Science Plan on Hazards and Disasters

Special Vulnerability of Islands



ICSU

International Council for Science

Regional Office for Asia and the Pacific

Strengthening International Science for the Benefit of Society

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ICSU Regional Office for Asia and the Pacific was inaugurated on the 19 September by the Deputy Prime Minister of Malaysia, Y.A.B. Dato' Seri Najib Tun Abdul Razak. The new office will promote the development of science throughout Asia and the Pacific and help strengthen the voice of developing countries in this region. It will also ensure that its scientists become involved in those aspects of the ICSU 2006-2011 Strategic Plan that are especially relevant for this area.

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ICSU mobilizes the knowledge and resources of the international science community for the benefit of society, to:

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- Facilitate interaction amongst scientists across all disciplines and from all countries
- Promote the participation of all scientists in the international scientific endeavour, regardless of face, citizenship, language, political stance or gender
- Provide independent, authoritative advice to stimulate constructive dialogue between the scientific community and governments, civil society, and the private sector

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SCIENCE PLAN ON HAZARDS AND DISASTERS

Special Vulnerability of Islands

Report of ICSU ROAP Planning Group on Natural and Human Induced Enviromental Hazards and Disasters

June 2008

contents

PREFACE	2
ACKNOWLEDGEMENTS	2
EXECUTIVE SUMMARY	3
INTRODUCTION TO SPECIAL VULNERABILITY OF ISLANDS	4
HAZARDS ASSESSMENTS	6
Physical Parameters	7
Plate Boundary Associations	7
Steep Lands Mantled by Weathered Regolith	7
Wet Climates and Tropical Cyclones	7
Small Sizes and Low Elevations	8
Human Parameters	8
Remoteness and Inaccessibility	8
Marginalisation and Dependency on Local Resources	8
High Population Densities	8
Dependence on Tourism	9
CASE STUDIES	10
Case Study 1	11
Case Study 2	12
MAJOR RESEARCH PROJECTS	13
Tropical Cyclones and Islands	13
Islands River Systems	15
Island Steep Lands	15
Adaptation – A Cross-Cutting Theme	16
PRIORITIES FOR ASIA AND THE PACIFIC	19
BIBLIOGRAPHY	21
ANNEXURES	22
Annex I Terms of Reference	22
Annex II Planning Group on Hazards and Disasters	23
Annex III Abbreviations and Acronyms	25

Preface

This is the second plan arising from the work of the ICSU Regional Office for Asia and the Pacific, Science Planning Group on Natural and Human Induced Environmental Hazards and Disasters. Originally prepared together with the ICSU ROAP Science Plan on Hazards and Disasters: Earthquake, Floods and Landslides, it was decided to publish the section on the special vulnerability of Island in Asia and the Pacific seperately because of the particular need to highligh the vulnerability of the Pacific Islands to hazards and disasters. Many of these islands are found along active tectonic plate boundaries, have rugged interiors with unstable slopes, are highly exposed to the risks associated with tropical cyclones, and with global warming many of the attols and limestone islets are at risk of inundation. With the publication of a seperate ICSU plan on the special vulnerability of islands it is hoped that greater focus and attention will be brought to hazards and disaster issues in the islands expecially in the Pacific.

Harsh Gupta
Chair
ICSU ROAP Science Planning Group on Hazards and Disasters

Acknowledgements

Many individuals and organizations contributed to the preparation of this plan. A full list of the members of the ICSU ROAP Science Planning Group is given in Annex II at the end of the plan.

Special thanks are due to James Terry who prepared the main body of this report. Other members provided vital input and feedback in developing the plan.

Thanks are also due to the members of the ICSU Regional Committee for Asia and the Pacific under the chairmanship of Anupam Varma for their ideas and review of early drafts of the plan.

Vineet Gahalaut, Uma Anuradha, Nor Zaneedarwaty Norman, and Hizam Jaafar all contributed to various stages in the production of the plan.

Executive Summary

The majority of the vast Asia-Pacific region is made up of tens of thousands of islands, ranging from tiny and remote islets to large and highly populated insular landmasses. The Asia-Pacific is also unique as within it lay all 5 of the world's nations that are entirely atolls.

For various reasons, islands are inherently more vulnerable to natural hazards and disasters (H&D) than many continental or mainland areas. Physical influences include: the origin of island formation along active plate boundaries; the rugged highland interiors of volcanic islands which have unstable slopes; wet or very wet maritime climates with associated risk of cyclones (typhoons); the low elevation of small atoll and limestone islets which are at risk of inundation. Socio-economic factors which increase H&D vulnerability of many islands include their remoteness, isolation, inaccessibility, economic marginalisation and dependence on local resources. Some recent examples given for illustration are the earthquake (M 8.1) and resulting tsunami of April 2007 in Solomon Islands and the exceptional flooding produced by a cyclone in Fiji in January 2003.

All of the above mean that islands (and island communities) deserve special scientific attention in terms of assessing and monitoring hazard risk, understanding hazard impacts and longer-term effects, preparing for hazard occurrence, and implementing feasible disaster-adaptation programmes.

In response, several major areas for future research that should be given priority in the Asia-Pacific region are identified:

- Research into the behaviour and characteristics of tropical cyclones. This is because cyclones are associated with storm surge, coastal inundation, landslides and river flooding. Investigation should focus on changing patterns in storm development, occurrence, intensity, track movements, and their consequent impacts on island environments.

- Island river systems need better understanding. This can be achieved through increased monitoring and analysis of hydrological processes, especially to improve existing knowledge of island river responses to intense precipitation (leading to floods).

- Research on island steep lands is a third priority, in particular investigation of thresholds and processes in slope failure. This is due to the instability of steep slopes on volcanic islands in the Asia-Pacific region, together with the problem of earthquakes and large rainfall events that commonly trigger slope failure.

- Island adaptation to hazards and disasters deserves strategic attention, for better preparedness against hazards, and to reduce socio-economic losses after future hazard occurrence.

Related to these themes, a plan for scientific activity is presented, targeted for the island territories and nations of the Asia-Pacific region.

01 Introduction to Special Vulnerability of Islands

Many of the Asia-Pacific nations and the majority of its vast area comprises islands (and island states), and islands are inherently more vulnerable to natural hazards owing to a number of factors and influences. Within the Asia-Pacific region lie thousands of islands belonging to many developing nations and territories (Table 1).

Table 1 Selected island nations of the Asia-Pacific region

Examples of nations or territories comprising islands only	
Cook Islands	New Zealand
Federated States of Micronesia	Niue
Fiji	Papua New Guinea
French Polynesia	Philippines
Guam	Singapore
Indonesia	Solomon Islands
Japan	Sri Lanka
Kiribati	Taiwan
Maldives	Tokelau
Marshall Islands	Tonga
Nauru	Tuvalu
New Caledonia	Vanuatu
Examples of continental/mainland nations with offshore islands and/or significant island populations	
Australia	Korea
China	Thailand
India	Malaysia

They range in size from very large islands (>100,000 km2) such as Borneo and New Guinea to tiny islets (<10 km2) such as the Ha'apai group of central Tonga. These islands display enormous physical diversity. Some are rugged volcanic mountains with elevations reaching above 1500 m, whereas others are flat limestone platforms emerging only a few metres in height, or low coral islets resting just above sea level on coral reef foundations. The Asia-Pacific is also a unique region because it contains all five of the world's nations that are entirely atolls – Tuvalu, Kiribati, Tokelau, the Marshall Islands and the Maldives.

The factors influencing the special vulnerability of islands to natural hazards fall into two broad categories – physical and human parameters. These are discussed in the next section under Hazard Assessment.

02

Hazard Assessment

Physical Parameters

Plate boundary associations

The majority of the islands in the Asia-Pacific region owe their origin to plate boundary tectonics, and fall along the so-called "Pacific Ring of Fire". This means that many islands are volcanically and/or seismically active. (Figure 1) and tsunamis occur (see Case Study 1). Volcanic activity can trigger different types of landslide processes, such as debris slides, earth flows and lahars.

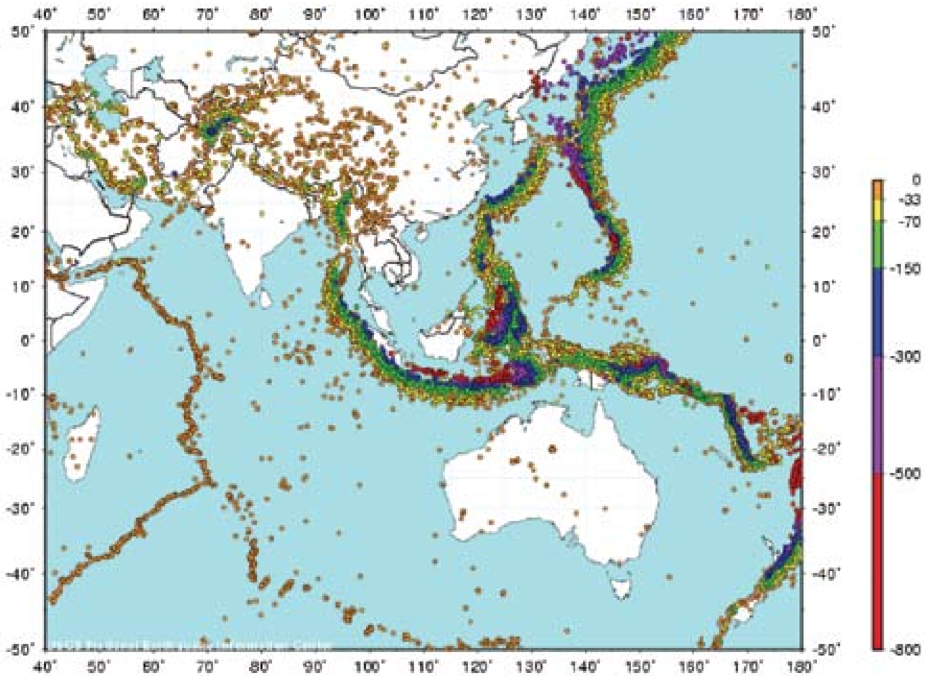


Figure 1 Earthquakes associated with plate boundaries in the Asia-Pacific region (USGS).

Steep lands mantled by weathered regolith

Volcanic islands typically have rugged topography and steep slopes. Recently erupted volcanic materials such as volcanic ash and pyroclastic flows of mixed composition are unstable and prone to slope failure. Yet on ancient volcanic islands, landslides are common too, because deep chemical weathering of the principal volcanic rocks produces thick clay saprolite under humid climates. Clay saprolites are much weaker than solid rocks – in particular they lose shear strength and cannot support steep-angled slopes when saturated after long periods of rain or extreme precipitation events.

Wet climates and tropical cyclones

Islands surrounded by large oceans have maritime climates that are characteristically wet compared to continental interiors. The majority of islands in the Asia-Pacific region have either humid tropical or humid temperate climates. Abundant annual rainfall (> 1500 mm/yr, but on many islands very much higher), often delivered mainly during wet or monsoon seasons, means that rivers are prone to display large seasonal variations in their hydrological behaviour, and often flood. Another climatic feature of the region is typhoons (tropical cyclones) – approximately 20 typhoons per year form in the North West Pacific and 10 in the South West Pacific. During these extreme events, the delivery of torrential rainfall generates fast and large responses in island fluvial systems (which are steep and flashy), often leading to catastrophic river floods.

Small size and low elevations

Thousands of islands in the Asia-Pacific region are very small and/or low lying. Tsunami waves (generated by submarine earthquakes) and storm surges (generated by tropical storms) can completely engulf such places. Populations inhabiting such islands are therefore incredibly vulnerable to sea flooding as there is no high land providing opportunities for evacuation (Figure 2)

Figure 2 Sea flooding of Nukunonu atoll in Tokelau, during Tropical Cyclone Percy on 26 February 2005. The low-lying coral islands of the atoll were completely swamped by storm waves. Photo courtesy of the Tokelau Public Works Department.

Human Parameters

Remoteness and inaccessibility

Many islands in the Asia Pacific region are remote and their populations are isolated. For nations comprising widely-scattered islands separated by large ocean distances, communications can be unreliable and transport networks are costly to maintain. For example, most of the outlying atolls of Tuvalu are serviced only by infrequent government ships as they have no airstrips. The situation is similar for upland areas of very large islands – such as the central highlands of New Guinea and Borneo. In these places thousands of scattered communities live in relative isolation from busy urban areas on the coast.

When natural hazards strike remote islands (or remote interiors of islands), the lack of easy communications means that:

- Hazard warnings systems are inadequate or non-existent.
- It is difficult for government authorities to make rapid assessments of the scale and severity of hazard impacts and the number of people affected and in need of assistance
- There can be long delays in evacuating communities to safe locations.
- Emergency supplies such as food, medicines and temporary shelter cannot be easily or quickly transported to the afflicted areas.

Marginalisation and dependency on local resources

Island populations generally benefit less from national funding programmes and large-scale development projects. They also tend to be marginalised from the mainstream of economic activities in major conurbations. As a consequence, island communities are more dependant on natural resources and their local environments (forest products, freshwater resources, coral reefs, mangroves and coastal fisheries), as well as subsistence agriculture for their traditional livelihoods. This increases their vulnerability to hazards because in the event of a natural disaster, the health and productivity of these natural ecosystems are also badly affected, which can have a severe long-term impact on the food security of island populations in addition to the short-term impacts that are suffered immediately.

High population densities

Some small islands in the Asia Pacific region are at great risk because of their extremely high population densities. Overcrowding has become a serious problem in many national capitals of island states because of the limited land area available for habitation, coupled with the ‘pull’ factors influencing in-migration from outlying locations where access to employment and services are limited. For example on Betio the main islet of the capital of Kiribati, located in the south west of Tarawa atoll, 15,000 people live on an area less than 1 km^2 in size (Figure 3).

Figure 3 In Betio on Tarawa atoll (capital of Kiribati) 15,000 people live on just 0.8 km^2 of land. This overcrowding on a tiny low-lying islet greatly increases the vulnerability of the population to natural hazards.

The population density exceeds that of Bangkok and Tokyo. Similar situations exist in the capitals of the Marshall Islands and the Maldives. The effects of a major tsunami would clearly be devastating for such islands, where the provision of adequate healthcare, freshwater and sanitation already poses significant development challenges for limited national budgets.

Dependence on tourism

The mainstay of economic activity and income generation is the tourist industry on many islands in the Asia Pacific region. Tourism-dependant island economies exist for example in parts of the Cook Islands, Fiji, Indonesia, Japan, Palau, Papua New Guinea, Samoa, Sri Lanka, Tahiti and Vanuatu. A major natural hazard can have a long-term negative effect on international tourist arrivals, causing a decline in the local economy, loss of income and prolonging the period of post-disaster recovery.

03
Case Studies

Case Study 1

Solomon Islands earthquake and tsunami, April 2007

The Solomon Islands in the Western South Pacific is an archipelagic nation of more than 200 islands. They lie on the Pacific Basin's so-called 'Ring of Fire', an arc of volcanoes and fault lines where earthquakes are frequent. The population is only 550,000, but the country faces extreme poverty, with an annual per capita income of less than US$500. At least 40 people died in the Solomons after a tsunami swept ashore following a strong undersea earthquake (10 km deep) of M 8.1 at 07:40 local time on Monday 2 April 2007, located 45 km South South-East of Gizo, in New Georgia province in the Western Solomons (Figure 4). The Solomon Islands arc as a whole experiences a high level of earthquake activity, and many shocks of M7 and larger have been recorded since the early decades of the twentieth century

Because of Gizo's proximity to the epicentre, the destructive tsunami waves struck before warnings could be issued. Within five minutes of the earthquake the town was hit by a wall of water up to several metres high that ploughed into the coast, swamped buildings and washed people out to sea. It also caused damage to main airport and knocked out phone and electricity lines. Solomon's Prime Minister declared a state of emergency. Over 2,000 people spent several unsheltered nights on hillsides following the coastal inundation and diarrhoea broke out quickly among camps of tsunami survivors. International aid was slow to trickle in, particularly in the hardest-hit town of Gizo. A supply boat left the capital Honiara three days after the event for the 10-hour journey to New Georgia, but other ships were delayed because provisions could not be found in the capital to fill them. Getting aid to affected villages farther afield took longer still because of damaged roads, airstrips and wharves.

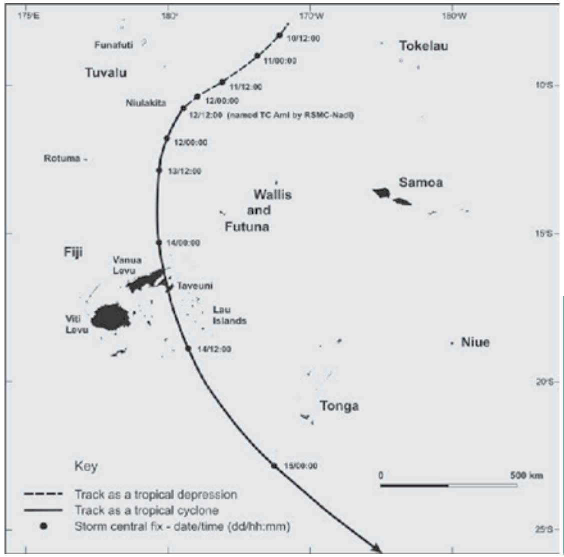
Figure 4 Location of earthquake epicentre in the western Solomon Islands on 1 April 2007 (left) and flood devastation caused by the tsunami in Gizo. Source: US Geological Survey and http://www.usatoday.com/news/world/2007-04¬01-world_N.htm.

Case Study 2

Exceptional river flooding in Fiji, January 2003

Cyclone Ami was the third cyclone to form in the Fiji area during the wet season of 2002-2003. Formed at about 12 midday Fiji Standard Time, the system deepened to storm intensity before midnight on 13 January, and then to hurricane intensity during 14 January. The cyclone moved quickly through the Fiji archipelago with peak-sustained winds of 200 km hr-1. Across Fiji's northern and eastern divisions the destruction caused by Ami was extensive and communications were completely cut off for several days. One-day rainfall data from climate stations on Vanua Levu island indicate that large-scale rainfalls were widespread. Of the 18 climate stations listed, 16 recorded more than 100 mm of rain in 24 hours. Of these, 5 stations received more than 200 mm because of orographic rainfall enhancement by the volcanic relief. Due to the torrential rainfall dumped by the storm, some of the worst-ever flooding occurred in many rivers on Vanua Levu, causing 17 fatalities.

In 5 of the 8 major rivers on Vanua Levu Island, Cyclone Ami generated the biggest floods on record. On the north coast, the Labasa and Qawa rivers, both drain into the same sheltered bay near Labasa town, which is the primary urban centre for the northern division of Fiji. The climax flows in these rivers, 2377 and 1802 $m^3\ s^{-1}$ respectively were record-breaking. The simultaneous discharge of these enormous volumes of water onto the same coastal plain coincided with a strong storm surge that was felt along the entire north coast of the island. This caused inundation of 3 to 4 m over a wide area around Labasa. Unprecedented despoliation of farms and homes across many rural communities was inflicted, causing extensive damage to infrastructure and property.



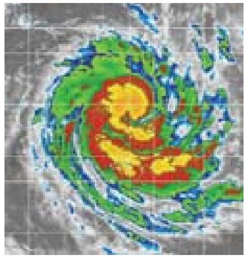


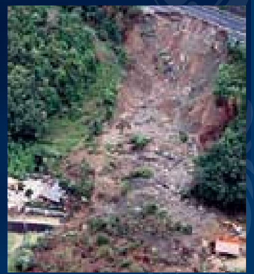
Figure 5 Cyclone Ami approaching the Fiji Islands on 12 January 2003 (top), the storm's subsequent track (left), and flooding caused in Labasa Town (right).

04

Major Research Activities

Tropical Cyclones and Islands

The most extreme meteorological conditions for many island groups in Asia-Pacific occur during tropical cyclones. Landslides, river inundation and sea flooding of low-lying coasts (the focus hazards for this report) are all generated as a consequence. Greater understanding of tropical cyclone characteristics and behaviour should therefore be a major research priority in the region, especially with scenarios of climate change suggesting the possibility of more intense cyclones occurring in future. Although many uncertainties remain, climate scientists now predict that Pacific regional climates will experience more frequent or sustained El Niño-like conditions. The implications for tropical cyclone generation include the potential for increased intensities, greater cyclone numbers, changes to the current spatial patterns of storm origins, and farther pole ward travel after vortex formation. Such changes mean that international assistance continues to be needed in national disaster preparedness and mitigation planning.



A recent report from the World Meteorological Organization neatly summarizes our existing knowledge on the theme of global tropical cyclones and climate change (WMO[1]). The report lists a number of 'consensus statements' by leading scientists, which include the following:

1. There is an observed multi-decadal variability of tropical cyclones in some regions [which] makes detecting long-term trends in tropical cyclone activity difficult.
2. It is likely that some increase in tropical cyclone peak wind-speed and rainfall will occur if the climate continues to warm. Model studies and theory project a 3-5% increase in wind speed per degree Celsius increase of tropical sea surface temperatures.
3. Although recent climate model simulations project a decrease or no change in global tropical cyclone numbers in a warmer climate, there is low confidence in this projection. In addition, it is unknown how tropical cyclone tracks or areas of impact will change in the future.
4. Large regional variations exist in methods used to monitor tropical cyclones. Also, most regions have no measurements by instrumented aircraft. These significant limitations will continue to make detection of trends difficult.
5. If the projected rise in sea level due to global warming occurs, then the vulnerability to tropical cyclone storm surge flooding would increase.

Overall, in a greenhouse-enhanced warmer world characterized by stronger or more persistent El Niño episodes, it seems likely that there will be some evolution in tropical cyclone activity for islands in the Pacific. As a result, some or all of the following effects may be experienced (Terry 2007):

1. Changes to the pattern of cyclone origins, with less clustering and more spreading to the east than at present,
2. Generally more storminess east of 180° longitude,
3. Increased tropical cyclone intensities, with lower central pressure and greater maximum wind speeds,
4. Enhanced precipitation,
5. Longer cyclone lifespans,
6. Extended track lengths and farther poleward travel before cyclone decay.

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[1]A detailed statement and a summary statement (WMO 2006) were released by the World Meteorological Organization following their International Workshop on Tropical Cyclones-VI. This meeting was held over two weeks in November 2006 in Costa Rica and was attended by invited participants and prominent scientists on both 'sides' of recent debates about climate change and its impact on tropical cyclone activity.

In light of the above, a concerted scientific effort should be directed towards improving our understanding of the development, occurrence, intensity and path characteristics of future tropical cyclones. All island communities will benefit from increasing awareness of cyclone behaviour and future change with global warming, with better information on the associated hazards (river flooding, storm surge, landslides, and coastal erosion). Investigation of the spatial and temporal behaviour of cyclone tracks in Asia-Pacific should include identifying changes in degree of sinuosity and patterns across the region. The findings will be helpful for climatologists in identifying causal factors that have changed over time, and hence increase our understanding of the formation and behaviour of cyclones in the Asia-Pacific island archipelagoes. Because there are some deficiencies in current cyclone track databases, future work should also proceed to reconstruct an accurate GIS dataset and make this freely available via the internet as open source information.

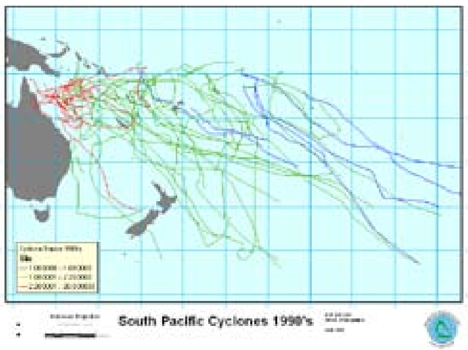

Figure 6 Sinuosities of tropical cyclones in the South Pacific in the 1990s. Note the variation from west to east. New research into track behaviour will benefit islands by increasing awareness of regional differences in cyclone movement, and the consequent risks of floods and landslides.

Island River Systems

For the mountainous islands in Asia-Pacific, extremely high river flows are linked to the response of island fluvial systems to large storms, often related to ENSO-enhanced periods of unusually prolonged or intense rainfall. The big rainfalls brought by tropical storms generate swift responses in Asia-Pacific streams and rivers and often severe overbank inundation. Flood problems include channel erosion and siltation, destruction of homes and infrastructure, contamination of water resources, damage to subsistence agriculture (threatening food security), and obvious risks to human life and health. Thus the short and long-term consequences of river floods can place heavy socio-economic burdens on developing island nations. Yet in spite of the problems, the characteristics of storm-related river floods remain generally poorly understood in the Asia-Pacific islands. Improved mitigation of flood disasters has been identified as a priority by many island nations, but this requires a better grasp of the hydrological behaviour of island fluvial systems during high-magnitude rainfall events (Figure 7). If the Pacific regional climate changes towards more sustained El Niño-like conditions, then a research focus on improving understanding of the factors and controls on island river responses to intense precipitation will enhance island disaster preparedness, risk management and adaptation. However, one major hurdle to overcome is the lack of established hydrometric stations on many island rivers, and the resulting poor record of flood discharges, which means that useful rainfall-runoff models cannot be developed. This needs to be addressed before flood forecasting on islands can improve.

Figure 7 Smashed bridge over the Lungga River near the capital Honiara in Solomon Islands, shortly after a major flood in May 1986. The behaviour of island rivers remains poorly understood due to a lack of consistent hydrometric gauging and analysis.

Island Steep lands

The rugged terrain of the high volcanic islands in the Asia-Pacific region is susceptible to landslides, debris flows and other types of mass movements (Figure 8). Slope susceptibility to failure is influenced by the predominance of clay-rich soils overlying residual regolith (weathered rock and sediments in situ.), formed by chemical weathering of volcanic rocks and associated sediments. The regolith often has structural weaknesses inherited from the bedrock and sediments from which it is derived. Many islands have histories of past landslides; such that hill slopes formed on weak residual materials are prone to further failures. When landslides occur, shear failure within the regolith is normally responsible, or in the case of debris flows at least for their initiation.

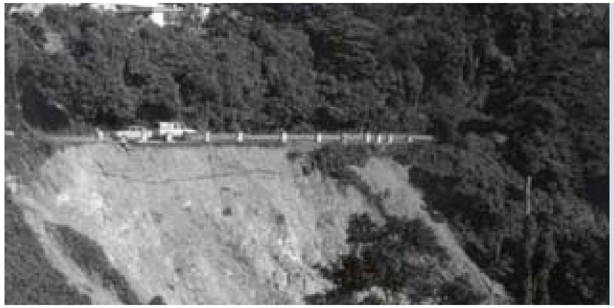

Figure 8 Shallow translational landslide in Suva city, the capital of Fiji, after prolonged wet weather in may 1997. Slides, debris flows, rockfalls and other types of landslides are responsible for many deaths on steep islands each year, but warning systems are non-existent or inadequate.

Earthquakes, volcanic eruptions and tropical storms are all effective landslide trigger mechanisms for different islands across Asia-Pacific. However, there are many gaps in our current knowledge of different landslide types and the relevant thresholds for their initiation, the failure processes responsible for transporting sediment into valley bottoms (where people live), how landslide warning systems can be implemented, and so on. Research is needed in all these areas. In particular, little is known about the links between landslides and floods. Landslides can cause temporary sediment dams across river channels, which subsequently fail some time later, releasing ponded water and upsetting the normal rainfall-discharge relationship for the river downstream. Landslide dams and their contribution to floods would therefore be a priority subject for investigation on high islands in the Asia Pacific region.

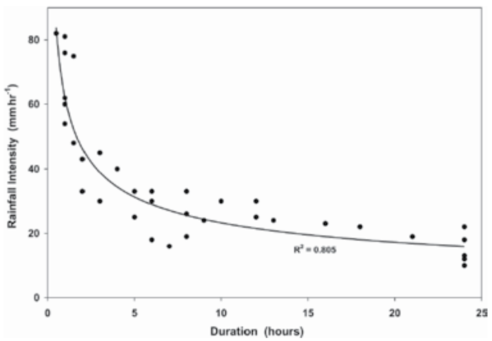

Figure 9 Rainfall intensity–duration relationships for 35 storms that caused landslides in on Viti Levu Island in Fiji. Data from Lawson (1993). On most high islands in the Asia Pacific region, such thresholds for landslide initiation have not been fully investigated.

Adaptation – A Cross-Cutting Theme

The understanding of how to implement adaptation to natural hazards (several of which are linked to climate change in the Asia Pacific region) is at its early stages of development worldwide. Very few island territories have implemented comprehensive risk management and adaptation policies. This reflects the uncertainties in future hazard predictions, which are often magnified as one moves towards the development of scenarios of local-scale and social effects of earthquakes, landslides and floods. Most work to date has therefore been generic. To reduce losses from natural hazards and disasters in future, Asia-Pacific islands and island states need to consider implementing vulnerability reduction and adaptation strategies, involving preferably ‘no regrets’ strategies, which will render benefits even if the projected hazards are not experienced in the short term.

Figure 10 Modern seawall protecting Apia, the capital of Samoa. These kinds of seawalls are expensive to construct (from limited budgets) and are not appropriate for every type of island shoreline. Mangrove rehabilitation may be a cheaper option in the face of increased threats of sea flooding due to sea-level rise.

Island adaptation processes need to be aimed at curbing natural vulnerability to hazard events, but it is difficult to identify specific adaptive options. For each natural hazard, there will be a specific set of actions. Broad sets of measures may include improving public health services to cope with any disaster, increasing emergency management capabilities and relocation of low-lying coastal communities. However, it is useful to consider some of the criteria that might be used to evaluate possible adaptations. Selecting adaptation options will require a long-term dialogue between island governments, local communities and the private sector, on who would most likely take responsibility for their implementation. But how should specific adaptation activities be selected? Recent research suggests several major criteria for their selection:

1. ***No regrets***. Preference would be given to measures that would be beneficial even in the absence of any immediate natural disaster

2. ***Multiple benefits.*** Of highest priority would be activities, such as awareness raising or population control that would have benefits across a large number of the sectors of the islands' economies (e.g. tourism, agriculture, and fishing).

3. ***General.*** General adaptation measures, such as coastal conservation, should take precedence over site-specific measures such as seawalls, at least until there is more certainty over location-specific impacts.

4. ***Bottom up.*** Community-based interventions, such as traditional multicrop systems resistant to cyclones, should in principle be preferable to top-down interventions. Top-down interventions are needed, however, when community action is likely to be insufficient (such as legislation against housing development on steep slopes that are vulnerable to landslides).

5. ***Low environmental impacts.*** Adaptation options should be chosen based on their impact on the overall vulnerability of the islands, and not only on their impact in particular sites. Seawalls for example (Fig. 3.25) could help solve the flood problems of a particular site, but increase coastal erosion elsewhere.

6. ***Culturally acceptable.*** Adaptation measures should be compatible with the socio-cultural traditions of local communities and not lead to social conflict or disruption.

7. ***Urgent.*** Most urgent measures should be implemented first, such as those needed to protect those islands that face current hazard threats.

8. ***Positive cost-benefit.*** The potential benefits of adaptation measures should clearly exceed their costs.

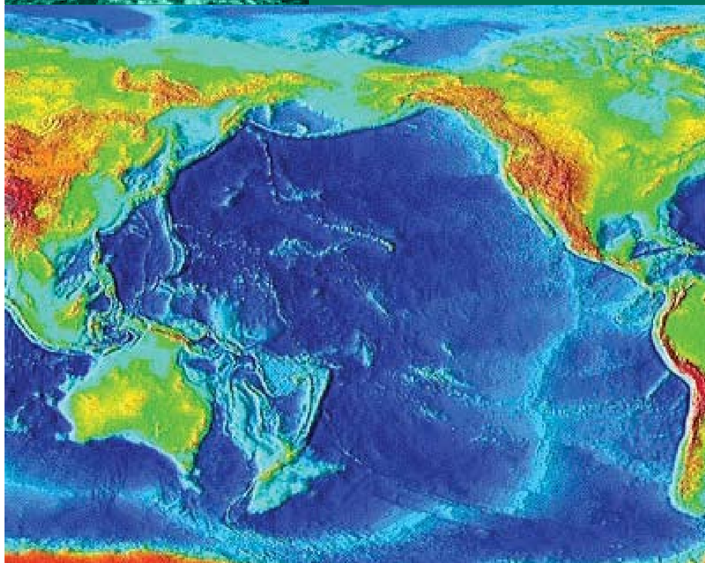

Table 2 presents selected examples of adaptation measures classified according to these criteria. While the criteria can serve as a guide, they should not be overriding: difficult adaptation choices, such as population relocation or infrastructure set-back, may be needed in low-lying areas despite failing to meet many of the recommended criteria. Nonetheless, this list can help guide a process of prioritization as the discussions continue on how best to implement adaptation on islands in the Asia-Pacific region.

Table 2 Selected Examples of Adaptation Measures

Adaptation Measure	*No Regrets*	*Multiple Benefits*	*General*	*Bottom up*	*Low Environmental Impacts*	*Culturally Acceptable*	*Culturally Acceptable*	*Positive Cost-Benefit*
Population control	+	+	+	-	+	-	+	+
Public awareness campaigns	+	+	+	+/-	+	+	+	+
Coastal hazard mapping	+	-	-	+/-	+	+/-	+	+
Development set back (from shore)	-	-	-	+/-	+/-	-	-	+/-
Watershed management	+	-	+/-	+/-	+	+	+	+
Avoiding development in hazard-prone areas	+	-	-	-	+	-	+	+
Poverty reduction programs	+	+	+/-	-	+/-	+	+	+/-
Improved sanitation	+	-	+/-	+/-	+	+	+	+
Management of squatter settlements	+	-	-	+/-	+/-	+	+	+
Vector-borne disease control	+	-	+/-	+/-	+	+	+	+
Strengthen preparedness for disease	+	-	+	-	+	+	+	+
Reduce destructive practices to coral reefs	+	-	+	+/-	+	+/-	+	+
Better ENSO forecasting	+	+	+	+	+	+	+	+

Source: Bettencourt et al. 2002.

05
Priorities for Asia and The Pacific

Priorities For Asia And The Pacific

Based on the above summary discussion of work that is necessary to reduce the vulnerability of Asia-Pacific islands to natural hazards and disasters, the following is a list of priorities for future scientific activity.

1. Analysis of El Niño influences on cyclone longevity, intensity and rainfall delivery, plus a focus on climate change/variability links with tropical cyclone behaviour and associated meteorological conditions. This must include assessment of storm surge generation, influences, and effects on coastal flooding of low-lying islands.

2. Development of a modern, accurate and freely-available archive of historical tropical cyclone records, with tracks and intensity characteristics stored in a GIS database. Using this, investigation of cyclone track patterns (shapes, lengths, sinuosities, regional geographical variations) and documenting changes observed over the period of reliable record (1970 to present) should be undertaken to assess future risks to islands.

3. Increased understanding of the flow characteristics in island rivers with limited or no gauging instrumentation, and improving the established network of river hydrometric stations.

4. Establishing statistical links between the SOI (and other climatic indices) and maximum river discharges, and examining the effects of current climate change and variability on river flows, to project future flood risks.

5. Improving our knowledge of different types of landslide processes and their influencing factors, including the response of landslide activity on islands to climate change and increasing climatic variability.

6. Determining the thresholds (climatic, seismic, volcanic, geomorphic, etc.) triggering hill slopes failure on islands.

7. Studies of relationships between landslide occurrence on steep valley-side slopes and the resulting behaviour of peak river flows, leading to unpredictable flood hydrographs and flood events.

8. Investigating the links between submarine landslides and local tsunami generation.

9. Development and implementation of appropriate and culturally-sensitive (i.e. ‘no regrets’) adaptation options to natural hazards that will yield maximum benefit to all sectors of developing island economies.

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Annexures

Annex I Terms Of References

GOAL

To provide a science plan submitted as a report to the ICSU Regional Office for Asia and the Pacific to use to further engage stakeholders in the region in activities to enhance the science of hazards and disaster management in Asia and the Pacific and contribute to similar efforts at the global level.

Terms of Reference

1. Provide an overview the current status of research activities on earthquakes, floods and landslides in Asia and the Pacific.
2. To assess the interests of the ICSU Scientific Unions, Interdisciplinary Bodies and Joint Initiatives in EFL.
3. To formulate a set of immediate, medium- and long-term objectives for H&D (EFL) in Asia and the Pacific.
4. To suggest major areas of research and development to achieve the goals of addressing and mainstreaming H&D in ICSU (ROAP).
5. To examine capacity building needs that would enable broad dissemination and application of the results of research on H & D towards achieving the goals of sustainable development in Asia and the Pacific.
6. To identify ways by which the results of the research in the priority themes can be made meaningful and more available to decision- and policy-makers and other stakeholders in the region.
7. To propose an estimated minimum budget to promote the ICSU ROAP H & D programme of activities and suggest fund-raising strategies and possible funding sources.
8. To propose a mechanism for guidance and oversight of the proposed programme of activities including ensuring there is minimum overlap and maximum complementarities with other activities in the Region.
9. Submit a Draft Science Plan in each priority theme to the ICSU Regional Committee for Asia and the Pacific by October 2007.

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Figure 1 USGS – US Geological Survey

Figure 2 is courtesy of the Tokelauan Government, Public Works Dept.

Figure 3 Copyright SOPAC (Pacific Applied Geoscience Commission)

Figure 4 USGS and USA Today news.

Figure 5 Fiji Meteorological Service and NOAA.

Figure 6 USP GIS Unit

Figure 7 Solomon Islands Dept. of Mines

Figure 8 Fiji Times newspaper

Figure 9. Lawson 1993

Figure 10 Prof. R.R. Thaman

Annex III Abbreviations and Acronyms

ICSU	International Council for Science
ROAP	Regional Office for Asia and the Pacific
USGS	United States Geological Survey
GIS	Global Information System
SOI	Southern Oscillation Index
m	metre
m^3s^{-1}	metre cube per second
mm	milimetre
mm/yr	milimetre per year
km^2	kilometre square
US$	United States Dollar
M	magnitude

Notes

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