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Sarakata Flood Mitigation and Early Warning System Gap Analysis report

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Table of contents

Executive summary

The Secretariat of the Pacific Environment Programme (SPREP) is implementing the Climate Information Services for Resilient Development in Vanuatu (CISRD), or Vanuatu Klaemet Infomesen blong redy, adapt mo protekt (Van-KIRAP) Project. As the first part of this project, Tonkin & Taylor International Ltd (T+TI) has been engaged to provide technical expertise on the Van KIRAP Project and the Department of Water Resources to review and update existing flood mitigation guidelines for the Sarakata catchment in Espiritu Santo Island, and to support the development of flood early warning systems in Sarakata.

This report provides a review of the existing Flood Mitigation Guidelines for Sarakata, Pepsi and Solwei Areas (2011) including the evaluation and identification of gaps in terms of early warning systems and long-term climate change considerations. The review has identified the gaps across governance, institutional arrangements, observations, risk knowledge, warning dissemination, and preparedness and response. The following recommendations are provided to address the identified gaps and to inform the development of updated flood mitigation guidelines:

- Strengthened governance and institutional arrangements, relating to:
  - Strengthened policies and institutional frameworks at the provincial level including clear roles and responsibilities.
  - Clear standard operating procedures for flood early warning system management.
  - Development of forums to enable coordination and partnerships.
  - Update and finalise the Sarakata Flood Management Plan, including establishment of a monitoring and evaluation plan to ensure effective and coordinated governance of flood disaster risk reduction and to foster sustainable development.
- Strengthened observation, monitoring, analysis, and forecasting, relating to:
  - Additional observational equipment and supporting services and capacity.
  - Inclusion of empirical models or probabilistic modelling to inform hazard and risk assessments.
- Strengthened disaster risk knowledge, relating to:
  - Adoption of hazard thresholds.
  - Updating and strengthening risk assessment and risk management practices.
- Strengthened warning dissemination and communication, relating to:
  - Community-focussed warning and dissemination.
  - Community-specific evacuation plans.
- Strengthened preparedness and response, relating to:
  - Training and capacity building.
  - Community-based disaster risk management.
  - Grass-roots level involvement.

This report will inform the development of a new flood management plan (FMP) and early warning system (EWS) for the Sarakata-Luganville catchment using the existing flood mitigation guidelines, the Sanma Province Disaster Response Plan and other relevant policies and plans.

1 Introduction

The Secretariat of the Pacific Environment Programme (SPREP) is implementing the Climate Information Services for Resilient Development in Vanuatu (CISRD), or Vanuatu Klaemet Infomesen blong redy, adapt mo protekt (Van KIRAP) Project. T+TI has been engaged to provide technical expertise on the Van KIRAP Project for the Department of Water Resources (DoWR) to review and update existing flood mitigation guidelines for the Sarakata catchment in Espiritu Santo Island (Department of Water Resources, 2011), and to support the development of flood early warning systems in Sarakata.

The specific objectives of the consultancy services are:

i Review of the Flood Mitigation Guidelines for Sarakata, Pepsi and Solwei Areas (2011) including the evaluation and identification of gaps in terms of early warning systems and long-term climate change considerations.

ii Development of a new flood management plan (FMP) and early warning system (EWS) for the Sarakata-Luganville catchment using the existing flood mitigation guidelines, the Sanma Province Disaster Response Plan and other relevant policies and plans.

iii Development of scenarios and simulations of the Sarakata-Luganville FMP and EWS in partnership with national and provincial stakeholders.

iv Institutionalise the new Sarakata-Luganville FMP and EWS into the DoWR and with external stakeholders through drafting a Memorandum of Understanding (MoU) and completion of a training workshop.

This report presents the findings of Objective i. It provides a summary of the review of the existing guidelines and includes an evaluation and identification of gaps in the current status of early warning systems and long-term climate change considerations.

Objectives ii to iv will be addressed in subsequent reports.

1.1 Methodology

The Flood Mitigation Guidelines for Sarakata, Pepsi and Solwei Areas (2011) and other more recent documentation relevant to early warning systems and hazard management within Luganville and the Sarakata Catchment were reviewed with reference to two different frameworks:

- Early warning system elements consider the WMO multi-hazard early warning framework and people-centric early warning guidelines (Figure 1.1)
- Flood management activities are reviewed with reference to the benchmarks outlined in the Urban Floods Community of Practice (UFCOP) Urban Flood Risk Management in the Pacific (Yeo, Esler, Taaffe, Jordy, & Bonte-Grapentin, 2017).

Supplementary data obtained through discussions with key stakeholders and responses from key stakeholders to a survey have informed which of the actions recommended in the Sarakata Catchment flood mitigation guidelines have been implemented and to develop an understanding of the remaining gaps.

Section 2 presents the gap analysis by evaluating the elements of the multi-hazard early warning framework. The flood-specific benchmarks identified in the UFCOP Urban Flood Risk Management are incorporated into each element of the gap analysis.

Section 2.5.3 presents a list of recommendations to be considered in the flood mitigation guidelines to be developed under Objective ii of this project.

Figure 1.1: Ten steps of the impact-based early warning system (Fakhruddin, 2018)

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 1.2: 12 Benchmarks of Urban Flood Risk Management in the Pacific (UNFCOP, 2017)

1.2 Luganville context

Luganville is the second most densely populated urban centre in Vanuatu after Port Vila[1]. The total population of Luganville is 17,719 (2020 estimate), with an average annual growth rate (2.7% pa) slightly higher than the national average (2.3% pa). As the only urban centre on Espiritu Santo Island, Luganville serves as the island's primary economic hub, with economic activity centred around retail, wholesale, banking, hospitality, and tourism sectors. Luganville has one of country's busiest ports, with much of Vanuatu's copra and cacao shipments passing through it. The town is also served by the Santo-Pekoa international airport.

Many of the fastest growing neighbourhoods in Luganville are informal settlements, including several located within flood-prone areas alongside the Sarakata River. Informal settlements are frequently situated on land with disputed tenure arrangements, making enforcement of land use controls and other regulation challenging (Beca, GNS Science and NIWA, 2015).

[1] 2020 National Population and Housing Census, VNSO

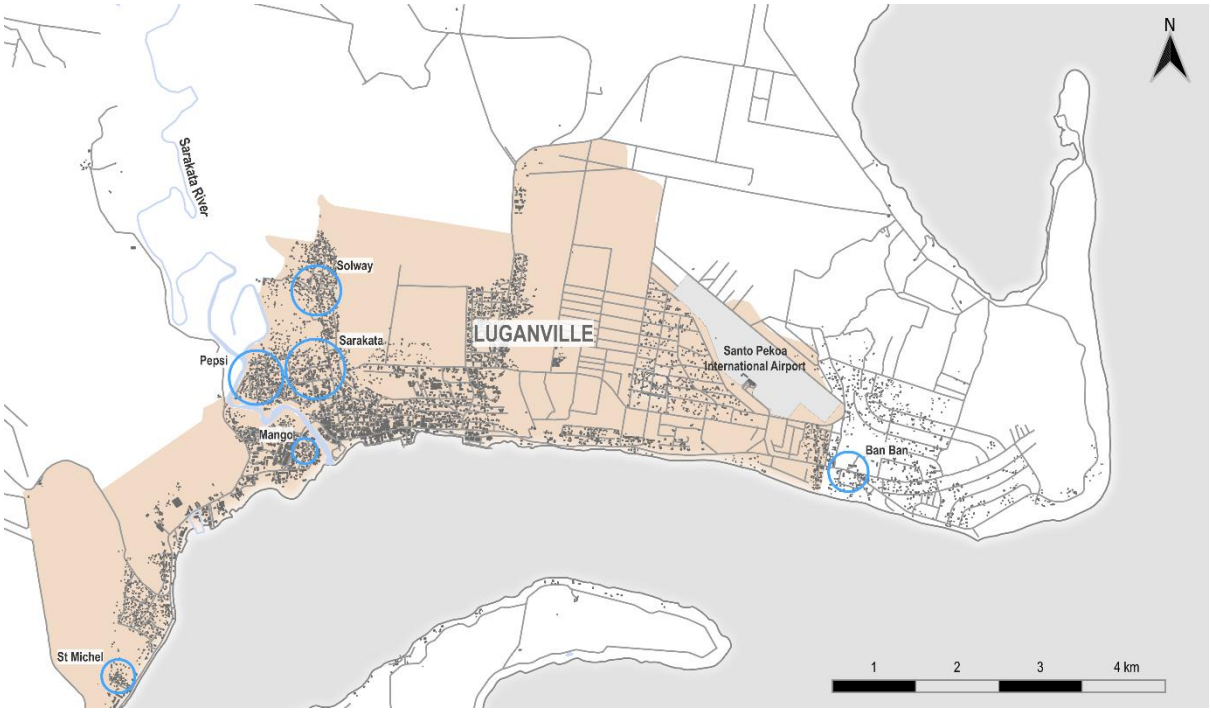

Figure 1.3: Map of Luganville showing locations of informal settlements (blue circles)

Land along the Sarakata River margins is vulnerable to fluvial flooding, particularly the numerous informal settlements established within the flood plains of the river. Elsewhere in the catchment, pluvial flooding is exacerbated by shallow groundwater and inadequate surface water drainage (Department of Water Resources, 2011). During heavy rainfall saturated subsoils prevent infiltration leading to high volumes of runoff and frequent flooding. Natural stream networks throughout the lower Sarakata catchment have reportedly been modified, and in some instances filled, to accommodate agriculture and construction activities. Urban drainage networks throughout the catchment are reportedly in poor condition with many networks no longer maintained or functioning.

Flooding in Luganville and throughout the wider Sarakata catchment is a frequent problem. In recent years excessive rainfall has generated serious flooding and forced evacuations[2]. Climate change impacts are projected to increase the magnitude of extreme rainfall events, both those rainfall events associated with tropical cyclones and non-tropical cyclone events, contributing to increased flooding impacts in future (Anil Deo, et al., 2021)[3].

2 Gap analysis

2.1 Governance and planning

Governance plays a crucial role in flood disaster management and preparedness. Effective governance involves the coordination and collaboration of multiple stakeholders, including

[2] Three families evacuated in Luganville due to flooding | News | dailypost.vu
Cyclone Harold updates: Storm makes landfall on Vanuatu's Santo | RNZ News

[3] Australia-Pacific Climate Partnership (2021). 'NextGen' Projections for the Western Tropical Pacific: Current and Future Climate for Vanuatu. Technical Report, Australian Aid, CSIRO, SPREP. Retrieved from https://www.rccap.org/uploads/files/2c538622-72fe-4f3d-a927-7b3a7149e73f/Vanuatu%20Country%20Report%20Final.pdf

government agencies, non-governmental organisations, and community members, to ensure a comprehensive and timely response to floods. This can involve implementing flood preparedness measures, such as early warning systems, evacuation plans, and infrastructure improvements, as well as providing immediate relief and long-term recovery support to affected communities. Good governance also ensures transparency, accountability, and the involvement of all stakeholders in decision-making processes, to build trust and promote a culture of resilience in the face of future flood events.

The institutional arrangement of Sarakata describes the way relevant organisations and community operates, manages, delegates, or undertakes their policies or institutional mandate. Establishing roles and responsibilities, identifying key decision-makers and stakeholders, and ensuring accountability and transparency in decision-making processes are essential components of effective institutional arrangements. By implementing strong institutional arrangements, disaster management efforts can be coordinated, efficient, and well-resourced, reducing the impact of floods on communities and infrastructure. In addition, institutional arrangements can also promote a culture of preparedness in the face of future flood events.

2.1.1 Review of flood risk management governance

There is a range of existing plans and policies to manage flood risk, including Vanuatu's Climate Change and Disaster Risk Reduction (CCDRR) Policy (2016-2030). The vision of CCDRR is to enable Vanuatu to be a "*nation whose communities, environment and economy are resilient to the impacts of climate change and disaster risks*".

The Vanuatu National Sustainable Development Plan (NSDP) for the period 2016 to 2030 serves as the country's highest-level policy framework, through which Ni-Vanuatu resoundingly called for a balance between the social, environmental, and economic pillars of sustainable development, with cultural heritage as the foundation of an inclusive society. In addition, there are other relevant policies and plans that have been developed to address the climate change and disaster risks identified for Vanuatu. Below is a summary of these policies and other policies and plans that assist in managing flood risk.

Table 2.1: Policies and plans

Policies and plans	Objectives
CCDRR Policy (2016-2030).	This national scale policy identifies a vision to enable Vanuatu to be a "*nation whose communities, environment and economy are resilient to the impacts of climate change and disaster risks*"
Vanuatu National Sustainable Development Plan (NSDP, 2016-2030)	This Plan is the country's highest-level policy framework, which highlights the importance of a balance between the social, environmental, and economic pillars of sustainable development, with cultural heritage as the foundation of an inclusive society.
National Water Strategy 2018-2030 (NWS)	The NWS encompasses priority areas identified to ensure safe, sufficient, accessible, affordable, and reliable access to water sustainably. Identifies the need for effective planning and coordination among key water sector stakeholders where Vanuatu's vulnerability to various disaster risks is anticipated to increase with climate change.
Provincial Disaster and Climate Response Guideline (PDCRP)	This guideline intends to guide the Provincial Governments and the National Disaster Management Office to develop Provincial Disaster and Climate Response plans with the support of the DRM stakeholders such as the Vanuatu Humanitarian Team who involve Non-Government Organisations and Vanuatu Red Cross Society.
Department of Water (DoWR) Standard Operating Procedures	This SOP addresses the timing for DoWR partner agencies which have key responsibilities for disaster response in close coordination with the DoW.
National Gender Equality Policy 2020-2030 (NGEP)	The NGEP provides a unifying strategic framework for government, civil society, and development partners to coordinate actions to advance gender equality and the wellbeing of women and girls. It acknowledges that climate change and disaster risks have different impacts on women and men, that gender differences should be considered when planning and managing climate and disaster risks, including gender-specific needs and priorities to cope and adapt to climate change impacts.
Sanma Gender Equality Action Plan 2020-2024	This Action Plan provides a clear plan of action for government, civil society, private sector, and development partners to coordinate actions to advance gender equality and the well-being of women and girls in Sanma Province in line with the NGEP.
Vanuatu Meteorology and Geo-hazards Department (VMGD) Strategic Plan 2014-2023	The VMGD Strategic Plan seeks to strengthen capacity and delivery of its services focusing on the areas of weather services, climate services, climate services, climate change services, geo-hazard services, observations monitoring, research, administration, and finance.
Vanuatu Klaemet Infomesen Blong Redy, Adapt Mo Protekt (Van KIRAP) Water and Climate Information Services (CIS): policy review, action, and communication plan. Apia, Samoa	This plan aims to increase the ability of decision makers, development partners, communities, and individuals across five target sectors (agriculture, fisheries, infrastructure, tourism and water) to plan for and respond to the long- and short-term impacts of climate change.
Vanuatu Strategic Roadmap for Emergency Management 2021-2023 (SREM)	The SREM is designed to operationalise the objectives of the Disaster Risk Management Act (2019) guide a stronger and more coordinated approach to disaster and emergency management in Vanuatu.

2.1.2 Existing institutional arrangements for flood management

At the national level, DoWR is responsible for monitoring surface and ground water levels, whereas VMGD is responsible for assessing climate change risk, forecasting heavy rainfall, and for the development and management of early warning systems. The local flood response is conducted by the Sanma Provincial Emergency Operation Centre (PEOC) in coordination with NDMO. Inter-agency coordination is a key requirement for delivering effective flood management outcomes. A list of national and provincial institutions related to floods is summarised in Table 2.2.

Table 2.2: Institutions relevant to Sarakata catchment flood management and related EWS .

Institution	Responsibility
NDMO	NDMO coordinates preparation and responses to emergencies and disasters across Vanuatu.
Provincial Disaster and Climate Change Committee (PDCCC)	The PDCCC comprises of key provincial authorities and officers, including the Red Cross, Sanma Provincial health department, and education department. The PDCCC is responsible for disaster preparedness and response, including mainstreaming disaster preparedness in the 5-year provincial development plan.
Sanma PEOC	The PEOC was established in 2018 and is the main body of the emergency, response and early recovery coordination system. The PEOC roles are executed by the PDCCC under direct leadership of the Secretary General of the province. PEOC has the appropriate technology to send and receive real-time disaster information along with three or more National Disaster Management Officers[4]. During an emergency, PECO acts as a communication channel between provincial and national officers and supports them in better decision-making during emergencies.
VMGD	VMGD ensures that the meteorological and geophysical data and knowledge are effectively applied to Vanuatu's national goals. One of the objectives is to contribute to achieving national sustainable development. It has six Technical Divisions responsible to provide the required services and products (Observation, Forecasting, Climate, IT and Engineering, Administration and Geohazards Divisions). VMGD provides regional and national atmospheric forecasts, marine forecasts, tidal information, tropical cyclone warnings and outlooks, tsunami information and warnings, climatological information.
Vanuatu Humanitarian Team	The Vanuatu Humanitarian Team is a collaboration between Vanuatu NGOs, Red Cross, United Nations and government agencies The Vanuatu Humanitarian Team supports NDMO during response and recovery activities.
DoWR	DoWR sits under the Ministry of Land and Natural Resources and is mandated to regulate and coordinate the water-related activities (surface and ground water) at all levels of governance in Vanuatu. DoWR has responsibilities for developing flood policy and legislation, monitoring and evaluation, and maintaining water quality. It also has a Project and Operations Unit to deliver on the Department's mission to "*develop and manage the nation's water resources for the social and economic wellbeing of the people of Vanuatu*".
Department of Energy (DoE)	DoE is responsible for development of energy policies, legislation and regulations to guide the development of energy services and improve

[4] https://www.spc.int/updates/news/2018/07/vanuatu-officially-opens-two-provincial-emergency-operations-centres-in

Institution	Responsibility
	service delivery; identification, implementation, management and evaluation of energy projects, monitoring and facilitating energy activities; providing awareness and training activities.
Department of Local Authorities	The Department of Local Authorities is responsible for overseeing local government, which comprises six provincial, three municipal and 72 area councils. It leads and supports planning processes that draw on community-driven vulnerability and risk assessment processes.
Department of Women's Affairs	The Department of Women's Affairs has a primary role in capacity development and institutional strengthening activities related to the mainstreaming of gender equity, disability, and social inclusion considerations into climate change adaptation, mitigation, and disaster risk reduction activities.
Vanuatu's National Cluster System	Vanuatu's National Cluster System was established following the Tropical Cyclone Pam in 2015, to ensure humanitarian organisations and government agencies develop and implement disaster preparedness and response activities in the country. It comprises Education Cluster, Emergency Telecommunications Cluster (ETC), Food Security and Agriculture Cluster (FSAC), Gender and Protection Cluster (G&P), Health and Nutrition Cluster, Logistics Cluster (VLC), Shelter Cluster, and Water Sanitation and Hygiene Cluster (WASH). The clusters are led by a government agency and co-led by a humanitarian partner. There is an Inter-Cluster which acts as a coordinating mechanism for the eight technical clusters. Relevant clusters will be activated based on need during disasters.
Luganville Municipal Council	Luganville Municipal Council is responsible for disseminating flood warnings to the communities, conduct awareness programmes, ensure households do not access the flood affected roads, and support in recovery related activities following the floods[5].
Luganville Community Climate Center	Luganville Community Climate Center acts as a hub for receiving Climate Information Services (CIS) from the VMGD and further dissemination of CIS to 'last mile' communities.
Vanuatu Red Cross Society (VRCS)	VRCS assists communities in Vanuatu in disaster preparedness activities such as "*community risk assessments, awareness sessions, first aid trainings, the development of mitigation and response plans, the improvement of early warning systems and the establishment of Community Disaster and Climate Change Committees*"[6]. VRCS has established emergency operation centres in Sanma, Malampa, and Penama Branches to coordinate the operations in the field, which can be activated during emergencies[7]. Also, Emergency Response Teams (ERT) are available across the different branches of VRCS, including Sanma, to conduct disaster response operations.

2.1.3 Review of flood management planning measures

The existing Flood mitigation guidelines for Sarakata, Pepsi and Solwei areas (Department of Water Resources, 2011) have been reviewed in relation to their governance and planning mechanisms. The objective of this document is to provide guidelines that are designed in such a way to help decision-

[5] As per the draft Flood Mitigation Guidelines for Sarakata, Pepsi, and Solwei Areas
[6] https://vanuaturedcross.squarespace.com/disaster-management
[7] Vanuatu Red Cross Society – 2020 Annual Report

makers identify their needs and provide a range of mitigation options to flood-related disasters. The guidelines are developed to provide an introduction to the communities and various mitigation measures from the impacts associated with floods.

Measures identified in the guidelines include recommended flood management actions as part of a broader integrated water resources management approach:

- Structural flood modification measures.
- Catchment management.
- Exposure and vulnerability reduction.
- Risk informed land use planning.

These areas of flood risk management are discussed below.

2.1.3.1 Structural flood modification measures

The Sarakata catchment flood mitigation guidelines acknowledge the limitations of structural approaches to flood management. Structural approaches include the high cost to construct and maintain largescale infrastructure, and the potential for these to generate misconceptions around the level of protection and residual risk associated with physical flood protection. However, structural flood management measures are necessary in certain circumstances, such as to enable development in certain locations, or to protect existing development in exposed locations (Kundzewicz, 2002). The guidelines (Department of Water Resources, 2011) recommend that any structural flood mitigation measures must be supported with in-depth hydrological and hydraulic studies.

While the guidelines mention trenches to lower elevated groundwater levels, and the restoration of natural channels to improve conveyance, they do not provide a more detailed assessment or further recommendations regarding either option.

Few structural flood management measures have been constructed in the Sarakata catchment. Existing measures include the hydropower dam situated in the catchment, bridge widening works, and river widening (as identified through Survey and the Urban Floods Community of Practice's review of flood risk management in the Pacific (Yeo, Esler, Taaffe, Jordy, & Bonte-Grapentin, 2017, p. 45)).

There is little information available about the extent or functionality of the existing drainage infrastructure in either Luganville or the wider Sarakata catchment. The Sarakata catchment flood mitigation guidelines note that "most of the stormwater drains around the Sarakata area are no longer functioning due to being blocked or damaged" (Department of Water Resources, 2011, p. 9).

2.1.3.2 Catchment Management

The Sarakata catchment flood mitigation guidelines emphasise the importance of catchment management and the potentially adverse impacts of human activities and land-use changes on catchment hydrology and the severity of flood impacts. The guidelines advocate the development of a catchment management plan which includes afforestation.

The guidelines recommend that a multi-stakeholder participatory approach is adopted for the catchment planning process, with input from community groups, provincial advisory committees, and provincial and national government agencies. DoWR is suggested as the lead agency for catchment planning, however, this initiative has not been implemented.

2.1.3.3 Exposure and vulnerability reduction measures

The Sarakata catchment flood mitigation guidelines emphasize the socio-economic aspects which contribute to the heightened vulnerability of marginalised groups. The guidelines suggest that targeted policy focused on poverty reduction through the promotion of diverse income-generating activities is essential for reducing vulnerability to natural hazards, however, no specific policies or programmes are proposed.

The flood guidelines also highlight the importance of an effective building code as a measure for reducing the level to which buildings are exposed to flood hazards, and the vulnerability of structures within flood prone areas. Locally appropriate guidelines and codes for the design and construction of hazard resilient housing are essential in areas where total retreat from flood plains is not practical. The Vanuatu Building Code, originally drafted in 1990 and revised in 2000, was gazetted in 2017 (Pacific Region Infrastructure Facility, 2021) following review of Vanuatu's existing land use planning framework (Beca, GNS Science and NIWA, 2016b). That review also recommended the development and dissemination of new guides in simpler formats which address construction techniques and retrofitting of existing structures for greater resilience to hazards. The Building Code includes requirements for site drainage and flood protection. The code stipulates that 'the land immediately surrounding a building should be free of standing water within one hour of a storm with a 5-year return period', and also requires that 'no flood water resulting from a storm with a 30-year return period should enter a building' (Government of Vanuatu, 2000). Enforcing these regulations would limit the flood exposure of new buildings in more frequent flood events (less than a 30-year return period). The Code states that rainfall intensities may be ascertained from the Vanuatu Meteorological and Geo-hazards Department.

2.1.3.4 Risk informed land use planning

The Sarakata catchment flood mitigation guidelines state that non-structural measures should be the primary approach to flood management in the catchment and suggest that appropriate planning and land use controls are central to this objective (Department of Water Resources, 2011).

The existing land use planning framework in Vanuatu consists of National Legislation (primarily the Physical Planning Act and Land Leases Act), National policy documents including the Land Use Planning and Zoning Policy, and local zoning plans (Beca, GNS Science and NIWA, 2016b).

A Zoning and Development Control Plan for the Luganville Physical Planning Area was approved by the Luganville Municipal Council and Sanma Provincial Government Council in 2018. Zoning plans in Vanuatu are only prepared for public land, the Luganville Zoning and Development Control Plan is applicable only to the urban area within the Luganville Physical Planning Area (Ministry of Lands and Natural Resources, 2023). Consequently, flood prone areas outside of the Luganville Municipal boundary are not included in the Luganville Zoning Plan and land use is ultimately controlled by customary landowners. Vanuatu's existing land use planning processes include applications to register leases, planning permits for subdivisions and foreshore development and environmental impact assessment processes (Beca, GNS Science and NIWA, 2016b).

2.1.4 Gaps identified relating to flood risk management governance and planning

The following gaps were identified in the review of relevant policies and plans (also drawn from the Urban Risk Management Strategy review (Beca, GNS Science and NIWA, 2016b):

- At national level, the plans and policies lack emphasis on the coordination at local level.
- The plans available at provincial level lack details, especially, the roles and responsibilities.
- The DoWR SOP lacks a level of detail that would make it useful (i.e. the roles and responsibilities are not clear).

- Currently, there is no finalised comprehensive flood management plan in place to ensure effective and coordinated governance of flood disaster risk reduction and to foster sustainable development. For instance, poor coordination between non-governmental organisations and community-based organisations created many bottlenecks during Tropical Cyclone Harold response operations. The roles and responsibilities of the agencies mentioned in the draft Flood Mitigation Guidelines for Sarakata, Pepsi, and Solwei Areas lack detail, and do not include all the necessary and relevant stakeholders. The strengthening of response and recovery mechanisms was a key objective of Vanuatu's recovery strategy following the compound disasters of Tropical Cyclone Harold and COVID-19 (Government of Vanuatu, 2020).
- The Flood Management Guidelines include a range of recommendations, many of which have not been actioned. The roles and responsibilities identified are not clear.
- Land use zoning currently allows for areas exposed to high potential hazard risks be revised to avoid future intensification and instead be considered for alternative land uses.
- The Sarakata River riparian reserve area within the Luganville Zoning and Development Plan is not aligned with the flood hazard mapping undertaken by NIWA (2015).
- Informal settlements in areas within the flood plain of the Sarakata River do not have any formal lease agreements, making the enforcement of planning controls extremely difficult. Previous government efforts to relocate residents from flood prone settlements have been unsuccessful.

2.2 Observation, monitoring, analysis, and forecasting

A suitable data observation system is critical for detecting hazards to inform the early warning notification. The performance of the whole system is limited by the accuracy and timeliness of the data.

A multi-hazard data observation network is multi-faceted and would typically comprise local hydro-met stations, local seismic networks, local tide gauge networks, Doppler radars, Automatic Weather Stations, and upper air observations. Each of these observation sites must be monitored at an appropriate interval relative to the warning time required for the hazard. Whole of life maintenance and running costs of the monitoring equipment must be considered at the inception of the system.

Coordination on regional and global hazards such as weather systems, climate and earthquakes are managed through international agencies such as the WMO. Data used for hazard forecasting are typically high density, and need to be continuously updated which requires a lot of resources. For some countries lacking resources this can be difficult, and results in out-of-date information being used for forecasts and warnings. For warnings to be useful across multiple areas and provinces, they should be based on Common Alerting Protocols (CAP) to allow for interoperability with other systems[8].

A poor communication system can increase disaster risk.

2.2.1 Observation network

A river gauging station (river monitoring system) was installed on the Sarakata River in September 2022 (Figure 2.1), at a location approximately 10 km upstream of the Luganville Municipal Boundary. The gauge reports the river level, river discharge, rate of rise, rainfall total, rainfall intensities and other parameters at five-minute intervals and transmits data via the cellular network, with satellite

[8] Lendholt, M.; Hammitzsch, M.-Generic Information Logistics for Early Warning Systems

redundancy in the event of a cell network failure. Data from the station are transmitted to both VMGD and a publicly accessible online platform[9].

There are also six ground water monitoring stations to support planning and decision-making by provincial water advisory committees, Luganville Municipal Council, and the Sanma Provincial government.

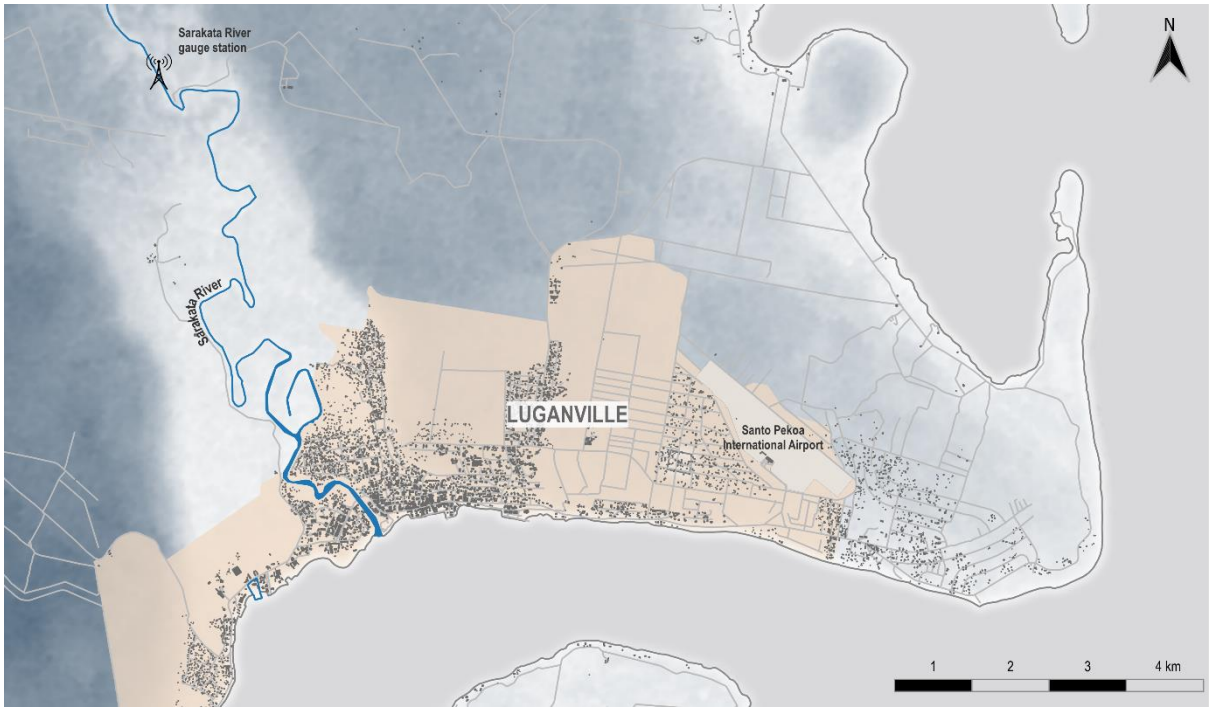

Figure 2.1: Sarakata river gauge station location

As of December 2022, river gauging of the Sarakata River at the gauge station was yet to be completed. River gauging (established from river cross sections and velocity measurements) would enable the river gauge station to deliver near real time river discharge data[10]. NIWA personnel were also reportedly investigating options to expand the observation network in the Sarakata Catchment through the installation of an automatic rainfall gauge further up the catchment[11]. This would enable a more detailed understanding of the relationships between rainfall in the Sarakata Catchment and runoff in the river.

The only long-term rainfall datasets available on Espiritu Santo Island is from the Pekoa Airport gauging station which lies outside of the Sarakata catchment, approximately 6 km east of the Sarakata River. Daily rainfall data from the Pekoa Gauge is available from 1960.

A flow gauge on the Sarakata River and a rain gauge within the Sarakata catchment were operated by the French Hydrology Agency (ORSTOM) between 1982 and 1985. The data were published at the time and used to develop flow duration curves for the Sarakata River (SMEC, 2014).

Since the late 1990s there have been two donor-funded initiatives to establish hydro-meteorological monitoring stations within the Sarakata catchment, upstream of the hydroelectric power plant. However, neither of these initiatives has been sustained and hydrology data from these stations were unavailable at the time of writing.

[9]Sarakata River Gauge online portal accessible at: https://bit.ly/3fRFuT1
[10] Campbell Scientific meeting with T+T December 1 2022
[11] SPREP meeting with T+T December 1 2022

2.2.2 Data and information collection

VMGD currently hosts all the collected river and rainfall data, and holds the historical data captured through the observation network. Gauged data is streamed to VMGD and is available through the online portal. Options for sharing of data with DoWR are being investigated.

2.2.3 Gaps identified relating to observation, monitoring and analysis

The following gaps have been identified relating to observation, monitoring and analysis to inform a strong flood early warning system:

- Improved instrumentation required to support real-time data capture to provide accurate warnings. An additional upper catchment flow gauge and a rainfall gauge would support this.
- Established procedures for coordination and data sharing between VMGD and DoWR.
- Current lack of capacity and training to support the necessary flood forecasting capability.

2.3 Disaster risk knowledge

Hazard assessment, exposure and vulnerability assessments, and risk assessments are important for establishing an effective flood management plan.

Risk assessments involve identifying hazards, evaluating exposure to those hazards, identifying vulnerability, and responding to risk via prevention or mitigation. This process assists decision makers to identify the potential locations that are most at risk and helps to determine relevant mitigation/management measures such as identifying low risk areas to be designated as evacuation zones.

Conducting risk assessments requires specific expertise and experience to cover its various aspects.

2.3.1 Flood hazard assessments

The Sarakata Catchment flood mitigation guidelines (Department of Water Resources, 2011) affirm that a comprehensive understanding of flood hazards and flood risk within a catchment is a necessary precursor to the development of a catchment flood management plan and supporting policy.

Hydrodynamic flood models and hazard maps have been developed for Luganville and the Sarakata catchment (NIWA, 2015). The flood hazard detailed in the modelling and data report was mapped for the Mele catchment in Port Vila and the Sarakata River catchment.

Hydrological investigations derived rainfall estimates for 10%, 2% and 1% annual exceedance probability (AEP) events. Climate change impacts were not included in the development of these. A storm tide with a one-year return period and peak of 1.7m above mean sea level were selected for the downstream boundary condition of the Sarakata River model. The timing of the tidal peak was aligned with the peak of the modelled flood hydrograph. Roughness heights for different land uses were developed based on aerial imagery, lidar datasets and ground inspection.

The results of the model simulations (Figure 2.2) suggest that in a 1% AEP flood event, large sections the Luganville town centre east of the Sarakata River, will be completely inundated, with modelled depths and velocities indicating high damage potential and a threat to life across much of the town centre. The modelling and data report (NIWA, 2015) noted that localised filling of floodplains to form bridge embankments exacerbated flooding upstream of bridges at several locations in the catchment.

Work is currently underway by NIWA to incorporate climate change projections into an updated flood model as part of an Asian Development Bank funded multi-hazard disaster risk assessment. However, the results of this assessment are not available at the time of writing this review.

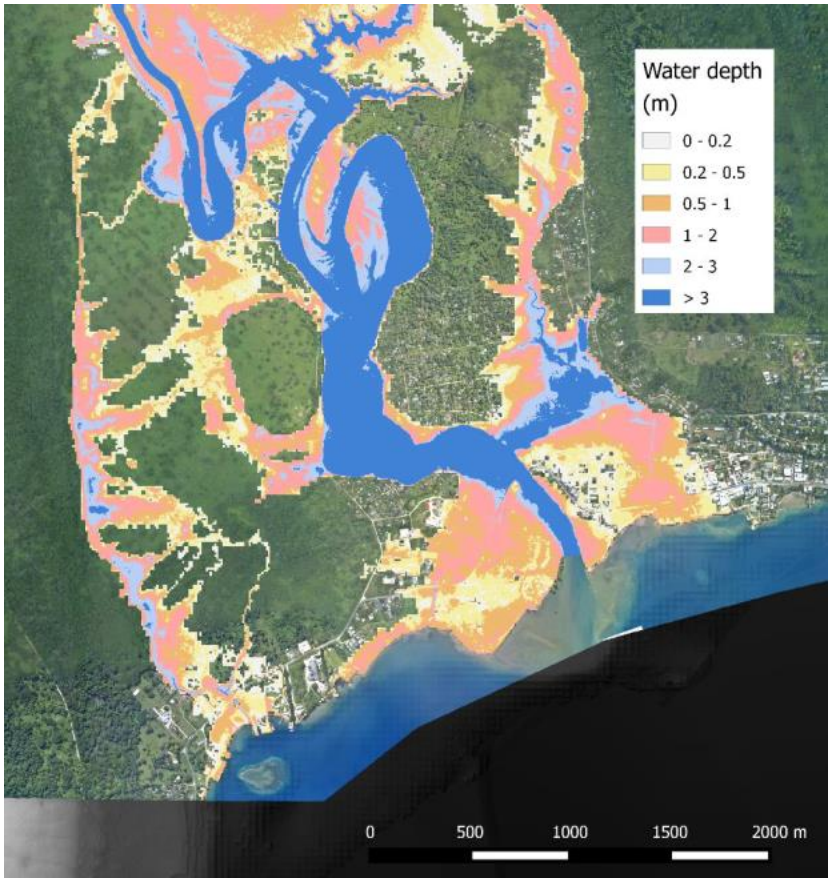

Figure 2.2: Maximum water depths in Sarakata River Catchment during 1% AEP flood event (NIWA, 2015)

2.3.2 Risk assessment

The Vanuatu Urban Risk Management Strategy was developed in 2016 (Beca, GNS Science and NIWA, 2016a) to respond to the hazards, risks and urban growth trends for Luganville and the greater Port Vila urban areas. This strategy involved hazard and risk mapping for the Sarakata River catchment, which determined that most of Luganville is at high risk from coastal, river flood, seismic and/or wind hazards.

The assessment determined that at a 1% annual exceedance probability (AEP), some 730 buildings are prone to flooding from the Sarakata River and are exposed to moderate to very significant levels of potential damage (Beca, GNS Science and NIWA, 2016b). The potential risk from river flooding at a 1% AEP is shown in Figure 2.3, and the full breakdown of flood-prone buildings is shown in Figure 2.4. This study also modelled the riverine flooding risk to Luganville at 2% and 10% AEP-flows.

The Urban Risk Management Strategy also considered the potential damage to buildings resulting from flood events. Damage functions were developed based on floods in Samoa in 2012, and the damage descriptors for different flood depths/velocities are provided in Figure 2.5 (Beca, GNS Science and NIWA, 2016a).

The potential risks and damages depicted in Figure 2.3 are based on a simulated spread of typical buildings and inferred construction styles. It is noted in the assessment report that these should be treated with caution and are intended to assist planners and other stakeholders in making strategic-

level planning decisions and not for work requiring detailed site-assessment of risk (Beca, GNS Science and NIWA, 2016a).

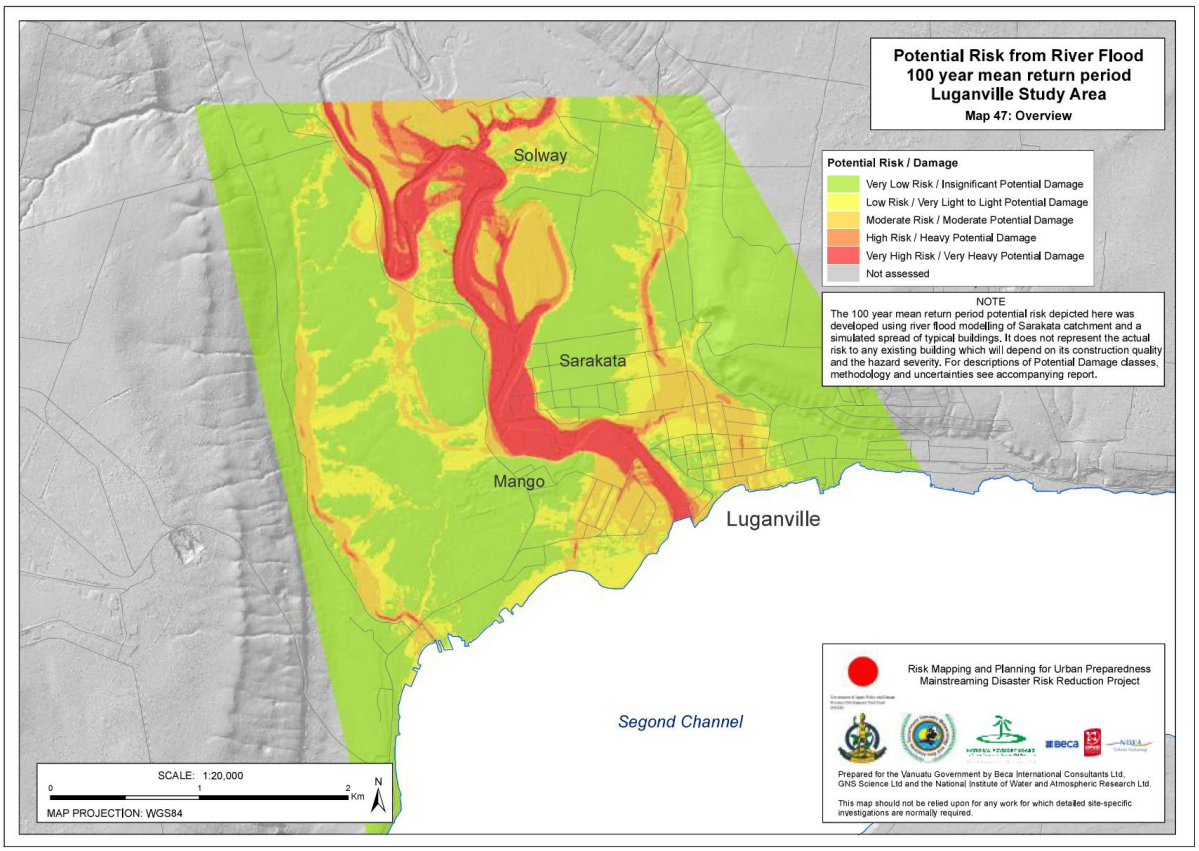

Figure 2.3: Combined maximum potential risk for Luganville for the 100 year mean return period (Beca, GNS Science and NIWA, 2016b)

	Unknown	None	Insignificant	Very Light - Light	Moderate	Heavy	Very Heavy
Seismic	0	0	0	0	5066 (98%)	79 (2%)	0
River Flood	2353*	0	1588 (57%)	476 (17%)	608 (22%)	44 (<2%)	76 (3%)
Wind	0	0	0	0	0	5145 (100%)	0
Coastal Inundation	0	4825 (92%)	53 (1%)	163 (3%)	144 (3%)	50(1%)	10 (< 1%)

* Buildings falling outside of the flood modelling area.

Figure 2.4: Assessment of potential damage to existing buildings within the Luganville study area (Beca, GNS Science and NIWA, 2016a, p. 45).

POTENTIAL RISK		VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
POTENTIAL DAMAGE		INSIGNIFICANT	VERY LIGHT - LIGHT	MODERATE	HEAVY	VERY HEAVY
Description of potential damage		No damage to very minor damage to weak structures	Buildings of poor construction slightly damaged.	Buildings of poor construction damaged, many heavily damaged, some collapse. A few buildings of average construction damaged some with partial collapse. Some buildings of good construction damaged.	Many buildings of poor construction destroyed. Buildings of average construction heavily damaged, some collapse. Buildings of good construction damaged some with partial collapse.	Most buildings of poor construction destroyed. Many buildings of average construction destroyed. Buildings of good construction heavily damaged, some collapse.
Water Depth Velocity		< 0.2 m	0.2 - 0.6 m < 0.5 m/s	0.6 - 1.3 m 0.5 - 1.5 m/s	1.3 - 2.0 m 1.5 – 3.0 m/s	> 2.0 m > 3.0 m/s
Damage State*	Class 1	DS0-DS1	DS1-DS2	DS2-DS3	DS3-DS4	DS4-DS5
	Class 2	DS0-DS1	DS1-DS2	DS2-DS3	DS3-DS4	DS5
	Class 3	DS0-DS1	DS1-DS3	DS3	DS4-DS5	DS5
	Class 4	DS0-DS1	DS1-DS3	DS3-DS4	DS4-DS5	DS5

Figure 2.5: Potential damage descriptors for flooding, which is applied to the greater Port Vila Urban Area and Luganville (Beca, GNS Science and NIWA, 2016b)

The assessment by Beca, GNS Science and NIWA (2016a) evaluated the potential risk to people from flooding by overlaying flood risk data with geolocated 2009 census data to estimate the number of people exposed to flood hazards. This analysis suggested that 25% of the population of Luganville (1,811) occupy houses which are exposed to a moderate, high, or very high flood risk. It is stated in the assessment that flood damage in the "Moderate", "Heavy" or "Very Heavy" ranges could lead to deaths without evacuation, and that people would likely be swept away by flood waters at higher velocities (Beca, GNS Science and NIWA, 2016a).

2.3.3 Gaps identified relating to disaster risk knowledge

Flood hazard mapping is available for the Sarakata catchment, with a range of limitations identified for that information. A review of the flood hazard mapping and other relevant information has identified the following gaps that are relevant to incorporation of disaster risk knowledge into the flood early warning system:

- Flood hazard modelling requires updating to include for climate change (this is currently underway).
- Risk to people and informal settlements included in the previous flood risk assessment for Luganville relied on a simulated spread of buildings and inferred construction styles, and on census data from 2009 (work is underway to develop updated exposure data with an update to the Pacific Catastrophic Risk Assessment and Financing Initiative building database.
- Assessment of risks to people and health associated with frequent flood events has not been evaluated.
- Hazard detection has not been fully integrated with land use planning and controls.

- An integrated risk assessment that combines the latest information about flood-related hazards, exposure and vulnerability for the current climate and future climate change scenarios (this is currently underway as part of a collaboration between NIWA and the Van KIRAP project).

2.4 Warning dissemination and communication

Early warning systems (EWS) are a major component in disaster risk reduction through emphasis on disaster preparedness. These need to be end-to-end systems that work together to create a single, cohesive, and robust system. The failure of any individual component will lead to the overall failure of the entire EWS and likely increase negative impacts on lives and livelihoods. Therefore, it is essential that the responsibility for the dissemination of the warnings and the responses necessary to avoid potential harm or loss lies with government and local community decision makers. Generally, warnings of potential hazards are issued via weather watches, advisories, and statements mostly in deterministic forms. These are required to be updated at a frequency, which is appropriate to the warning lead-time relevant to the hazard.

An important element of EWS is the incorporation of impact-based warnings. Communities not only need scientific hazard information, but also information about how to ensure their safety and protect their property (WMO, 2011). There is often a significant disconnection between the forecasts and warnings and an understanding of their potential impacts. However, this information is vital for producing accurate warning information which includes the likely impact associated with the forecast. This enables users to interpret the hazard warning in a meaningful way that relates to their needs. Impact-based forecasting is informed through hazard assessment, vulnerability assessment, risk assessment, impact assessment, and studies of risk perception. Warning advisors must work with local communities and sectors to ensure they understand the likely impacts through local knowledge from past events to ensure they appropriately incorporate impact information into their warnings.

2.4.1 Early warning and other information products, dissemination and notification methods

Flash flood warnings are currently issued by VMGD. These are triggered when rainfall is forecast to be greater than 100 mm rainfall/day. VMGD issues these warnings to local authorities, government offices, community disaster climate change committees, church leaders, women in community and NDMO. Wider dissemination of warnings is managed through NDMO via SMS, radio, TV, and social media. Radio Vanuatu has been identified as the only medium which can be accessed by the entire population of the country, regardless of remoteness, and therefore it is considered a key factor in information and communication sharing. Fiji Met Service is the regional centre for cyclone warnings, which are provided for Vanuatu. Uptake of warnings generally has been effective, particularly as a result of improvements in warnings following Cyclone Harold. Ten tsunami sirens are in place around Luganville urban and semi-urban areas[12].

A dashboard for the new river monitoring system was developed by VMGD for public to access the information online. It is estimated to benefit around 17,700 residents of Luganville. Data collected from this gauge can be used to verify the warnings.

VIKAP-2 project is underway to install VHF radio for improved communication to provinces and meteorological stations for use during Tropical Cyclones, severe weather or when other communications are down.

[12]VMGD meeting with T+T December 2022

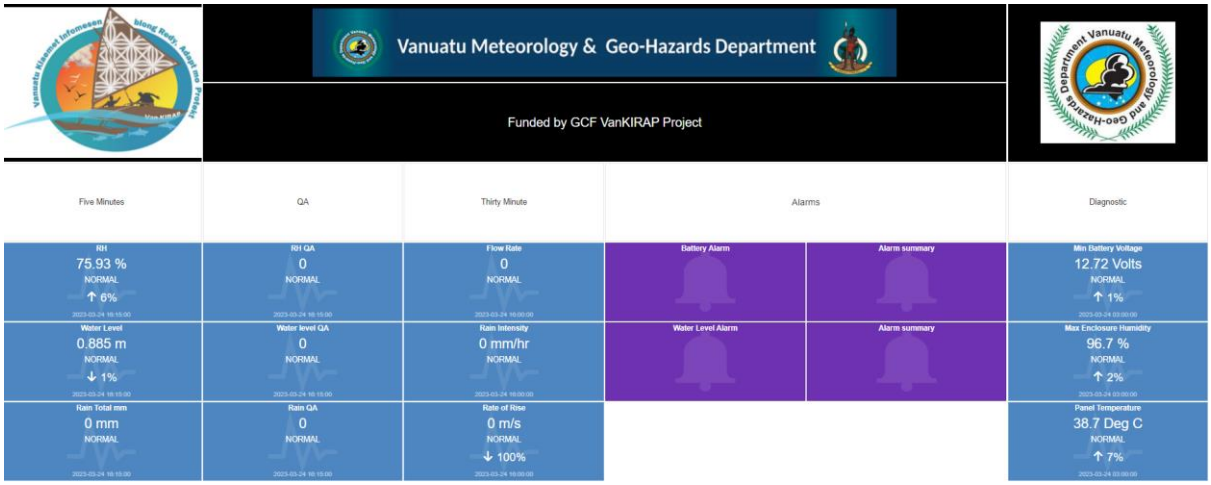

Figure 2.6: Public dashboard for new river monitoring system installed in September 2022 (Source: VMGD[13])

2.4.2 Risk communication

Risk communication systems must be well established, ensuring all stakeholders are effectively notified, including government, public, local community, community leaders and tourists. Channels of communication and procedures for monitoring the warning must be clearly understood by all parties and systems regularly checked.

Early warning functions need to be linked to risk assessment and preparedness programmes within a coherent disaster-management strategy. Communication from scientists is important for informing members of the public of potential hazards, so that individuals can assess their own level of safety and take preparation measures. A top-down approach is not appropriate or sufficient for an EWS. Communities should be involved in the risk mapping and analysis process to ensure their perspectives are included when decisions are being made.

2.4.3 Gaps identified relating to warning dissemination and communication

Gaps identified in flood warning dissemination and communication include:

- Flash flood warnings are based on basic metrics (100 mm/day rainfall depth), the basis of which is not confirmed.
- Absence of a flood management plan that clearly identifies roles and responsibilities and standard operating procedures.
- A lack of co-ordination of flood warnings and procedures with established early warning procedures for other multi hazard warnings, e.g. cyclones.
- A lack of integration with training and awareness programmes to include flood warnings into other existing hazard awareness and response programmes.
- A lack of evacuation plans for areas that are at-risk.

2.5 Preparedness and response capabilities

The ultimate test of any flood management plan depends on the response shown by the people at-risk. This is the result of a chain of preparedness, that is integrated across government, private sector, NGOs and communities. Community members are more likely to respond to warnings when they have been educated about the risks in advance of an event, and when they know what actions, they can take to minimise their impacts. It is critically important to work with the community to

[13] https://bit.ly/3fRFuT1

understand local knowledge, raise public awareness, tailor warnings to ensure accurate community interpretation of the key messages, and to ensure appropriate response plans and safe evacuation procedures are adequately resourced. Community connection and response and community preparedness are two essential elements under the community capacity.

2.5.1 Emergency management facilities, planning, and capabilities

The Sarakata catchment is serviced by one of the country's four Provincial Emergency Operations Centres (PEOC). The Santo (Samna) is operated by NDMO and is linked to the National Emergency Operations Centre (NEOC) in Port Vila. Incident organisational structure of PEOCs are guided by ToRs, and are activated in line with standard operating procedures with functions of agencies pre-agreed. Standard Provincial Disaster and Climate Change Plans are drafted for the Samna province.

In addition to activation through the NEOC, the VRCS can activate EOCs at national and at local level. For example, in response to TC Harold, the VRCS set up operations centres in Santo, Malekula and Pentecost to coordinate activities in the field. The establishment of these centres follows existing Standard Operating Procedures (SoPs) of the VRCS (NDMO, 2020).

At a national scale, relief items are stored by NDMO in shipping containers (three in number). Locally, a warehouse was constructed in Sanma (Logistics Cluster, 2023) in 2017 which is managed by Vanuatu Red Cross. Medical storage facilities are limited, with the country's only dedicated medical storage facility located in the Port Vila region, managed by the Ministry of Health. In addition, there is a lack of cold chain options for relief supplies, where electricity and refrigeration are generally unavailable and generators may be needed in emergency situations to cool sensitive supplies (e.g. vaccines) (Logistics Cluster, 2023). Transportation of relief items to Samna can be problematic due to the status of the roads, limited aircraft availability, and limited shipping infrastructure.

Communications in support of emergency operations can be challenging, particularly as telecommunications infrastructure is vulnerable to damage from Tropical Cyclones, and not all responders have access to adequate devices. The VRCS media and communications team has established a coordination network across its branches. This intended to support its multi-hazard contingency plan, and to deliver public, operational, and internal information, as well as reporting and institutional communication. Hospitals and airports on the island are reported to possess high frequency (HF) radios. Customs operates through very high frequency (VHF) channel. The Office of the Government Chief Information Officer (OGCIO), World Vision and the Red Cross work with satellite phones (Logistics Cluster, 2023).

The NDMO Strategic Plan 2016-2020 identifies the need to strengthen linkages between National and Provincial levels to reduce by-passing of PDCCC and stated an objective to strengthen the Incident Command System within the EOC by establishing a clearer command structure for response. Also, the NDMO Strategic Plan 2016-2020 highlights the need for provincial EOCs and Provincial Disaster Committees to work more consistently with the NEOC.

In 2015 a risk-informed decision-making training course was delivered to urban planners and engineers in Vanuatu, including members of the Sanma provincial disaster management office, to strengthen existing land use planning and disaster risk reduction processes through the integration of hazard information and risk-based decision-making (Secretariat of the Pacific Community, 2015). Following the training it was recommended that additional training to a broader group of planning officers from local authorities and municipal councils was necessary to further develop the capacity of town planning departments and to better integrate the management of flooding and other hazards into the planning process (Yeo, Esler, Taaffe, Jordy, & Bonte-Grapentin, 2017).

2.5.2 Community connection and response

In 2019, the NDMO became the leader of the Communication and Community Engagement Sub-Cluster, supported by VRCS. The role of this sub-cluster is to strengthen communication with communities during disasters and ensure a timely and effective communication with the affected communities.

As mentioned in Section 2.2, Luganville Community Climate Centre was established to provide Climate Information Services (CIS) from the VMGD to the community. They are also responsible for building adaptive capacity of communities and households in the uptake of, use and translation of CIS into actions to build resilience. Posters and outreach materials are available in these centres. However, only two posters have been published to date: one describing six steps for communication with communities and one drawing attention to communication (both in Bislama). More than 20 information fact sheets are being developed as part of the Van KIRAP project with the objective of documenting how CIS can inform climate change resilience.

The SREM developed for 2021-2023 does not account for provincial and community engagement, but since it is a developing document, future iterations might appropriately include references to a comprehensive programme for volunteer engagement, an important aspect currently lacking at country level.

2.5.3 Gaps identified relating to preparedness and response capabilities

Gaps identified in flood warning dissemination and communication include:

- Unclear uptake on the recommendations for continuation or expansion of risk-informed decision-making training for flood management.
- Underutilisation of community connection and outreach through the Luganville Community Climate Centre.
- No inclusion of provincial and community engagement in the SREM (2021-2023).

3 Recommendations

3.1 Governance and institutional arrangements

Key recommendations relating to governance and institutional arrangements are:

- Strengthened policies and institutional frameworks at the provincial level including clear roles and responsibilities.
- Clear standard operating procedures for flood early warning system management.
- Development of forums to enable coordination and partnerships.
- Update and finalise the Sarakata flood management plan.

3.1.1 Policy and institutional framework

Effective implementation of the flood management plan, hazard forecasting, and warning dissemination requires a strong policy and institutional framework. Creating an enabling environment by developing a simple and well understood law, or a policy, or an institutional framework for implementing the FMP and forecast services is necessary.

Inter-agency coordination is a key requirement for delivering effective flood management outcomes, where a critical element of this is clear identification of roles and responsibilities.

3.1.2 Standard Operating Procedure

A standard operating procedure (SOP) is a set of detailed step-by step instructions developed by an organisation to manage complex tasks and routine operations. To support the development of protocols and SOPs, case studies of past high impact flooding events with sufficiently documented impacts, response, forecast and warning information and available hydrometeorological data analysis are essential. SOPs could assist in establishing a chain of command, the production of uniform and reliable results, improved efficiency, and assist with the definition of clear roles and responsibilities. Therefore, creation of SOPs for hazard prediction and early warnings in Sarakata Catchment is important.

3.1.3 Coordination and partnerships

Providing platforms such as workshops or conferences for stakeholders to engage can improve their partnership. This could also be in the form of regular (e.g. three-monthly meetings) of the relevant public and private organisations, plus an online Community of Practice for daily/weekly interactions. Creating partnerships between the public organisations and private telecommunication enterprises can enhance the information dissemination channels.

3.1.4 Update and finalise the Sarakata Flood Management Plan

The updated FMP should be designed to ensure effective and coordinated governance of flood disaster risk reduction and foster sustainable development. The plan should address unclear coordination between NGOs and community-based organisations and should include consideration of the gaps identified in Section 2.1.4. The Plan should also include annual monitoring and evaluation to assess the effectiveness and efficiency of actions undertaken, leading to continuous improvement.

Effective flood management also requires incorporation of flood management measures. These can be broadly categorised into three categories:

- those measures which change the nature of the flood hazard itself.

- those measures which alter the exposure and vulnerability of people and property within flood affected areas.
- those measures aimed at influencing the behaviours and responses of individuals and communities impacted by flooding (Yeo, Esler, Taaffe, Jordy, & Bonte-Grapentin, 2017).

A further distinction can be made between structural and non-structural flood management measures. Structural measures are those which employ engineered physical infrastructure to reduce or otherwise manage flood hazards. In contrast, non-structural approaches make use of non-engineered and distributed measures to reduce losses associated with flooding. Non-structural flood management measures include legislative and regulatory responses, flood insurance and financial aid, early warning systems and catchment management.

It is recommended that elements of all three categories of flood protection measures, that utilise both structural and non-structural solutions are incorporated into the updated FMP. Examples of these types of measures are outlined in Table 3.1 (adapted from Yeo, Esler, Taaffe, Jordy, and Bonte-Grapentin, 2017), which when applied comprehensively can accommodate uncertainty and proactively manage residual risk.

Table 3.1: Common flood management measures

Modify flood hazard	Modify exposure and vulnerability	Modify human responses
Non-structural • Source control through catchment management, afforestation, enhanced infiltration • Stream restoration, maintenance of riparian margins **Structural** • Construction of flood barriers, levees, and embankments, dikes, and diversions • Flood detention basins, dams, and wetlands • Enhanced flood plain storage, polders and washlands • Enhanced channel capacity, dredging, debris management.	**Non-structural** • Legislation and land use planning, zoning regulations • Development controls, building codes • Stimulation of permanent relocation • Development of safe evacuation routes and flood refuges **Structural** • Distributed small-scale structural measures – raised building foundations, waterproofing of buildings, localised drainage and flood protections	**Non-structural** • Flood forecasting and early warning systems • Flood preparedness and awareness raising. Improving information and education on floods and flood response • Flood insurance schemes and risk financing • Post disaster assistance and financial aid • Community self-protection and emergency response teams • Post-flood recovery plans

Following updating of the FMP (as above), a separate exercise will be to develop flood management options, and to specify planning zones based on actual and/or residual flood risk.

3.2 Observation monitoring, analysis, and forecasting

Key recommendations relating to observation, monitoring, analysis, and forecasting are:

- Additional observational equipment and supporting services and capacity.

- Inclusion of empirical models or probabilistic modelling to inform hazard and risk assessments.

3.2.1 Additional observational equipment

There are limited hydrological monitoring and meteorological data available in the Sarakata catchment.

Data gathered from the Sarakata flow gauge (installed in 2022) is an important first step in improving the observational network. Data from this gauge may be used to validate the existing flash flood warnings and floodplain mapping. Additional flow and rainfall gauges are necessary to strengthen the observational equipment network needed to support flood monitoring and forecasting. Increased instrumentation also requires procedures for coordination and data sharing between VMGD and DoWR, and improved capacity and training to support the necessary flood forecasting capability.

Further detail relating to these requirements could be included as part of the development of the VMGD strategic plan, specifically addressing the requirements for flood-related meteorological services for the Sarakata catchment.

3.2.2 Empirical models or probabilistic modelling

Vulnerability, exposure and hazard-based data assist in informed decision-making for developing policies and plans, then selecting and implementing appropriate flood mitigation measures.

To augment low data availability, empirical models or probabilistic modelling could be developed using global, regional, and local hydrometeorological, geo and socioeconomic databases. These could be calibrated with historical losses to support an evaluation of the impacts of hazards on infrastructure, ecosystems, people and society that are typically too complex to model accurately. The risk assessment or loss modelling would help assess future disaster loss and damage assessment to people, infrastructure and natural resources. At the same time, an indirect loss data collection process could be introduced for risk and impact assessment.

3.3 Disaster risk knowledge

Key recommendations relating to disaster risk knowledge are:

- Adoption of hazard thresholds.
- Updating and strengthening risk assessment and risk management practices.

3.3.1 Hazards threshold

Defining hazard thresholds is essential for FMP to ensure flood risk is communicated accurately to the communities. A proper hazard threshold for each vulnerable area should be well articulated in the SOPs. Table 3.2 presents definitions and thresholds of indicators and risk scenario classifications.

Table 3.2: Example of definitions and thresholds of indicators to monitor flood risk

Key Monitoring Indicators	Definition	Thresholds	Normal	Alert	Alarm	Emergency	Warning Source
Rainfall/ Precipitation	Percentage of long-term mean (monthly)	Percentage increase above average in mm (based on thresholds)	No change	Any increase	20% to 60% increase	Greater than 60% increase	VMGD
River levels/ flooding	Monitoring river level for flooding or high-risk levels	River level above critical levels or flooding	Minimal risk level compared to long term mean flow of the river	Low risk level	Moderate risk level	Greater than High risk level but less than Bank full	DOWR

3.3.2 Risk assessment and risk management

Existing flood hazard mapping of the Sarakata Catchment is being updated to include the effects of climate change. Once available, these maps should be used to update the risk assessment for the catchment, including assessing the risk to buildings, infrastructure, people and informal settlements. This risk assessment should feed into local planning measures.

Furthermore, creation of a risk register can be a useful tool in risk reduction by identifying and documenting risks, their likelihood and impact on the systems of interest (e.g. a community, a business, a sector). Risk is typically placed in a register in the form of a matrix consisting of risk scores (likelihood versus consequences or using hazard, exposure, and vulnerability assessment). A risk register should also outline proactive actions to mitigate the risks with assigned responsibilities, thus ensuring good risk governance. Ideally, risk registers highlight systemic risk and cascading effects. Outlining risks in a public risk register enables effective risk communication.

3.4 Warning dissemination and communication

Key recommendations relating to warning dissemination and communication are:

- Community-focussed warning and dissemination.
- Community-specific evacuation plans.

3.4.1 Community-focussed warning and dissemination

As identified in Section 3.1.4, an updated Flood Management Plan will support the development of clear roles and responsibilities as well as improved training and awareness programs. For flood management to be effective, warnings must be implemented within the local context through a combination of technological and non-technological solutions designed with the community, and understanding how it best receives warning information. Warnings should be tailored to the provincial context, and be readily accessible (i.e. information available via community notice boards) Currently, flash flood warnings are based on basic metrics (100 mm/day rainfall depth), the basis of which is not confirmed and should be validated and refined as observational data become available. Community knowledge of the river flood response to previous events may be an alternative when technology fails (i.e. Observations or Traditional Knowledge).

Communications systems relay information on observed hazards to other specialists and link the technical community to the body of officials, politicians, government agencies, other organisations, or community leaders, which are responsible for determining the relevance of hazard data to populations at-risk.

Communication problems, due to equipment and human failure, are the most significant causes of poor warning dissemination. Redundancy in the systems provides alternative means of communication in the event of failure. Inclusion of flood warnings into the established warnings, procedures, and training and awareness initiatives developed for other hazards may provide a greater reach to the community and provide necessary redundancy.

3.4.2 Community-specific evacuation plans

Working with community leaders to develop evacuation plans for areas that are at risk is an important component of ensuring flood warnings are effectively acted upon.

3.5 Preparedness and response capabilities

Key recommendations relating to preparedness and response are:

- Training and capacity building.
- Community-based disaster risk management.
- Grass-roots level involvement.

3.5.1 Training and capacity building programs

As identified in the FMP, continued roll-out of risk informed decision making training to planning officers from local authorities is necessary to further develop the capacity of town planning departments and to integrate better the management of flooding and other hazards into the planning process (Department of Water Resources, 2011).

Conducting training and mock drill/simulation exercises through school safety programmes or awareness raising programmes on preparedness could be beneficial for improving community's knowledge on floods.

Educating communities on flood risk reduction/mitigation measures might save lives and protect assets during flooding. Outreach material on forecasting, disaster risk reduction, and climate change adaptation could guide the communities on flood response procedures. It would also assist the communities in taking informed decisions.

3.5.2 Community-based disaster risk management

Ensuring the direct involvement of the community through community-based disaster risk management (CBDRM) will be a crucial part of strengthening flood risk management in the settlements alongside the Sarakata River. The assessment of flood risks outlined in Section 3.3.2 should incorporate principles of CBDRM to identify and engage vulnerable groups to ensure that their specific needs and capacities are understood. This will ensure that flood management policies and interventions align with the needs and capabilities of the community.

3.5.3 Grassroots level involvement

For an effective implementation of FMP, Luganville Municipal Council should actively involve the communities at-risk, facilitate public education and awareness of risks, and disseminate effectively messages and warnings to ensure they are prepared for future events. It should encourage communities to participate in design and implementation of disaster risk reduction programmes. Effective functioning of the Luganville Community Climate Centre is also crucial to implement this recommendation.

4 Applicability

This report has been prepared for the exclusive use of our client Secretariat of the Pacific Regional Environment Programme, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

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