at least five nations facing ruin primarily as a result of catastrophic natural disasters striking their capital cities. The portfolio at risk in the region as a whole, and the extent of those risks, has been outlined and is significant. It is clear that the risk-transfer and risk-financing measures being undertaken by Vanuatu (as in most of the other countries) are insufficient to deal with the long-term threat of disasters. Under the current circumstances, and in the event of the first truly catastrophic event in the region, risk-transfer to aid donors will suddenly emerge as a major issue. The magnitude of this looming issue behoves a careful planning to avoid such surprises.

The first and crucial step in the path to developing a regional catastrophe insurance scheme is for the countries involved to demonstrate the political will to establish realistic and truly comprehensive national risk-management regimes. At the same time comes the need to organise on a regional level to bring to bear economies of scale. From this first step, there is a need then to gain financial backing, establish the detailed knowledge of the assets portfolio at risk, employ scientific risk-loss analysis, and perform economic and financial-risk analysis to finally develop a scheme that complements other mitigation efforts to ensure economic and social stability in the face of catastrophe.

Any initiatives towards a catastrophe insurance scheme should be closely integrated with the broader issue of comprehensive risk management in the Pacific context. The work through UNFCCC to develop risk-transfer and financing options for climate-related disasters and the Small Island States Insurance Scheme are two such parallel initiatives on the international scale. The World Bank, too, is acting in the role of a global knowledge provider, bringing a global perspective to the Pacific to investigate what relevance catastrophe risk management in the Caribbean might have in the Pacific.

On the regional scale, SOPAC has the role of coordinating all disaster risk management for the Pacific Islands Forum Countries, feeding in turn into the UN ISDR initiatives to raise disaster awareness in developing countries. SOPAC has forged a path with practical risk-treatment solutions which demonstrates that there is a comprehensive way of redressing the lack of mitigation measures in place.

Pacific Island Governments generally find it difficult to cope with the demands being made on them. However, the fundamental issue is that both donor funding agencies and Pacific Island Governments urgently need to recognise, and act on, the fact that all forms of risk management are linked, and that the issue and its solutions rest with the highest levels of government with the support of the grass-roots level of community.

Some of the important questions that need to be asked of any potential scheme for catastrophe insurance in the region are shown in Table 39:

Table 39: Important questions for a Catastrophe Insurance Scheme

Among the many important decisions to be made in establishing a sustainable disaster insurance system, the following are among the most important:

- Which **risks** should be covered and with what **limits** and/or deductibles?
- What is the appropriate technical price for each type of risk exposure (residential, commercial, agriculture etc.) and therefore the **premium** to be charged, based on premium volumes likely to be written at different rates, and how this impacts on the overall profitability of the company?
- What is the probability of **ruin** of the scheme (generally linked to the probability of the level of solvency for the entity falling below a given point) and is this acceptable?
- How much **capital** does the scheme require to be sustainable?
- How much **re-insurance** should be purchased, recognising the value of reinsurance as a form of capital and a key financial management tool? (Another benefit is to provide a specific management focus on the risk retention policy, reinsurance leverage, credit risk and administrative cost.)
- How should the **assets** of a company be invested? What asset mix should the company employ, and how should this change to ensure optimal returns in both the short and long terms.

Each of these questions is obviously dependent upon the others. One cannot answer how much capital is required until one knows what coverage will be offered, the premium volume, the overall insurance exposure risks, and how the assets will be invested and the associated risks. Similarly, one cannot determine the optimal asset mix until one knows the premium volume, its volatility and the amount of capital available. To boot, the premium depends as much on the policy conditions and the insured risk, as well as being restrained by affordability.

These various factors can be described as the system variables, with the object of the system design being to determine the appropriate combination of values of them. However doing this in a rational way has only become possible very recently.

Most of the current schemes were probably designed in a somewhat ad hoc manner as a result of particular political imperatives at the time. A major problem with disaster insurance schemes is that they are concerned with risks for which the level of loss is very high and the associated risk of occurrence is low. As a consequence it is very difficult to derive reliable information on the risks by extrapolation of past losses.

There is a strong body of opinion that it will be important for a Pacific scheme to build a pool of reserves through taxation as early as possible. In the interim, any risk in the early years might need to be carried by a sympathetic financier in order to avoid re-insurance provisions taking most of the profit.

In view of the experience of other attempts at national pooling arrangements elsewhere, one of the most significant challenges in developing a disaster insurance pool might be in arriving at a common agreement over the contributions to be made by each state.

Whatever the scheme chosen, all parties agree on one point: Without a firm baseline including detailed knowledge of the hazards, the elements at risk together with their vulnerabilities, and the risks facing the Pacific, any financial analysis, and the scheme itself, would be fundamentally flawed.

Recommendations

Actions

A number of recommendations arise from the preceding conclusions, and are presented below as a logical list of necessary actions:

1. Pacific Leaders, in realising the value of such a scheme to national development, must act to instruct a peak Pacific regional political organisation such as the Pacific Islands Forum Secretariat (PIFS) to champion the cause of Catastrophe Insurance. Support should be provided by a regional technical agency such as SOPAC where a broader programme of risk management is already in place, in order to initiate, guide and coordinate the process of developing a regional scheme for risk financing of catastrophes.

2. The lead organisations (PIFS/SOPAC) should act to develop a source of funding from traditional or non-traditional donors sufficient to take the work forward to the next stage.

3. PIFS/SOPAC should seek expressions of interest from individual PICs in participating in the insurance scheme. Such interest should be a prerequisite to undertaking such work in that PIC, recognising the need for commitment from PICs in order to ensure the scheme is sustainable in the long term.

4. PIFS/SOPAC should set up a working committee of representatives from interested PICs in order to maintain the direction of the initiative.

5. PIFS/SOPAC should draw together and publicise the inherent links between catastrophe insurance schemes, existing programmes of climate change risk management (Adaptation to Climate Change; UNFCCC), the established national disaster management structures in-country, incipient Government Risk Management initiatives, and traditional private disaster insurance and associated debt servicing schemes, to ensure that duplication of effort is minimised and that any scheme developed is holistic and focussed in its nature. Some of this work is underway in the SOPAC Community Risk Programme.

6. PIFS/SOPAC should bring together the relevant regional and international funding and support organisations and agencies currently working in these areas on the general issue of risk management, and should facilitate a consensus view on the consolidation of risk management in the Pacific, and to set up financial incentives for tackling risk in a coordinated manner.

7. The PICs, individually, should be encouraged to define and adopt the principals of comprehensive risk management (including a catastrophe insurance component) at the highest level, and draw the links between hitherto independent programmes in the Government Departments of Foreign Affairs, Economics, Strategic Planning, National Disaster Management, Environment, Public Works and others.

8. PIFS/SOPAC should engage a well recognised re-insurance consultant experienced in this field to perform a preliminary financial risk analysis to provide initial options for the Pacific region based on the broad, existing information available.

9. PIFS/SOPAC should arrange and organise a think-tank meeting of all parties between

high-level representatives of PICs, risk practitioners, insurance industry representatives and funding and support agencies to clearly define the prime issues.

10. PICs should meet independently to develop a consensus in the broadest terms on the most politically acceptable form of risk financing for catastrophes in the Pacific cultural and social context.

11. PIFS/SOPAC should engage risk-management consultants to take forward the process of developing suitable options for risk financing for catastrophes in the region of and to administer this process (see Important Questions; Table 39)

12. Risk-management consultants to PIFS/SOPAC should take the lead role and actively coordinate existing development partner support and seek new commitments while continuing to refine the ideas on the composition of a holistic approach specifically including a catastrophe insurance scheme.

13. SOPAC, at the same time and in order to provide the technical foundation for realistic decisions on a Catastrophe Insurance scheme, should be commissioned to expand the hazard and risk-loss investigations from a local pilot study into a Pacific regional scheme by:

    a. Defining the complete regional risk environment including natural and human-induced hazards, vulnerability and portfolio description;

    b. Developing a rapid objective means of assessing and verifying damage levels from any disaster in the region for the purpose of claims assessment and input to a regional database on which to build future decisions;

    c. Expanding the current SOPAC risk-loss modelling to the regional context;

    d. Commissioning specific financial risk-management models to better define the parameters of the scheme;

    e. Implementing more widely its existing work in comprehensive risk management in the region.

14. PICs, PIFS/SOPAC and consultants should select the most appropriate options or package of risk financing methods to deal with the specific context and problems of the region, including a comprehensive mitigation programme as part of that package.

15. PICs should then adopt for implementation the most suitable regional catastrophe insurance scheme for risk financing of catastrophes in the Pacific.

16. PICs should arrive at an agreement relating the risk-perceptions of each country with the others, and then determine the proportional contributions that should be made by each state

17. Consultants should be engaged to calculate the cost of the specific programme and the means of funding it, while involving joint regional and international support and funding agencies in the process.

18. PICs and regional and international support and funding agencies should jointly implement a catastrophe insurance scheme in keeping with the overall theme of comprehensive risk management in the Pacific.

Statements

The recommendations for further action can be further summarised in the following four broad statements:

1. **Develop further support for the concept** by SOPAC/PIFS and the World Bank reporting to FEMM and continuing to raise awareness on the issue, using the SOPAC report and brochure on the Port Vila Pilot Study. A working group should be established representing all the stakeholders, including donors, to maintain the direction of the initiative and to develop a source of funding which is crucial to take the work forward. At the same time the work in the Pacific needs to be disseminated to international agencies working in the area of risk management and related issues such as climate change to ensure coordination and cooperation, establishing links and support where possible. The PICs should be further encouraged to adopt the principles of comprehensive risk management (including a consideration of catastrophe insurance) as prudent to economic planning at a national and regional level and essential to good governance.

2. **Develop preliminary options for risk financing and risk transfer** though engaging a re-insurance/risk management consultant to administer the process (see Important Questions for a Catastrophe Insurance Scheme), arrange stakeholders meetings, promote a consensus on the most acceptable form of catastrophe risk financing/transfer in the Pacific context, and develop preliminary options for the Pacific using risk-finance modelling based on existing limited information.

3. **Define the hazards, assets portfolio and risk environment** through SOPAC expanding the hazard and risk-loss investigations and modelling from a local pilot study into a Pacific regional scheme. In order to achieve this it will be necessary to define the complete regional risk environment including natural and human-induced hazards, vulnerability and portfolio description; develop a rapid and objective means of assessing and verifying damage levels from any disaster in the region for the purpose of claims assessment or trigger events for insurance payouts, and more widely implementing its existing work in comprehensive risk management in the region.

4. **Develop detailed risk financing arrangements** through PICs, SOPAC/PIFS and consultants jointly selecting the most appropriate options or package of risk financing methods to deal with the specific context and problems of the region, including a mitigation programme as part of that package. PICs should work to arrive at an agreement relating the risk perceptions of each country with the others and the proportional contributions to be made by each state, and adopt for implementation the most suitable regional catastrophe insurance scheme for risk financing of catastrophes. PIFS/SOPAC should engage risk financing consultants to calculate the cost of programme and the means of funding it, and to involve regional and international support and funding agencies in this process so that PICs and regional and international support and funding agencies are able to jointly implement a catastrophe insurance scheme in keeping with the overall theme of comprehensive risk management in the Pacific.

References

Barr J. 2001. Building Safer Urban Communities in the South Pacific – Regional Workshop. Joint Report by SOPAC and UNOCHA.

Biukoto L., Swamy M., Shorten G.G., Schmall S., and Teakle G. 2001. Pacific Cities CD, Port Vila. GIS Hazards Dataset, Version 1. 1. *SOPAC Data Release Report*, **4**.

Blong R. 1992. Natural Perils in the Port Vila Area, Vanuatu. *Macquarie Park Research Limited Report*, **4**.

Chung M., and Hill D. 2002. Urban Informal Settlements in Vanuatu: Challenge for equitable development. Report prepared for the Pacific Islands Forum Secretariat and UN ESCAP Pacific Operation Centre.

Dowrick D.J. and Rhoades D.A. 1999. Attenuation of Modified Mercalli intensity in New Zealand earthquakes. *Bulletin of the New Zealand Society for Earthquake Engineering,* **32**(2): 55-89.

Garaebiti E., Shorten G.G., Regnier M., Naidu P., and Swamy M. 2002. Assessment and study of the Port Vila Earthquake, 2nd January 2002. *SOPAC Joint Contribution Report*. **142**.

Granger K. 1998. ASDI (Australian Spatial Data Infrastructure) from the ground up: A public safety perspective. Australia New Zealand Land Information Council and AGSO, Canberra.

Hofstetter A., Shapira A., Bulehite K., Jones T., Mafi K., Malitzky A., Papabatu A., Prasad G., Regnier M., Shorten G., Singh A., Stephen M., and Vuetibau L. 2000. Frequency-magnitude relationships for seismic areas around the capital cities of Solomon, Vanuatu, Tonga and Fiji Islands. *Journal of Seismology*. **4**: 285-296.

Holmes J.D. 1996. Vulnerability curves for buildings in tropical-cyclone regions for insurance loss assessment. *ASCE EMD/STD Seventh Specialty Conference on Probabilistic Mechanics and Structural Reliability*, Worcester, Massachusetts, U.S.A., August 7-9.

Howorth R. 1983. Baseline coastal studies, Port Vila, Vanuatu. Geology and stability. *CCOP/SOPAC Technical Report*, **29**.

Howorth R. 1985. Baseline coastal studies, Port Vila, Vanuatu. Holocene uplift record and evidence for recurrence of large earthquakes. *CCOP/SOPAC Technical Report*, **51**.

Jarrard R.D. 1986. Relations among subduction parameters. *Reviews in Geophysics*, **24**(2): 217-284.

Kumar P. 1987. Tropical Cyclone Report – Tropical Cyclone Uma. *Fiji Meteorological Report*, **87/8**.

Linnerooth-Bayer, J., Mace, M.J., and Verheyen, R. 2003. Insurance-related actions and risk assessment in the context of the UNFCCC. Background Paper for UNFCCC workshops. Unpublished.

Leicester R.H., Bubb C.T.J., Dorman C.M.L., and. Beresford F.D. 1979. An assessment of potential cyclone damage to dwellings in Australia. Proceedings, 5th International Conference on Wind Engineering, Fort Collins, Colorado, July. (Pergamon Press).

Louat R., and Baldassari C. 1989. Chronologie des seismes et des tsunamis ressentis dans la région Vanuatu-Nouvelle Calédonie / Chronology of felt earthquakes and tsunamis in the region Vanuatu-New Caledonia. *ORSTOM Report*, pp.1-89.

Noyem B.J., 1976. Recording of tsunamis by tide wells, in *Proceedings of Tsunami Research Symposium 1974*, ed: R.A. Heath and M.M. Crisswell. pp.87-94.

Okada Y., 1985. Surface deformation due to shear and tensile faults in a half space. *Bulletin of the Seismological Society of America*, **75**: 1135-1154.

Pacheco F., Sykes L.R., and Scholz C.H. 1993, Nature of seismic coupling along simple plate boundaries of the subduction type. *Journal of Geophysical Research*, **98**: 14133-14159.

Pollner J.D. 2001. Catastrophe Risk Management: Using alternative risk financing and insurance pooling mechanisms. Report of the Finance, Private Sector & Infrastructure Unit, Caribbean Country Department, Latin America and the Caribbean Region, World Bank.

Prevot R., and Chatelain J.L. 1984. Seismicity and earthquake risk in Vanuatu (Text), and 1983.

Seismicity and seismic hazard in Vanuatu (Figures). *ORSTOM Report*, pp.5-83.

Reardon G.F., and Oliver J. 1982. Report on damage caused by Cyclone Isaac in Tonga. Technical Report No. 13. James Cook Cyclone Testing Station, November 1982.

Regnier M., Morris S., Shapira A., Malitsky A., and Shorten G. 2000. Microzonation of the expected seismic site effects across Port Vila, Vanuatu. *Journal of Earthquake Engineering*, **4**(2): 215-231.

Satake K., Okada M., and Abe K. 1988, Tide gage response to tsunamis: Measurements at 40 tide gauge stations in Japan. *Journal of Marine Research*, **46**: 557-571.

Schmall S. 2002. Development and implementation of a methodology for community risk assessment utilising GIS database in peri-urban and squatter settlements of Port Vila, Vanuatu. Unpublished report to SOPAC.

Schmall S. 2003. Participatory vulnerability assessment and community mitigation planning: Development of a participatory approach for risk mitigation in peri-urban settlements of Port Vila, Vanuatu. Unpublished report to SOPAC.

Shapira A., and van Eck T. 1993. Synthetic uniform-hazard site specific response spectrum. *Natural Hazards*, **8**: 201-215.

Shapira A. 1999. Seismic Microzoning in Capital Cities in the South Pacific. The Geophysical Institute of Israel, Final report, submitted to the US Agency for International Cooperation - CDR Program, USAID Grant No.: TA-MOU-95-C13-024.

Shorten G.G. 2001. Seismic risk in Pacific cities: Implications for planning, building code legislation, and urban search and rescue services. Invited Speaker. *Proceedings, Australian Earthquake Engineering Society Conference: Earthquakes in the Real World*, Canberra, ACT, 7-9th November, 2001. AEES, Melbourne, pp.2.1-2.9.

Shorten G.G. 2002a. Preliminary Report: Earthquake and tsunami damage assessment in Port Vila. *SOPAC Preliminary Report*, **135**.

Shorten G.G. 2002b. Pacific Cities urban planning and risk management: Port Vila and peri-urban areas case study. Proceedings, Sustainable Urban Services: PECC Sustainable Cities Noumea Seminar, Noumea, New Caledonia, 4-5th November, 2002, pp.107-116.

Shorten G.G. 2003a. Challenges for the application of earthquake engineering in the Pacific Islands. Keynote Speaker. Proceedings, PCEE 2003: 7th Pacific Conference on Earthquake Engineering, University of Canterbury, Christchurch, NZ, 13-15th February, 2003. PCEE Paper, **150**.

Shorten G.G. 2003b. Catastrophe insurance in the Pacific: Managing disaster risk in the Pacific Islands region. *SOPAC Miscellaneous Report,* **550**.

Shorten G.G., and Schmall S. 2003. Disaster risk management in marginal communities of Port Vila, Vanuatu: Project Summary. *SOPAC Miscellaneous Report,* **507**.

Shorten G., Shapira A., Regnier M., Teakle G., Biukoto L., Swamy M., and Vuetibau L. 1999. Applications of the uniform-hazard site-specific acceleration response spectrum in Pacific Cities. *Proceedings, Australian Disaster Conference*, Canberra, 1st-3rd November 1999, pp69-74.

Shorten G., Shapira A., Regnier M., Teakle G., Biukoto L., Swamy M., and Vuetibau L. (Compilers) 2001. Site-specific earthquake hazard determinations in capital cities in the South Pacific. Second Edition. *SOPAC Technical Report*, **300**.

Shorten G.G., Schmall S., Granger K., and Naidu P. 2003. Blending custom knowledge and science to reduce risk in three settlements near Port Vila, Vanuatu. Proceedings, 2003 Australian Disaster Conference, Canberra, 10-12th September, 2003.

Shorten G.G., Schmall S., Caron A., Goosby S., Granger K., Naidu P., Oliver S., Sope D., Stewart K., and Titov V. *in prep*. Disaster risk management in marginal communities of Port Vila, Vanuatu. *SOPAC Joint Contribution Report*, **148**. 2 Volumes, SOPAC Secretariat, Suva.

SOPAC 2002. Comprehensive Hazard and Risk Management (CHARM): Guidelines for Pacific Island Countries. SOPAC, Suva.

SOPAC 2003. South Pacific Applied Geoscience Commission Work Programme and Strategies. *SOPAC Miscellaneous Report,* **499**.

Standards Association of Australia 1999. Joint Australian/New Zealand Standard. Risk Management. Revised AS/NZS 4360:1999.

Tiedemann H. 1992. Earthquakes and Volcanic Eruptions - A Handbook on Risk Assessment. Swiss Re, Zurich.

Vermeiren J. 2000. Risk transfer and finance experience in the Caribbean. *World Bank's Disaster Management Series No.2: Managing Disaster Risk in Emerging Economies*, A. Kreimer and M. Arnold, eds.

Walker G.R. 1995. Wind vulnerability curves for Queensland houses. Alexander Howden Insurance Brokers (Australia) Ltd.

Walker G.R. 2003. Engineering disaster insurance schemes for the 21st Century. Proceedings, PCEE 2003: 7th Pacific Conference on Earthquake Engineering, University of Canterbury, Christchurch, NZ, 13-15th February, 2003. PCEE Paper, **32**.

World Bank 2000. Pacific Regional Strategy. Papua New Guinea and Pacific Islands Country Unit, East Asia and Pacific Regional Office. Report No. 20370-EAP.

Appendices – Volume 2

Appendix 1: **Quantitative Assessment of Risk to Infrastructure due to Large Natural Catastrophes in the Port Vila-Mele Area, Vanuatu**

Kerry Stewart, DunlopStewart Ltd, Auckland, New Zealand

Appendix 2: **Port Vila Peri-Urban Settlements Risk Analysis: Methodology**

Ken Granger, RiskScience, Buderim, Australia

Appendix 3a: **Catastrophe Insurance Pilot Project, Port Vila, Vanuatu: Vanuatu Wind Storm**

Appendix 3b: **Disaster Risk Management in Marginal Communities of Port Vila, Vanuatu: Extreme Wave Risk**

Stephen Oliver, Global Environmental Modelling Systems Pty Ltd, Melbourne, Australia

Appendix 4a: **Tsunami Inundation Modelling for Pilot Project Harbour.**

Appendix 4b: **Tsunami Inundation Model of Mele Bay**

Vasily Titov, Consultant, Seattle, USA

Appendix 5a: **Risk and Vulnerability Assessment for Selected Building Types on the Island of Efate, Vanuatu**

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Stan Goosby, Pacific Disaster Center, Hawaii, USA

Appendix 6: **Preliminary Report and Vanuatu Government Risk Management System**

Kevin Lindsay, Risk Management International Consulting (Riskman) Ltd, Port Vila, Vanuatu

Appendix 7: **Catastrophe Insurance Pilot Project, Port Vila: A Framework for the Development of a Disaster Insurance Scheme**

George Walker, Aon Re Australia Ltd, Sydney, Australia