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Urban Floods Community of Practice

URBAN FLOOD RISK MANAGEMENT IN THE PACIFIC:

TRACKING PROGRESS AND SETTING PRIORITIES

Urban Floods Community of Practice

KNOWLEDGE NOTES

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ABBREVIATIONS

AAD	Average annual damage
ADB	Asian Development Bank
AEP	Annual Exceedance Probability
CCA	climate change adaptation
CRISP	Community Resilience to Climate and Disaster Risk in Solomon Islands Project (World Bank Group)
DRR	disaster risk reduction
EWS	early warning system(s)
FRM	flood risk management
FRMP	Flood Risk Management Plan
GDP	gross domestic product
GPVURCAP	Greater Port Vila Urban Resilience and Climate Adaptation Plan
HEDSUP	Honiara Economic Development Support Programme
HURCAP	Honiara Urban Resilience and Climate Action Plan
IWMP	Integrated Watershed Management Plan
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
MNRE	Ministry of Natural Resources and Environment (Samoa)
NDMO	National Disaster Management Office
NEOC	National Emergency Operations Centre
NGO	nongovernmental organization
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
Pacific-HYCOS	Pacific Hydrological Cycle Observing System
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PDNA	Post-Disaster Needs Assessment
PIC	Pacific Island Country
PREP	Pacific Resilience Program (World Bank Group)
PUMA	Planning and Urban Management Agency (Samoa)
SPC	Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
TC	Tropical Cyclone
URMS	Urban Risk Management Strategy (Vanuatu)

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WORLD BANK GROUP

GFDRR

ACP-EU Natural Disaster Risk Reduction Program

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SUMMARY

Floods have caused significant damage to urban communities in Pacific Island Countries (PICs). The principal driver of this increasing problem is the growth of exposure to flooding associated with population growth and urbanization. Flood hazards are also expected to increase with climate change.

This Knowledge Note describes a benchmarking method developed to track the progress of PICs toward best-practice flood risk management (FRM). FRM is a process for assessing flood risk, evaluating options to manage the risk, and implementing a strategic plan to reduce risk. The method was applied to assess current urban FRM practices in Fiji, Samoa, the Solomon Islands, and Vanuatu, focusing on riverine flood hazards[1]. The results show the following:

- The quality of hydrological data available for hydrodynamic modeling is generally poor, reflecting institutional and resourcing issues. Nonetheless, in recent years significant advances have been made in flood modeling and mapping for some of the most urbanized floodplains in the region.
- Reasonably good exposure data sets are available for some of the most flood-prone cities and towns in the region, but few studies have assessed the risk to property and life for the full range of floods that may be experienced.
- There has been a tendency for PICs to implement structural works rather than softer solutions, sometimes without comprehensive assessments and engagement.
- Risk-informed land use planning has faced many challenges, including the extent of customary land ownership and the growth of informal settlements, and has been slow to take hold.
- There has been some progress in flood early warning systems, though the "flashy" nature of floods and the maintenance of monitoring and dissemination systems present challenges.
- Although high-level Disaster Management Plans exist, there remains a need for flood hazard subplans, local plans, standard operating procedures, and resourcing and training of personnel.
- Some good initiatives to enhance community preparedness have been implemented, but they need to be better sustained and targeted to address common misperceptions.
- Although various FRM projects have been implemented over recent years, the lack of robust governance arrangements impacts the integration and sustainability of this work.
- PICS have some way to go to achieve an evidence-based, integrated mix of FRM interventions that include both structural and nonstructural measures.

[1] This Knowledge Note does not address coastal flooding (from high tides, storm surge, or tsunami) or pluvial inundation following heavy local rain.

Eight priorities for advancing current practice in PICs are proposed:

1. Develop holistic, integrated, and sustainable FRM governance arrangements.
2. Involve affected communities and other stakeholders from the outset of the FRM process.
3. Apply a flood risk management process that includes efforts to understand the flood risks (through data collection, flood studies, and community studies) and a thorough evaluation of options.
4. Reframe the problem to understand flood risk holistically as the integration of flood hazard, exposure, and vulnerability.
5. Broaden the solutions to draw on a portfolio of structural and nonstructural options, including measures to promote the broader resilience of urban communities.
6. Preserve and enhance the capacity of river channels and floodplains to convey flows.
7. Reduce exposure and vulnerability through risk-informed land use planning, resilient buildings and infrastructure, and voluntary relocation from high-hazard areas.
8. Enhance people's flood awareness, preparedness, and responsiveness through early warning systems, improved emergency management plans and capacities, and locally effective approaches to community readiness.

Achieving best-practice FRM is challenging, but small steps toward better practice can produce significant beneficial outcomes. Simply by recognizing two important points—that a process is needed to understand and reduce flood risk, and that flood risk can be addressed through a broad suite of options—countries could move in the right direction.

The first critical step is to establish in each country a multisectoral forum for the holistic and integrated governance of FRM. Such a forum would promote the understanding and application of the FRM process, prioritize investigations and implementation of actions emerging from Flood Risk Management Plans (thus ensuring a coordinated approach among agencies and development partners), and routinely review gains and needs. Regional forums could also facilitate knowledge sharing and inspire continued progress toward the goal of flood-resilient communities in PICs.

INTRODUCTION

In Pacific Island Countries (PICs), flooding arising from the overflow of rivers and streams has caused significant damage to urban communities. One approach to reducing the impacts of flooding is to use an integrated FRM. This Knowledge Note describes development of a benchmarking tool to assess current FRM practices and trajectories. Benchmarking helps to advance FRM by identifying gaps in current practice and priorities. With a focus on towns in Fiji, Samoa, the Solomon Islands, and Vanuatu, this Knowledge Note aims to inform the understanding and practice of FRM in PICs, to provide guidance in improving FRM, and ultimately to increase the resilience of Pacific Island communities to this frequently experienced hazard. The development of this guideline for effective disaster risk management is consistent with the priority actions of the Framework for Resilient Development in the Pacific (Pacific Community et al. 2016).

Floods are a frequent and natural occurrence in PICs. Islands in the Pacific Ocean are subject to severe weather from tropical storms that carry torrential rain. The high elevation of volcanic islands—some are over 1,000m (table 1)—is also associated with intense rainfalls; for example, 928mm of rain was recorded in 24 hours at one station in Fiji in January 2009, causing severe flooding (Turner 2011). High soil moisture leading to increased runoff has also been implicated in severe floods, including the January and March 2012 floods in western Viti Levu (Kuleshov et al. 2014). Most rivers and streams in these islands are relatively short and steep, leading to swiftly rising water levels. Flooding is characterized by high depths, high velocities, and large debris loads.

Table 1. Elevation of select Pacific islands

Country	Island	Mountain	Maximum elevation	Flood-prone cities/towns
Fiji	Viti Levu	Mount Tomanivi (Victoria)	1,323m	Ba, Greater Suva, Lautoka, Levuka, Nadi, Nausori, Navua, Rakiraki, Sigatoka, Tavua
	Vanua Levu	Mount Nasorolevu	1,032m	Labasa
Samoa	Upolu	Mount Fito	1,100m	Greater Apia
	Savai'i	Mount Silisili	1,858m	Salelologa (coastal and pluvial flooding only)
Solomon Islands	Guadalcanal	Mount Popomanaseu	2,449m	Greater Honiara
	Malaita	Mount Kalourat	1,435m	Auki
Vanuatu	Éfaté	Mount McDonald	647m	Greater Port Vila
	Espiritu Santo	Mount Tabwemasana	1,879m	Luganville

Source: Elevation data from Nunn et al. 2016.

FLOOD IMPACTS IN PICS

Loss of life

Severe floods that inundate houses have caused tens to hundreds of fatalities in PICs. **Numbers in table 2** provide an indication of the scale of fatalities in several recent floods in Fiji, Samoa, and the Solomon Islands[2]. While they may not appear to be large on an international scale, they represent a major consequence when measured as a proportion of the national population, and they have a pronounced impact on the communities and families directly affected. According to a risk to life model, a Nadi catchment flood with a 1-in-100 chance of occurring or being exceeded in a given year (i.e., one with a 1 percent Annual Exceedance Probability, or AEP) would result in the loss of 12 to 15 lives, even when some warning time was available for partial evacuation (NIWA 2014). The potential for higher loss of life exists. For example, had the Mataniko River flash flood struck Honiara at night, when houses were fully occupied and darkness would have made detection and escape more difficult, several hundreds of lives could have been lost (GoSI 2014). This order of magnitude of disaster fatalities is not unknown in PICs—at least 225 fatalities occurred in Fiji in 1931; and at least 111 fatalities occurred in the Solomon Islands in 1986, when slow-moving tropical cyclones generated severe floods and landslides (Yeo and Blong 2010; Blong and Radford 1993).

Table 2. Estimated human and economic costs of some recent PIC floods

Flood	Death Toll	Damage and Loss	% GDP	Source
Northern Fiji, *Jan. 2003*	16	F$105 million[a]	Data not available	NDMO 2003; Yeo 2011
Central Fiji, *Apr. 2004*	12	F$13 million (Navua only)	Data not available	Holland 2008; Yeo 2011
Western Fiji, *Jan. 2009*	7	F$440 million (government and private losses)[b]	~7%	Holland 2009; Ambroz 2009; Yeo 2011
Western Fiji, *Jan. 2012*	8	F$41 million (government only)	Data not available	"Fiji Live," May 8, 2012, "March floods cost govt $90 million"; Kuleshov et al. 2014
Western Fiji, *Mar. 2012*	12	F$90 million (government only)	Data not available	Fiji Live," May 8, 2018, "March floods cost govt $90 million"; Fiji Times, April 7, 2012, "Loss and grief".
Apia, Samoa, *Dec. 2012*[c]	5	SAT 465 million	~25%	GoS 2013
Honiara and Guadalcanal, Solomon Islands, *Apr. 2014*	24	SI$787 million	9.2%	GoSI 2014; MHA 2014

2 No flood fatality information was located for Vanuatu.

a. Amount includes wind damage from Tropical Cyclone Ami.

b. Amount is largely based on estimates of damage to houses and businesses in Nadi and Ba, as well as national flood damage assessments to infrastructure, agriculture, etc.

c. Data include wind damage from Tropical Cyclone Evan.

Many flood fatalities have been associated with the risky choice to cross flood waters. Actions based on this decision tend to claim relatively few lives per event but make up the majority of total flood fatalities (Yeo 2011). The higher death tolls reflected in table 2 tend to be associated with particularly high floods inundating and destroying houses, as occurred near Labasa in 2003 and Honiara in 2014.

Impacts on health and education

Floods have damaged health facilities and had other adverse impacts on health. Three health clinics in Honiara City sustained damage to building structures as well as contents in the April 2014 flood (GoSI 2014). Health impacts reported after floods include increased incidences of diarrhea, leptospirosis, and typhoid due to contaminated water; increased incidences of dengue fever due to mosquitoes breeding in stagnant water pools; and increased skin infections. Evidence from other countries suggests that floods have large negative implications for children's health, as families cut down on health care in the aftermath of flooding, due to competing requirements for limited family budgets which may be constrained by the need to rebuild.

Floods have damaged schools and had other adverse impacts on education. Some schools, such as the Ba Muslim Primary School (Fiji), have been flooded frequently, and inundation of homes has destroyed children's textbooks. Education is disrupted when schools close in anticipation of poor weather and when schools used as evacuation centers are slow to reopen. Evidence from other countries also suggests that floods have large negative implications for children's education, as families recover from economic losses by engaging children in household or economic activities.

Impacts on infrastructure

Floods have caused major damage to infrastructure, especially to roads, bridges, and water supply pipes exposed to floodwater and flood-borne debris. The bridges at Ba and Sigatoka in Fiji that were destroyed in the January 1993 flood cost many millions to replace and caused massive disruption to transport in the interim, with significant effect on local economies (Yeo 1998). The 2014 flood in Honiara completely destroyed one bridge over the Mataniko River, causing unprecedented traffic congestion at the remaining bridge and adding to transport costs. In addition, the Solomon Islands international airport was closed for two days due to submergence of the runway and apron (GoSI 2014) (figure 1).

Figure 1. Flooding of Henderson International Airport, Honiara, during the April 2014 flood
Source: Regional Assistance Mission to Solomon Islands (RAMSI).

Financial and economic costs

Floods have caused substantial damage and loss to PIC economies. Table 2 lists the estimated financial impacts of several recent floods in Fiji, Samoa, and the Solomon Islands.[3] Even using the incomplete and inconsistently derived data for Fiji,[4] floods since 2004 have cost government and communities more than F$50 million a year. The damage and loss to private businesses in the low-lying towns of Nadi and Ba represent a high proportion of total financial impacts (Holland 2009; Ambroz 2009). What is not readily detected by viewing raw damage figures is the severe

[3] No flood damage or loss information was located for Vanuatu.

[4] Methods of estimating damages and loss vary between studies. The government of Fiji's estimate of damages from the January and March 2012 floods is low compared to the estimated flood damage from the January 2009 flood, and considering that in Nadi, the March 2012 flood was the highest on record.

impact of flooding on national economies. For example, flooding in and around Honiara in April 2014 had an economic impact equivalent to 9.2 percent of Solomon Islands gross domestic product (GDP). The largest share of damage in that event was sustained to housing (56 percent of damage), followed by transport infrastructure (23 percent). The largest economic loss was for the mining sector (50 percent of economic loss), followed by the agriculture sector (31 percent) (GoSI 2014).

Flood and exposure models provide an alternative means of estimating potential damages from flooding. The 1 percent AEP flood in the Nadi River catchment is estimated to cost ~F$794 million (~US$380 million) (NIWA 2014). Only one study in the region is known to have estimated the average annual damage (AAD) from flooding. For the Vaisigano catchment in Apia, Samoa, this study estimated ADD at SAT 24,824,000/year (~US$10 million/year) (Water Technology 2016).[5] Expanding the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) to include a robust riverine flood module would provide a more comprehensive understanding of potential flood impacts through the region.[6]

DRIVERS OF FLOOD DISASTER RISK IN PICS

Disaster risk is a function of three interlinked components: hazard, exposure, and vulnerability (GFDRR 2016). For flood risk in particular, hazard refers to the likelihood and intensity of a flood. Exposure refers to the location and value of people and assets (such as buildings and infrastructure) that are exposed to the flood hazard. Vulnerability is the potential extent to which people and assets may become damaged or disrupted when exposed to a flood event. This section briefly reviews the dynamic flood risk drivers in PICs.

Climate variability and change

Floods in PICs are influenced by interannual climate variability (e.g., El Niño–Southern Oscillation, position of South Pacific Convergence Zone) and interdecadal climate variability (e.g., Interdecadal Pacific Oscillation). For example, floods at Ba, Fiji, have been much more frequent in La Niña periods (McAneney, van den Honert, and Yeo 2017). But large floods in Fiji can also occur during El Niño periods, typically associated with tropical cyclones (Kostaschuk, Terry, and Raj 2001; Yeo, Blong, and McAneney. 2007; McAneney, van den Honert, and Yeo 2017).

Climate change is projected to increase damages from riverine flooding in PICs. Climate models show high confidence that extreme rainfall events in many PICs will become more frequent and intense (table 3) as emissions continue, though the magnitude of changes is uncertain (Australian Bureau of Meteorology and CSIRO 2014). Given rising sea levels and higher storm surges associated with more intense tropical cyclones, estuarine towns already affected by frequent—and occasionally severe—flooding are likely to experience increasing problems. A study of two catchments in Fiji estimated that with "moderate" climate change, annual flood losses would increase by 90 percent. With "severe" change, annual flood losses could increase by nearly 275 percent (Brown et al. 2014; Daigneault, Brown, and Gawith 2016).[7] In Samoa, the AAD for eight catchments in the greater Apia area is predicted to increase by 42 percent (from SAT 72 million to SAT 102 million) for projected 2100 climate conditions (Water Technology 2016).

5 Previously, Woodruff (2008) estimated the AAD for the Vaisigano catchment at only SAT 620,000/year (~US$215,000). The much higher AAD estimated by Water Technology (2016) is due to several factors: the new assessment (1) is based on an updated flood frequency assessment that resulted in higher flows for given design floods; (2) has a larger model extent; (3) includes climate change; (4) is based on tailwater levels that include 2100 levels and storm surge (i.e., all low-lying land is inundated); (5) has more complete building layers and replacement costs from PCRAFI; and (6) includes contents and car replacement costs at each building.

6 PCRAFI currently includes catastrophe loss models for earthquake, tsunami, and tropical cyclone. The tropical cyclone model calculates damage caused by tropical cyclone-induced wind, flood from storm surge, and flood from tropical cyclone–induced precipitation. But some assumptions of the model are very coarse, for example, that flood intensity is proportional to cyclone intensity. Yeo, Blong, and McAneney (2007) argued that the size and speed of movement of a tropical cyclone were more influential than a cyclone's intensity for riverine flooding. It is noted that the very severe TC Pam (Vanuatu, March 2014) and TC Winston (Fiji, February 2016) were not associated with severe riverine flooding. Further, riverine flooding not associated with tropical cyclones, including five of the seven events listed in table 2, has been very damaging.

7 But this study applies several very coarse assumptions. For example, it assumes that the January 2012 flood is a 2 percent AEP event and the March 2012 flood is a 5 percent AEP event under the current climate scenario. (Even the relative flood heights may be problematic, since the March 2012 flood is judged to be higher than the January 2012 flood at Ba town—see Yeo [2015]). The January 2012 flood is assumed to become a 5 percent AEP event under a "moderate" climate change scenario and a 10 percent AEP event under a "severe" climate change scenario; and the March 2012 flood is assumed to become a 10 percent AEP event under a "moderate" scenario and a 20 percent AEP event under a "severe" scenario.

Table 3. Projected changes to 1-in-20-year rainfall over a 24-hour period by 2050

Country	Baseline (existing climate) rainfall (mm)	Median climate change rainfall (mm)	Extreme climate change rainfall (mm)
Fiji	245	292	348
Samoa	79	97	116
Solomon Islands	84	102	119
Vanuatu	189	230	281

Source: World Bank 2016a.

Note: Projections are based on Representative Concentration Pathway (RCP) 4.5 for the 90th percentile climate case.

However, it is too early to detect changing PIC flood regimes or to ascribe any observed changes to global climate change with confidence. The new flood records set successively in Nadi in 1993, 1999, 2009, and 2012 (Yeo 2013) have been taken by some as evidence of climate change (Hay 2009). But an analysis of Nadi's annual maximum one-day rainfall from 1942 to 2011 shows a negative trend that is not statistically significant (Australian Bureau of Meteorology and CSIRO 2014, 99).[8] This decline is attributed to a reduction in nearby tropical cyclone activity (McGree et al. 2014). An analysis of Fiji's longest flood data series—for Ba, going back to 1892 (figure 2)—shows no evidence for an increasing flood frequency and only a weakly significant trend for increasing peak flood depths, a result that is very sensitive to the start and finish dates of the analysis (McAneney, van den Honert, and Yeo 2015). The regression is no longer significant when corrected for average sea-level rise, which suggests that thus far the impact of climate change on flooding in this catchment is restricted to rising sea levels in the Ba River estuary (McAneney, van den Honert, and Yeo 2017).[9]

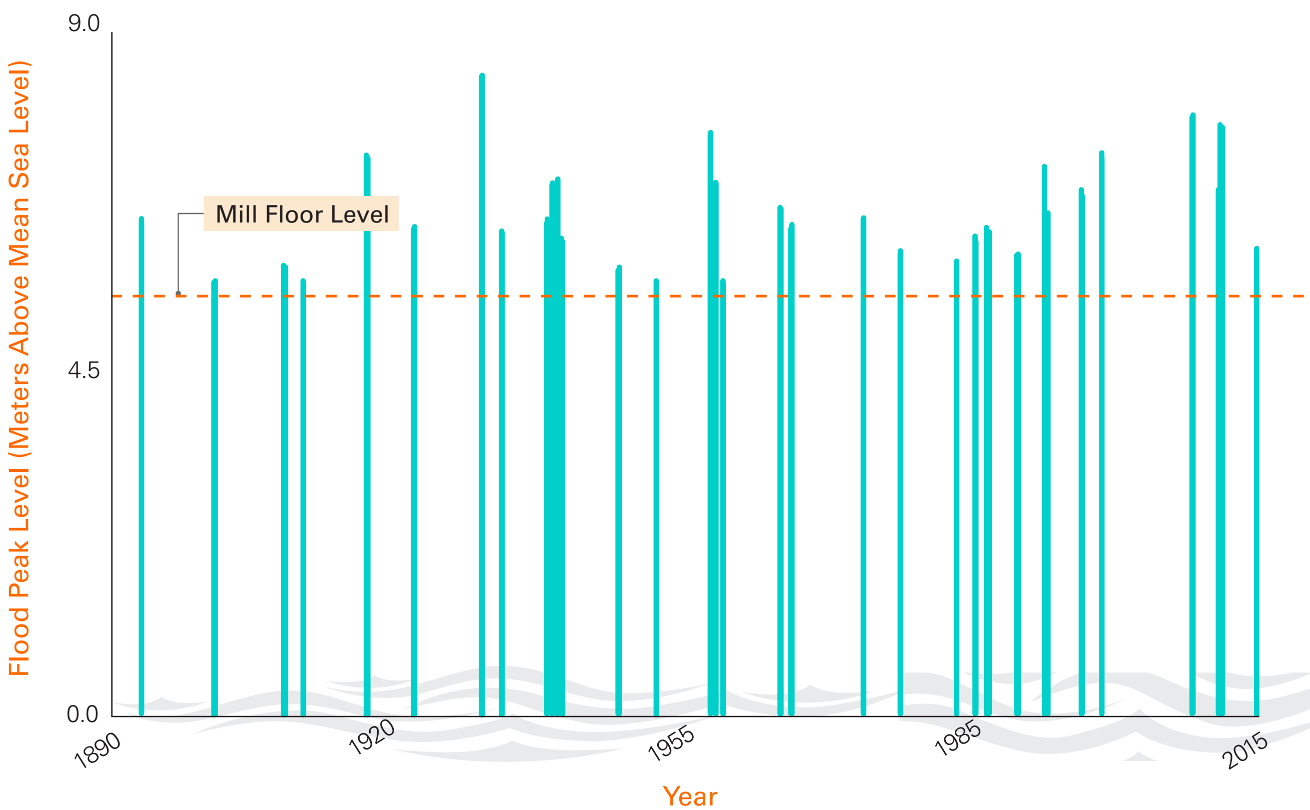
[8] A preliminary examination of annual maximum one-day rainfalls at Nadi Airport from 2012 to 2016 suggests that inclusion of these data would be unlikely to alter this finding.

[9] A complicating factor contributing to "noise" in long-term flood and rainfall signals is the influence of interannual and interdecadal variability.

Environmental change

Land use changes may also affect flooding. The burning of vegetation in western Viti Levu in the 1960s was linked to accelerated erosion, siltation of the river channel, and increased flooding (Cochrane 1969). Deforestation has been cited as causing more frequent and higher floods in places such as Nadi (Chandra and Dalton 2010; Nunn 2010). There is some support for this theory from an empirical study for a small catchment in Fiji, which found increasing peak flows after harvesting of a pine plantation. However, the effect of harvesting on flows diminished with increasing rainfall (Waterloo et al. 2007). NIWA (2015) also concluded that for high-rainfall areas such as the Nadi catchment, "forests are good at preventing erosion and retaining or attenuating smaller floods," but that "in very large floods the flood peak magnitude is typically unaffected by forested areas" (19). Moreover, Yeo, Blong, and McAneney (2007) detected no significant increase in the frequency of major Ba River floods despite significant land use changes.

Figure 2. Record of major floods, Rarawai Mill, Ba, Fiji, 1892–2016



Source: Yeo 2015; April 2016 flood height is estimated from interviews.

Floodplain development and urbanization

A more immediate driver of flood damages and losses is the increasing exposure of assets and people on floodplains (Kundzewicz et al. 2014; GFDRR 2016). Yeo (1997) examined the history of Ba town in Fiji and concluded that "the largely unfettered development of the floodplain has been the real problem". Since the publication of this study, commercial development of the floodplain has continued apace, likely leading to increased flood impacts, both directly through increased exposure and also through the effect of new building in the floodplain raising flood depths and velocities elsewhere.

In Honiara, the loss of life in the April 2014 disaster, while linked to an extreme flood, was fundamentally a result of highly exposed houses—located on dangerously low ground, especially at Koa Hill, where residents say the land was once a swamp (figure 3). Development in high-risk areas is linked to rural-urban migration in the Solomon Islands, which has been driven largely by employment and livelihood opportunities or prospects, and by the inadequate supply of new serviced land to accommodate arrivals. It is also linked to the political instability from 1998 to 2003, which reportedly drove Malaitan settlers from Guadalcanal Province into Honiara City. As a result of these circumstances, both new migrants into the city and new households that have grown naturally out of existing households have had to find their own land and housing solutions, often in areas prone to flooding or landslides (GoSI 2014). Rebuilding has occurred on floodplains devastated by the April 2014 floods (figure 4). This may be some people's only option due to economic or social constraints.

Figure 3. Floodplain before (left) and after (right) the April 2014 flood, Koa Hill, Honiara

Source: Google Earth. *Source: Google Earth.*

Figure 4. New house on the floodplain, one month after the April 2014 flood, Marble Street, Honiara

Source: S. Yeo, WBG.

FLOOD RISK MANAGEMENT PROCESS

Flood risk management may be defined as "the process of data and information gathering, risk assessment, appraisal of options, and making, implementing, and reviewing decisions to reduce, control, accept, or redistribute risks of flooding" (Hall et al. 2003, 126). As part of the FRM process, hydrological data such as rainfall and river flows are collected and stored. Topographic data may be captured through LiDAR. These are among the key inputs for flood studies, which typically use hydrodynamic models to investigate the spread of floods across the landscape (see UFCOP 2017). Flood study outputs include maps showing flood extents, depths, and velocities, including for climate change scenarios. Good FRM practice also includes the investigation and mapping of communities' exposure and vulnerability, including projected urban growth patterns. Combining flood hazard with community exposure and vulnerability enables an assessment of flood risk, including both financial risk and risk to life. Once the flood problem is defined, the full suite of available interventions (table 4) can be evaluated to develop a strategic plan with sequenced priorities for managing the risk. As funds become available, the plan is implemented. Good governance, including community and stakeholder engagement, is critical to the success of the overall FRM process.

Table 4. Standard flood risk management measures

Modify flood behavior	Modify exposure and vulnerability	Modify human response
Permanent levees	Land use zoning compatible to hazard	Early warning systems
Temporary barriers	Building codes, development controls	Emergency response plans
Floodgates	Relocation of development	Community awareness/ readiness
Flood mitigation dams	House raising	Recovery plans
Detention basins, wetlands	Flood proofing	Insurance, risk financing
Watershed management (e.g., reforestation)	Evacuation route improvement	
Improved flow conveyance • Channel works • Bypass floodways • Debris control		

TRACKING FLOOD RISK MANAGEMENT PRACTICE IN THE PACIFIC ISLANDS

This Knowledge Note uses a benchmarking tool for assessing and tracking current FRM practices in Fiji, Samoa, the Solomon Islands, and Vanuatu. The tool is adapted and extended from Babister and Retallick (2013) and includes 12 benchmarks; these are listed in table 5 along with associated limitations. For example:

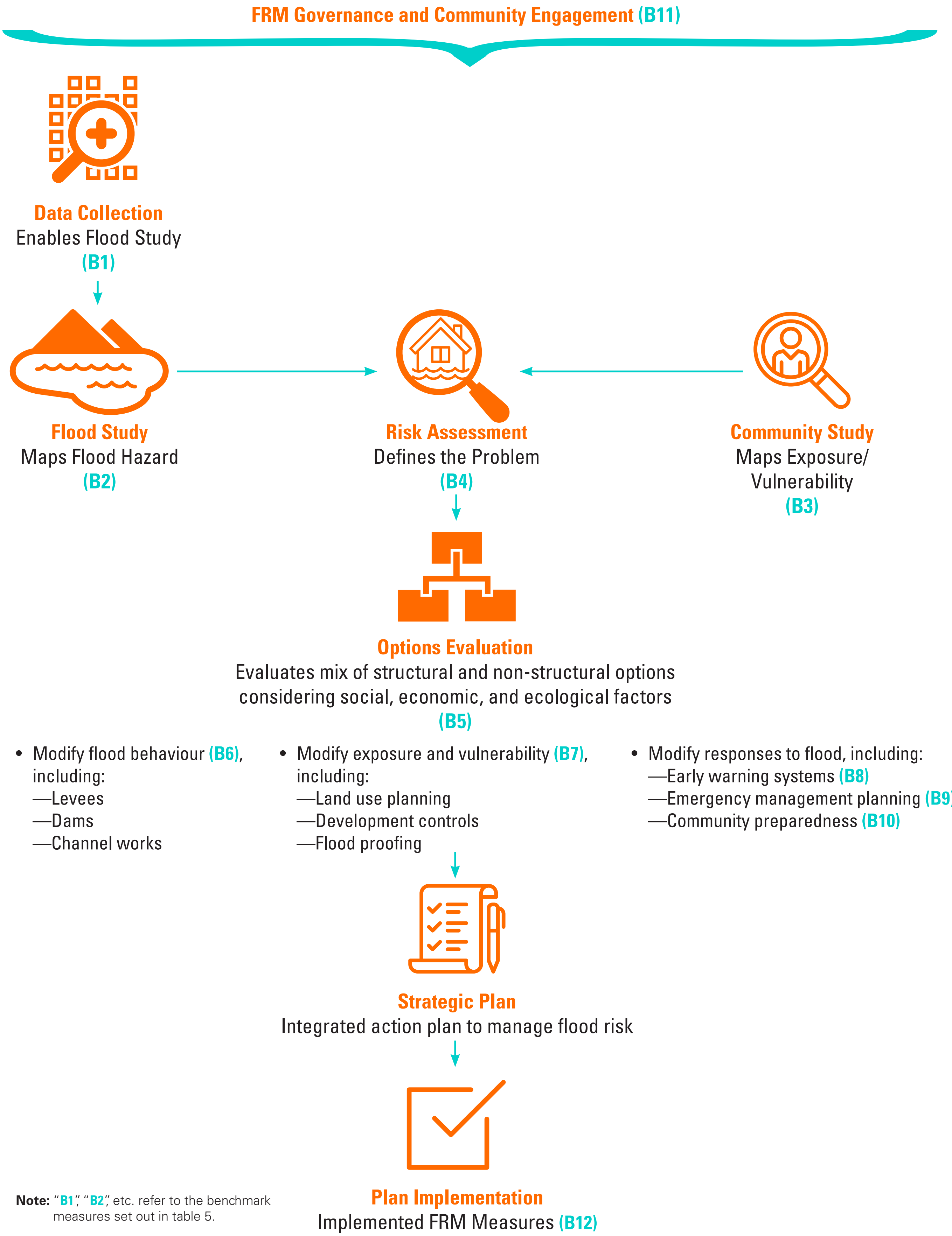
- Ideally benchmarks should be readily measurable. Here, governance is included despite the difficulty in precisely measuring its quality.
- A benchmark assessing the quality of hydrological data combines several attributes on a single scale in the quest for simplicity.
- The judgments reflect the best example in a country, whereas there may be a considerable range of practice within a country.
- The benchmarks do not cover every component of resilience, such as the strong social support networks that traditionally assist recovery from disasters in PICs.
- The benchmarking exercise was conducted in 2016–2017 and is expected to change over time.

Despite some limitations, the 12 benchmarks cover most aspects of the FRM process (figure 5). They are intended as an initial tool that will help stakeholders consider areas of need and prioritize investments to target any deficiencies. For each country, current practice is plotted in figures 6–17 and is summarized in the accompanying discussion; more details on the practices of each of the four countries are in annex 1. Figures 6–17 also estimate trajectories from recent past practice to future practice as judged by planned programs.

Table 5. Benchmarks for Flood Risk Management Practice in PICs

Benchmark	Description	Limitations
1. Hydrological data collection/storage/ reliability	Assesses the overall quality of hydrological data for flood modeling, including network coverage, frequency of readings, quality of ratings, length/ completeness/ standardization/accessibility	Gives only a rough average across different submeasures
2. Hazard assessment (mapping)	Assesses the quality of available flood hazard mapping (including climate change projections)	Does not capture the quality of the flood model or topographic surface that controls the outputs
3. Exposure and vulnerability assessment (mapping)	Assesses the spatial resolution and type of information (including urban growth projections) available to assess building and household exposure and vulnerability	Does not capture completeness, quality (e.g., whether floor heights are surveyed), or currency of data
4. Risk assessment	Assesses the completeness of risk assessments in terms of both financial damage and risk to life, and for multiple design events up to the probable maximum flood	
5. Flood risk management measures	Assesses the degree to which the full suite of FRM measures (structural and nonstructural) is utilized and integrated	
6. Flood modification measures	Assesses the quality of cost-benefit, environmental, and social impact assessments and community engagement as part of project evaluation	
7. Risk-informed land use planning and development controls	Assesses the type of planning controls, and the basis of the flood planning area/level, used to manage flood risk	Effectiveness depends on implementation, which is difficult for informal settlements
8. Flash flood warning systems	Assesses the precision of flood warnings and dissemination methods, recognizing the limits for flash flood catchments	
9. Emergency management planning/capability	Assesses the degree to which national and local emergency service organizations have planned for, are resourced for, and have trained for flood operations	Does not take into account nongovernmental organization (NGO) plans and capability
10. Community preparedness	Assesses the degree to which governments have invested in promoting community awareness and readiness to respond to flooding	Investments in community education may not necessarily translate to better behaviors
11. FRM governance	Assesses the overall quality of governance structures for FRM	Gives only a rough average across different submeasures
12. FRM process roll out	Assesses the degree to which the FRM process has been rolled out across a jurisdiction (country)	

Figure 5. Flood Risk Management Process, With Links To Benchmarks

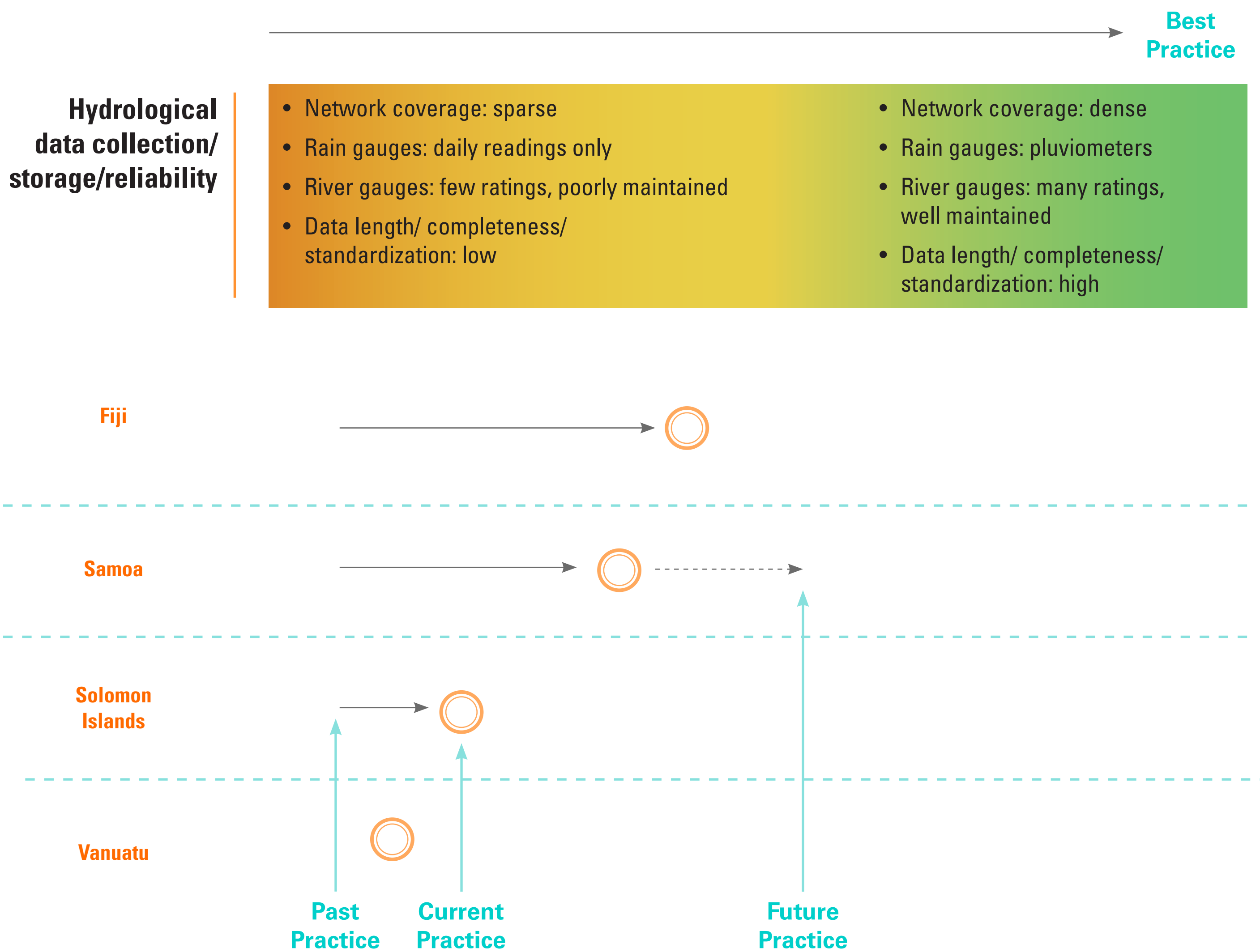


Note: "B1", "B2", etc. refer to the benchmark measures set out in table 5.

Benchmark 1: Hydrological data collection/storage/reliability

The collection, storage, and reliability of appropriate hydrological data—rainfall, water level, and flow discharge—are prerequisites for modeling and mapping flood hazards. This benchmark considers the density of gauges in a catchment, the frequency with which readings are measured, the accuracy of river flow estimates, and the length, completeness, standardization, and accessibility of gauge records.[10]

Figure 6. FRM Practice and Trajectories in PICs: Benchmark 1



Note: For more information on Benchmark 1 for each country, refer to annex 1.

[10] In terms of density, ideally rain gauges are located not just along the coast but in mountainous areas, given steep rainfall gradients with elevation. In terms of frequency of readings, for the typically small river catchments in PICs, subdaily rainfall data are often critical for rainfall-runoff modeling. Ideally, continuous rainfall data are measured by a pluviometer, and continuous river stage data are measured by an automated water-level recorder. In terms of the accuracy of river flow readings, ratings curves—including at high flows—are required for more accurate estimation of flood flows to calibrate with rainfall-runoff models. The length, completeness, and standardization of gauge records influence the accuracy of rainfall intensity-frequency-duration data used in rainfall-runoff modeling, as well as flood frequency analysis using river flow series.

Summary and challenges

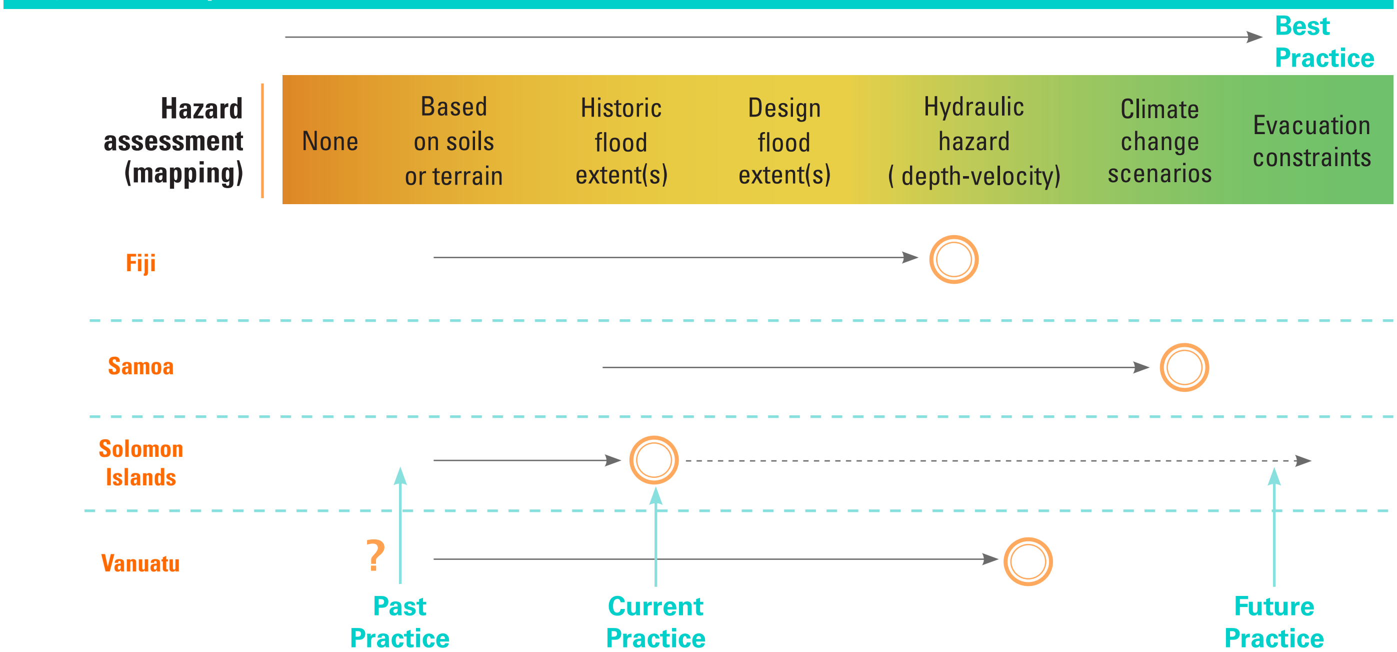
The collection, storage, and reliability of hydrological data in PICs are a long way from best practice. Issues include very limited ratings (to convert river stages into flows), particularly for larger floods. The deficiencies reflect institutional and resourcing issues that have prevented national hydrological services from even accessing motor vehicles to service gauges (SOPAC 2010). Vandalism of hydrological infrastructure has also been a significant problem; the solution entails careful placement of gauges, vandal-proof construction, and, possibly, the payment of retainers to manual gauge readers.[11] External donors have invested considerably to improve hydrological services, but it appears that once a particular program is concluded, sustained monitoring is at serious risk.

PIC governments need to appropriately resource their national hydrological services to expand and maintain their hydrological networks and data storage repositories. An increasing array of innovative techniques (e.g., Global Precipitation Measurement using satellites) can compensate for incomplete local monitoring networks, but having on-the-ground hydrological data will provide better calibration.

Benchmark 2: Hazard Assessment (Mapping)

Flood or floodplain mapping is foundational for understanding and managing flood risk. Maps can take many forms, from simple maps based on proxies such as soil types to complex maps that convey information about the depth-velocity (hydraulic hazard) for various design floods. Hydrological and hydrodynamic modeling is required to generate the more sophisticated mapping products (see UFCOP 2017) and should consider the potential interactions of river flooding with storm tides. The quality of inputs to these models—including hydrological and topographic data—influences the quality of the mapping outputs. Advanced hazard mapping now considers climate change scenarios as well as constraints to evacuation.[12]

Figure 7. FRM practice and trajectories in PICs: Benchmark 2



Note: Question mark indicates uncertainty about past practice. For more information on Benchmark 2 for each country, refer to annex 1.

[11] Planning Institute of Jamaica (2014) describes vandal-proof construction for river gauges. See especially pp. 68–70.

[12] "Flood emergency response" classification mapping has been developed in Australia (DECC 2007; AIDR 2017b). This approach recognizes that land that is first isolated before being inundated (a "low flood island") presents a higher risk to life.

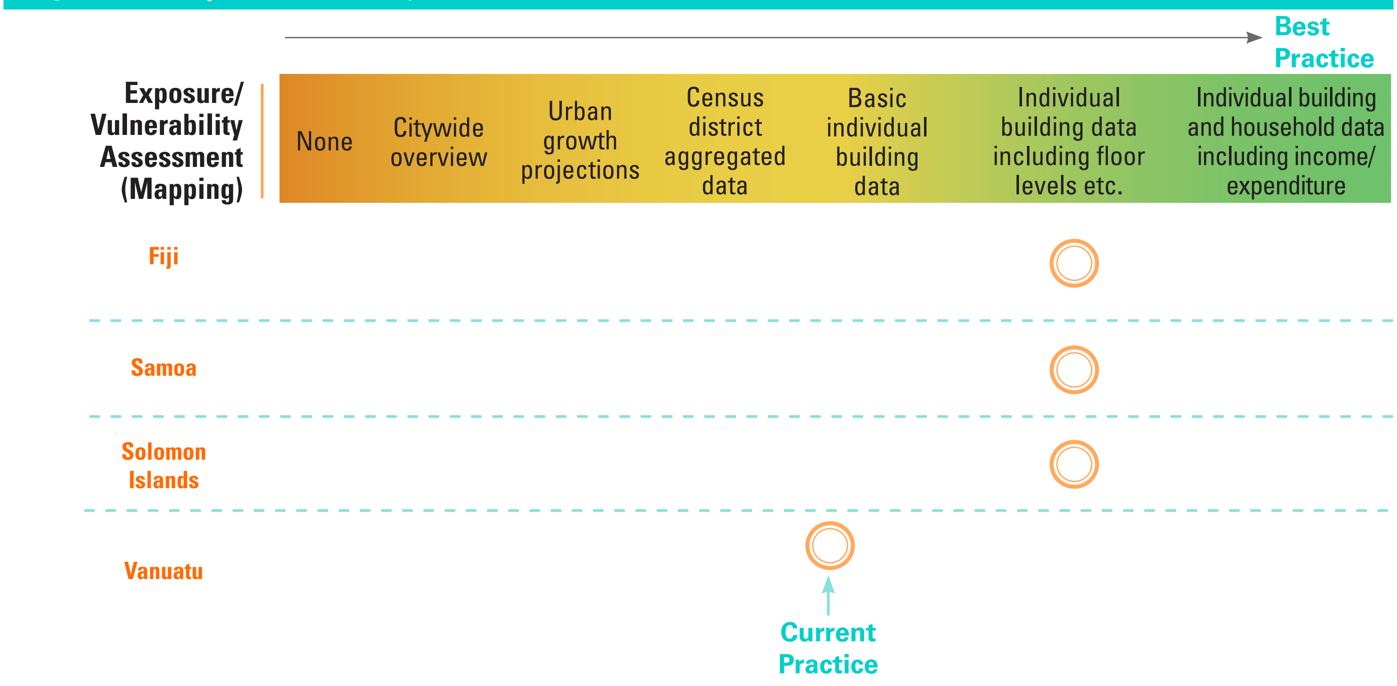
Summary and challenges

Over the last few years, significant advances have been made in the quality of flood mapping for some of the most urbanized floodplains in PICs (e.g., Nadi, Apia, Port Vila). However, all these flood studies are to some degree compromised by the lack of reliable long-term hydrological data. There is a pressing need to prepare flood studies for Fiji's many flood-prone towns (listed in table 1).

Benchmark 3: Exposure And Vulnerability Assessment (Mapping)

A sound understanding of a community's exposure and vulnerability is a key input for understanding and managing flood risk. Exposure relates to factors such as the distribution of people, housing, transport infrastructure, and health and education facilities, whereas vulnerability describes the susceptibility of people and assets to floods. For flood risk assessment, exposure is ideally measured with high granularity (e.g., individual building data describing floor heights, wall materials, etc.). Similarly, data showing household income and expenditure would provide insight into people's ability to cope with floods and other shocks—their vulnerability. Like flood hazard, exposure and vulnerability are dynamic, so studies that project future states are valuable.

Figure 8. FRM practice and trajectories in PICs: Benchmark 3



Note: For more information on Benchmark 3 for each country, refer to annex 1.

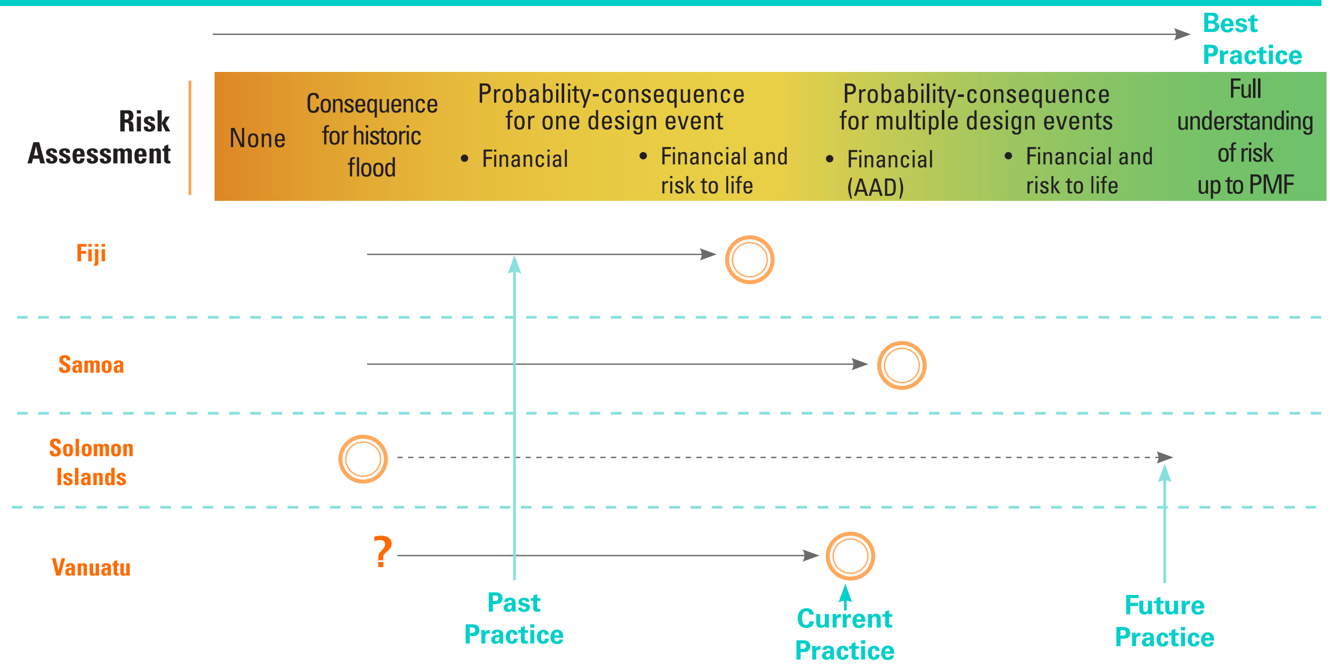
Summary and challenges

Reasonably good exposure data sets are available for some of the most flood-prone cities and towns in the region. The PCRAFI database is a key resource, but one challenge will be to maintain the currency of the exposure data, given rapid urbanization. Accordingly, there are plans to update the PCRAFI data set in 2017–2018. The work of UN-Habitat in understanding urban vulnerabilities provides another useful information source (especially for Honiara and Port Vila; see Trundle and McEvoy [2015, 2016]).

Benchmark 4: Risk Assessment

A risk assessment considering both the likelihood and consequences of flooding is essential for quantifying flood risk and comparing the economic merits of alternative FRM options.

Figure 9. FRM practice and trajectories in PICs: Benchmark 4



Note: Question mark indicates uncertainty about past practice. For more information on Benchmark 4 for each country, refer to annex 1.

Summary and challenges

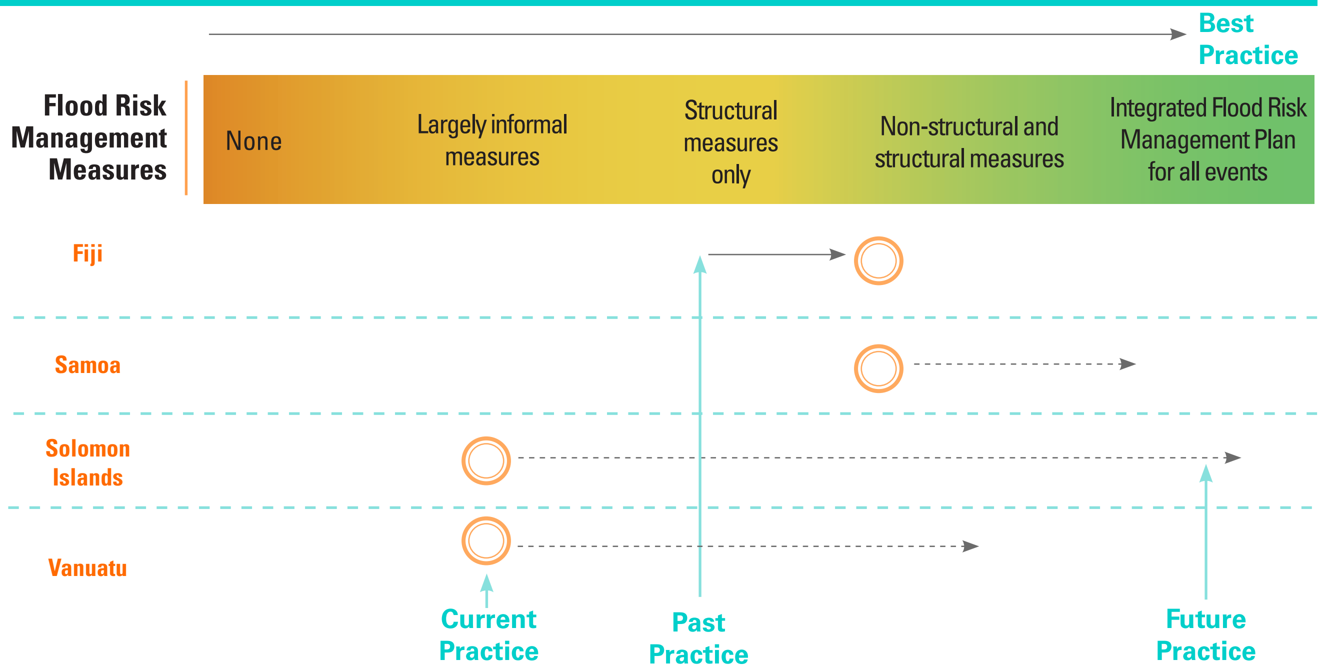
Few studies in PICs have derived estimates of average annual damages, often taken as standard for risk assessments. One assessment of risk to life has been conducted (for Nadi). A standardized set of locally tailored building and infrastructure damage functions is required.[13] While empirical investigation after flooding in Apia in 2012 resulted in depth-damage functions for a range of dwelling types (NIWA 2013), there is a need to incorporate both flood depth and velocity for a wider range of dwelling types. In addition, the cost of buildings and their contents needs to be tailored for each country. The National Institute of Water and Atmospheric Research (NIWA) has commenced a Pacific RiskScape project in Samoa and Vanuatu to improve damage functions.

[13] Damage functions relate the depth of flooding, and ideally also the velocity of flooding, to dollar damages, for example, for building structures or building contents, which reflect local styles and economies.

Benchmark 5: Flood Risk Management Measures

Best-practice FRM involves the considered implementation of a range of structural and nonstructural measures (table 4), following a robust evaluation of the social, economic, and environmental implications of potential options. This benchmark assesses the current mix of options and the degree to which an integrated approach has been pursued to the current time.

Figure 10. FRM practice and trajectories in PICs: Benchmark 5



Note: For more information on Benchmark 5 for each country, refer to annex 1.

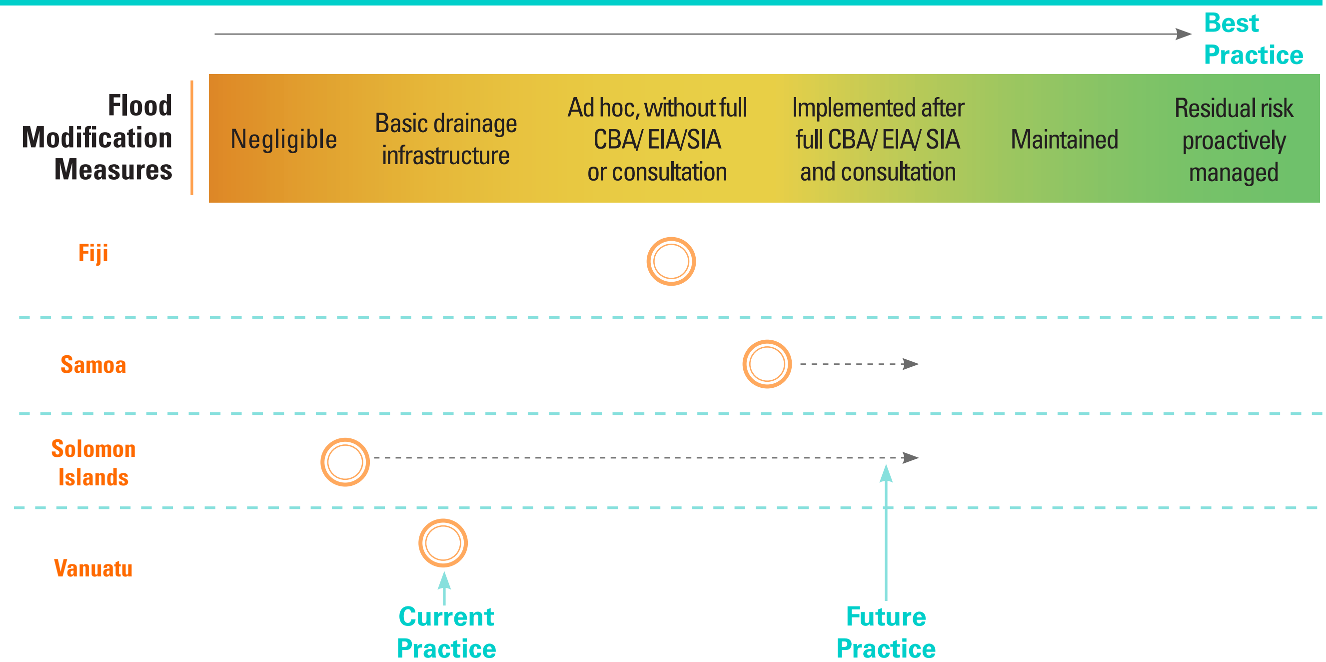
Summary and challenges

All four countries have a way to go to achieve an evidence-based, integrated mix of FRM interventions. Both Fiji and Samoa show a preference for structural works that attempt to confine the movement of floodwater, especially dredging of rivers, and levees. It is not clear that this approach represents the most effective way of reducing flood disaster risk. The global experience has been one of increasing flood damages despite structural works, partly due to increased development and induced complacency in "protected" areas (e.g., Tobin 1995; Yeo 1997; Ludy and Kondolf 2012). It is not feasible to completely engineer natural systems to prevent all flooding (Jha, Bloch, and Lamond 2012). Nonstructural measures deserve greater attention in an integrated Flood Risk Management Plan (FRMP).

Benchmark 6: Flood modification measures

Measures to modify the way floods behave can provide significant risk-reducing benefits but should be implemented only following comprehensive cost-benefit analysis, environmental impact assessment, and social impact assessment. It is also vital that affected communities be genuinely engaged as part of the evaluation process, and that structural works be appropriately maintained. As part of an integrated FRMP, the limits of any works (e.g., the design standard of a levee) ought to be openly acknowledged and steps taken to proactively manage the residual risk (e.g., of a levee being overtopped or breached). This benchmark assesses the degree to which such robust processes have been implemented to the current time.

Figure 11. FRM practice and trajectories in PICs: Benchmark 6



Note: CBA = cost-benefit analysis; EIA = environmental impact assessment; SIA = social impact assessment. For more information on Benchmark 6 for each country, refer to annex 1.

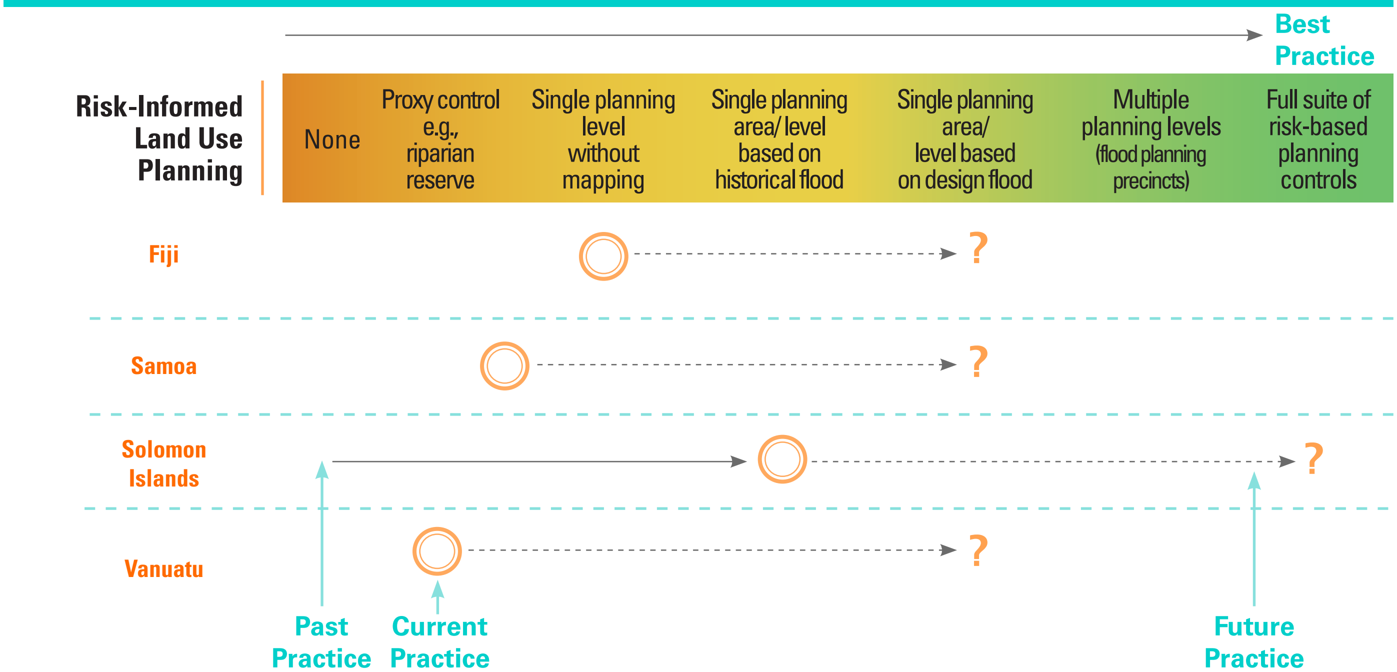
Summary and challenges

Robust processes to evaluate the merits of flood modification measures before their implementation have been slow to take root. There is some evidence that decisions to implement dredging and levees have been made before the projects' economic viability and social and environmental impacts were assessed. Projects to improve urban drainage have been implemented in some countries (i.e., Samoa and Vanuatu). In the Solomon Islands, the Honiara FRMP will evaluate several structural options, including flood mitigation dams.

Benchmark 7: Risk-informed land use planning and development controls

One of the most effective FRM measures is risk-informed land use planning. This seeks to ensure that land uses are compatible with the flood hazard and that any buildings located in floodplains are designed to minimize the damage caused by floodwater, for example, through building codes. For existing floodplain exposure, resettlement to higher ground can eliminate the risk.

Figure 12. FRM practice and trajectories in PICs: Benchmark 7



Note: Question marks indicate uncertainty about future changes. For more information on Benchmark 7 for each country, refer to annex 1.

Summary and challenges

A risk-informed land use planning process has been slow to take hold in PICs. A number of difficult challenges remain to be overcome if planning schemes are to prove effective in managing floodplain risk exposures:

- The extent of customary land ownership in PICs, which has often been cited to explain the ineffectiveness of planning controls and which affords local communities the final word in decisions affecting their land (Carter, Chung, and Gupta 1991; Nunn 2009; ADB 2013).
- The growth of informal settlements that circumvent formal planning controls, a lack of alternative sites, and the inability or unwillingness of established residents of informal settlements to relocate to a site with lower risk exposure if non-hazard-related attributes of their current dwelling site (e.g., access to employment or services; security of tenure) are compromised.

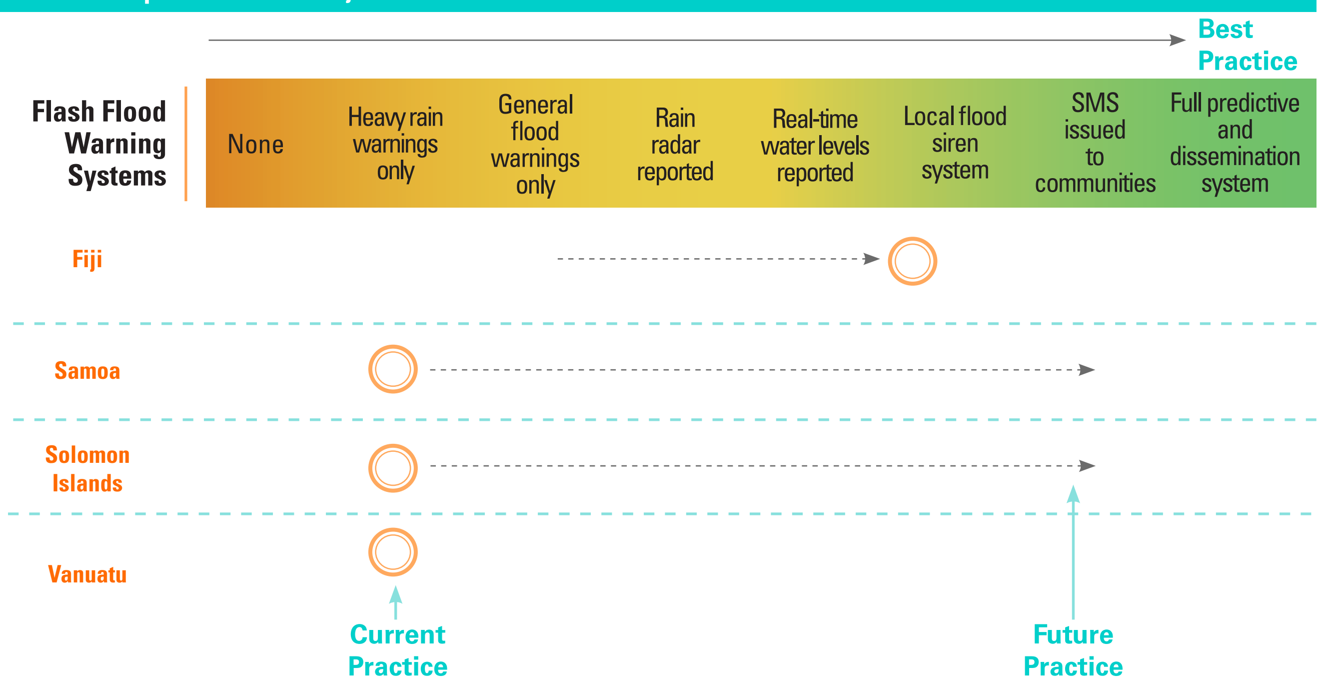
- Inadequate controls in existing plans—that is, the absence of best-practice requirements such as minimum floor levels, flood-compatible building components, structural soundness, evidence that the building will not worsen flooding elsewhere, and provision for safe evacuation in rare events up to the probable maximum flood.
- Inadequate linkages between the engineering and planning spheres, so that mapping outputs from flood studies are not suitable for translation into planning schemes.
- Lack of capacity, or lack of political will, to implement FRM-related controls.
- Lack of integration between policies at national, provincial, and local levels.
- Conflicts of interest whereby the consenting authority (e.g., a town council) is the developer
- Ministerial intervention in land use planning decisions (Beca International Consultants, GNS Science, and NIWA 2016b)

Two recent projects have sought to increase the consideration of natural hazard risk in urban development planning practice: the Introduction to Risk-Informed Decision Making in Urban Development Planning, a training course delivered to town planners in six countries in the region (see Pacific Community 2015), and the preparation of the Urban Risk Management Strategy (URMS) for Port Vila and Luganville (Beca International Consultants, GNS Science, and NIWA 2016b).

Benchmark 8: Flash flood warning systems

Accurate, timely, and meaningful flood warnings offer significant potential for increasing safety and reducing damages. Flood warning systems require detection of rainfall and/or water levels and dissemination of messages that are heard, understood, and acted on appropriately. The generally small catchments in the region mean that flooding is "flashy" in nature; this limits the ability to predict flooding and the time available for effective response.

Figure 13. FRM practice and trajectories in PICs: Benchmark 8



Note: For more information on Benchmark 8 for each country, refer to annex 1.

Summary and challenges

At the current time, no specific flood warnings are issued for Samoa, the Solomon Islands, or Vanuatu, while near real-time river levels are reported for Fiji. PICs face several challenges to sustaining effective flood warning systems:

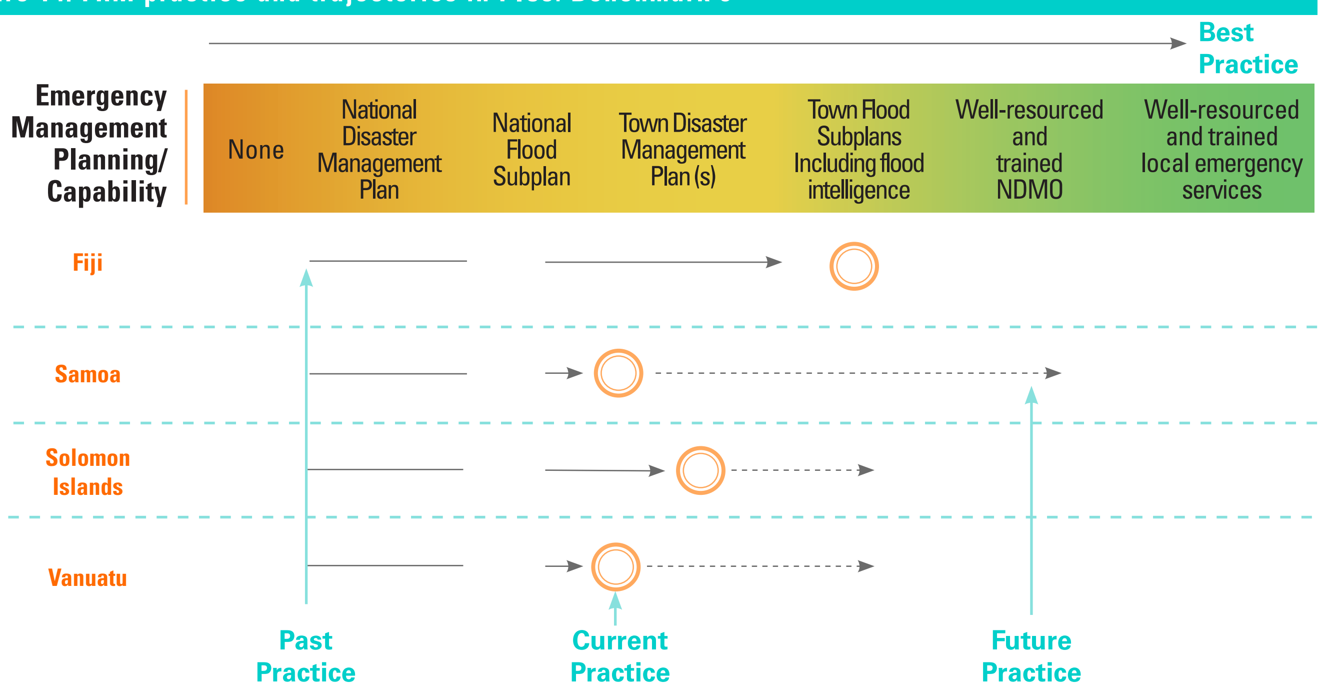
- For some small, steep catchments like Apia's Vaisigano catchment, it may not be possible to provide even one hour's warning based on observed water levels.
- Using observed (or forecast) rainfall may extend warning times at the expense of certainty, possibly undermining confidence in a warning system.
- All warning systems need to be maintained, including hydrological infrastructure, but funding of national hydrological services has often been insufficient for this essential work.

Other technologies may be considered for flood warning, such as rain radars (available in Fiji), SMS, and social media. The effectiveness of warning systems should be critically and openly reviewed after every event in order to identify any failings that could be remedied before the next flood.

Benchmark 9: Emergency management planning and capability

Effective responses to flood warnings require coordinated, flood-specific response plans, adequate resources, and trained personnel. Responsibilities for the emergency services organizations tasked with flooding include the collection of flood intelligence, deployment of personnel, opening of evacuation centers, closure of roads, and rescue of people in danger.

Figure 14. FRM practice and trajectories in PICs: Benchmark 9



Note: NDMO = National Disaster Management Office. For more information on Benchmark 9 for each country, refer to annex 1. Gaps in the Past Practice arrows indicate that the countries have not prepared a National Flood Subplan.

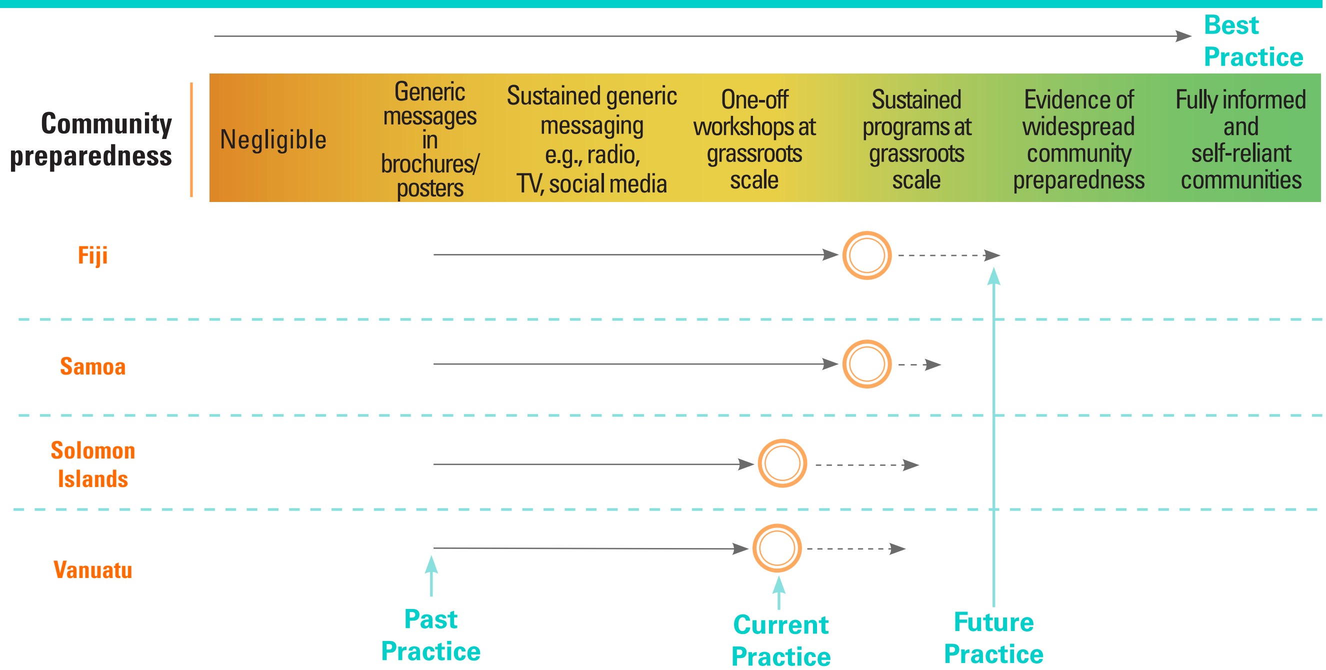
Summary and challenges

Although high-level Disaster Management Plans exist in each country, there is a need for flood hazard subplans and for local plans that incorporate emerging flood information and tailor responses to the circumstances of each flood-prone community. Importantly, all plans need to be viewed as works in progress, subject to routine reviews after five years. Standard operating procedures are required to ensure that the various stakeholders understand and accept their responsibilities. Local emergency services need to expand, be adequately resourced, and train staff in closing roads and performing flood rescues. These functions are difficult in the context of flash flooding, and especially in the context of flash flooding unrelated to a cyclone, when there is even less lead time, but they are nevertheless crucial.

Benchmark 10: Community preparedness

Community preparedness is a vital component of flood resilience. Particularly for flash flood situations, it may be difficult for official emergency responders to provide timely assistance to communities. Effective responses—including early evacuation—require at-risk communities and individuals to have a good appreciation of the flood threat and to implement their own plans to prepare for, respond to, and recover from flooding. It is difficult to measure a community's flood preparedness, because there may be considerable variation from one household/business to another, and variation over time depending on how recently it flooded. Also, some forms of preparedness may not be readily perceived, such as the existence of kinship networks, which continue to be important for recovery including in informal settlements (Bryant-Tokalau and Campbell 2014).[14] In figure 15, community preparedness is estimated based on the degree to which governments and nongovernmental organizations (NGOs) have invested in measures to inform communities of their risk, and to raise and sustain flood readiness as well as any evidence of implemented preparedness measures.

Figure 15. FRM practice and trajectories in PICs: Benchmark 10



Note: For more information on Benchmark 10 for each country, refer to annex 1.

[14] Community surveys could be conducted to assess the proportion of businesses or households that have prepared a business/household flood action plan and/or have implemented any measures to better prepare for flooding. Such measures may include detecting approaching storms through the movement of sea birds, cutting cassava tops, collecting water, tying down roofs, and moving to strong structures (Bryant-Tokalau and Campbell 2014).

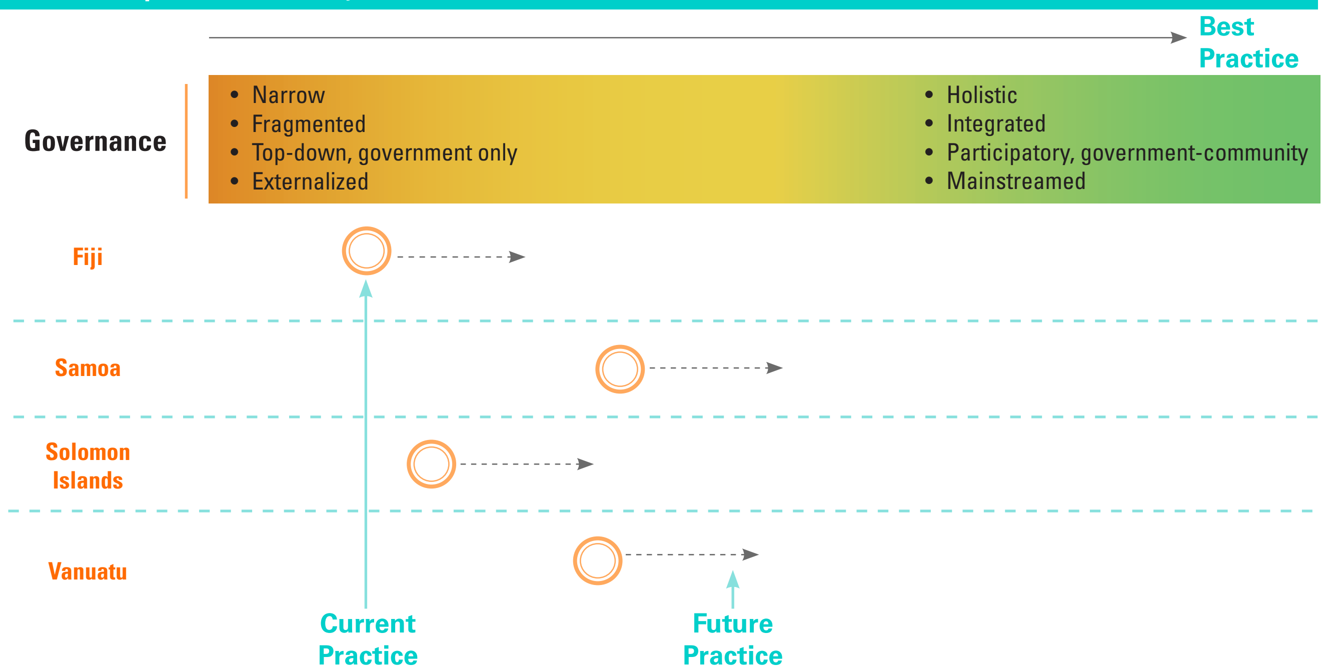
Summary and challenges

In all four countries, investments to build community preparedness have moved beyond the preparation of brochures and now include engagement with communities. This work may not necessarily translate to changed behaviors, however, and there is evidence of poor preparedness at the time of recent extreme cyclones and floods. A challenge for educators is to persuade communities that future floods could be bigger and faster-rising than those they have experienced in the past, in part due to the impacts of climate change. In communities where structural works such as dredging, diversion channels, and levees have been implemented, the challenge is to correct residents' misperception that they are fully protected by the adopted "solution." This misperception has been widely accepted and uncritically reported by the media.[15] Greater care is needed to clearly communicate the limited security afforded by structural options so that residents understand dredging is a short-term fix, diversion channels divert only part of the flow, and levees can be overtopped. Changing community attitudes and behaviors will require a sustained effort.

Benchmark 11: Flood risk management governance

Best-practice FRM requires "a coordinated, multidisciplinary effort across all levels of government, and between agencies and departments with different responsibilities… Hydrologists, floodplain managers, engineers, emergency response managers, land-use planners, environmental managers" and affected communities all have a role (AIDR 2017a 11). Risk governance may be defined as the enabling environment for risk-informed decision making and implementation (Selby and Jiwanji 2016). It exerts a powerful influence on every step of the FRM process and the degree to which the process is integrated (figure 5). It is difficult, however, to measure a country's practice; hence the scale in figure 16 considers a spectrum of possible practices—from narrow to holistic, from fragmented to integrated, from top-down government-based arrangements to participatory government-community partnerships, and from externalized to mainstreamed.

Figure 16. FRM practice and trajectories in PICs: Benchmark 11



Note: For more information on Benchmark 11 for each country, refer to annex 1.

[15] See, for example, Fiji Sun, "The Nadi River Diversion Project Is Expected to Provide a Major Solution for the Town's Notorious Flooding Problems," July 23, 2013; or Fiji Times, "Dredging Saves Town from Floodwaters," April 10, 2014.

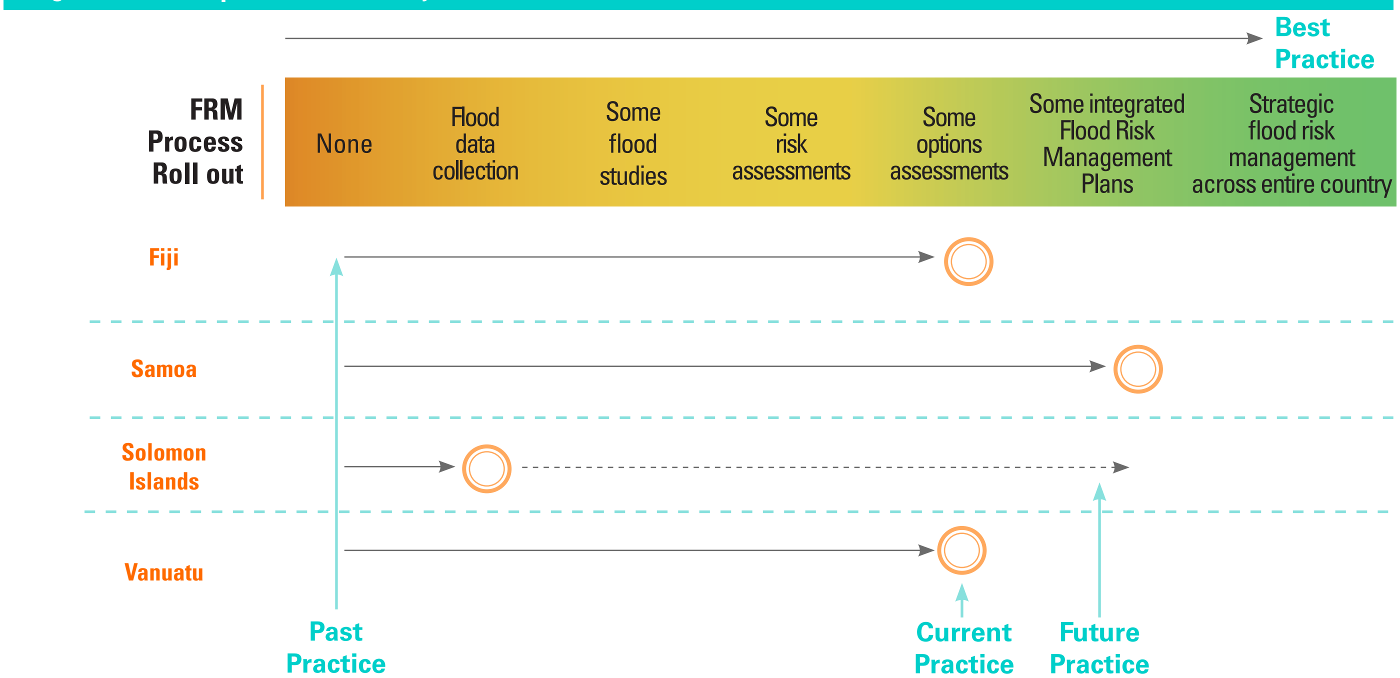
Summary and challenges

Although many FRM projects have been implemented over recent years, the lack of robust governance arrangements raises doubts about the integration and sustainability of this work. Recent efforts to improve FRM practice include detailed assessments of flood risk (Nadi, Apia, Port Vila, Luganville), the piloting and roll out of ecosystem-based adaptation approaches (Lami, Port Vila, Honiara), a focus on risk-informed land use planning (Nadi, Port Vila, Luganville), investments in flood warning systems (especially Fiji), and efforts to promote resilience in urban communities (notably Honiara and Port Vila). Cumulatively, this activity is encouraging, since it involves more holistic and participatory approaches than have previously been practiced. However, since most of this activity has been project-based, it is not clear that countries are pursuing a truly integrated approach to flood risk management, and more generally to disaster risk reduction (DRR) and climate change adaptation (CCA). Nor is it clear that they are directing limited resources to the most strategic areas. There is also a question of the long-term effectiveness of these projects. One danger is that the many overlapping policies and plans will overwhelm the national workers responsible for implementing them (well demonstrated for Samoa). Pursuing quick impacts at a local level, projects can also fail to connect or institutionalize their outcomes to national development planning, budgetary systems, and development priorities (Selby and Jiwanji 2016).

Benchmark 12: Flood risk management process roll out

The final benchmark assesses the degree to which the FRM process (figure 5) has been rolled out in each country.

Figure 17. FRM practice and trajectories in PICs: Benchmark 12



Note: For more information on Benchmark 12 for each country, refer to annex 1.

Summary and challenges

An integrated FRMP has been prepared for only one urban center across these four countries. In recent years, flood modeling consistent with best practice has significantly enhanced the understanding of flood risks for key floodplains in Fiji, Samoa, and Vanuatu, although the results have been limited by the quality of hydrological data. Only in Samoa, however, has this work led to an integrated FRMP that was prepared after evaluating the full suite of potential FRM interventions. Advancing a *process* for FRM requires better governance and champions to advocate for the process, which may be difficult after a disaster when political pressure is exerted for immediate solutions. One case in point is Nadi, where severe floods in 2009 and 2012 created heavy pressure to implement a diversion channel option previously recommended by the Japan International Cooperation Agency (JICA 1998). Once new and superior flood modeling, risk assessment, and analysis of costs were carried out, however, the diversion channel option was abandoned in favor of other measures.

PRIORITIES FOR IMPROVING FLOOD RISK MANAGEMENT PRACTICE

Based on the benchmarking exercise, including its identification of gaps in current practice, this section proposes a suite of priorities for advancing integrated FRM practice in PICs. These priorities are relevant to all four countries considered in this Knowledge Note. The priorities listed below should be taken as a complementary suite of interventions, and are not ranked in any particular order of importance.

1. Improve governance

Holistic, integrated, and *sustainable* governance arrangements for FRM are required, so that responsibilities for managing flood risk are assigned, understood, and supported at a national level. Meeting this priority requires ongoing capacity building and institutional strengthening (for all ministries involved, including those taking the engineering, planning, and emergency management leads), the development of repeatable governance structures for the preparation of FRM plans, and ongoing mainstreaming of DRR and CCA into national and sectoral programs and budgets. The need for holistic and collaborative governance is well described by Sayers et al. (2015, 146):

> To be effective, flood management strategies must be implemented across a range of sectoral interests (flood risk, water resources, development, energy and so on). This requires national, regional and local governments to ensure multiple policies, regulations and programmes that they promote are appropriately integrated, and that work done at one level of government, or in one sector, is in harmony with associated activities in other levels of government and sectors. As such "sound" flood management planning requires a paradigm of governance that is collaborative and blurs the distinction between the disciplines of spatial, coastal zone, river basin and water resources planning as well as flood defence engineering and environmental management.

Given the importance of risk-informed land use planning for limiting risk, good governance is especially required in that arena. Selby and Jiwanji (2016) argue that mainstreaming risk into national development agendas and processes should be an ongoing process, since deep-seated changes in governance are required. They propose nine building blocks for risk governance relating to people, mechanisms, and processes. Current risk governance initiatives in PICs show strong prospects for more resilient development outcomes (Selby and Jiwanji 2016).

2. Involve communities and other stakeholders

Early and genuine engagement of affected communities and other stakeholders is required to ensure that their knowledge and opinions are fully incorporated in the investigation. Participatory mapping of historical flood extents and depths may be used for flood model calibration. Crowdsourcing flood photographs may be especially useful where formal information sources are lacking (Dufty 2017). Especially if relocation to less hazardous land is an option, it is vital that vulnerable households actively participate in the decision-making process (Orcherton, Mitchell, and McEvoy 2016).

3. Apply a flood risk management process

A sound FRM process is key to improving resilience. There is no substitute for a process that assesses the existing risk, considers future risk (in light of climate change and urbanization), evaluates the merit of various interventions to increase resilience, recommends a plan that through community and stakeholder engagement has won broad acceptance, and then implements well-founded solutions. Too often following a damaging flood, PICs have short-circuited the FRM process depicted in figure 5, leading to expensive, ineffective, and even counterproductive "solutions" to the problem.[16]

Improve and sustain hydrological monitoring

A starting point in the process is better collection, quality assurance, retention, and sharing of hydrological data. The quality of inputs to flood studies necessarily affects the quality of outputs.[17] Maintaining upgraded hydrological networks has proved problematic in the past, with inadequate funding from PIC governments. Addressing this priority requires a changed *modus operandi.*

Conduct flood studies

Flood studies are required to provide a robust basis for understanding where flood depths and velocities pose intolerable risks to life and property. They provide an understanding of the full range of flooding, including larger and rarer floods than have been experienced, as well as the potential impacts of climate change. Contemporary models also generate dynamic outputs that help emergency services understand the likely timing of impacts. Peer review of flood studies is recommended to provide confidence in the quality of flood modeling.[18]

Conduct community studies

Community studies are also required to better understand a population's exposure and vulnerability. This includes understanding root causes and projected changes.

Develop local damage functions for risk assessments

Estimating the potential costs of floods requires a standardized set of locally tailored building and infrastructure damage functions, which relate depths and velocities to the costs of damage. Some work was done after the 2012 floods in Apia (NIWA 2013), and a new Pacific RiskScape project is under way in Samoa and Vanuatu to improve damage functions.

16 On the other hand, it is acceptable to identify and implement affordable, "no regrets" measures prior to the conclusion of a flood risk management study. These could include ecosystem-based adaptation approaches such as watershed management.

17 Intensity-frequency-duration rainfall data for design flood modeling are known to exist for only a few locations within the region, with poor representation for mountainous areas where rainfalls are typically heavier.

18 Some flood studies and option evaluation studies conducted in PICs are of questionable quality. Because PIC governments lack engineers trained in FRM, there is limited scrutiny of these studies. In the long term, this limitation may be remedied by investing in human resources, particularly water engineers. In the short term, peer review by consultants whose core business is FRM (and who use 2D hydraulic models) is recommended.

Identify risk tolerability

Before assessing options to reduce the flood risk, the acceptability or tolerability of flooding should be considered. This step is important because it is not possible to totally eliminate floods or the impact of flooding. Given the pressures on PIC floodplains, adopting a 1 percent AEP flood planning level for residential development may be impractical. Perhaps an inundation depth of 30cm may be deemed tolerable, as it is for Vietnamese cities. Different standards may apply for different land uses—e.g., hospitals would ideally be free of flooding even in extreme events.

Employ multicriteria analysis

Best-practice FRM requires evaluation of the entire suite of possible options (Jha, Bloch, and Lamond 2012, 44–45) (see table 4). Multicriteria analysis is used to compare options according to factors such as these:

- Impact on flood behavior
- Number of houses benefiting
- Critical infrastructure benefiting
- Economic merit (benefit-cost ratio)[19]
- Life safety benefit
- Environmental impact
- Social impact
- Technical feasibility
- Financial feasibility
- Political/legislative acceptance
- Community acceptance
- Performance in rare floods (> 1 percent AEP)
- Long-term performance (design life, climate change)

An important component of evaluation is weighing up the adverse effects of proposed interventions. For example, bypass channels may benefit one area but increase flood depths, velocities, and erosion and damage sensitive ecologies in the "receiving" area. Filling the floodplain to increase the immunity for one site will redirect floodwater toward other areas.

Prepare FRM plan

Having evaluated the options, a recommended, costed, and prioritized portfolio of FRM interventions should be listed in an integrated FRM master plan. Interventions set out in the FRM master plan should be implemented in a coordinated fashion as funds permit. FRM plans need to be periodically reviewed to ensure that they continue to meet the changing flood risk.

19 One need in PICs is for standardized approaches to benefit-cost analysis (e.g., selection of discount rates). This would make it easier to compare preferred options *between* studies and hence provide a strategic basis for governments to direct funds to the most urgent problems.

4. Reframe the problem

Understanding flood risk holistically as the integration of flood hazard, exposure, and vulnerability will promote a more balanced and integrated approach to managing flood risk. Hence, a key need for PICs is to reframe the problem, looking beyond "undersized channels" and "low river banks" to inappropriately located urban development, and even further to the root causes of this development, including migration drivers and poverty.

5. Broaden the solutions

The solutions are likely to include a portfolio of structural and non-structural options. Addressing flood problems at a river basin scale is vital (UFCOP 2017) and is well exemplified in the "ridge to reef" philosophy upon which the Greater Apia Integrated Watershed Management Plan is based. The solutions will also go beyond traditional FRM measures to more integrated approaches that tap into broader action plans for building the resilience of urban communities (e.g., Trundle and McEvoy 2016). For example, one solution to Honiara's urban drainage problems—made worse by waste being dumped in creeks, blocking culverts, and exacerbating flooding upstream; see figure 18—is to provide improved solid waste disposal services and educate the public about proper waste disposal. Litter traps could also be installed to capture residual solid waste. Broader environmental benefits as well as flood benefits would result.

Figure 18. Solid waste limiting flow conveyance in a Honiara creek

Source: S. Yeo, WBG.

6. Preserve and enhance the capacity of river channels and floodplains to convey flows

Figure 19. Filling the floodplain and riverbank protection works on one side of the Mataniko River in Honiara

Source: S. Yeo, WBG.

Better legislation and enforcement is required to ensure that the impacts of development on flooding are scrutinized in the development approval process. Evidence has been seen in all four countries of encroachment upon waterways, filling of floodplains for bridge approaches or other purposes (see figure 19), and inappropriate siting of buildings, all of which reduce the conveyance of floodwaters and in turn contribute to higher flood levels and riverbank erosion elsewhere. Where conveyance has already been lost, opportunities to restore channel capacities should be considered.

7. Reduce exposure and vulnerability

Strategies to reduce exposure and promote resilience need to be devised and implemented.

As indicated above, increasing exposure, along with the vulnerability of communities on floodplains, represents the biggest driver of flood risk in PICs. However, reducing this exposure through relocation and limiting its growth through land use planning are notoriously difficult to achieve in PICs (see the discussion of Benchmark 7 above).

Consider voluntary relocation

Disastrous floods can act as powerful forces for land use change and can in extreme cases lead to relocation of vulnerable populations. For example, the 1931 Fiji flood led people to abandon flood-prone house locations in favor of higher land (Yeo and Blong 2010). In Honiara in 2014, after flooding killed people on the Koa Hill floodplain along the Mataniko River, that area was abandoned for residential use. But it is not easy to keep houses off dangerously low-lying land, including sites where residents can be first trapped and then overwhelmed in a rising flood. In Honiara, it is conceivable that shortage of land will eventually drive new settlers, inexperienced with the risk, to set up "temporary" leaf houses on land that was flooded to depths approaching five meters in 2014. At Koa Hill, one approach could be to work with the community to identify a land use for the floodplain—e.g., a formally demarcated football field, which would also add much-needed recreational space—that would quarantine it from future residential use.[20] New houses could then be accommodated through densification of safe areas.

It is also necessary to design and service new subdivisions on low-hazard land, targeted at people dislocated by a flood or occupying unacceptably dangerous land. Though not without its implementation issues, Honiara's April Ridge subdivision is an example of this kind of approach. Even better would be proactive efforts to increase supply and persuade residents to relocate from high-hazard sites before a disaster occurs. This approach would require bottom-up engagement processes, planning for livelihoods and services, and secure tenure in the new communities (Orcherton, Mitchell, and McEvoy 2016).

Practice risk-informed land use planning

Legislation, policies, and zoning plans relating to urban land use in PICs need to be reviewed and revised to ensure that flood risk is considered as an integral part of urban development planning (ADB 2013). This corresponds to the "development first" approach advocated by Selby and Jiwanji (2016), who argue for a fundamental transformation of development practice such that risk is brought into the center of development decision making, budgeting, policies, processes, and practices. The importance of correctly implementing land use plans was highlighted in a recent policy review conducted for Vanuatu's URMS; focusing on the need to improve existing land use decision-making tools and apply a consistent land use planning approach, the review identified the need for a number of changes to existing legislation, policies, and practices. URMS reviewed land use planning policies and practices, identifying a need to strengthen the existing planning instruments and their implementation. (Beca International Consultants, GNS Science, and NIWA 2016b).

Risk information needs to be provided to planners in a fit-for-purpose format. This requirement was also exemplified in Vanuatu's URMS.

There also need to be improvements in human resources. In Nadi and Apia, for example, the few town planners reportedly struggle to keep pace with development applications and to monitor compliance with any conditions of development. Training of town planners is also required, and the courses delivered to planners in Nadi, Apia, Honiara, and Port Vila, together with the decision support tools developed for those courses, are an admirable step for advancing risk-informed land use planning (see e.g. Pacific Community 2015). Follow-up training is required in order to better integrate local practice with national policy frameworks and reinforce the improved capacity of town planning departments to effectively manage future flood risk though the planning process. On the issue of customary land, participatory approaches that engage landowners may help to direct sensitive land uses away from the most hazardous areas.

20 Installing permanent, visible reminders of the flood height would also act to preserve community memory.

Encourage resilient buildings

The risk of damage can be reduced for new buildings by implementing appropriate development controls. This requires reviewing and revising building codes, and increasing capacity to check compliance with controls. Authorities can also work with industry associations to prepare locally tailored guidelines for hazard-resilient housing, including for low-income groups (GoSI 2014). This priority recognizes that it may not be practical to relocate communities away from high-risk areas or to keep floodplains entirely free of new development.

Encourage resilient infrastructure

In the aftermath of floods, a priority is to "build back better" rather than replace infrastructure at the same level of exposure. Meeting this priority could include elevating bridges, reducing the number of piers, and providing debris deflectors to enhance structures' resilience to floods. Checks are required to ensure that any added resilience measures do not shift the problem (e.g., via raised bridge embankments, which can function as a dam, elevating water on the upstream side).

8. Enhance response

Investment is required to enhance communities' ability to respond to and cope with flooding. This includes investments in early warning systems (EWS), emergency management planning, and community preparedness. This priority recognizes that it is not practical to relocate all communities away from high-risk areas or to retrofit all existing buildings.

Develop EWS

Early warning of floods offers prepared households and businesses the opportunity to evacuate themselves and their assets to safe ground. EWS are known to be a cost-effective investment, with the Navua Flood Warning System estimated to have a benefit-cost ratio of between 3.7 and 7.3 (Holland 2008). But every EWS requires maintenance and standard operating procedures to ensure it is functional when called upon to warn communities. Neglecting these aspects can reduce the system's effectiveness: during the April 2016 flood in Nadi, for example, the alarm was not sounded. Given the large risk exposures, priorities for new EWS in the region include Ba, Labasa, Apia, and Honiara. However, the small, steep catchments above many of the cities and towns in the region, and the flash floods they generate, present real challenges for EWS. Technologies for early detection of likely flooding, such as rain radar, and for efficient dissemination of warnings, such as SMS and social media, may help to address these challenges.

Improve emergency management planning and capability

At the current time, official emergency management planning gives less attention to flood hazards than to tropical cyclones (which riverine flooding is one of several hazards) and tsunami. There is a need for flood hazard subplans and for local plans that incorporate flood information being generated from flood studies and flood risk management studies. It is especially important to identify potential 'low flood islands' (where access is lost before possible inundation), since very early evacuation may be needed there to save lives. There is also a need to grow, resource and train local emergency services' responders (including growing a volunteer base) to close roads and perform flood rescues.

Foster community preparedness

While governments can do much good, it is the communities living and working on floodplains who bear the brunt of the risk to life and property and who must be equipped to manage their risk. This is because floods can never be completely controlled and flood risk can never be completely eliminated. Science, such as verified flood model outputs, can be used to inform communities, particularly about floods beyond their experience. Traditional knowledge also has a role. Participatory approaches that promote mutual learning and sharing offer the best chance of success, for example, as communities pre-plan their evacuation routes and shelters (Beca International Consultants, GNS Science, and NIWA 2016b). Possible methods for communicating messages include radio shows, theatre plays, school curricula and youth groups (Trundle & McEvoy, 2016).[21]

CONCLUSION AND KEY MESSAGES FOR POLICY MAKERS

In PICs, flooding arising from the overflow of rivers and streams has caused significant damage to urban communities. For example, flooding in and around Honiara in April 2014 had an economic impact equivalent to 9.2 percent of Solomon Islands GDP and was associated with 24 fatalities. With heavier rain and sea-level rise associated with climate change, impacts are projected to increase significantly. The more immediate driver of flood risk in the cities and towns of PICs is unplanned urbanization, resulting in more people living and working on floodplains.

This Knowledge Note advocates the application of an integrated flood risk management process to reduce the impacts of flooding in PICs. A tracking tool has been developed and used to track current FRM practices in Fiji, Samoa, the Solomon Islands, and Vanuatu; the tool has also been used to track the trajectories of past practices and project future practices in light of projects currently under way. At least for some catchments, the assessment of flood risks has improved significantly in recent years, although assessment results are compromised by generally poor hydrological data. Some PICs prefer to rely on structural works to control floods, and in all countries, efforts to control the key drivers of flood risk—increasing exposure and vulnerability—have met with little success. The flashy nature of flooding in PICs presents challenges for EWS, though Fiji has made significant advances in this area. Overall, governance of FRM has tended toward narrow, fragmented, top-down, and externalized models.

Eight priority interventions for advancing current practice in PICs are proposed. These interventions should be considered as a complementary suite of initiatives that will help improve FRM in PICs, rather than as ranked in order of importance.

1. **Improve governance.** Holistic, integrated, and sustainable FRM governance arrangements are required, so that responsibilities for managing flood risk are assigned, understood, and supported at a national level.
2. **Involve communities and other stakeholders.** Communities and other stakeholders should be involved from the outset of the FRM process to ensure local ownership of the problem and proposed solutions.
3. **Apply a flood risk management process.** A sound FRM process is key to improving resilience, and should include investment in understanding the flood risks (via flood studies and community studies) and evaluation of all potential options.
4. **Reframe the problem.** Flood risk should be considered holistically as the integration of flood hazard, exposure, and vulnerability.

21 A puppet play was written for the Ba Flood Preparedness Project (Yeo 2000) that sought to persuade proprietors and residents that managing flood risks was their business rather than the government's. It was presented by the Fiji Red Cross and appeared to resonate well with the workshop participants and schoolchildren.

5. **Broaden the solutions.** Flood risk interventions should include a portfolio of structural and non-structural options that promote the broader resilience of urban communities.
6. **Preserve and enhance the capacity of river channels and floodplains to convey flows.** Better legislation and enforcement is required to ensure that development does not exacerbate flood problems elsewhere.
7. **Reduce exposure and vulnerability.** Strategies include risk-informed land use planning, resilient buildings and infrastructure, and the potential for voluntary relocation from high-hazard areas.
8. **Enhance response.** Flood early warning systems, better emergency management plans and capacities, and efforts to promote community understanding and preparedness are required to improve people's responses to floods.

Achieving best-practice FRM across all 12 of the benchmarks articulated within this Knowledge Note will be challenging. A primary obstacle is competing demands for limited budgetary resources. However, countries can take a step in the right direction by recognizing that (1) a process is required to understand and reduce flood risk, and (2) a broad suite of FRM options is available. It is not realistic to think that best-practice FRM will be quickly attained. However, small steps along an improving trajectory can produce significant beneficial outcomes.

The first step is to establish in each country a multisectoral forum for the holistic and integrated governance of FRM. There is potential for existing DRR/CCA forums to take on this task, provided their membership is sufficiently broad and the vision is holistic. Both government and NGOs should be represented on such a forum. Key functions would be to promote the understanding and application of the FRM process, to prioritize investigations and implementation of actions emerging from FRM plans, to ensure a coordinated approach among agencies and development partners, and to routinely review national advances and needs. There would also be value in using regional forums (such as the Pacific Meteorological Council and the Pacific Resilience Partnership) for sharing knowledge and experiences and inspiring continued progress toward the goal of flood-resilient communities in PICs.

REFERENCES

ADB (Asian Development Bank). 2013. Moving from Risk to Resilience: Sustainable Urban Development in the Pacific. Mandaluyong City, Philippines: ADB.

AIDR (Australian Institute for Disaster Resilience). 2017a. Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia. Australian Disaster Resilience Handbook 7. 3rd ed. Canberra: AIDR.

———. 2017b. Flood Emergency Response Classification of the Floodplain. Australian Disaster Resilience Guideline 7-2. 2nd ed. East Melbourne: AIDR.

Ambroz, A. 2009. Economic Costs of January 2009 Ba Floods. SOPAC Technical Report 425. Suva, Fiji: SOPAC.

Australian Bureau of Meteorology and CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report. Australian Bureau of Meteorology, and CSIRO, Melbourne.

Babister M., and M. Retallick. 2013. "Defining Best Practice in Floodplain Management." Paper presented at Floodplain Management Association National Conference, "National Floodplain Management—Shared Experiences, National Solutions," Tweed Heads, NSW, Australia, May 28–31. http://www.floodplainconference.com/papers2013/Mark%20Babister%20Full%20Paper.pdf.

Beca International Consultants, GNS Science, and NIWA. 2016a. "Hazard and Risk Maps and Geo-data Report: Planning for Urban Preparedness." Prepared for Vanuatu Meteorological and Geohazard Department. January.

———. 2016b. "Urban Risk Management Strategy: Risk Mapping and Planning for Urban Preparedness." Prepared for Vanuatu Meteorological and Geohazard Department. August.

Blong, R. J., and D. Radford. 1993. "Deaths in Natural Hazards in the Solomon Islands." Disasters 17 (1): 1–11.

Brown, P., A. Daigneault, D. Gawith, W. Aalbersberg, J. Comley, P. Fong, and F. Morgan. 2014. "Evaluating Ecosystem-based Adaptation for Disaster Risk Reduction in Fiji." Manaaki Whenua Press, Landcare Research, New Zealand. https://reliefweb.int/sites/reliefweb.int/files/resources/FJI_LCR_USP_2014_Evaluating_EBA_DRR_Report.pdf.

Bryant-Tokalau, J., and J. Campbell. 2014. "Coping with Floods in Urban Fiji: Responses and Resilience of the Poor." In Disaster Relief in the Asia Pacific: Agency and Resilience, edited by M. Sakai, E. Jurriën, J. Zhang, and A. Thornton, 132–46. Abingdon, UK: Routledge.

Carter W. N., J. M. Chung, and S. P. Gupta. 1991. "South Pacific Country Study." In: Disaster Mitigation in Asia and the Pacific, 255–308. Manila, Philippines: Asian Development Bank.

Chandra A., and J. Dalton. 2010. "Mainstreaming Adaptation within Integrated Water Resources Management (IWRM) in Small Island Developing States (SIDS): A Case Study of the Nadi River Basin, Fiji Islands." In Building Resilience to Climate Change: Ecosystem-Based Adaptation and Lessons from the Field, edited by A. A. Pérez, B. H. Fernández, and R. C. Gatti, 47–59. IUCN, Gland, Switzerland: IUCN.

Cochrane, G. R. 1969. Problems of Vegetation Change in Western Viti Levu, Fiji." In Settlement and Encounter: Geographical Studies Presented to Sir Grenfell Price, edited by F. Gale and G. H. Lawton, 115–47. London: Oxford University Press.

Daigneault, A., P. Brown, and D. Gawith. 2016. "Dredging versus Hedging: Comparing Hard Infrastructure to Ecosystem-Based Adaptation to Flooding." Ecological Economics 122: 25–35.

DECC (Department of Environment and Climate Change). 2007. "Flood Emergency Response Planning Classification of Communities." Floodplain Risk Management Guideline. NSW Government.

Dufty, N. 2017. "How Can We Improve Community Engagement for Floodplain Management?" Paper presented at the Floodplain Management Australia National Conference, "Preparing for the Next Great Flood," Newcastle, NSW, Australia, May 16–19.

GFDRR (Global Facility for Disaster Reduction and Recovery). 2016. The Making of a Riskier Future: How Our Decisions Are Shaping Future Disaster Risk. Washington, DC: GFDRR.

GoS (Government of Samoa). 2013. "Samoa Post-Disaster Needs Assessment, Cyclone Evan 2012." March. https://openknowledge.worldbank.org/handle/10986/15977.

GoSI (Government of the Solomon Islands). 2014. "Rapid Assessment of the Macro and Sectoral Impacts of Flash Floods in the Solomon Islands, April 2014." World Bank, Washington, DC.

GoV (Government of Vanuatu). 2015. "Vanuatu Post-Disaster Needs Assessment, Tropical Cyclone Pam March 2015." https://www.gfdrr.org/en/vanuatu-post-disaster-assessment-tropical-cyclone-pam-march-2015.

Hall, J. W., I. C. Meadowcroft, P. B. Sayers, and M. E. Bramley. 2003. "Integrated Flood Risk Management in England and Wales." Natural Hazards Review 4 (3): 126–35.

Hay J. 2009. "Institutional and Policy Analysis of Disaster Risk Reduction and Climate Change Adaptation in Pacific Island Countries: Final Report." Prepared for United Nations International System for Disaster Reduction and United Nations Development Programme. JEH+ Ltd., Rarotonga, Cook Islands.

Holland, P. 2008. Fiji Technical Report: An Economic Analysis of Flood Warning in Navua, Fiji. EU-SOPAC Project Report No. 122. Suva, Fiji: SOPAC.

———. 2009. Economic Costs of January 2009 Nadi Floods. SOPAC Technical Report 426. Suva, Fiji: SOPAC.

Jha, A. K., R. Bloch, and J. Lamond. 2012. Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. Washington, DC: World Bank.

JICA (Japan International Cooperation Agency). 1998. "The Study on Watershed Management and Flood Control for the Four Major Viti Levu Rivers in the Republic of Fiji." JICA.

Kostaschuk, R., J. Terry, and R. Raj. 2001. "Tropical Cyclones and Floods in Fiji." Hydrological Sciences Journal 46: 435–50.

Kuleshov, Yuriv, Simon McGree, David Jones, Andrew Charles, Andrew Cottrill, Bipen Prakash, Terry Atalifo, Salesa Nihmei, and Fata Lagomauitumua Sunny K. Seuseu. 2014. "Extreme Weather and Climate Events and Their Impacts on Island Countries in the Western Pacific: Cyclones, Floods and Droughts." Atmospheric and Climate Sciences 4: 803–18.

Kundzewicz, Z. W., S. Kanae, S. I. Seneviratne, J. Handmer, N. Nicholls, P. Peduzzi, R. Mechler, et al. 2014. "Flood Risk and Climate Change: Global and Regional Perspectives." Hydrological Sciences Journal 59 (1): 1–28.

Ludy, J., and G. M. Kondolf. 2012. "Flood Risk Perception in Lands 'Protected' by 100-Year Levees." Natural Hazards 61: 829–42. doi:10.1007/s11069-011-0072-6.

Lumbroso, D., A. Titmaea, A. Penia, and M. Bonte-Grapentin. 2008. Samoa Technical Report: 13th July–3rd August, 2006. WS 3.5.4 Capacity Building in Flood Risk Management. EU EDF–SOPAC Project Report 69c. Suva, Fiji: SOPAC.

McAneney, J., R. van den Honert, and S. Yeo. 2015. "Lies, lies . . . and Wretched Statisticians." Risk Frontiers Quarterly Newsletter 15 (1): 1–2.

———. 2017. "Stationarity of Major Flood Frequencies and Heights on the Ba River, Fiji, over a 122-Year Record." International Journal of Climatology. doi:10.1002/joc.4989

McGree, S., K. Whan, D. Jones, L. V. Alexander, A. Imielska, H. Diamond, E. Ene, et al. 2014. "An Updated Assessment of Trends and Variability in Total and Extreme Rainfall in the Western Pacific." International Journal of Climatology 34 (8): 2775–91.

MHA (Ministry of Home Affairs). 2014. "2014 Flash Flooding Victims National Memorial Service, St Barnabas Cathedral Sunday 11 May 2014 Program". Solomon Islands Government

MNRE (Ministry of Natural Resources and Environment). 2007. "Samoa Flood Management Action Plan 2007–2012 with Specific Reference to Vaisigano River." Prepared in collaboration with SOPAC and HR Wallingford. Apia, Samoa.

NBCC (Nadi Basin Catchment Committee). 2014. "Minutes of the Nadi Basin Catchment Committee (NBCC) First Quarter Meeting 2014 No. 15 held on Thursday, 13th March 2014 at Nadi Town Council Chambers, Nadi."

NDMO (National Disaster Management Office). 2003. "Report on Tropical Cyclone Ami." April. http://www.pacificdisaster.net/pdnadmin/data/documents/10964.html. Suva, Fiji.

NIWA (National Institute of Water and Atmospheric Research). 2013. "Preliminary Pacific Flood Depth-Damage Functions from Tropical Cyclone Evan, December 2012, Samoa." Prepared for RiskScape. November.

———. 2014. "Nadi River Flood Risk Assessment Report." Prepared for Applied Geoscience and Technology Division (SOPAC) of the Secretariat of the Pacific Community (SPC). April. http://www.pacificdisaster.net/pdnadmin/data/original/NIWA_FJI_2014_Flood_risk_assessment_report.pdf.

———. 2015. "Vanuatu Flood Hazard Models: Modelling and Data Report for the Mele and Sarakata Floodplains." Prepared for Beca International Consultants. May.

Nunn, P. D. 2009. "Responding to the Challenges of Climate Change in the Pacific Islands: Management and Technological Imperatives." Climate Research 40: 211–31.

———. 2010. "Bridging the Gulf between Science and Society: Imperatives for Minimalizing Societal Disruption from Climate Change in the Pacific." In Adaptation and Mitigation Strategies for Climate Change, edited by A. Sumi, K. Fukushi, and A. Hiramatsu, 233–48. Tokyo: Springer.

Nunn P. D., L. Kumar, I. Eliot, and R. F. McLean. 2016. "Classifying Pacific islands." Geoscience Letters 3 (7). doi:10.1186/s40562-016-0041-8.

Orcherton, D., D. Mitchell, and D. McEvoy. 2016. "Perceptions of Climate Vulnerability, Tenure Security and Resettlement Priorities: Insights from Lami Town, Fiji Islands." Australian Geographer. http://dx.doi.org/10.1080/00049182.2016.1236429.

Pacific Community. 2015. "Training Report: Introduction to Risk-Informed Decision Making in Urban Development Planning, 21–13 September 2015, Nadi, Fiji." (Unpublished report). Pacific Community, Suva, Fiji.

Pacific Community, Secretariat of the Pacific Regional Environment Programme, Pacific Islands Forum Secretariat, United Nations Development Programme, United Nations Office for Disaster Risk Reduction, and University of the South Pacific. 2016. "Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management (FRDP) 2017–2030." Pacific Community, Suva, Fiji.

Planning Institute of Jamaica. 2014. "Project Operational Manual: Improving Climate Change Data and Information Management Project (ICDIMP)." January 31.

Rao, N. S., T. J. B. Carruthers, P. Anderson, L. Sivo, T. Saxby, T. Durbin, V. Jungblut, T. Hills, and S. Chape. 2013. "An Economic Analysis of Ecosystem-Based Adaptation and Engineering Options for Climate Change Adaptation in Lami Town, Republic of the Fiji Islands." Technical report by the Secretariat of the Pacific Regional Environment Programme (SPREP). Apia, Samoa.

Sayers, P., G. Galloway, E. Penning-Rowsell, L. Yuanyuan, S. Fuxin, C. Yiwei, W. Kang, T. Le Quesne, L. Wang, and Y. Guan. 2015. "Strategic Flood Management: Ten 'Golden Rules' to Guide a Sound Approach." International Journal of River Basin Management 13 (2): 137–51. doi:10.1080/15715124.2014.902378.

Selby, S., and M. Jiwanji. 2016. "Risk Governance—Building Blocks for Resilient Development in the Pacific: A Policy Brief." United Nations Development Programme.

SOPAC. 2010. "Pacific HYCOS Final Progress Report." SOPAC, Suva, Fiji.

Tobin, G. A. 1995. "The Levee Love Affair: A Stormy Relationship." Water Resources Bulletin 31 (3): 359–67.

Trundle, A., and D. McEvoy. 2015. "Greater Port Vila Climate Change Vulnerability Assessment (Full Report)." Prepared for UN-Habitat. October. doi:10.13140/RG.2.1.3930.4404.

———. 2016. "Honiara Urban Resilience & Climate Action Plan." Prepared for UN-Habitat. RMIT University Climate Change Adaptation Program, Melbourne.

Trustrum, N. A., I. E. Whitehouse, and P. M. Blaschke. 1989. "Flood and Landslide Hazard, Northern Guadalcanal, Solomon Islands." Division of Land and Soil Sciences, Department of Scientific and Industrial Research, Palmerston North, New Zealand.

Turner D. 2009. "Pacific HYCOS Mission—Fiji Flood Response—Nadi and Ba, January-February 2009." SOPAC Technical Report No. 433 (Restricted Access). SOPAC, Suva, Fiji.

UFCOP (Urban Floods Community of Practice). 2017. "Flood Risk Management at River Basin Scale: The Need to Adopt a Proactive Approach." World Bank, Washington, DC.

UN-Habitat. 2013. "Honiara City Climate Change Vulnerability and Adaptation Assessment."

UNISDR/GETI (United Nations Office for Disaster Risk Reduction/Global Education Training Institute). 2015a. "Make Your Enterprise Disaster Resilient: Final Report. The Business Case for Disaster & Climate Risk Management, Nadi, Fiji, 6–7 August 2015." http://www.unisdr.org/files/24981_fijiaugust2015makeyourbusinessdisas.pdf.

———. 2015b. "Final Report: The Business Case for Disaster Risk Reduction. From Shared Risk to Shared Value, Suva, Fiji, 13–14 January 2015." http://www.preventionweb.net/files/41837_fijiprivatesectorforumjanuary2015fi.pdf.

Water Technology. 2014. "Updated Flood Study of the Vaisigano Catchment." Prepared for MNRE. June.

———. 2016. "Integrated Watershed Management Plan for Greater Apia—Flooding and Drainage Technical Appendix." Prepared for UNDP and MNRE. November.

Waterloo, M. J., J. Schellekens, L. A. Bruijnzeel, and T. T. Rawaqa. 2007. "Changes in Catchment Runoff after Harvesting and Burning of a Pinus caribea Plantation in Viti Levu, Fiji." Forest Ecology and Management 251: 31–44.

Woodruff, A. 2008. "Economic Analysis of Flood Risk Reduction Measures for the Lower Vaisigano Catchment Area." EU EDF–SOPAC Project Report 69g. February.

World Bank Group. 2016a. "Pacific Possible: Climate Change and Disaster Resilience." http://pubdocs.worldbank.org/en/720371469614841726/PACIFIC-POSSIBLE-Climate.pdf.

———. 2017. "Honiara Flood Risk Management Study and Plan: Terms of Reference."

Yeo, S. W.. 1997. "Disasters, Dredging and Development: Approaches to Flood Management in the Ba River Valley, Fiji." In Proceedings of the Disasters and Development Session, VIII Pacific Science Inter-Congress, 13–19 July 1997, The University of the South Pacific, Suva, edited by A. Planitz and J. Chung, 84 – 103. Suva, Fiji: UNDHA–SPPO.

———. 1998, "Natural and Human Controls on Flood Damages in the Ba River Valley, Fiji." PhD diss., Natural Hazards Research Centre, Macquarie University, Sydney.

———. 2000. The Ba Community Flood Preparedness Project. SOPAC Technical Report No. 309. Suva, Fiji: SOPAC.

———. 2011. "Flood Fatalities in Fiji, 2000–2009." In Abstracts of Papers Presented at the Science, Technology and Resources Network (STAR) Session 2011, edited by J. Collen and L. Bukarau, 37. SPC SOPAC Division Published Report 26. Suva, Fiji: SPC SOPAC.

———. 2013. "A Review of Flood Resilience in Fiji." Paper presented at the International Conference on Flood Resilience, "Experiences in Asia and Europe," University of Exeter, UK, September 5–7.

———. 2015. "Refining the Historical Flood Series for Ba, Fiji." Risk Frontiers Technical Report, Macquarie University, Sydney. doi:10.13140/RG.2.2.32251.31522.

Yeo, S. W., and R. J. Blong. 2010. "Fiji's Worst Natural Disaster: The 1931 Hurricane and Flood." Disasters 34 (3): 657–83.

Yeo, S. W., R. J. Blong, and K. J. McAneney. 2007. "Flooding in Fiji: Findings from a 100-Year Historical Series," Hydrological Sciences Journal 52 (5): 1004–15.

ANNEX 1. TRACKING FLOOD RISK MANAGEMENT PRACTICE

Benchmark 1: Hydrological data collection/storage/reliability

Fiji A number of chronic deficiencies in hydrological monitoring were identified following Fiji's 2009 flood (Turner 2009). Over recent years, Fiji has expanded its gauge network. As part of the Integrated Water Resources Management (IWRM) pilot in the Nadi basin, several gauges were installed and have recorded data used for calibrating flood models (NIWA 2014).

Samoa Flood modeling in Samoa has been difficult due to the sparsity of hydrological data (Lumbroso et al. 2008). Nonetheless, sub-hourly rainfall, a partial flow hydrograph, and observed flood depths for the Vaisigano River flood associated with Tropical Cyclone (TC) Evan (December 2012) proved valuable for recent flood modeling (Water Technology 2014). An expansion of hydrological infrastructure to improve flood warning capability is a possible outcome of the Pacific Resilience Program (PREP) now under way.

Solomon Islands Due to limited resources for gauge maintenance and to vandalism, none of the rainfall or water level recorders installed near Honiara as part of the Pacific Hydrological Cycle Observing System (Pacific-HYCOS) mission (from 2007 to 2010) were operational at the time of the 2014 Honiara floods (World Bank 2017; figure 20 shows data collection efforts following the flood). The available data for this flood include three-hourly rainfall at one site, flood extents for two floodplains, and surveyed flood peak levels. The data constraints will present a challenge for calibrating the flood modeling to be undertaken as part of the Honiara FRMP.

Vanuatu Flood modeling in Port Vila and Luganville was made difficult by the sparsity of hydrological data. This deficiency reflects institutional issues.[22] A 30-year record of three-hourly rainfall data was available, but no flow hydrographs were available for the calibration of rainfall-runoff models (NIWA 2015).

Figure 20. A World Bank mission to collect data after the April 2014 flood, Koa Hill, Honiara

Source: S. Yeo, WBG.

22 A large flood was known to have been recorded during TC Pam at the Sarakata River hydro dam recorder, but "personnel to download data from the recorder could not be organized and it is believed that this data is lost" (NIWA 2015, 8).

Benchmark 2: Hazard assessment (mapping)

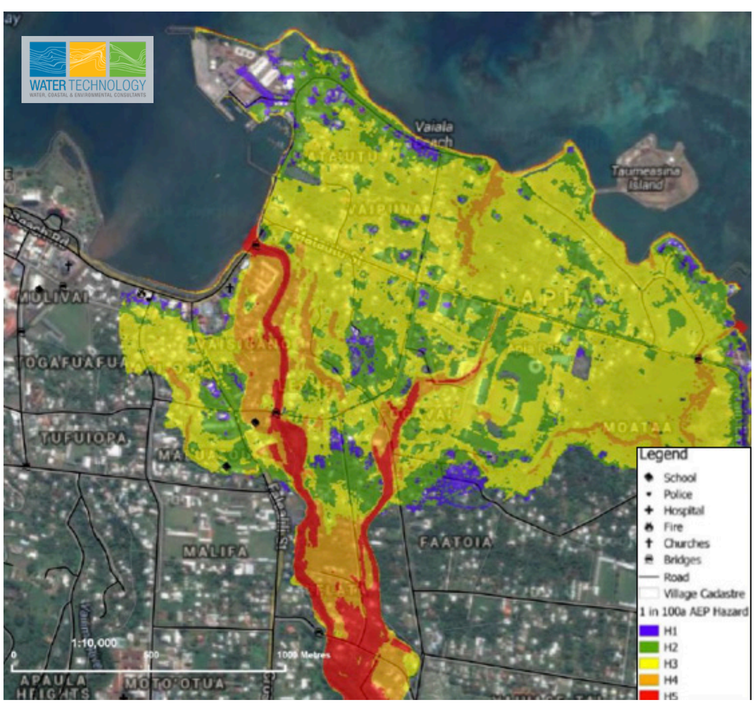
Fiji Fiji's most advanced flood study and mapping products have been prepared for the Nadi floodplain, using LiDAR to define topography, a 2D flood model, and observations from the record March 2012 flood to map flood depth, velocity, and hydraulic hazard for the 1 percent AEP design flood (NIWA 2014).

Samoa Samoa's most advanced flood investigation was undertaken for the Vaisigano floodplain in Apia, using LiDAR to define topography, a 2D flood model, and observations from the 2001 and 2012 floods to map flood depth, velocity, and hydraulic hazard for 10 design floods (figure 21; Water Technology 2014). This work was followed up by 2D modeling for eight catchments in and around Apia as part of the Greater Apia Integrated Watershed Management Plan (IWMP) (Water Technology 2016).

Solomon Islands Mapping in the Solomon Islands has been confined to historical flood extents, including the 1986 flood for the Lungga River floodplain (Trustrum, Whitehouse, and Blaschke 1989) and the 2014 flood for the Mataniko River and White River floodplains, shown as overlays in the 2015 Honiara Local Planning Scheme. The forthcoming Honiara FRMP will significantly enhance mapping of flood hazards in the greater Honiara area.

Vanuatu Vanuatu's most advanced flood modeling and mapping has been undertaken for floodplains in Port Vila and Luganville, using LiDAR to define topography and a 2D model to map depth, velocity, and hydraulic hazard for the 10 percent, 2 percent, and 1 percent AEP floods (NIWA 2015; Beca International Consultants, GNS Science, and NIWA 2016a).

Figure 21. Flood hazard mapping, 1 percent AEP event, Vaisigano River floodplain, Apia



Source: © Water Technology 2014.

Note: H1 to H5 refer to hydraulic hazard categories that combine flood depths and velocities.

Benchmark 3: Exposure and vulnerability assessment (mapping)

Fiji The Nadi River Flood Risk Assessment drew upon the PCRAFI exposure database, though this database did not contain all flood-prone buildings or all required attributes such as floor heights (NIWA 2014).

Samoa The PCRAFI exposure database was used for flood risk assessments undertaken as part of the Greater Apia IWMP (Water Technology 2016).

Solomon Islands PCRAFI data will be used for the forthcoming Honiara FRMP. The data may need to be updated using aerial photography to identify buildings washed away in the 2014 flood and new buildings constructed since the data were captured. In addition, Trundle and McEvoy (2016) have done considerable work to assess people's vulnerability—including mapping of vulnerability hotspots —at the scale of enumeration areas.

Vanuatu Risk assessments conducted for Port Vila and Luganville drew upon aggregated exposure data sets from PCRAFI and the SOPAC Catastrophe Insurance Pilot Study (Beca International Consultants, GNS Science, and NIWA 2016a). Trundle and McEvoy (2015) have done considerable work to assess people's vulnerability in Greater Port Vila, including mapping of vulnerability hotspots.

Benchmark 4: Risk assessment

Fiji Holland (2008) assessed the benefit-cost of the Navua Flood Warning Scheme based on the assessed damage from the April 2004 flood. NIWA (2014) assessed the benefits of the proposed Nadi flood diversion channel based on an assessment of potential financial damage and loss of life in the 1 percent AEP event.

Samoa Woodruff (2008) used relatively coarse design flood modeling and a database of exposure/vulnerability to estimate AAD and to assess the benefit-cost of a variety of FRM options. This work has been overtaken by risk assessments conducted for the Greater Apia IWMP (Water Technology 2016).

Solomon Islands The Rapid Impact Assessment of the April 2014 flash floods (GoSI 2014) described the disaster's impacts, and paved the way for the forthcoming Honiara FRMP, in which flood risks will be fully assessed.

Vanuatu The risk assessments undertaken for Port Vila and Luganville adopted a semiquantitative methodology that mapped risk according to potential damage to building structures, but not building contents, financial costs, or risk to life (Beca International Consultants, GNS Science, and NIWA 2016a).

Benchmark 5: Flood risk management measures

Fiji Fiji's dominant FRM measure since the 1980s has been river dredging. Many millions of dollars have been expended on dredging, but with questionable benefits (Yeo 1997; 2013). For example, dredging of the Ba River commenced after floods in 1993. But six large and damaging floods have occurred since then (figure 1 shows the 2014 flood). There has been a growing appreciation of the utility of nonstructural measures, particularly EWS (Yeo 2000; Holland 2008), as well as ecosystem-based adaptation approaches (Rao et al. 2013; Brown et al. 2014). However, a fully integrated and supported FRMP based on best-practice flood modeling has yet to be prepared in Fiji.[23] The Nadi Integrated Flood Management Project focused on assessing the benefits of the Nadi River flood diversion channel proposed in the 1990s (NIWA 2014). In 2014, JICA commenced a Nadi River Flood Control Structures Project, which in 2016 recommended river widening and straightening, new bridges to accommodate the river widening, retarding basins, and levees—recommendations that are in keeping with Fiji's preference for structural measures to control floods.

Samoa In Apia, the Samoa Flood Management Action Plan 2007–2012 evaluated and recommended a range of FRM options, including nonstructural options (MNRE 2007). The plan was reviewed following the severe flooding associated with TC Evan in 2012 (Water Technology 2014). Further refinements have occurred through preparation of the Greater Apia IWMP (Water Technology 2016). The centerpiece of current efforts to reduce flood disaster risk is construction of a levee along the lower Vaisigano River that provides protection to the 5 percent AEP flood level. Other structural and nonstructural measures are also recommended (Water Technology 2016), though relocation of residences is likely to be resisted.

Solomon Islands Flooding problems in the Solomon Islands have been managed largely on an ad hoc and informal basis. Some villages have relocated after floods. Houses are sometimes raised well above the ground, and while this practice may reflect traditional building styles, there is little doubt that floors have been deliberately raised in flood-prone locations. Some community-based early warning systems have been implemented. However, a considered, integrated application of the full suite of FRM measures has yet to find expression. The forthcoming Honiara FRMP will address this need. Also relevant is a five-year project promoting the implementation of ecosystem-based approaches in planning for CCA, which the Secretariat of the Pacific Regional Environment Programme (SPREP) launched in 2016 with Honiara as one of the project sites.

Vanuatu Flooding problems in Vanuatu have also been managed largely on an ad hoc and informal basis. Much disaster resilience springs from the actions of individuals and communities in the face of hazards (Beca International Consultants, GNS Science, and NIWA 2016b). A recently prepared URMS considers scope for improving land use planning and education, information, and communication resources (Beca International Consultants, GNS Science, and NIWA 2016b). In addition, a five-year SPREP project launched in 2015 will promote implementation of ecosystem-based approaches in planning for CCA, with Port Vila as one of the project sites.

23 JICA (1998) did consider both structural and nonstructural options for four watersheds: Rewa, Sigatoka, Ba, and Nadi. But the flood modeling was coarse and the focus of investigation was on measures to control flooding. Rao et al. (2013) evaluated the merits of a range of ecosystem-based and hard infrastructure options to manage climate risk in Lami. But flood modeling was evidently not conducted. Brown et al. (2014) and Daigneault, Brown, and Gawith (2016) also compared ecosystem-based adaptation options to engineering measures such as dredging for the Ba River and Penang River catchments. A relatively simple HEC-RAS model was adopted, and very coarse assumptions applied.

Benchmark 6: Flood modification measures

Fiji Fiji, with support from international partners, has since the 1980s relied on river dredging in an attempt to reduce the frequency, height, and duration of floods. Many millions of dollars have been expended on dredging, with limited pre-assessments and sometimes overstated benefits (Yeo 1997, 2013). In 2014, JICA commenced a Nadi River Flood Control Structures Project, which in 2016 recommended river widening and straightening, new bridges to accommodate the river widening, retarding basins, and levees. There are concerns over the quality of the evaluations that led to these recommendations and the degree to which the concerns of affected communities have been considered.

Samoa A significant measure to reduce the frequency of flooding in Apia is the construction of a levee along the Vaisigano River. This project secured funding in 2016. Water Technology (2016) demonstrates that the cost-benefit ratio of the entire levee scheme is economically attractive. But the political endorsement of the levee prior to hydraulic modeling of the option and prior to cost-benefit analysis does not represent best practice. Elsewhere in Apia, works to improve urban drainage (funded by the Asian Development Bank, ADB) have been implemented over several years.

Solomon Islands GoSI (2014) identified several options to modify the flood hazard in Honiara, including watershed management, riverbank protection and rehabilitation, maintaining flow conveyance in waterways and across floodplains, a levee and floodway to increase the flood immunity of Henderson Airport, and a drainage master plan. Many of these options, as well as flood mitigation dams, will be evaluated as part of the Honiara FRMP.

Vanuatu Apart from initiatives to improve drainage measures in Greater Port Vila (funded by ADB), no flood modification systems are known to be implemented or planned.

Benchmark 7: Risk-informed land use planning and development controls

Fiji Fiji's Town Planning Scheme General Provisions (Schedule G) lists minimum floor levels of habitable rooms for 11 towns, including 6.0m above mean sea level for Nadi. However, a singular planning level is not appropriate for all land within the town boundary because flood levels change with changing ground levels. It would be more appropriate to relate the minimum floor levels to a design flood such as the 1 percent AEP event, for which GIS mapping is available (NIWA 2014).[24] Nadi Town Council's planners benefited from a training course—Introduction to Risk-Informed Decision Making in Urban Development Planning—that NIWA and the Pacific Community (SPC) delivered for the ADB in 2015. This course presented tools to help planners make risk-informed, appropriately conditioned development consent decisions. However, local planners are constrained by the lack of formal legislation to undergird the consideration of risk in the development consent process. There are also too few town planners to cope with the volume of applications.[25] An additional need identified for Fiji is that reclamation of mangroves for development should satisfy not only the environmental impact assessment provisions but also risk provisions.[26]

Samoa A variety of legal mechanisms are available to manage land use in Apia. These include development consent enforceable under the Planning and Urban Management Act 2004; the National Building Code (under review); various Watershed Management Plans under the Water Resources Management Act 2008, which require a 20m buffer zone from riverbanks; and the Survey Act 2010, which requires a 5m reserve from riverbanks. The development consent process can impose conditions such as floor heights and setbacks. However, the Post-Disaster Needs Assessment (PDNA) following TC Evan concluded that regulation of buildings in floodplains was either "absent or not enforced" in Apia (GoS 2013, 59). It is also unclear whether the flood hazard outputs from recent flood modeling are being used to inform decision making—some areas have such a high flood hazard that it would be very difficult to ensure buildings' structural integrity and residents' safety during floods. Other challenges include the multitude of responsibilities for staff from the Planning and Urban Management Agency (PUMA), which results in inefficient processing of development consents and limited oversight of building construction,[27] and the limited reach of formal land use planning measures where village-based governance prevails.

Solomon Islands The Honiara Local Planning Scheme 2015 includes a flood overlay for the Mataniko and White Rivers, proscribes subdivision of land within that overlay, and requires that a risk assessment report be submitted in support of proposed development within the overlay. This approach represents a significant step forward. More flood information will become available through the forthcoming Honiara FRMP, which may allow for more nuanced controls. Implementation of planning controls is difficult, however, given a large number of informal settlements and limited capacity.

24 Schedule G of the Town Planning Scheme General Provisions does allow for variation from the stipulated, singular minimum habitable floor levels, with this language: "or any other relative heights applicable to any Town, township or settlement areas, as determined from time to time by the Director" (46). It is not clear whether this variation has ever been included in building design. Nadi Town Council planners feel bound by the stipulated 6.0m level and so have been advising rather than requiring that developers build with appropriate floor levels based on the variable 1 percent AEP flood level. Nadi Town Council, personal communication, June 2016.

25 Nadi Town Council, personal communication, June 2016.

26 Fiji NDMO, personal communication, June 2016.

27 Samoa MNRE, personal communication, February 2016. See also GoS (2013, 61).

Vanuatu A URMS has been developed for Port Vila and Luganville, which contains a comprehensive review of existing legislation, policies, development controls, zoning plans, and building code (Beca International Consultants, GNS Science, and NIWA 2016b). The Vanuatu Land Use Planning Policy 2013 has a section on risk and vulnerability management, but apart from a riparian corridor in the Luganville zoning plan, there are few mechanisms to ensure consideration of risk in land use planning. Moreover, the URMS found that "implementation of existing legislation through national policy and development controls is extremely weak" (Beca International Consultants, GNS Science, and NIWA 2016b, 31). The URMS contains several recommendations to strengthen the existing instruments, including barring development in high-risk areas and enforcing the building code.

Benchmark 8: Flash flood warning systems

Fiji During the April 2016 floods, the Fiji Meteorological Service issued near real-time flood alerts, flood warnings, and information on water levels for stations along the most important river systems in the country. These actions represent a significant advance on previous practice (see Yeo 2000) and were made possible by a significant investment in hydrological infrastructure under the Nadi basin IWRM and other projects and through Fiji government funding. Further work is needed on disseminating meaningful warnings so that people can relate reported flood heights at a gauge to their own situations. This could involve comparing the observed flood heights to a well-remembered historical flood such as the March 2012 event (at Nadi). It is also important to clarify responsibilities for sounding sirens.

Samoa In Samoa, warnings broadcast prior to flooding have been confined to heavy rain alerts and warnings as well as flood advisories (for storm surge only), which provide little indication of the magnitude, timing, and specific location of riverine flooding. The potential to use real-time water levels from a stream gauge as a basis for providing 30 minutes' warning for the lower Vaisigano catchment has been considered (Water Technology 2014). The World Bank–funded PREP will improve multi-hazard early warning systems by improving observation networks, warning dissemination capability, and professional development of staff.

Solomon Islands In Honiara, warnings broadcast prior to flooding have been confined to heavy rain alerts and warnings, which failed to elicit the necessary community responses in the April 2014 flood (GoSI 2014). There has been significant investment in community-based early warning systems in rural Guadalcanal, and three out of four of these systems were operational and effective in the April 2014 flood. Developing effective early warning systems for the Mataniko and Lungga Rivers in Greater Honiara is a key objective of the forthcoming Honiara FRMP.

Vanuatu In Vanuatu, the relatively limited loss of life during TC Pam—a category 5 storm—was attributed to timely and accurate warnings and the public's responsiveness to them (GoV 2015). The Vanuatu Meteorological Service issues three-day Severe Weather Outlooks that include forecasts of the likelihood of 100mm or more rainfall in a 24-hour period. But no warnings for river flooding are currently issued, and hydrological infrastructure to facilitate such warnings is lacking (Beca International Consultants, GNS Science, and NIWA 2016b).

Benchmark 9: Emergency management planning and capability

Fiji

Fiji has a National Disaster Management Plan (1995), but subplans—including a Flood Hazard Support Plan—have yet to be prepared. This reflects capacity constraints; since 2000, the National Disaster Management Office (NDMO) has been staffed by 12 people who have limited qualifications and who are diverted from meeting their key performance indicators when disasters occur or when a high volume of programs and workshops requires their input.[28]

Greater Navua has a detailed Flood Response Plan, prepared to accompany the Flood Early Warning System established in about 2008. Some other towns have Disaster Management Plans, but these tend to describe only general responsibilities; they do not identify flood hotspots and may not be collectively owned by the many organizations responsible for implementing them (Yeo 2000).

Emergency management services are compromised by limited resources. For example, in the 1990s, the Ba police found difficulty securing boats for rescue work (Yeo 1998, 222). In the March 2012 flood, the National Fire Authority station at Nadi had only two trucks (not suitable for water), one rubber boat (without an outboard motor), no wetsuits, and no proper footwear (Yeo 2013).

Samoa

Samoa's National Disaster Management Plan is maintained as a living document, with the current plan prepared for 2016–2019. The need to develop a National Flood Hazard Plan that provides more detail is recognized but awaits the outcomes of projects now under way to model flood behavior and to set thresholds for activation of alerts. The National Emergency Operations Centre (NEOC) is not well resourced, but the PREP and other projects under way should address this.

An evacuation plan has been prepared for the Apia Central Business District that lists evacuation routes and destinations, though this is primarily for tsunami and storm surge hazards; the plan needs to be expanded to include lessons learned from the flooding associated with TC Evan in 2012, as well as the flood modeling prepared for the Greater Apia IWMP.

During TC Evan, responders from several government organizations were involved in rescue work, but the event demonstrated that resourcing and training for swift water rescue are needed.

Solomon Islands

The Solomon Islands has a National Disaster Risk Management Plan (2010) but still requires hazard-specific contingency plans. To ensure that these plans will work, institutional arrangements must first be improved. In particular, terms of reference and standard operating procedures should be developed for the National Disaster Committee and subcommittees, including the Risk Reduction Committee.[29]

With support from the New Zealand Aid Programme–funded Honiara Economic Development Support Programme (HEDSUP), the Honiara City Council prepared disaster operating procedures in 2013. These were reviewed after the 2014 flood to incorporate lessons learned from that event. HEDSUP recognizes the desirability of expanding the scope of the current procedures to form a community-focused City Disaster Management Plan. The Honiara Urban Resilience and Climate Action Plan (HURCAP) (Trundle and McEvoy 2016) includes several recommendations to enhance disaster management. The forthcoming Honiara FRMP is tasked to consider appropriate responses for each flood-prone community, including confirmation of appropriate evacuation shelters.

Following the 2014 flood, a senior police officer argued that many lives could have been saved with a more focused and timely response from police and rescue teams.[30]

28 Fiji NDMO, personal communication, June 2016.

29 Norton Consulting Ltd., personal communication, May 2014.

30 Solomon Star, "Police Criticised for Failing to Respond in Time to Save Lives," April 14, 2014.

Vanuatu

A variety of relevant plans have been prepared, including the National Disaster Plan, standard operating procedures for the NDMO, annual National Cyclone Support Plan Review, and Vanuatu Climate Change and Disaster Risk Reduction Policy 2016–2030.

Evacuation maps have been prepared for Port Vila and Luganville, but currently these are focused on tsunami and do not explicitly cover riverine floods (Beca International Consultants, GNS Science, and NIWA 2016b).

The PDNA prepared following TC Pam (GoV 2015) made several recommendations to improve emergency management planning and capability in Vanuatu, including a comprehensive review of arrangements at the NEOC, training of NDMO staff to develop competencies required for particular roles, improved coordination between emergency services organizations, and the establishment of a national emergency services volunteer scheme that would augment disaster preparedness and response capacities at national and provincial levels.

Benchmark 10: Community preparedness

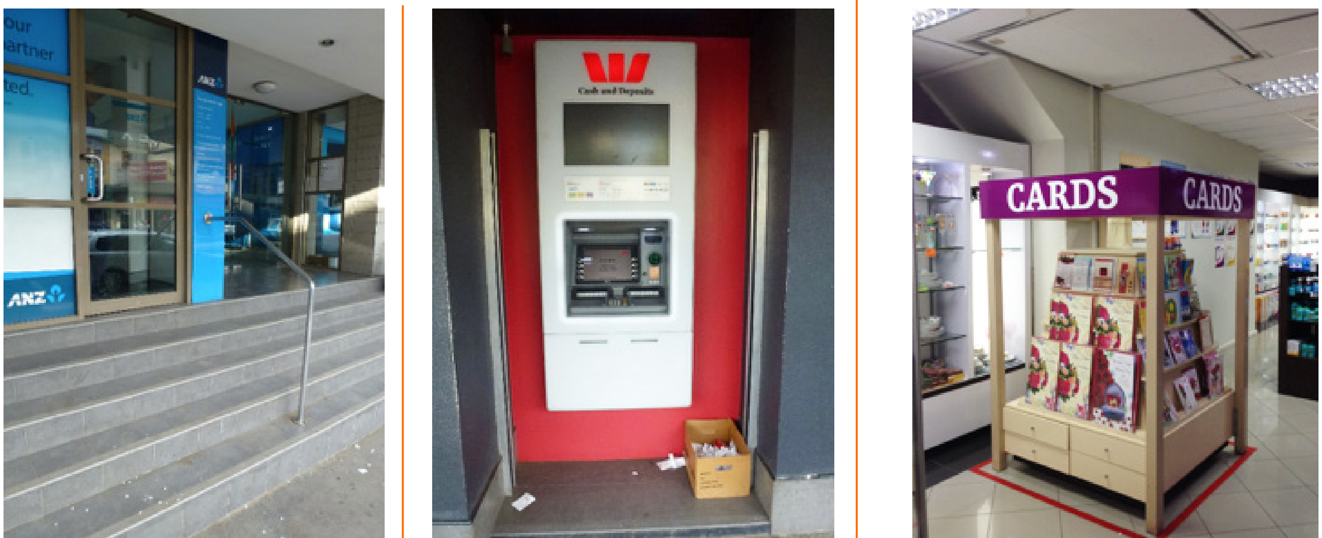
Fiji

Damaging floods in western Fiji in 2009 and 2012, along with less severe floods in 2016, have likely raised awareness of the potential for further flooding in the affected communities. Many businesses in Ba and Nadi have instituted innovative practices to reduce their risk, including the following:

- Raised floor levels (shown in figure 22a)
- Floodgates to keep water out (shown in figure 22b)
- Water-compatible floor coverings and furnishings
- Reduced stock levels during flood season (UNISDR/GETI 2015a)
- Stock storage to enable rapid removal
- Access to first story above shop floor and lift/pulley system to enable rapid removal of stock (shown in figure 22c)

A flood preparedness guide for businesses in Fiji was developed, and a workshop was convened in Ba in 1999 to help businesses improve their resilience (Yeo 2000). The United Nations Office for Disaster Risk Reduction's Global Education and Training Institute conducted workshops in Suva and Nadi in 2015, persuading businesses that "investing in disaster risk management is not so much a cost but an opportunity to strengthen resilience, competitiveness and sustainability" (UNISDR/GETI 2015b). A community capacity-building project and DRR workshops have also been rolled out in rural communities. Further education programs are needed, in particular in informal settlements in peri-urban areas and for the many small businesses not represented at recent workshops.

Figure 22. Flood Preparedness Measures by Businesses, Nadi



Sources: S. Yeo, WBG (photos a and b), D Ramsay, NIWA (photo c).

Samoa

A comprehensive community-based disaster risk management initiative called the Community Disaster and Climate Risk Management Programme has been under way in Samoa since 2010. It includes development of village disaster plans and training for response. Community Integrated Management Plans also include solutions for flooding that were developed through a community-based, participatory process. Nonetheless, the PDNA found that at the time of the floods caused by TC Evan, none of the communities visited had a disaster preparedness plan, and the speed and intensity of the flooding took all respondents by surprise (GoS 2013, 108). Preparedness was described as "weak" for all villages visited (123).

Solomon Islands

In recent years, RMIT University has conducted a series of community-level workshops to shape the formation of HURCAP. Similarly, the Solomon Islands government and World Bank have been implementing the Community Resilience to Climate and Disaster Risk in Solomon Islands Project (CRISP), which is enhancing the availability of climate and disaster risk information in rural communities. Nonetheless, anecdotal reports indicate that at the time of the 2014 floods in Honiara, some people decided not to evacuate their houses as the flood was rising. Their responses may have been influenced by lower floods in 2009 and 2012, which did not destroy houses. But the 2014 flood was 2.5m higher than previous flooding (as observed at a church in Koa Hill), and destroyed some 235 houses in the valley. While community members had some appreciation of flood hazards (see e.g. UN-Habitat 2013), their experience of relatively low-magnitude floods did not prepare them for an extreme flood. Flood-prone communities should be supported in developing their own response plans and self-help mechanisms to reduce the risk of disaster when next the Mataniko River floods.

Vanuatu

A URMS has been developed for Port Vila and Luganville, which contains a detailed review of existing education, information, and communication materials related to CCA and DRR (Beca International Consultants, GNS Science, and NIWA 2016b). The materials include a Bislama-language comic book and poster that show how to prepare for, respond to, and recover from flooding. The URMS recommends that the messages be expanded to help people consider flood hazard when deciding where to locate houses and to promote building of resilient structures.

The URMS also recommends that Community Disaster Committees be used to help flood-prone communities prepare their own evacuation plans.

In recent years RMIT University has conducted a series of community-level workshops to shape the formation of the Greater Port Vila Urban Resilience and Climate Adaptation Plan (GPVURCAP).

One challenge to building and sustaining community preparedness in Vanuatu is to help people imagine and prepare for larger floods than those they have previously experienced. The PDNA for TC Pam found that it was difficult to prepare people for a category 5 cyclone because the majority of the population had not experienced such an event (GoV 2015, 144).

Benchmark 11: FRM governance

Fiji

For Fiji, Yeo (2013) argued that FRM has been weakened by narrow, fragmented, and externalized governance. Narrow governance is illustrated by the tendency—beginning in the 1980s and still present in some circles today—to view FRM largely as the domain of a single government division, the Land and Water Resource Management Division (or its predecessor), and river dredging as the solution to all problems.[32] Although the need for a different approach has begun to be recognized, mechanisms to integrate the various stakeholders have been lacking—a function of fragmented governance. The Nadi Basin Catchment Committee was an effective structure and good model for bringing together government stakeholders and local representatives for the governance of multiple projects, including the Nadi Basin IWRM project. But it was disbanded in 2014 when funding expired, without a clear pathway for future governance (NBCC 2014). This is one effect of externalized governance, in which the majority of funding to advance DRR, CCA, and FRM practice is sourced from international donors as part of fixed-duration projects. Dependency on external funding means that FRM practice may advance during a project (e.g., a warning system may be developed) but fall back when the project ceases (e.g., river gauges used in a warning system are not maintained).

Samoa

In Samoa, there appears to be reasonably good coordination between different government stakeholders with a role in FRM. This has been helped by strong leadership and a structure in which key stakeholders, including PUMA and NDMO, are located within the Ministry of Natural Resources and Environment (MNRE). It has also been helped by the recently prepared Greater Apia IWMP, which intentionally attempts to integrate the various flood and watershed management "silos." In addition, the PREP will support a multisectoral planning process for integrating climate and disaster risk into development decisions. However, one issue identified for Samoa is the need for greater policy coherence to reduce the overlap and duplication of DRR and CCA policies and plans, and in turn reduce the administrative burden on the Samoa government. These overlapping plans include Community Integrated Management Plans, Watershed Management Plans, the Greater Apia IWMP, Water Safety Plans, Apia City Spatial Plan and Development Strategy, Sustainable Management Plans, and Community Disaster and Climate Risk Management Plans. A related issue is the continued reliance on project funding for capacity building, which highlights the need for mainstreaming DRR and CCA into national and sectoral budgets.

32 The formation in June 2017 of a Ministry for Waterways responsible for maintenance of drainage systems and waterways suggests a continuing narrow model of governance. See Fiji Sun, "New Waterways Ministry Gets $24.4 Million," June 30, 2017, http://fijisun.com.fj/2017/06/30/new-waterways-ministry-gets-24-4million/.

Solomon Islands A review conducted after the April 2014 Honiara floods found scope for better coordination between the many players involved in FRM. More specifically, for improved risk-based land use planning, better coordination is needed between the Physical Planning Division of the Ministry of Land, Housing and Survey and the Honiara City Council; for the delivery of integrated hydrometeorological warning services, better coordination is needed between the Meteorological Division of the Ministry of Environment, Climate Change and Disaster Management and the Hydrology Unit of the Ministry of Mines, Energy and Rural Electrification (GoSI 2014). HURCAP is one integrating plan that aims to build urban resilience through a broad-based action plan relating to urban planning and land development, housing, infrastructure, water and sanitation, ecosystem services, health, communication, behavior change, DRR, and governance. Importantly, HURCAP was deliberately developed through a bottom-up and stakeholder-led process (Trundle and McEvoy 2016). In addition, the forthcoming Honiara FRMP will intentionally seek to build capacity and governance structures for the management of flood risks. But the challenge for both these plans will be sustainable governance beyond the lives of the projects—a challenge that highlights the need for mainstreaming DRR and CCA into national and sectoral budgets.

Vanuatu Risk governance work in Vanuatu started substantively in 2013, with a national risk governance assessment. This led to the formation of the National Advisory Board as an overarching coordinating body for DRR and CCA, which formulated the national Climate Change and Disaster Risk Reduction Policy (Selby and Jiwanji 2016). GPVURCAP is one integrating plan that aims to build urban resilience through a broad-based action plan relating to urban planning and land development, housing, infrastructure, water and sanitation, ecosystem services, health, communication, behavior change, DRR, and governance. Importantly, GPVURCAP was deliberately developed through a bottom-up and stakeholder-led process.[33]

33 School of Engineering, RMIT, personal communication, November 2016.

Benchmark 12: FRM process roll out

Fiji

FRM initiatives in Fiji have typically been reactive, in response to damaging flooding and subsequent community demands for action. One flood study has been completed for Nadi, which also considered some engineering options (NIWA 2014). But the scale of the flooding problem in Fiji requires that comprehensive and genuinely integrated FRM plans—which consider the full suite of structural, nonstructural, and resilience-building measures—be prepared on a prioritized basis for Fiji's other urban areas exposed to flood risk.

Samoa

Of the countries considered here, Samoa has achieved the most advanced FRM by this measure, largely as a result of the EU-SOPAC project conducted from 2006 to 2008, which developed the Samoa Flood Management Action Plan 2007–2012 focused on the Vaisigano River floodplain (MNRE 2007). This work gained further momentum following the severe flooding associated with TC Evan in 2012, with more advanced flood modeling for the greater Apia area and reassessment of options (Water Technology 2014, 2016).

Solomon Islands

FRM initiatives in the Solomon Islands have been relatively few, with some community-based early warning systems installed in rural areas. The 2014 flood, with 24 fatalities, highlighted the need for further interventions to reduce the risk of future disaster in Honiara. The World Bank conducted a mission in Greater Honiara to collect flood data, including 66 surveyed flood peak levels, to facilitate the calibration of flood models being developed under the Honiara FRMP. This project will produce the Solomon Islands' first integrated FRMP.

Vanuatu

A URMS prepared for Port Vila and Luganville was based on multi-hazard risk assessments, including flood modeling (NIWA 2015). Its main focus was to incorporate risk into land use planning and development controls, though there was also attention to education, information, and communication materials (Beca International Consultants, GNS Science, and NIWA 2016b).

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