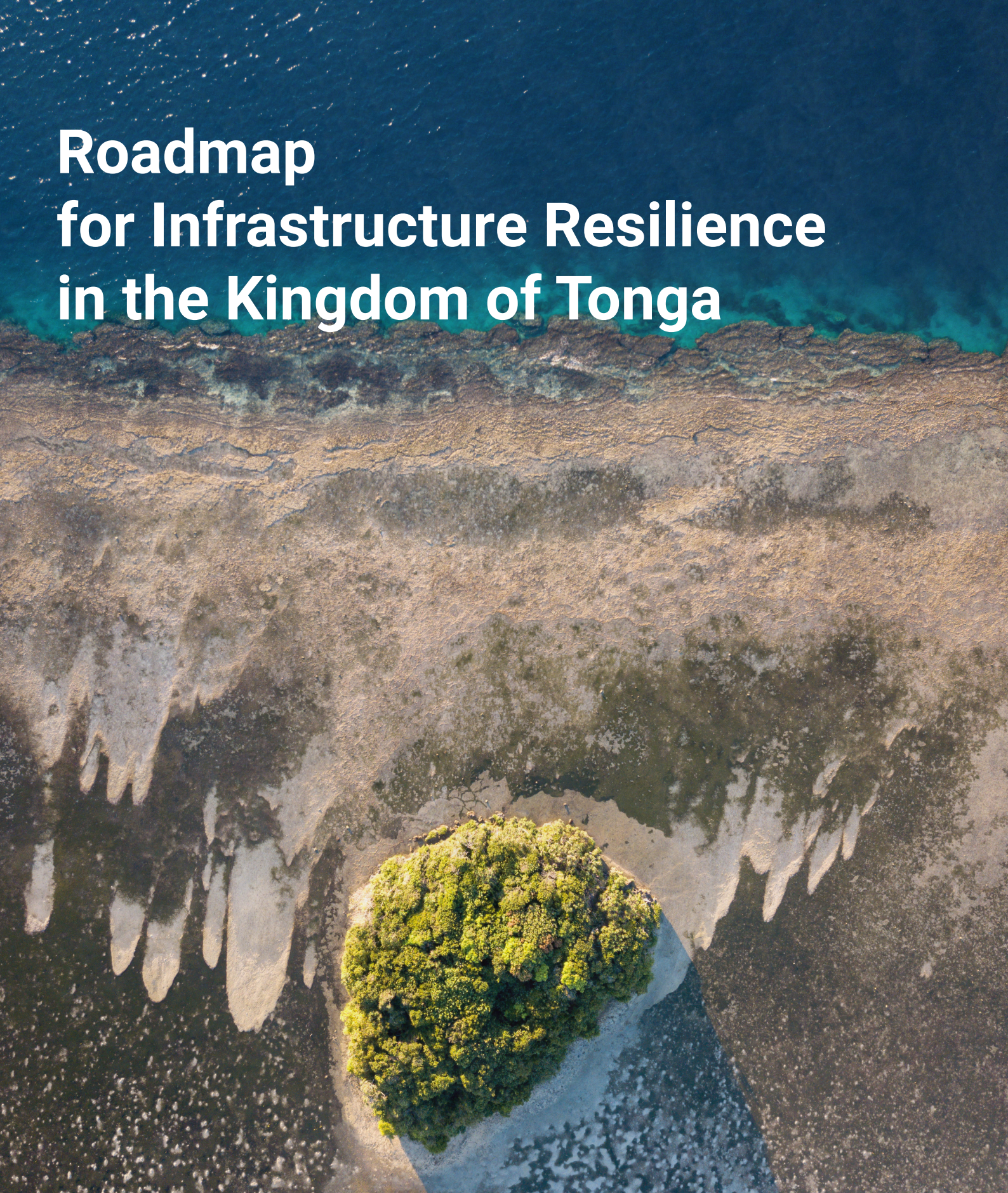
Roadmap for Infrastructure Resilience in the Kingdom of Tonga



Kingdom of Tonga

In collaboration with:

UNDRR
UN Office for Disaster Risk Reduction

CDRI
Coalition for Disaster Resilient Infrastructure

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ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
CDRI	Coalition for Disaster Resilient Infrastructure
DGSF	Digital Government Strategic Framework 2019-2024
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EIA	Environmental Impact Assessment
ENSO	El Niño Southern Oscillation
GIRI	Global Infrastructure Risk Model and Resilience Index
GIS	Geographic Information Systems
GMIRR	Global Methodology for Infrastructure Resilience Review
HMAF	His Majesty's Armed Forces
HTHH	Hunga-Tonga-Hunga-Ha'apai
ICT	Information and Communication Technology
MEIDECC	Ministry of Energy, Information, Disaster, Environment, and Climate Change
MFAT	Ministry of Foreign Affairs and Trade
MLSNR	Ministry of Lands, Survey and Natural Resources
MOH	Ministry of Health
MPE	Ministry of Public Enterprise
NCDs	Non-communicable diseases
NDRMO	National Disaster Risk Management Office
NEMO	National Emergency Management Office
NGOs	Non-Governmental Organizations
NIIP	National Infrastructure Investment Plan
PAT	Ports Authority of Tonga
PCRAFI	Pacific Catastrophe Risk Insurance Company
SDG	Sustainable Development Goals
SES	Société Européene des Satellites
SOPs	Standard operating procedures
SPC-R2R	Pacific Ridge to Reef Programme
TAL	Tonga Airports Limited
TCC	Tonga Communications Corporation
TEEMP	Tonga Energy Efficiency Master Plan 2020
TERM Plus	Tonga Energy Roadmap 2021 - 2035
TPL	Tonga Power Limited
TSDF	Tonga Strategic Development Framework 2015 - 2025
TWB	Tonga Water Board
UNDRR	United Nations Office for Disaster Risk Reduction
UNOSAT	United Nations Satellite Centre
VWC	Village Water Committees
WASH	Water, sanitation and hygiene

Executive Summary

As a low-lying small island developing state, the Kingdom of Tonga is especially vulnerable to climate-related hazards. Climate change impacts are evident globally and locally, with increasing extreme events affecting sectors like health, food, water, and energy, thus heightening risks to human security.[1]

Reliable infrastructure is crucial for economic and social growth but requires considerable investment. Tonga's National Infrastructure Investment Plan III estimates nearly T$1.49 billion (USD 6.18 billion)[2] is needed for 99 projects over the next 15 years. For example, water supply projects alone will cost T$103.4 million (USD 42.9 million). As the country plans new infrastructure, it must ensure its resilience to protect its investment and make large-scale investments future-proof.

Proactive measures to reduce disaster risk and build resilient infrastructure are essential to reduce long-term costs and ensure continuity of services during disruptions. Resilient infrastructure must be able to anticipate, absorb, adapt to, and recover rapidly from disruptive events, reducing the scale and duration of impacts. By prioritizing resilience, the country can support sustainable economic growth, adapt to climate change, and protect communities, while minimizing economic and human losses.

To advance resilient infrastructure in the country, Tonga has developed the following roadmap through close collaboration with the United Nations Office for Disaster Risk Reduction (UNDRR), and the Coalition for Disaster Resilient Infrastructure (CDRI), with support from the United Nations Satellite Centre (UNOSAT). This roadmap outlines a series of governance measures designed to enhance the resilience of Tonga's critical infrastructure and provides a concrete way forward for the country in this area.

OVERVIEW OF KEY GAPS AND CAPABILITIES IN TONGA'S CRITICAL INFRASTRUCTURE RESILIENCE

Throughout the analysis and consultations, the following gaps were identified and served as the basis for laying out priorities for building infrastructure resilience within Tonga.

1. *BoE Declaration on Regional Security. (Nauru, 2018), https://forumsec.org/publications/boe-declaration-regional-security*
2. *Tonga National Infrastructure Investment Plan 2021 - 2030: Hunga Tonga–Hunga Ha'apai Volcanic Eruption and Tsunami update. (2023), https://tinyurl.com/mb73pt9z*

GOVERNANCE, LEADERSHIP AND COLLABORATION

Tonga's legal and policy frameworks currently do not emphasize resilience in a clear or explicit way. As a result, governance structures and operational practices do not have clear mandates or standards for resilient infrastructure development. A shared strategic vision with clear expectations for all actors and stakeholders is essential to guide Tonga's efforts in developing adaptive and disaster-resilient critical infrastructure. Ideally, this would take the form of a National Infrastructure Strategy aligned with Tonga's broader development goals.

In addition, sectors tend to operate in silos, which hinders effective collaboration. Key sectors, including Water, Transport, Telecommunications, and Energy, already have established authorities, regulatory bodies, and service providers that recognize the need for enhanced resilience. However, greater collaboration and more coordinated planning are needed to fully achieve this goal. Currently, development plans tend to focus on individual sectors, with limited consideration of interdependencies or opportunities for multi-sector and multi-agency collaboration.

Tonga's National Spatial Planning Authority, under the Ministry of Lands, Survey and Natural Resources (MLSNR), could provide a platform for integrated infrastructure investment. Additionally, the Inter-Cluster Coordination Committee could be leveraged for better information sharing and planning, particularly concerning disaster risk management. Leveraging these existing structures could significantly improve integrated planning and implementation.

POLICY, REGULATORY FRAMEWORKS AND PLANS

While frameworks and plans exist, they tend to be somewhat limited in scope and do not always provide a strong focus on building infrastructure resilience against disasters and shocks. When resilience is considered, it often overlooks the interdependencies between critical functions, which can lead to cascading vulnerabilities. This gap is visible at national, sectoral, and organisational levels.

To build the Roadmap, stakeholders used the Principles for Resilient Infrastructure to pinpoint specific policy and regulatory areas that could benefit from targeted interventions, fostering a more supportive environment for resilient infrastructure.

For instance, incorporating disaster post-event analysis into national infrastructure policies would enhance organisational practices. Following the Hunga Tonga–Hunga Ha'apai (HTHH) event, lessons learned on disaster vulnerability should have informed updates to infrastructure regulations.

Another gap is the lack of credible, up-to-date necessary data for informed policy development. Although sectors possess some relevant data, the quality needs improvement through better systems, trained personnel, and additional resources. To address this issue, regulators should require operators to develop policies for collecting vulnerability data and establishing safeguards.

Policy and governance reforms have been utilized in Tonga in the past to usher in policy change in various domains, from climate change to disaster risk management. These processes offer an avenue for the integration and development of resilient critical infrastructure for Tonga.

RESOURCING AND SUSTAINED PERFORMANCE

As a small island developing state with a limited economy, Tonga faces significant resourcing challenges for critical infrastructure investment and maintenance. Infrastructure investments are costly, and the ongoing cost of maintenance adds additional strain on the national budget. Budgeting and financing mechanisms to support critical infrastructure development and management remain underexplored.

In the water and transport sectors, aging infrastructure underscores the persistent challenge of balancing cost efficiency with service quality. A centralized database could support resource assessment and infrastructure monitoring to address this issue. To achieve this, integrated planning and management strategies are essential.

DATA AND CAPACITY

Throughout the analysis, data management and capacity-building emerged as consistent challenges voiced by stakeholders. Three key data issues were identified:

1. Lack of data collection mechanisms,
2. Outdated or inaccessible data, and
3. Limited integration of sectoral data, preventing a comprehensive understanding of the broader context.

In addition to addressing these data issues, there is a need for training in data analysis to make the information more meaningful for decision-making.

Tonga has qualified data practitioners, particularly in Geographic Information Systems (GIS), within the MLSNR (Ministry of Lands, Survey and Natural Resources) and the National Disaster Risk Management Office (NDRMO). While these professionals cater to most GIS data requirements, continued training is necessary, especially to build GIS capacity in critical infrastructure sectors.

MLSNR has developed the National Integrated Geospatial Action Plan 2023–2027, which addresses many of the identified data issues. However, the successful implementation of this plan requires adequate funding.

ROADMAP KEY PRIORITIES

The following actions were selected as priorities for implementation by a group of Chief Executive Officers and/or their representatives after concluding the in-depth analysis in Tonga of the 'Global Methodology for Infrastructure Resilience Review' (GMIRR) developed by UNDRR and CDRI; the results of which are presented in the next sections of this report. These actions were selected based on their short-term implementation timeframe, cost and impact on resilience. Table 1 provides a summary of the prioritized actions.

Table 1. Summary of prioritized actions

SECTOR & SUB-SECTOR	FOCUS AREA OF ASSET	JUSTIFICATION FOR PRIORITIZED ADAPTATION NEED
CROSS-SECTORAL *ENABLING ENVIRONMENT*	**Institutional Strengthening**	• Gap: Weak governance due to a lack of a dedicated group for coordinating and implementing infrastructure-related activities. • Action: Establish a Critical Infrastructure Working Group within the Essential Services Cluster (National Cluster System)
CROSS-SECTORAL *ENABLING ENVIRONMENT*	**Regulatory Framework and Policy**	• Gap: There is no national-level framework to provide clear direction, guidance, and coordination for critical infrastructure stakeholders on integrated/coordinated planning, implementation, and performance monitoring of infrastructure. • Action: Develop a National Critical Infrastructure Strategy to provide clear direction and guidance for sector and agency in strengthening resiliency linked to national security frameworks.
CROSS-SECTORAL *ENABLING ENVIRONMENT*	**Regulatory Framework and Policy**	• Gap: There is a lack of standardized risk assessment that can be applied to small and large-scale development within the public and private development investment space. • Action: Develop a standardized risk assessment tool that is applicable to both large and small-scale CI development integrated/aligned to existing national infrastructure investment planning processes.
WATER *ENABLING ENVIRONMENT*	**Regulatory Framework and Policy** **Capacity Building and Resource Provision**	• Gap: Lack of systemized risk-informed water management, monitoring of water extraction, quality, generation and distribution for Village Water Committees. • Action: Develop a Manual of Guidance for Village Water Committees to promote good governance and resilient management practices to improve water security, access, construction, monitoring, and sanitation. • Action: Develop a long-term programme of sustainable groundwater management.
WATER *RAIN WATER HARVESTING*	**Capacity Building**	• Gap: Uncertain water quality from rainwater tanks and limited testing availability. • Action: Develop coordinated and collaborative training programmes to improve quality and education relating to rainwater harvesting.
TELECOMMUNICATIONS *ENABLING ENVIRONMENT*	**Data Management**	• Gap: The regulating body does not deliver effective monitoring and planning, and service providers do not effectively share data. • Action: Communications Department (MEIDECC) to enforce and collect data from service providers and review against set indicators annually and regularly update NDRMO.
ENERGY SECTOR *ENABLING ENVIRONMENT*	**Climate Risk assessment**	• Gap: Climate change and natural hazard considerations are not fully accounted for in energy sector planning, design, operations, emergency response and investment planning. • Action: Conduct an in-depth study of climate change and hazard risks posed to power, gas, and fuel systems and infrastructure in Tonga.
ENERGY SECTOR *NATURE-BASED SOLUTIONS*	**Infrastructure Protection**	• Gap: Power network assets located along exposed coastlines are at risk of coastal inundation, storm surges, and tsunamis so they are often damaged from hazards disrupting power distribution. • Action: Collaborate with existing climate change and environment coastal protection initiatives that are nature-based i.e. mangrove planting along shores.
TRANSPORT *ROADS*	**Exposed Roads**	• Gap: Increasing inundation of low-lying areas coupled with inadequate drainage systems continue to damage and increase the risk of damage to roads within the area, disrupting transport and mobility. • Action: Integrating climate adaptation into road infrastructure design, construction, and operations to minimize exposure to all hazards.

The summary of gaps and actions listed above (Table 1) has been further refined into the detailed recommendations presented below. These recommendations were selected by senior government officials as priorities to be addressed and advanced.

CROSS-SECTORAL PRIORITY RECOMMENDATIONS

Development of a National Resilient Critical Infrastructure Strategy

Building resiliency within the critical infrastructure sector against hazards is hampered by weak coordination between institutions and regulatory frameworks that do not fully recognize the interdependencies between critical infrastructure functions. A clear national direction set by the government to build critical infrastructure resilience would benefit Tonga.

ENABLING ENVIRONMENT SUPPORTING ACTIONS
- Create a national framework setting vision and direction for critical infrastructure sectors guiding coordinated planning and coordination among stakeholders contributing to Tonga's overall resiliency.
- Establish and formalize governance processes designed to build resilient critical infrastructure in the country.

EXPECTED OUTPUTS AND IMPACTS
- Strengthened institutional coordination and integrated planning based on risk assessments improving decision-making and policy development within the critical infrastructure sector.

CLIMATE HAZARD
All Hazards

ELEMENTS OF THE ENABLING ENVIRONMENT
Governances, policies, plans and standard operating procedures, risk assessment, data management, stakeholders

INSTITUTIONS
- Lead: PMO (National Planning)
- Support: MEIDECC, AGO

POTENTIAL FINANCING SOURCES
- Government
- Development partner assistance

Establishment of the Critical Infrastructure Working Group

While governances and institutional arrangements exist such as the National Cluster mechanism which can be leveraged to address infrastructure resilience, without a specific working group to coordinate, drive, and implement policy decisions, developing resilient infrastructure would continue to be challenging.

ENABLING ENVIRONMENT ACTIONS
- Update and develop Cluster Terms of References to reflect the establishment of a Critical Infrastructure Working Group nested under the Essential Services Cluster.
- Seek funding for the establishment of a National Critical Infrastructure Coordinator.

EXPECTED OUTPUTS AND IMPACTS
- Strengthened institutional coordination, improved communications, and information sharing between critical infrastructure sectors and agencies.
- Quick execution of policy decisions and their implementation.

CLIMATE HAZARD
All Hazards

ELEMENTS OF THE ENABLING ENVIRONMENT
Governances, policies, staffing, organizational structures.

INSTITUTIONS
- Lead: MEIDECC (NDRMO)
- Support: Ministry of Finance

POTENTIAL FINANCING SOURCES
- Government
- Development partner assistance

Establish a Central Disaster Data Centre

Consistent, reliable and updated data has been highlighted by government and private sector as a shared weakness that impacts risk-informed decision-making. A unified approach and appropriate resourcing are necessary where climate change and hazard data and scenario modelling are centrally housed allowing access and shared use.

ENABLING ENVIRONMENT ACTIONS
- Establish a centralized data centre with appropriate systems, resourcing, and capacity development of staff for the collection of hazard data and information and made available for critical infrastructure sector and agencies.
- Develop and update necessary supporting regulatory frameworks, organizational structure, policies to facilitate the establishment of a data centre i.e. National Integrated Geospatial Action Plan 2023 – 2027 to strengthen geospatial information management in Tonga.

RECOMMENDED INVESTMENTS
- Allocation of funds for the establishment of the Centre and its resourcing.

EXPECTED OUTPUTS AND IMPACTS
- Strengthened institutional coordination and integrated planning based on risk assessments improving decision-making and policy development within the critical infrastructure sector.

CLIMATE HAZARD
All Hazards

ELEMENTS OF THE ENABLING ENVIRONMENT
Governances, policies, plans and standard operating procedures, risk assessment, data management, capacity development

INSTITUTIONS
- Lead: MEIDECC (NDRMO),
- Support: MLSNR, Statistics Dept.

POTENTIAL FINANCING SOURCES
- Existing Projects
- Government
- Climate Change grants
- Development partner assistance

WATER SECTOR PRIORITY RECOMMENDATIONS

Develop Programmes to Improve Water Quality and Education

Water quality for urban areas is managed by the TWB, with village water under the Ministry of Health. There is no clear quality control on privately owned rainwater catchments. Overall, the fragmented responsibilities coupled with capacity issues result in water quality uncertainty, especially with potable water. Further awareness surrounding water quality and factors that affect water quality, including sustainable water use practices would benefit from increased awareness and training.

ENABLING ENVIRONMENT ACTIONS
- Develop and update sectoral policies to align and clarify roles and responsibilities for water education and awareness.
- Create standardized curriculum for education and awareness targeting schools, and communities.
- Identify training partners (NGOs and Civil Societies) to deliver training and awareness programmes.

EXPECTED OUTPUTS AND IMPACTS
- Education and awareness programmes delivered in various settings improving water usage and practices that pollute water sources.

CLIMATE HAZARD
All Hazards

ELEMENTS OF THE ENABLING ENVIRONMENT
Policies, plans and standard operating procedures, risk assessment, data management, capacity development

INSTITUTIONS
- Lead: Ministry of Health
- Support: MLSNR, MORDI, TWB, MEIDECC

POTENTIAL FINANCING SOURCES
- Existing Projects
- Government
- Climate Change grants
- Development partner assistance

Develop a Village Water Committee Manual of Guidance

About 65% of the Tongatapu population live in rural areas where water extraction and distribution are managed by a Village Water Committee (VWC) under the Water Regulations (Public Health Act). While VWC is the authority, its members are appointed from the village with no formalized system of management or operational budget. VWCs predominantly do not have the capacity and capability to efficiently manage and operate village water.

ENABLING ENVIRONMENT ACTIONS
- Selection of appropriate villages for trial of concept.
- Engagement of support for the development of the Manual of Guidance including necessary supporting policies and training.
- Develop and update sectoral policies i.e. National Water Sector Plan to align and clarify roles and responsibilities of regulating authorities and Committees to improve coordination and planning of water sector interventions.
- Strengthen coordinating mechanisms to support integrated planning and implementation of sector development plans.

RECOMMENDED INVESTMENT
- Resourcing for the development of training and tools for VWCs to function and carry out their responsibilities under the Guidance.

EXPECTED OUTPUTS AND IMPACTS
- Efficient functioning management system in place to improve water access, quality, and distribution reducing water disruption rates.
- Improved data collection at the village level to improve VWC and community development planning regarding water interventions.

CLIMATE HAZARD
Drought, Flood, Cyclone

ELEMENTS OF THE ENABLING ENVIRONMENT
Governances, policies, plans and standard operating procedures, risk assessment, data management, capacity development

INSTITUTIONS
- Lead: MEIDECC (NDRMO),
- Support: MLSNR, Ministry of Health, Tonga Water Board, Local Government (PMO).

POTENTIAL FINANCING SOURCES
- Existing Projects
- Government
- Climate Change grants
- Development partner assistance

ENERGY SECTOR PRIORITY RECOMMENDATIONS

Conduct a Study on Climate Change and Hazard Risks Posed to Power, Gas and Fuel

Tonga remains largely dependent on fossil fuels, with the energy sector having the most significant cascading impact on other infrastructure and the overall economy. While sector Plans acknowledge climate change and promote the use of renewable energy, a more in-depth study is needed to fully understand the physical and operational vulnerabilities of the sector to climate change. This analysis, based on climate and hazard data, would help guide future investments and strengthen the sector's resilience.

ENABLING ENVIRONMENT ACTIONS
- Engage the scientific community and academic institutions
- Update policies and plans embedding resilience considerations into planning and operational activities including design guidelines reflecting updated hazard and climate change data.

EXPECTED OUTPUTS AND IMPACTS
- Improve project prioritization avoiding the highest impact on services and other critical functions.
- Identify investments based on the greatest impact on reducing service disruptions.

CLIMATE HAZARD
All Hazards

ELEMENTS OF THE ENABLING ENVIRONMENT
Governances, policies, plans and standard operating procedures, risk assessment, data management, capacity development

INSTITUTIONS
- Lead: MEIDECC (Energy Dept.)
- Support: Tonga Power, MLSNR

POTENTIAL FINANCING SOURCES
- Existing Projects
- Government
- Climate Change grants
- Development partner assistance

Protect Power Network Assets along Exposed Coastlines using Nature-Based Solutions

Power poles and overhead cable networks that distribute electricity along the northern low-lying coastlines of Tongatapu are exposed to storm surges, coastal inundation and tsunamis.

INVESTMENT RECOMMENDATIONS
- Planting of natural buffers such as mangroves along shore to reduce wave impact on foreshore.

ENABLING ENVIRONMENT ACTIONS
- Sector design standards updated to integrate climate change and hazard risks.
- Climate resilience integrated into infrastructure development risk assessments.

EXPECTED OUTPUTS AND IMPACTS
- Reduce exposure and ensure flood protection of power assets along coastlines.
- Protect road infrastructure along same coastlines.

CLIMATE HAZARD
Cyclone, Flood, Tsunami

HAZARD IMPACT ON ASSET AND SERVICES
- Energy supply to 20,000 people at risk

ASSETS
- Power poles
- Transformers
- Overhead power cables (LV and HV)

INSTITUTIONS
- Lead: MEIDECC
- Support: Tonga Power Board, Ministry of Public Enterprise, Climate Change Dept.

POTENTIAL FINANCING SOURCES
- Existing Projects
- Government
- Climate Change grants
- Development partner assistance

TELECOMMUNICATIONS SECTOR PRIORITY RECOMMENDATIONS

Collect Service Provider Data and Review Against Set Indicators

The Disaster Connectivity Map (DCM) is an existing initiative mapping tool providing real-time or near real-time information on the coverage and quality of telecom connectivity on the ground before, during and after a disaster. This supports decision-making about where telecommunications need to be restored. Telecom/ICT network and service providers, including, mobile, satellite, cable, trunked radio, and radio and television broadcasters, should develop vulnerability analyses for the critical infrastructure of their networks and provide the relevant data to update the DCM. This should be

supported through the establishment of appropriate regulations to ensure that service providers collect, maintain, and provide this data when requested by MEIDECC (NDRMO).

ENABLING ENVIRONMENT ACTIONS
- Collect and communicate network vulnerability analyses from service providers on a regular basis and inform NDRMO (Data Centre).
- Update the Tonga Emergency Telecommunications Plan (NETP) and submit it for approval.
- Align the NETP with the current development of the National Disaster Risk Management Plan by the NDRMO and other national policies including the Early Warning System Policy and Sector-specific policies and plans.

EXPECTED OUTPUTS AND IMPACTS
- Strengthened institutional coordination and integrated planning based on risk assessments improving decision-making and policy development within the critical infrastructure sector.

CLIMATE HAZARD
All Hazards

ELEMENTS OF THE ENABLING ENVIRONMENT
Governances, policies, plans and standard operating procedures, risk assessment, data management, capacity development

INSTITUTIONS
- Lead: MEIDECC (NDRMO),
- Support: MLSNR, Statistics Dept.

POTENTIAL FINANCING SOURCES
- Existing Projects
- Government
- Climate Change grants
- Development partner assistance

TRANSPORT SECTOR PRIORITY RECOMMENDATIONS

Integrate Climate Adaptation and Resilience Measures into Road Infrastructure Design, Construction, and operation to Minimize Exposure to All Hazards

Frequent rainfall projection for Tonga is expected to increase in the future. Increasing inundation of low-lying areas within the Nuku'alofa area coupled with inadequate drainage systems continue to damage and increase the risk of damage to roads within the area disrupting transport and mobility.

ENABLING ENVIRONMENT ACTIONS
- Capacity building and integration of climate change research to support resilient design and construction of roads.
- Update the road design manual to reflect future projections on rainfall frequency.

EXPECTED OUTPUTS AND IMPACTS
- Reduced disruption to road transport, access to emergency services and economic services reliant on road transportation.
- Reduced impact of flooding on roads, transportation systems, and surrounding settlements.

CLIMATE HAZARD
Flood, Cyclone

ELEMENTS OF THE ENABLING ENVIRONMENT
Policies, plans, design standards, risk assessment, data management.

INSTITUTIONS
- Lead: MOI
- Support: MLSNR, MEIDECC

POTENTIAL FINANCING SOURCES
- Existing Projects
- Government
- Climate Change grants
- Development partner assistance

PART I. INTRODUCTION & COUNTRY CONTEXT

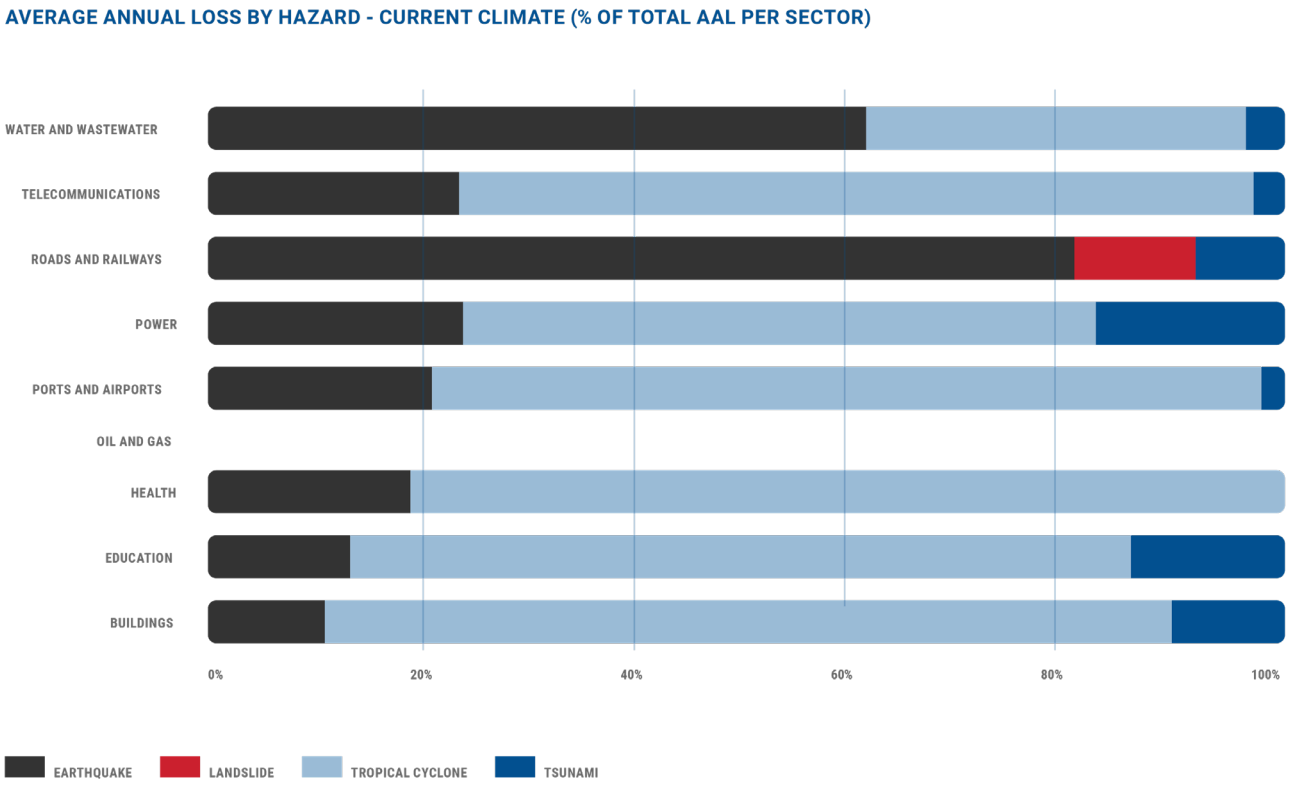
The Kingdom of Tonga is an archipelago of 172 low and raised coral and volcanic islands, covering a total area of 747 km². The islands sit atop two parallel submarine ridges running 50 km from southwest to northwest. Coral islands form on the eastern ridge, while volcanic islands, some still active, lie along the western ridge. Of the 172 islands, 36 are inhabited by 100,179 people across 18,817 households[3].

Residential distribution and infrastructure assets are mainly located in the coastal zone. Approximately 74% of the population resides on the main island, Tongatapu, and 34% are urban dwellers, living in Nuku'alofa, Kolomotu'a, Kolofo'ou, Ma'ufanga, and nearby villages.

Economically, Tonga is a lower middle-income nation with a constrained economy due to its geographic isolation, small market size, limited financial resources, and the high cost of basic services.[4,5] The economy is sensitive to external shocks as it is highly dependent on climate-sensitive sectors such as agriculture, fisheries, and tourism and has a limited resource base.

Disasters are also causing significant costs to the infrastructure assets, estimated at 12 million USD according to CDRI's Global Infrastructure Risk Model and Resilience Index (GIRI). Strengthening the resilience of Tonga's infrastructure is thus paramount to reducing losses and limiting long-term economic impact.

Figure 1. Expected Average Annual Loss by hazard under current climate conditions. Source: Global Infrastructure Risk Model and Resilience Index (GIRI), 2024.



3. Population and Housing Census | Tonga Statistics Department, https://tongastats.gov.to/census-2/
4. Kingdom of Tonga Disaster Management Reference Handbook. (2023) (ISBN 978-1-46-7), https://www.cfe-dmha.org/
5. Centre for Excellence in Disaster Management and Humanitarian Assistance, https://www.cfe-dmha.org/

The Roadmap for Infrastructure Resilience in the Kingdom of Tonga has been developed with this objective in mind and aims to strengthen the capacity of infrastructure systems. The underlying focus is to ensure that essential critical functions and services provided by infrastructure systems, which underpin the economic development and social well-being of the country, are capable of withstanding or rapidly recovering from disasters.

The Roadmap also targets enhancing the coordination across sectors, policymakers, regulators, owners and operators. Infrastructure systems are often interdependent, so vulnerabilities in one sector can trigger cascading effects in others. For example, if a disaster affects the energy sector, this impact can hinder water distribution, communication, and healthcare services. It is therefore important to better manage these interdependencies to ensure more effective and integrated resilience strategies.

PART II.
METHODOLOGY

The approach used to develop the Roadmap for Resilient Infrastructure in the Kingdom of Tonga is grounded in the 'Global Methodology for Infrastructure Resilience Review' (GMIRR) created by the United Nations Office for Disaster Risk Reduction (UNDRR) and the Coalition for Disaster Resilient Infrastructure (CDRI).

This participatory methodology is designed to help countries assess the current state of their infrastructure resilience, pinpoint areas for improvement, and guide actions. It does so by:

- Reviewing the resilience of infrastructure systems to various hazards (e.g. climatic, geological, and technological), using new data sources where possible;
- Examining interdependencies and cascading risks, where the failure of one infrastructure system component triggers failures in other systems;
- Identifying key measures to enhance infrastructure resilience and develop an action plan to address them effectively.

The review process involved the following key methodological components:

Mapping of institutional governance and policy review: This required identifying key stakeholders in infrastructure development, disaster risk reduction, and sectoral operations, followed by a review of existing policies and regulations to assess their adequacy in addressing disaster risks and supporting resilient infrastructure systems.

Stress testing and gap analysis conducted on ten critical infrastructure functions to identify vulnerabilities, interdependencies, and cascading risks through the following steps:

- Identification of key sectors and critical functions: This process highlighted the critical role of infrastructure functions in maintaining the country's functionality and supporting its socio-economic development.
- Hazard and risk profiling: A list of relevant hazards was identified and assessed considering their historical impacts as well as the likelihood and potential impacts of each hazard, particularly in the context of climate change.
- Economic impact and linkages: The analysis extended to the relationship between infrastructure services and key sectors of Tonga's economy. By understanding how infrastructure functions support economic activities, the methodology provides insights into how disruptions in infrastructure services can propagate through the economy, affecting industries such as agriculture, manufacturing, and other key sectors.
- Interdependencies and risk analysis: Recognizing that the failure of one system can trigger failures in others, the emphasis on analysing interdependencies among infrastructure systems helped us to understand and develop plans to mitigate risks.

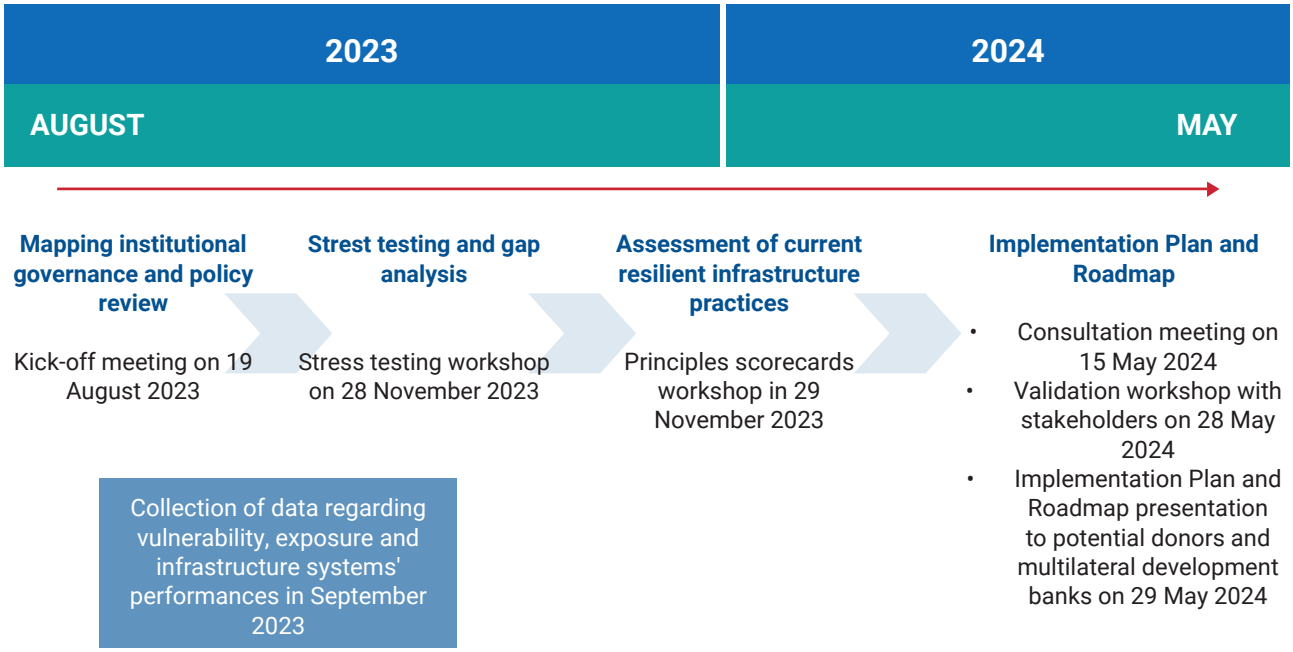
Assessment of current resilient infrastructure practices using the Principles for Resilient Infrastructure: The methodology is anchored in globally recognized principles for resilient infrastructure developed by UNDRR and consulted with over 100 countries. The principles guide policymakers to adopt resilient practices tailored to Tonga's unique risk landscape.

Implementation Plan and Roadmap: The entire process culminates in the drafting of implementation plans, consolidating the findings, and providing a roadmap for enhancing infrastructure resilience. The plan is validated through a stakeholder workshop and consultations to ensure broad support and alignment with national priorities.

See Annex IV. Activities and Consultations for more details.

A technical working group was established with stakeholders working on different aspects of infrastructure in Tonga to support the assessment. The technical working group was made up of 21 departments and agencies across six ministries. With the support of this working group, the review process commenced in August of 2023 with a kick-off meeting convening stakeholders from relevant government departments, ministries, and private sector agencies. The timeline of project activities is depicted in Figure 2 below.

Figure 2. Timeline of Tonga's Infrastructure Resilience Review Process.



The analysis and results were reviewed and discussed by the technical working group and the recommendations were developed to address infrastructure resiliency in Tonga. The following sections outline the analysis, findings and recommendations developed as part of this roadmap.

Institutional Mapping

The first component of institutional mapping is to review the institutional arrangements, their mandates and functions, roles and responsibilities, and draw a list of the main infrastructure actors in the country that can have an impact on disaster risk reduction and climate change adaptation. The review looked at cross-cutting sectors along the lines of DRR responsibilities, cross-sectoral coordination for infrastructure systems, and planning that include zoning and land-use plans, and critical infrastructure networks. The sector-wise institutional mapping was carried out along four major functions of an entity:

- **Policymakers** (often the Government) can initiate changes to national policy for infrastructure resilience, allocate the necessary funding to resilience-building activities, and require that the tendering process for infrastructure projects gives appropriate weighting to resilience considerations.
- **Regulators** can monitor disruptions to critical services, ensure adherence to codes and standards, require operators to improve their resilience and introduce obligations on infrastructure operators to develop and maintain long-term resilience strategies.
- **Operators** can monitor their capacity to absorb disruptions caused by different types of hazards and retrofit improvements that improve their ability to absorb future ones.
- **Owners** can raise infrastructure-resilience standards, invest in skills and capacity to achieve infrastructure resilience and require operators to assess potential hazards.

Policy and Regulatory Review

The second component involved reviewing policy and regulatory frameworks on disaster risk reduction and climate change adaptation in relation to infrastructure. The adequacy of policy and regulations for DRR within sectors as well as cross-cutting themes, directly determine the quality of assets and services, the effectiveness of public spending, and the incorporation of resilience measures. This review process, therefore, aims at identifying the relevant policies and regulations, which can influence the resilience of infrastructure systems in a country, as well as their key DRR components.

A number of key cross cutting policy frameworks and sector specific plans were reviewed and analysed in identifying priority gaps and recommendations.

Stress Testing Critical Infrastructure

The third component to develop the Roadmap is conducting a stress testing analysis on ten critical infrastructure functions to identify vulnerabilities and interdependencies. For Tonga, energy, transport, water and wastewater, and telecommunications were selected. These infrastructure systems serve as an essential backbone for the effective socioeconomic functioning of a country by providing indispensable functions and services.

From these infrastructure systems, ten key functions were assessed as part of a stress testing exercise, including:

1. **Supply water/water management;**
2. **Build and maintain ports, harbours, and airports;**
3. **Build and maintain roads;**
4. **Generate and distribute electricity;**
5. **Safe data connections;**
6. **Radio broadcast for emergency;**
7. **Evacuation centres;**
8. **Store fuel and maintain reserves;**
9. **Build and maintain healthcare facilities;**
10. **Provide educational services.**

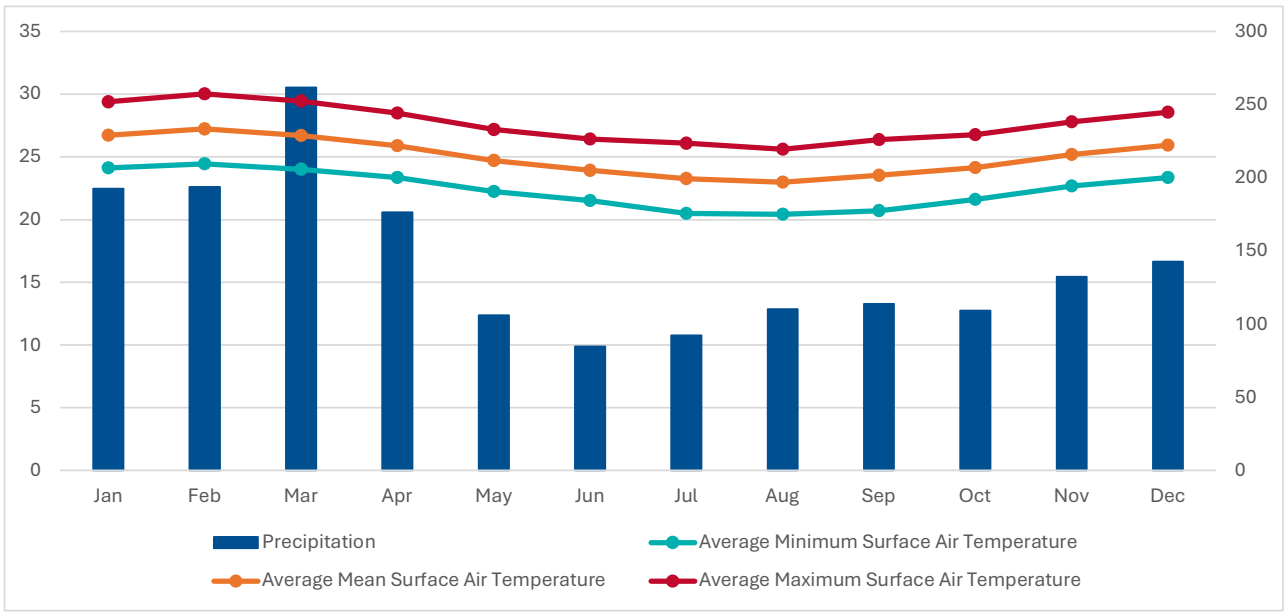
A. Tonga's Risk Profile

The stress test analysis included selecting and analysing the ten most relevant hazards to evaluate how infrastructure functions respond to multiple hazards simultaneously. This requires a good understanding of Tonga's risk profile.

In Tonga, volcanos are a key risk factor. There are 21 (submarine and terrestrial) volcanos, 7 of which erupted in the last 20 years, and 2% of the population live less than 30 km from a volcano.[6] In 2022, the Hunga-Tonga-Hunga-Ha'apai volcanic eruption and the resulting tsunami severely damaged the nation's critical infrastructure, underlining the cascading effects of such failures on essential services like water, electricity, and telecommunications. This disruption not only affected daily life but also had a profound impact on the economy, with damage equivalent to 18.5% of Tonga's GDP.[7]

Tonga also experiences a tropical climate with a wet, cyclone-prone season from November to April. Around 75% of the hazards that have affected Tonga since 1980 are tropical cyclones.[8] The El Niño Southern Oscillation (ENSO) also significantly influences Tonga's climate, impacting the frequency of droughts, floods, tropical cyclones, and coral bleaching. ENSO's effects extend to agriculture, ecosystems, water resources, health, and disaster risk management.[9]

Figure 3. Average monthly mean, max, and min temperatures and rainfall in Tonga 1991-2000.



6. *Pacific Risk Profile Tonga, Australian Aid, https://tinyurl.com/5n7ywwh5*
7. *Tonga Volcanic Eruption and Tsunami: World Bank Disaster Assessment Report Estimates Damages at US$90M, https://tinyurl.com/34ar8hu5*
8. *Public EM-DAT platform. (n.d.), https://public.emdat.be/data.*
9. *Department of Climate Change (MEIDECC). (2018). Joint National Action Plan 2 on Climate Change and Disaster Risk Management 2018 - 2028. Government of Tonga.*

As described in step 3 of the GMIRR, it is proposed to identify 10 relevant hazards for Tonga to be considered in the analysis. The goal is to create a broad yet manageable list, avoiding excessive detail that would complicate the analysis. For the Kingdom of Tonga, the 10 following hazards were selected:

CYCLONE	Tonga averages 17 tropical cyclones per decade, mostly between November and April, with higher frequency during El Niño years. From 1970 to 2020, 72 storms passed within 300 km of Nuku'alofa. Over the last 40 years, Tonga has been severely impacted by nine major storms, roughly one every four to five years. PCRAFI estimates annual cyclone-related damages at USD 9.5 million. While tropical cyclone frequency in the Southeast Pacific is expected to decrease in the 21st century, most projections show either no change or a decline in cyclone formations.[10]
DROUGHT	Droughts in Tonga, though infrequent, have serious impacts on agriculture, water resources, and food security. Four major droughts occurred between 1983 and 2015, often linked to El Niño. Droughts have reduced harvests of key crops, with squash exports dropping by 52% in 1998 and 69% in 2014. They also strain drinking water supplies, as most Tongans rely on rainwater collection. During the 1997-1998 El Niño, the government had to ship water to islands in the Ha'apai group.[11]
SEAWATER INTRUSION	Rising sea levels and storm surges during tropical cyclones lead to saltwater intrusion, contaminating groundwater and reducing the quality and quantity of freshwater. Since 1993, Tonga's sea level has risen by 6.4 mm per year. Increased salinity in groundwater has been observed during droughts, driven by sea level rise, saltwater intrusion, and over-pumping of aquifers.[12]
TSUNAMI	Tonga's low-lying islands with their proximity to tectonic plate boundaries are highly vulnerable to tsunamis, which can strike with little warning and cause widespread devastation. The economy, heavily dependent on coastal infrastructure, agriculture, and tourism, is particularly exposed to these risks. A major tsunami could severely damage vital infrastructure, including ports, roads, and homes, leading to significant economic losses and disrupting livelihoods. Given Tonga's limited resources for recovery, proactive tsunami risk assessment is crucial to safeguarding its people, economy, and long-term resilience.
VOLCANIC ERUPTION	Tonga, located in the Pacific "Ring of Fire", is highly vulnerable to volcanic eruptions, with Hunga Tonga-Hunga Ha'apai being a notable active volcano. The significant eruption in 2022 caused extensive ash fallout, tsunamis, and widespread damage across Tonga and neighbouring islands. This risk is heightened by limited resources for disaster preparedness, underscoring the need for improved risk management strategies. According to UNDRR, enhancing local capacities and infrastructure resilience is essential for Tongan communities facing geological hazards (UNDRR, 2022).[13]
NON-COMMUNICABLE DISEASES	Tonga has one of the highest rates of non-communicable diseases (NCDs) in the world. NCDs, such as cardiovascular disease, cancers, diabetes and chronic respiratory diseases, account for approximately 80% of deaths in Tonga.[14] NCDs are estimated to account for 83% of all deaths in Tonga.[15]
LAND DEGRADATION & EROSION	Land degradation and erosion in Tonga pose significant environmental challenges, driven by climate change and unsustainable land-use practices. Deforestation, agricultural expansion, and urban development have resulted in soil erosion and decreased land productivity. Coastal areas are particularly at risk, facing rising sea levels and more intense storms, exacerbating erosion. Effective management strategies are essential for mitigating these risks and enhancing the resilience of Tonga's ecosystems and agriculture.[16]
FLOOD	Analysis from the World Bank's Climate Change Knowledge Portal highlights that multi-day rainfall increases the risk of widespread flooding compared to single-day events. The 5-day cumulative rainfall indicator tracks maximum rainfall expected once in 25 years, with changes potentially impacting infrastructure, safety, and water quality. Understanding these shifts is crucial for mitigating risks.[17]
SEA LEVEL RISE	Tonga was ranked the third most at-risk country for natural hazards and sea level rise in the 2021 World Risk Report. A sharp rise in sea levels could devastate public infrastructure, including the waterfront capital, Nuku'alofa. The 2022 volcanic eruption and tsunami caused $90 million in damages (18.5% of GDP) and highlighted the potential impacts on infrastructure, tourism, and key sectors like agriculture and fishing. Early data suggests Tonga needs to raise its sea walls by another meter to better protect against future tsunamis.[18]
CYBERSECURITY BREACH	Tonga faces increasing cybersecurity risks as it adopts more digital infrastructure, with limited resources making it vulnerable to cyberattacks that could disrupt services and compromise data. The International Telecommunication Union (ITU) highlights the need for stronger cybersecurity policies and investment to address these vulnerabilities.[19]

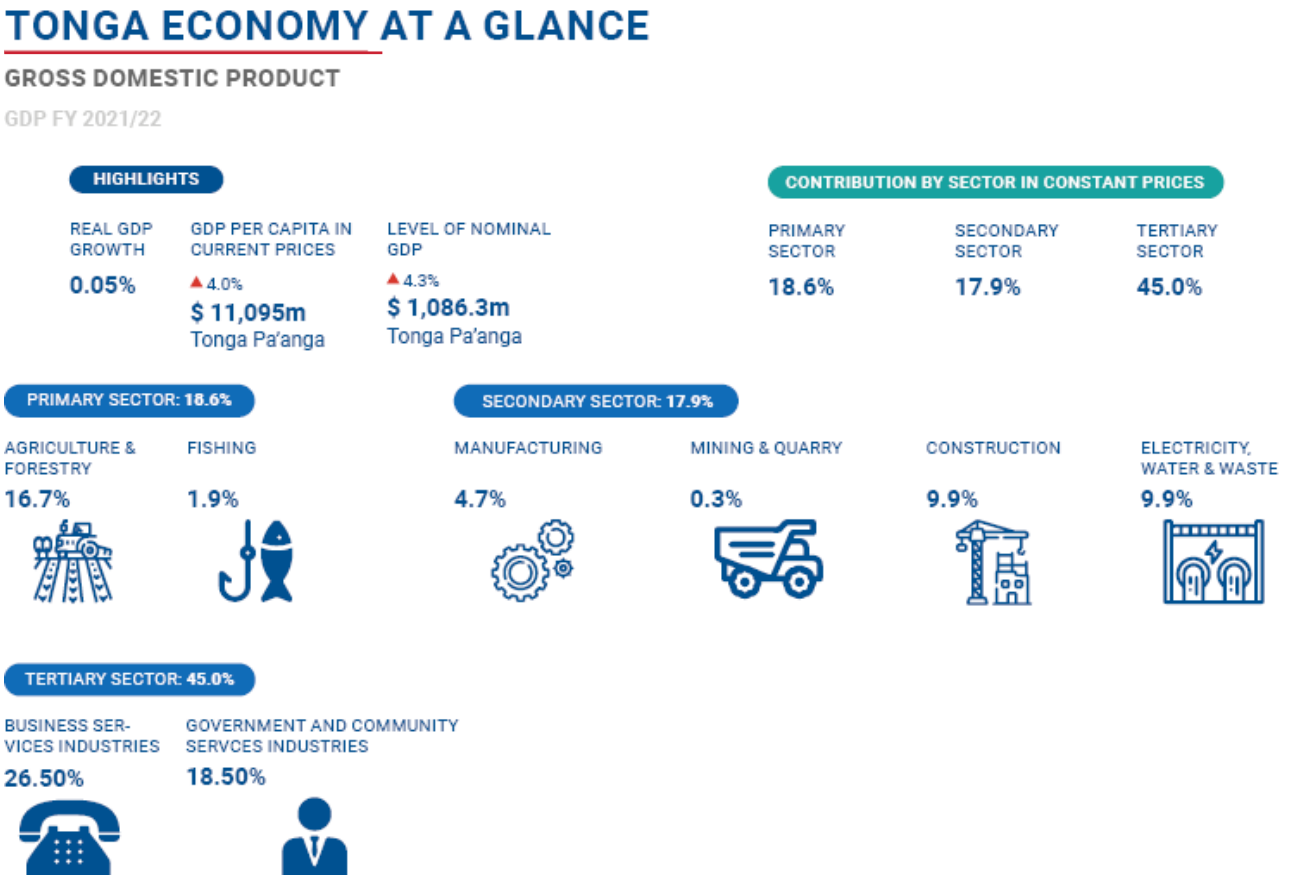
10. *Disaster Risk Reduction in the Kingdom of Tonga, UNDRR, 2022, https://www.undrr.org/media/83687/download?startDownload=20240924*
11. *Economic Impacts of Natural Hazards on Vulnerable Populations in Tonga, UNCDF, 2020, https://tinyurl.com/2ueuv6u6*
12. *Climate Risk Management in Water Sector in Tonga, SPREP, 2018, https://tinyurl.com/3zr84huj*
13. *Disaster Risk Reduction in the Pacific: A Call to Action, UNDRR, 2022, https://www.undrr.org/implementing-sendai-framework/drr-focus-areas/climate-action-and-disaster-risk-reduction*
14. *How communities in Tonga work together for healthier, longer lives, World Bank, 2020, https://tinyurl.com/yckmkjvu*
15. *Noncommunicable diseases Tonga country profile, WHO, 2016, https://cdn.who.int/media/docs/default-source/country-profiles/ncds/ton_en.pdf?sfvrsn=1ca6ba20_43&download=true*
16. *Food and Agriculture Organization (FAO). (2019). Tonga: Country Profile on Land Degradation. https://openknowledge.fao.org/home*
17. *Climate Risk Country Profile Tonga, World Bank, 2021, https://tinyurl.com/ewav7tj8*
18. *Tonga – On the frontline of sea level rise, The Commonwealth, https://tinyurl.com/4dm2sr2w*
19. *International Telecommunication Union (ITU). (2020). Global Cybersecurity Index 2020, https://tinyurl.com/mt6vhjt3*

B. Economic Linkages

Another crucial aspect of the Infrastructure Resilience Review is the examination of the relationship between infrastructure functions and services, and key economic sectors. Recognizing these links helps policymakers better understand the critical role that resilient infrastructure plays in supporting and sustaining these sectors. Due to their overall social and economic importance, the following vital economic industries were identified and assessed based on their contribution to Tonga's GDP and national employment:

1. Agriculture
2. Construction
3. Public administrations
4. Fisheries
5. Tourism
6. Manufacturing
7. Wholesale and Retail
8. Accommodation & Restaurants/bars/cafés
9. ICT
10. Financial services & remittances

Source: Authors, data collected during the workshop carried out following step 3 of the GMIRR



Source: National accounts division, Tonga statistics department

C. Stress Test Exercise

Once the infrastructure functions, economic sectors, and hazards have been defined, the core of the stress testing consists of scoring the links between them to identify key vulnerabilities and economic impacts. This requires considering:

- The level of dependency of each economic industry on each critical infrastructure functions
- The level of impact the selected hazards would have on the critical infrastructure functions
- The level of interdependencies between critical functions, or in other words, the cascading impact if a function fails

The results of the stress testing exercise conducted in Tonga, presented in *Annex I. Stress-test Results,* are used throughout the report to provide insights and evidence for designing appropriate recommendations.

Principles for Resilient Infrastructure

Another key aspect of this analysis is assessing the resilience of Tongan infrastructure using the *Principles for Resilient Infrastructure*.[20] Developed in collaboration with more than 100 governments and international experts, these principles serve as a global reference and form the foundation for the recommendations outlined in this roadmap.

Policymakers can target interventions at different stages of the infrastructure lifecycle to improve resilience. Broadly these lifecycle stages are: before construction (i.e. strategic planning and pipeline prioritization), during delivery (i.e. design, procurement and construction), during operations (operation and maintenance), and at end-of-life. The roadmap considers these different stages to select the most impactful interventions.

To define the roadmap, the rest of the report examines whether resilient practices, as defined in the principles, are already in place in the country and which ones should be improved based on the risks faced by the country and local circumstances. To do this, an assessment of national policies and legislation was carried out using the principles along with a workshop with key stakeholders using a scorecard to assess their current infrastructure practices. Annex II. Review of Policies and Integration of the Principles for Resilient Infrastructure contains detailed results of this analysis. The main findings for each of the principles are presented below.

PRINCIPLE 1 (CONTINUOUSLY LEARNING)

This principle aims to develop and update understanding and insight into infrastructure resilience. The table below illustrates how this principle can be implemented.

20. *For more information, please refer to the Handbook for implementing the Principles for Resilient Infrastructure, https://tinyurl.com/mrx6529r*

Table 2. Lifecycle stage and examples of interventions regarding Principle 1.

LIFECYCLE STAGE	EXAMPLES OF INTERVENTIONS (Number in parenthesis provides the reference to the related action included in the Principles for Resilient Infrastructure publication)
PLANNING	Set up a system to ensure the dissemination of lessons learnt from past disasters to inform future planning (P1.3)
DELIVERY / CONSTRUCTION	Review and validate the climate and disaster scenarios used for infrastructure project preparation and design (P1.1)
OPERATION AND MAINTENANCE	Enhance monitoring, sensing and early-warning systems to minimize outages of critical services (P1.2.) Require operators to carry out regular stress tests to identify vulnerabilities and options for improvement (P1.4)

Disaster policy learning in Tonga is a slow and gradual process. Despite recent progress in legal and policy frameworks, such as the DRM Act and the National DRM Policy, implementation remains a challenge due to limited resources and capacity development. The assessment of institutional arrangements and governance in the critical infrastructure sector, conducted following Steps 1 and 2 of the GMIRR, highlighted that systems and mechanisms for continuous learning are either lacking or, where they do exist, are not being effectively utilized.

PRINCIPLE 2 (PROACTIVELY PROTECTED)

This principle aims to determine and increase the level of hazard/threat preparedness and response. The table below illustrates how this principle can be implemented.

Table 3. Lifecycle stage and examples of interventions regarding Principle 2.

LIFECYCLE STAGE	EXAMPLES OF INTERVENTIONS (Number in parenthesis provides the reference to the related action included in the Principles for Resilient Infrastructure publication)
PLANNING	Develop a pipeline of safety-improvement interventions (P2.1) Identify critical components of national infrastructure systems and prioritize them for necessary upgrades (P2.2.) Establish cross-sectoral planning committees to ensure all infrastructure sectors coordinate efforts and share data about cascading risks (P2.3)
DELIVERY / CONSTRUCTION	Require infrastructure design to include safe-to-fail solutions (e.g., plan for back-up energy-supply solutions and design for hazardous substances controls) (P2.5) Require resilience assessments and interdependency analysis in infrastructure projects (P2.3) Require the development of long-term maintenance plans as part of the initial approval process for infrastructure projects (P2.7) Ensure that project appraisal takes a long-term approach and considers lifecycle costs, including those related to potential disasters (P2.8)
OPERATION AND MAINTENANCE	Build the capacity of local infrastructure operators to deal with disruptions (e.g., drills) (P2.4). Ensure that critical services can be delivered through a diversity of scales: national, regional and local and operationalize redundancy for smaller-scale solutions (P2.6) Establish dedicated funds specifically for ensuring proper maintenance (P2.7)

Over the past 15 years, Tonga's emergency and disaster legal and policy frameworks have evolved, from the Emergency Management Act of 2010 to the more recent Disaster Risk Management Act of 2023, which places a stronger focus on preparedness and mitigation. This shift is evident in the progress made within the country's critical infrastructure sector. However, there remains a need for a deeper understanding of infrastructure interdependencies and network connections, along with the development of coordinated multi-agency emergency plans, which have been identified as high-priority areas.

PRINCIPLE 3 (ENVIRONMENTALLY INTEGRATED)

This principle aims to work in a positively integrated way with the natural environment. The table below illustrates how this principle can be implemented.

Table 4. Lifecycle stage and examples of interventions regarding Principle 3.

LIFECYCLE STAGE	EXAMPLES OF INTERVENTIONS (Number in parenthesis provides the reference to the related action included in the Principles for Resilient Infrastructure publication)
PLANNING	Promote the use of environmental information in infrastructure planning (P3.3)
DELIVERY / CONSTRUCTION	Conduct audits to control the environmental impacts of infrastructure systems (P3.1) Include in project preparation documents an evaluation of the cost benefits of environmental solutions in comparison to other conventional or grey alternatives (P3.2) Identify local resources and encourage their use for infrastructure projects through selection criteria in procurement (P3.5)
OPERATION AND MAINTENANCE	Lay down policies and regulations so that contractors and operators maintain the surrounding natural environment to reduce the threat of disruptions to critical services (P3.4)

The Environment Management Act of 2010, which ratifies several key international conventions on environmental protection and climate change, has been a crucial factor in safeguarding Tonga's environment. Notably, it introduced the Environmental Impact Assessment (EIA) as a mandatory requirement for all development projects, significantly enhancing environmental protection efforts in the country.

PRINCIPLE 4 (SOCIALLY ENGAGED)

This principle aims to develop active engagement, involvement and participation across all levels of society. The table below illustrates how this principle can be implemented.

Table 5. Lifecycle stage and examples of interventions regarding Principle 4.

LIFECYCLE STAGE	EXAMPLES OF INTERVENTIONS (Number in parenthesis provides the reference to the related action included in the Principles for Resilient Infrastructure publication)
PLANNING	Define guidelines for providing clear emergency messages (e.g., select the lowest literacy level for emergency messages that are compatible with the literacy level of the population) (P4.1)

LIFECYCLE STAGE	EXAMPLES OF INTERVENTIONS (Number in parenthesis provides the reference to the related action included in the Principles for Resilient Infrastructure publication)
DELIVERY / CONSTRUCTION	Ensure contractors and operators incorporate appropriate channels for emergency communications in the project design (P4.1)
OPERATION AND MAINTENANCE	Define obligations for infrastructure sectors to adopt incentive policies or strategies for demand reduction, demand shifting, or demand avoidance (P4.3) Promote education about resiliency, taking advantage of formal education programmes and local media, depending on the target audience (P4.2) Encourage operators to develop community participation programmes (P4.4)

Community and stakeholder consultation has increasingly become an expected and formal component of public policy development in Tonga. Communities have become more involved in the policy-making process, and community engagements have seeped into these processes. However, incentive programmes aimed at reducing demand-based critical service disruptions can be improved.

PRINCIPLE 5 (SHARED RESPONSIBILITY)

This principle aims to share information and expertise for coordinated benefits. The table below illustrates how this principle can be implemented.

Table 6. Lifecycle stage and examples of interventions regarding Principle 5.

LIFECYCLE STAGE	EXAMPLES OF INTERVENTIONS (Number in parenthesis provides the reference to the related action included in the Principles for Resilient Infrastructure publication)
PLANNING	Engage with stakeholders and experts to select or devise information-sharing standards and incorporate them into regulation and law (P5.1) Work with stakeholders and experts to encourage multi- and trans-sectoral collaboration for better infrastructure resilience (P5.2) Develop and formalize data-security regulations for infrastructure resilience (P5.5)
DELIVERY / CONSTRUCTION	Collect construction and operational data formatted in compliance with relevant standards (P5.1)
OPERATION AND MAINTENANCE	Creates and utilizes data-sharing platforms with sufficiently robust communication channels to disseminate information to relevant stakeholders effectively (P5.4) Collate and share data rapidly during disruptions to enable a coordinated response (P5.4).

Although progress has been made in establishing shared responsibilities and accountabilities, further improvements for enhancing connectivity for information sharing and data safety are needed. For example, there is a need for harmonized open-data standards and greater collaborative management both between and within critical infrastructure sectors.

PRINCIPLE 6 (ADAPTIVELY TRANSFORMING)

This principle aims to adapt and transform to changing needs. The table below illustrates how this principle can be implemented.

Table 7. Lifecycle stage and examples of interventions regarding Principle 6.

LIFECYCLE STAGE	EXAMPLES OF INTERVENTIONS (Number in parenthesis provides the reference to the related action included in the Principles for Resilient Infrastructure publication)
PLANNING	Monitor demand and ensure that capacity can meet expected future demand either through demand reduction or increasing capacity (P6.4)
DELIVERY / CONSTRUCTION	Design systems according to local resources and capacity (P6.1) Provide designs that allow usage to be measured and enable future changes to capacity (P6.2)
OPERATION AND MAINTENANCE	Monitor compliance with override capacity requirements allowing for human discretion, and report on non-compliance (P6.5)

The adaptive capacities of critical assets require a greater level of attention to enable reliable operations during hazards and disruptive events. During the workshop, stakeholders identified "flexible management" as a high-priority area for improvement, while "choosing manageable solutions" was identified as a low priority.

The results of the analyses are presented in the following sections under: Part III. Cross-sector analysis and Part IV. Sectors vulnerabilities and resilience.

PART III.
CROSS-SECTORAL ANALYSIS

Disaster resilience initiatives are often fragmented, with individual sectors sometimes focusing narrowly on their own initiatives and responsibilities, without fully appreciating the wider consequences. A cross-sectoral approach addresses these issues, enhancing both coordination and collaboration, while ensuring more efficient use of resources.

Policy and Institutional Framework

Disaster Risk Reduction (DRR) involves a broad range of processes, actors, and stakeholders. Since 2007, Tonga's National Emergency Management Office (NEMO) has led DRR coordination and, in 2015, assumed responsibility for the national cluster system, which follows the international humanitarian cluster approach advocated by the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA). Tonga's ten clusters (see box 2) unite stakeholders, including government agencies, NGOs, His Majesty's Armed Forces (HMAF), and UN bodies such as WHO and OCHA.[21]

In 2021, Tonga enacted the Disaster Risk Management (DRM) 2021 Act,[22] replacing the nearly two-decade-old Emergency Management Act 2007 and promoting a whole-of-society approach while clarifying the roles of central government stakeholders. Key changes include restructuring the National Disaster Risk Management Organization (NDRMO) to accommodate increased responsibilities in the functional areas of disaster risk and resilience, policy advice, emergency operations, administration and finance, and donor and development partner engagement.

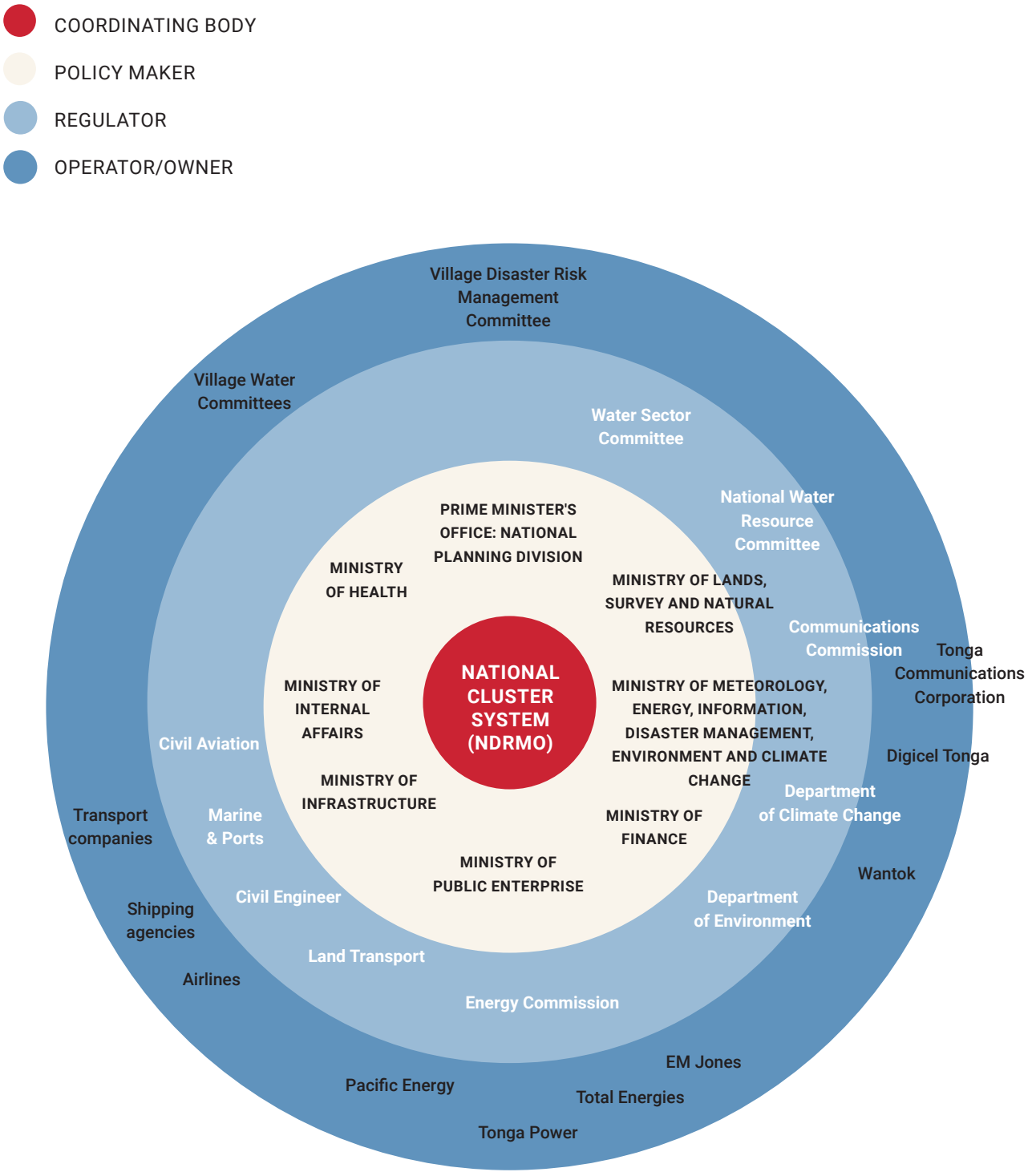
The National Spatial Planning and Management Act 2012 regulates Tonga's spatial development, ensuring the fair, orderly, economical, and sustainable use of land, along with the protection of natural and man-made resources, ecological processes, and genetic diversity. It establishes the National Spatial Planning Authority, headed by the Minister for Lands, whose primary responsibility is to enforce the Act's provisions in alignment with its objectives. Furthermore, the Authority plays a key role in coordinating infrastructure development and service delivery across ministries and public authorities, ensuring these efforts benefit the community as a whole.[23]

The National Infrastructure Investment Plan (NIIP) 2013–2023 outlines the Government of Tonga's priorities for key economic infrastructure projects, including energy, telecommunications, water, solid waste management, and transport. Spanning a ten-year period, the plan addresses several key challenges, including the need for a long-term, integrated approach to infrastructure planning and management, as well as a systematic method for identifying future priorities amid budgetary constraints. It emphasizes setting clear priorities, developing sustainable funding mechanisms for infrastructure delivery and maintenance based on sound economic principles, and integrating climate change adaptation and disaster risk management into infrastructure development and operations.[24]

21. *Tonga Disaster Management Reference Handbook, CFE-DM, 2023, https://tinyurl.com/yrkxdphu*
22. *Disaster Risk Management Act 2021, https://tinyurl.com/bdsvbwn8*
23 *National Spatial Planning and Management Act 2012, https://matangitonga.to/sites/default/files/NSPM_Act_2012.pdf*
24. *National Infrastructure Investment Plan (NIIP) 2013 – 2023, https://www.sprep.org/attachments/VirLib/Tonga/national-infrastructure-investment-ilan-2013-2023.pdf*

Following Step 1 of the GMIRR, several key government institutions essential for advancing infrastructure policies and implementation were identified based on their cross-cutting institutional arrangements and governance, including coordination with the NDRMO. This is illustrated in the institutional map in Figure 4 below.

Figure 4. Map of key stakeholders and governance structures within the infrastructure sector. Author: UNDRR-UNOSAT



THE KINGDOM OF TONGA'S NATIONAL CLUSTER COORDINATION STRUCTURE

OCHA

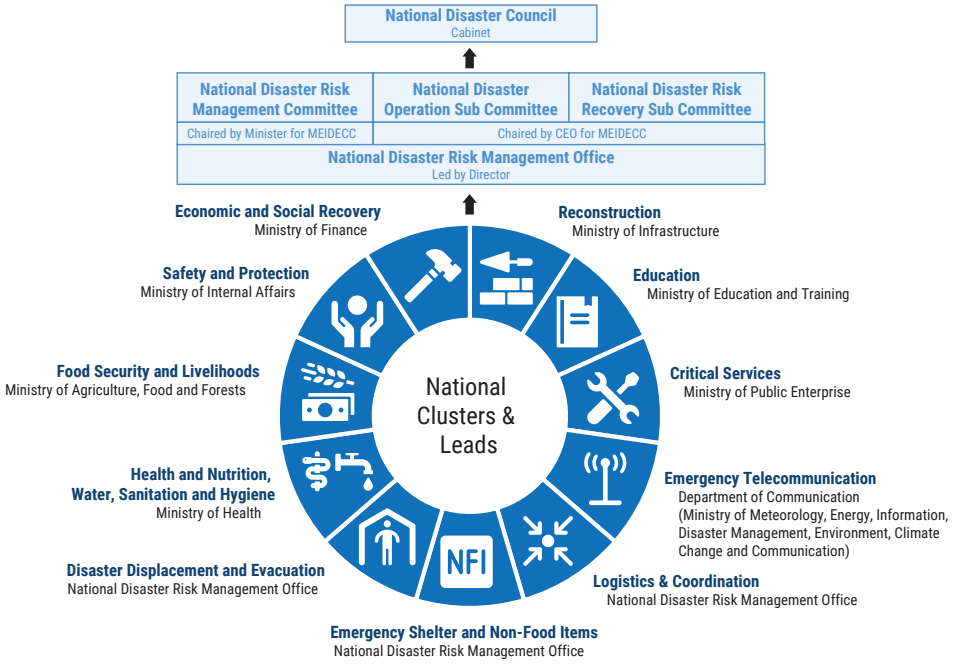
TONGA

Humanitarian Coordination Structure

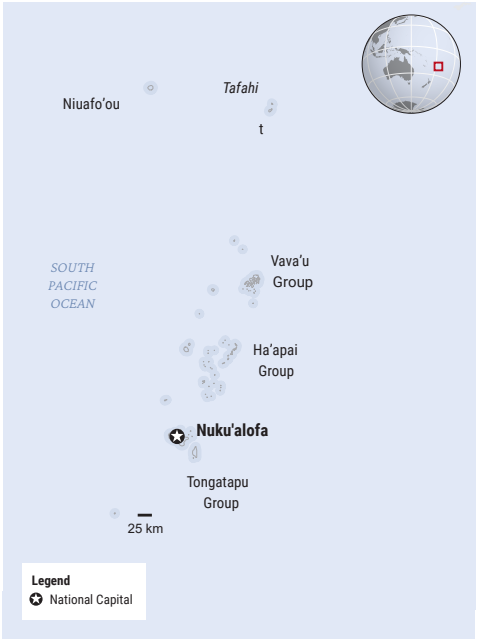
As of 10 July 2024

The Disaster Risk Management Act 2021 (Royal Assented 2023) describes the national framework, structures and committees, and functions and responsibilities of those responding to disaster. It also mandates the National Disaster Risk Management Plan which operationalises the legislative framework via disaster risk reduction and emergency management systems and processes. The National Disaster Council is at the strategic level and oversees three national committees: the National Disaster Risk Management Committee, the National Disaster Operation Sub Committee, and the National Disaster Risk Recovery Sub Committee; all chaired by Minister and CEO for the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communication (MEIDECC). The National Disaster Risk Management Office serves as a secretariat for emergency committees together with the Act. Tonga endorsed the cluster system in 2015. Its first activation occurred the same year when Tropical Cyclone Ian made landfall in the Ha'apai group.

National Coordination Structure



Location Map



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Creation date: 10/07/2024 **Sources:** National Disaster Risk Management Office, Government of Tonga OCHA/ReliefWeb **Feedback:** ochapacific@un.org www.unocha.org www.reliefweb.int

National Sectors
National Lead Ministry/ Authority

Photo credit. POIS Christopher Szumlanski-Australian Defence Force via AP

Cross-Sector Interdependencies and Cascading Risks

It is crucial to consider sector interdependencies when evaluating a country's infrastructure resilience, as described before in this report. Most functions and services are highly interdependent. For example, a power outage can disrupt communication networks, transport, and water supply. Understanding these links more thoroughly allows us to prevent cascading failures and maintain the continuity of essential services.

After identifying interdependencies, the risk of cascading failures can be calculated using the stress test tool developed by UNDRR. This tool simulates various crisis scenarios and assesses their potential impact on different infrastructure sectors. By pinpointing vulnerabilities and analysing domino effects, decision-makers can develop more effective prevention and mitigation strategies.

Input from stakeholders shows that nearly all critical functions heavily depend on storing fuel reserves and generating electricity. This creates a risk of significant disruptions to infrastructure systems, as Tonga relies heavily on imported fuels for its energy needs. In 2000, the last available energy balance showed that 75% of the country's energy supply came from imported petroleum products, with the remaining 25% from biomass and off-grid solar PV. Over 98% of Tonga's grid-supplied electricity is generated using imported diesel.

On the other hand, the maintenance of ports, harbours, and airports is shown to be highly vulnerable to disruptions of other critical functions, followed by the maintenance of healthcare facilities. In other words, import/export activities, tourism, and health services are highly likely to be impacted if one or more critical functions are disrupted.

Table 8 below shows the interdependencies by sector and their direct and cascading impact on the economy.

25. *Tonga Energy Roadmap 2010 – 2020, https://theprif.org/sites/theprif.org/files/2020-08/Tonga%20Energy%20Strategy.pdf*

Table 8. Critical Infrastructure Function, Interdependencies and Economic Impact (stress testing tool)

SECTOR AND SUB-SECTOR	INTERDEPENDENCIES		ECONOMIC IMPACT	CASCADING ECONOMIC IMPACT
	HIGH	MEDIUM		
WATER *Village and rural water*	Power: underground water extraction for urban areas uses electric pumps. Fuel Reserves: rural water extraction runs on diesel pumps.	Power: underground water extraction for urban areas uses electric pumps. Fuel Reserves: rural water extraction runs on diesel pumps.	High	Medium
PORTS AND AIRPORTS *Movement of goods and services*	Roads: movement to and from ports to allow exports and imports. Power: operation of facilities requires electricity. Fuel storage: machinery and equipment rely heavily on availability of fuel.	Health Facilities: services rely heavily on imported medicine.	High	Medium
ENERGY *Power*	Fuel Reserves: majority of water generators run on diesel. Roads: Electricity network facilitated by roads. Ports: All fuel is imported.	Water: Power plant generators require water for cooling	High	Medium
TELECOMMUNICATIONS *Data and connectivity*	Power: majority of communications equipment run on electricity.	Roads: provides network for overhead and underground telephone and internet cabling.	Medium	Low
TRANSPORT *Roads*	Ports: certain road construction materials are imported.	Fuel Reserves: Machinery and road construction equipment rely on fossil fuel.	High	High
EMERGENCY BROADCAST *Radio*	Power: services rely on electricity.	Roads: evacuation routes and emergency services depend on accessible and well-maintained roads	Low	Low
EVACUATION CENTRES *Facilities*	Water: once activated centres require clean and sufficient water to sustain evacuees. Ports: Importation of aid for affected population. Roads: access to evacuation centres require well-maintained roads.	Power: electricity is necessary to sustain people in evacuation centres.	Low	Low
FUEL STORAGE *Oil depots*	Ports: all fuel in Tonga is imported hence heavy dependence on ports. Roads: distribution and access to fuel requires well-maintained roads. Power: heavy reliance on fossil fuel.	Emergency Broadcast: equipment and services rely on electricity which fossil-fuel based.	High	High
HEALTH CARE FACILITIES *Hospitals*	Water: necessary for patients and services. Ports: necessary for the importation of medicine. Roads: for emergency services use and for public to have access to health services. Power: necessary for facilities and services to operate.		Low	Low
EDUCATIONAL SERVICES *School buildings*	Water: necessary for schools and sanitation. Roads: necessary for access to schools. Data and Connectivity: necessary or educational purposes.	Power: electricity to power schools. Health Facilities: necessary to maintain health of school population.	High	Low

Gaps and Recommendations

Based on the cross-sectoral assessment and analysis, the following gaps and recommendations have been developed to improve the enabling environment for infrastructure resilience.

KEY FINDINGS / GAPS	RECOMMENDATIONS (AREA OF FOCUS)	SPECIFIC ACTIVITIES/ ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
All Sectors (Water, Energy, Transport, Telecommunications, Education, Health) have established institutions, governances, and regulatory frameworks. There is however a lack of a unified explicit approach and guidance for critical infrastructure resiliency built into these structures. No clear national vision, mandate, and objectives for long-term national development of critical infrastructure.	**Government to develop a National Resilient Critical Infrastructure Strategy envisioning clear direction for Tonga's critical infrastructure to guide sectors and agencies on levelling up infrastructure resiliency.** Type: Policy and Regulation	• Develop a design plan for the development of the strategy • Consultation with key stakeholders • Seek approval from NDRMC and Cabinet to progress. • Develop Strategy guided by design plan. • Consultation with key stakeholders • Receive feedback and integrate into Strategy • Present final draft for approval	**Lead:** **MEIDECC (NDRMO)** Support: Ministry of Infrastructure Prime Minister's Office Ministry of Lands, Survey and Natural Resources	**High** Timeframe: 10 - 12 months
The established Inter-Cluster Coordination Committee, Water Sector Committee, and other sector-specific Committees exist with potential as platforms for improved coordination and collaboration between sectors. These Committees can be utilized for improved inter-sector collaboration to avoid a siloed approach among sectors. No designated governance and/or group to cultivate coordination, collaboration and communication between sectors.	**Integrate the Critical Infrastructure Working Group (CIWG) into the Essential Services Cluster tasked with improving coordination and communication between critical infrastructure sectors. Respective Cluster Coordinator Terms of Reference revised to encompass resilient infrastructure activity coordination. Government to develop information-sharing standards in sector regulations and policies. Regulators to enforce through compliance checks.** Type: Governance, Leadership and Collaboration	• Review existing TOR for CIWG • Consult with key stakeholders • Integrate feedback from stakeholders • Final draft presented to ICCC for endorsement • Submit to NDRMC for approval	**Lead:** **MEIDECC (NDRMO)** Support: Ministry of Public Enterprise Essential Services Cluster Inter-Cluster Coordination Committee (ICCC) National Disaster Risk Management Committee (NDRMC)	**High** Timeframe: 2- 3 months

KEY FINDINGS / GAPS	RECOMMENDATIONS (AREA OF FOCUS)	SPECIFIC ACTIVITIES/ ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
There are regulatory frameworks for each critical sector however resiliency as a concept and practice is not fully captured in existing legislation, policies, and practices of critical sectors resulting in resiliency not being a sustained priority. Regulations, policies and SOPs do not expressly address elements of resiliency.	**Policy submission to Cabinet via NDRMC proposing specific policy measures identified during the assessment to be integrated into key critical infrastructure Legislation/Regulations and policies.** Type: Policy and Regulation	• Compile policy change recommendations based on Implementation Plan • Consult AGO on legislative implications • Consult with key stakeholders • Submit to NDRMC for endorsement • Integrate NDRMC feedback • Submit for Cabinet approval and decision • Coordinate drafting with AGO • Amendments submitted to Law Committee for approval.	**Lead: MEIDECC** Support: Attorney General's Office Critical Infrastructure Technical Working Group Key infrastructure Sectors ICCC NDRMC Cabinet	**High** Timeframe: 10 - 12 months
Published in 2019 under the Public Finance Management Act, the Government of Tonga Fixed Assets Management Framework and Policy formalizes concepts and processes for asset management, but its focus is on the life-cycle phase. The document presents opportunities for integrating resilience interventions for infrastructure assets and not just a focus on asset operations and end-of-life. Linking of asset management to resilient infrastructures and having resilient infrastructure principles reflected in the Framework and Policy.	**Review the Government of Tonga Fixed Assets Management Framework and Policy and expand its scope to reflect high and medium priority principles of infrastructure resiliency actions identified during the assessment.** Type: Policy and Regulations, and Infrastructure Management	• Design TOR for Review of Policy • Consult relevant stakeholders • Submit TOR for approval by Ministry of Finance • Conduct review of policy • Consult stakeholders • Integrate feedback and present final draft for approval.	**Lead: Ministry of Finance** Support: MEIDECC Ministry of Public Enterprise	**Medium** Timeframe: 6 - 8 months
The Disaster Risk Financing Strategy 2021 – 2025 published prior to HTHH event and COVID-19 is Tonga's approach to disaster resilience which includes investments in DRR and preparedness, i.e. resilient infrastructure and multi-hazard early warning systems. The Implementation Plan encompasses actions which align with resilient infrastructure principles assessed as high priority. Funding allocation for actions supporting resilient infrastructure is vacant.	**Support resource mobilization to implement activities identified within the DRFS as under action to (i) Strengthen evidence base for identifying effective, value-for-money DRR interventions, (ii) Develop and establish a Disaster loss database, (iii) Design, prioritize and implement DRR activities based on available risk information.** Type: Governance, Leadership and Collaboration, Data Capturing, Management and Use, and Capacity Building	• Design Technical Adviser support TOR based on DRFS actions/sub-actions • Consult relevant stakeholders and development partners • Seek funding for TA deployment • Recruit and deploy TA	**Lead Ministry of Finance** Support: MEIDECC	**High** Timeframe: 10 -12 months

KEY FINDINGS / GAPS	RECOMMENDATIONS (AREA OF FOCUS)	SPECIFIC ACTIVITIES/ ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
The National Planning Department requires all development projects to provide a risk assessment as part of submission. Smaller-scale development projects that are not channelled through the Planning Department may not be required to meet similar standards of assessment. Hence risk assessments are not conducted for all infrastructure development but dependent on the scale of the development. Standardized risk assessment method applicable to all infrastructure development.	**National Planning to develop standardized risk assessment method that is applicable to both large- and small-scale projects.** Type: Policy and Regulations and Infrastructure management	• Develop TOR for TA • Consult with stakeholder and development partners • Recruit and deploy TA • Develop a risk assessment tool • Consultation on use and testing of tool • Submit for approval to be integrated as part of NIIP process	**Lead:** **National Planning Division (PMO)** Support: MEIDECC (NDRMO) Ministry of Public Enterprise	**Medium** Timeframe: 10 -12 months
Sector interdependencies are not fully recognized and integrated into emergency and disaster planning, contributing to response coordination issues. Not all sectors maintain a sector-specific Emergency Plan and those that do focus largely on their own emergency response. No guidance on coordinated multi-sector planning and response to emergencies and disasters.	**Government to develop a multi-sector emergency and disaster response plan inclusive of recovery phase post-disaster aligned to DRM Action Plan development.** **Operators to review existing emergency plans and recovery plans.** **Operators to develop a multi-sector incident command system to respond to emergencies and recovery.** Type: Policy and Regulations and Capacity Development	• Design TOR for Multi-agency Response Plan • Consult with key stakeholders for endorsement • Develop Response Plan • Consult on draft and receive feedback • Submit for approval from NDRMC	**Lead:** **MEIDECC (NDRMO)** Support: National Planning Division Ministry of Public Enterprise Essential Services	**High** Timeframe: 6 - 8 months
The depth of Sector leadership/management knowledge and understanding necessary to improve resiliency of critical functions is not adequate to ensure priority, adaptability and transformation in times of disaster because relevant information and data are not presented effectively to influence decision-making. Relevant data is not collected, analysed and presented in a meaningful way on a regular basis to decision-making bodies	**Integrate into the DRM Action Plan (pipeline for development) the requirement for infrastructure sector to collect assumption data and publish by Government.** **Regulator to request assumptions in data models and plans from operators.** **Operators to collect and investigate data on infrastructure failures and report to Regulators.** Type: Policy and Regulations	• Consult NDRMO on DRM Action Plan development process • Draft necessary provisions reflecting data collection, roles, processes, etc • Consult with stakeholders • Present to NDRMO for consideration of integration	**Lead:** **MEIDECC (NDRMO)** Support: MLSNR ICCC NDRMC	**Medium** Timeframe: 6 - 8 months
The hazard mapping in Step 3 identifies certain critical infrastructure assets located within disaster-prone areas. Not all critical infrastructure assets are climate-proofed or have emergency plans established to ensure rapid recovery or continued function during and after disasters. Sector and organizational Critical Infrastructure Risk Management systems and processes are not in place.	**Develop an "all-hazards" critical infrastructure protection plan to guide critical infrastructure sector/organizational and community infrastructure risk management.** Type: Data Capturing, Management and Use, and Policy and Regulation	• Develop Plan TOR • Consult stakeholder for feedback • Submit TOR for endorsement • Develop Infrastructure Protection Plan • Submit for NDRMC approval • Integrate into infrastructure operator/ owner policy manuals	**Lead:** **MLSNR** Support: MEIDECC (NDRMO) National Planning (PMO) ICCC	**Medium** Timeframe: 8 - 10 months

PART IV. SECTOR VULNERABILITIES AND RESILIENCE

An in-depth analysis of each infrastructure sector is essential to complement the cross-sector analysis and recommendations. The analysis presented below identifies vulnerabilities and disaster risk exposure for each critical infrastructure function, helping to determine the measures needed to strengthen their resilience.

A. WATER SECTOR

The Water Sector in Tonga is among the most vulnerable to impacts of climate change and disasters. Water is a vital resource and an essential source of life that Tongans critically depend on for a sufficient and sustainable supply of water not only for their very existence but also for social, economic, and environmental needs and development.[26]

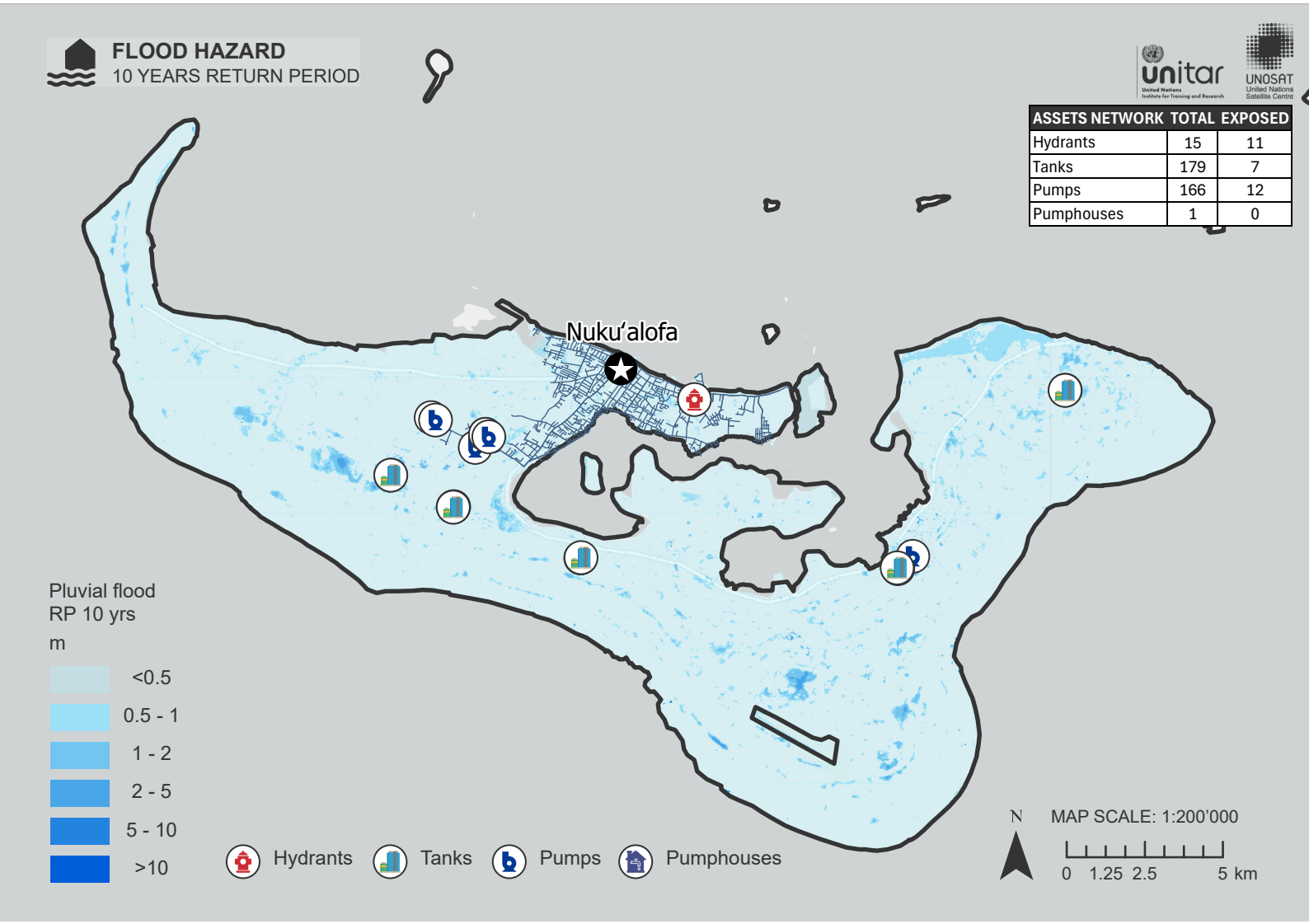
The Water Resource Act, administered by the Ministry of Lands, addresses the ownership, management, and protection of water resources. Together with the National Spatial Planning and Management Act 2012, it reflects the Ministry's ability to adapt policies to address sector-specific challenges. Although the regulation of rural and urban water is managed by separate ministries, this approach has advantages, particularly in aligning with the government's capacity and resource distribution.

Significant improvements are needed for the operators and owners of water infrastructure. Unlike Tonga Power Limited, the Tonga Water Board (TWB) is not subsidized, making financial stability a challenge, particularly for TWB and Village Committees when addressing regulatory standards requiring substantial capital investment. Financial stability is further impacted by fluctuations in demand, water conservation efforts, and economic downturns. Resource mobilization also remains a challenge for operators.

Climate change hazards pose a serious threat to water security. Sea-level rise and overtopping have caused seawater intrusion into freshwater lenses, reducing the availability of potable water.[27] Additionally, TWB's ageing infrastructure requires substantial investment for upgrades. Despite ongoing improvements, a large portion of the infrastructure is outdated and urgently needs replacement, contributing to service disruptions, slow data transmission, and increased downtime. Figure 6 below is a map produced by UNOSAT that highlights the extent to which assets from the water sector are exposed to flooding in Tongatapu. If flooded, these assets are at risk of damage by soil erosion or overflow. Data from the Multi Hazards Disaster Risk Assessment, ARUP 2021 is depicted in the map.[28]

26. *Department of Climate Change, MEIDECC, https://tinyurl.com/23wwbvr5*
27. *Fakhruddin, B. & Tonkin & Taylor Foundation. (n.d.). Climate Risk Management in Water Sector in Tonga, https://tinyurl.com/5bm8458e*
28. *ARUP. (2021). Multi Hazard Disaster Risk Assessment, Tongatapu: Hazard Assessment Report - Pluvial Flooding and Coastal Inundation (No. 276779–00). ADB. https://www.adb.org*

Figure 5. Water sector assets exposure map. Pluvial flood hazard 10-year return period model by ARUP and asset locations from the MHDRA geodatabase. A quantitative GIS analysis of the data results in 11 hydrants, 7 tanks and 12 pumps exposed to pluvial flood.



There is no centralized database or information exchange system to support water resource assessment and infrastructure monitoring in Tonga. Water resources are managed by various institutions with differing capacities and expertise in infrastructure development and maintenance. Integrated planning and management are urgently needed to ensure resilience in the water sector.

The groundwater extraction rate on Tongatapu is approximately 24,000 m³/day from the Mataki'eua wellfield and 10,867 m³/day for villages outside Nuku'alofa. Water hardness ranges from 135 mg/l to 290 mg/l, prompting households to rely on rainwater for drinking and cooking.[29] Figure 5 above summarizes the distribution of exposed water assets across Tongatapu, with TWB supplying water to around 30,000 people in the Nuku'alofa area. Water supply in villages outside Nuku'alofa, serving about 70,000 people, is managed by Village Water Committees.

In addition to climate-related hazards, Tonga's water utilities face challenges common to outer islands, including ageing infrastructure, which the TWB identifies as the primary issue, requiring costly maintenance, repairs, and replacements.

29. *Tonga Water Board. (2023). Tonga Water Board Annual Report 2023. In https://www.twb.to/. TWB*

A comprehensive assessment of Tonga's water sector is presented below, providing a deeper understanding of its vulnerabilities and the necessary actions to enhance infrastructure resilience in this sector.

Stakeholders and Regulatory Framework

WATER SECTOR	
POLICY MAKERS	Ministry of Lands, Survey, and Natural Resources (MLSNR) Ministry of Health (MOH) Ministry of Public Enterprise (MPE)
REGULATORS	Chief Executive Officers for MLSNR, MOH, MPE
OWNERS	Government of Tonga, Village Water Committees (VWCs)
OPERATORS	Tonga Water Board (TWB), VWCs, Commercial Water Companies
KEY POLICIES/ LEGISLATIONS	Tonga Strategic Development Framework II, Water Resources Act, Public Health Act, Water Supply Regulations, Tonga Water Board Act, Hydrology and Water Resources Strategy 2020-2030, National Water Resources Policy 2019, National Water Resources Implementation Plan 2019.
CRITICAL ASSETS	Pipelines, boreholes, reservoirs, storage tanks, treatment plants, pumping stations, oxidation ponds, and ocean outfalls.[30]

Sectoral Challenges

Tonga's water sector is fragmented and complex. This can be seen in the legislative framework, governances, and institutions within the sector which in itself presents a coordination challenge when planning or implementing initiatives.

Availability, accessibility, and quality of water are dependent on both hard and soft infrastructure to ensure it is received by users. Infrastructure to continuously adapt to changing environments and demand requires data and information – this is a key challenge for the sector. Further, how this data is used to develop its resilient capacity is another area requiring attention. For example, water extraction data does not capture all boreholes, nor is accurate rainwater harvesting catchment data available to allow for disaster mitigation and adaptation strategies.

The operators and owners of village water infrastructure are where significant improvements are warranted. Financial stability is a challenge for Village Water Committees (VWC) to address regulatory standards where substantial capital investment is required. VWC members are selected from village residents who vary in skills and knowledge required to efficiently manage water systems.

30. *Tonga National Infrastructure Investment Plan 2021 – 2030*

The necessary systems and equipment both for administration and operations are also lacking. For most villages, there is no formalized tariff system to support ongoing operations resulting in repair and maintenance issues. The necessary mechanical skills for maintenance are also lacking. Hence the support system to ensure the water infrastructure is planned, designed, monitored effectively and becomes more resilient to hazards is an area of need for VWC.

Sector Vulnerabilities

Based on results from the Stress Testing workshop, underground water in Tonga is perceived as highly exposed to seawater intrusion and pollution but with a medium rating in terms of vulnerability. This is followed by drought shown to have medium vulnerability and exposure impact on water sources. The dependency of water pumping stations on electricity means power outages caused by cyclone damage to electricity poles can disrupt water supply. TWB has noted that villages with water bores in western Tongatapu are particularly vulnerable to underground water contamination and pollution. Given the demographic characteristics of these rural areas, priority has been placed on improving the resilience of water infrastructure in these regions.

The following chart summarizes the interdependencies of water with other critical infrastructure functions identified as high through the stress testing workshop.

DEPENDS ON	CRITICAL FUNCTION	IMPACTS
High		**High**
Generate/distribute electricity: powers water pumps for extraction and distribution of water to users. Failure in power will affect watershed pumps and disrupt water supply. **Store/maintain fuel:** the majority of water pumps rely on diesel fuel or are powered by electricity fed from the national grid which runs on diesel fuel. Shortage of fuel will affect pumping stations sustained operation. **Roads:** water networks are routed along roads. Damage to roads risks damage to underground water pipes. **Build/maintain healthcare facilities:** water source quality is tested by Ministry of Health. Capacity and capability of facilities to provide water quality testing services is crucial.	**WATER/ MANAGEMENT SUPPLY**	**Evacuation centres:** water availability and sanitation in evacuation centres are affected posing health risks to any people seeking refuge in the centre. **Build/maintain healthcare facilities:** water availability and sanitation in hospitals are affected disrupting services. **Provide educational services:** water availability and sanitation are affected causing school services to be cancelled.

During the stress testing exercise, stakeholders identified the water sector as highly vulnerable, prompting a more in-depth analysis of the sector's challenges and needs.

The Kingdom of Tonga's Water-Sector Deep Dive

Tonga's primary urban water supply is managed by TWB, relying heavily on groundwater distributed through a reticulated system. Water is piped from reservoirs, though treatment levels vary. Rainwater also plays a crucial role in meeting daily needs through both individual and community-level collection systems, creating a dual-supply system.

This in-depth review identified critical resilience gaps and deficiencies in Tonga's water sector:

- **Fragmented Programmes and Initiatives:** Multiple agencies and donors have initiated water-related projects in Tonga, often with little coordination. This fragmentation results in duplicated efforts and inefficiencies in the sector.
- **Hazard Exposure:** Water assets in Tonga face a wide array of hazards, such as cyclones, volcanic eruptions, and tsunamis, each affecting the infrastructure differently.
- **Inconsistent Disaster Response Procedures:** Response procedures for the water sector during disasters are inconsistent, with limited standard operating procedures (SOPs).
- **Variable Water Quality:** Rainwater tanks, essential during disasters, often deliver inconsistent water quality, posing health risks during both emergencies and normal times.
- **Groundwater Vulnerability:** The country's reliance on groundwater faces risks from declining water quality and diminishing reserves, particularly in outer islands.
- **Village Water Committee Capacity:** Many Village Water Committees lack the necessary skills to manage water supplies effectively, hampering local resilience.
- **Ageing Infrastructure:** Poor maintenance and underfunding of water assets have led to leakages, water wastage, and inefficiencies.

HAZARD-RELATED DISRUPTIONS IN TONGA'S WATER SECTOR

Several major hazard events have disrupted Tonga's water infrastructure, highlighting the sector's vulnerabilities:

- **Tropical Cyclones:** Cyclone Gita (2018) damaged water distribution systems and rainwater tanks, while other cyclones have led to extensive system failures.
- **Volcanic Eruptions and Ashfall:** The 2022 eruption of Hunga Tonga-Hunga Ha'apai severely impacted water pumps and contaminated rainwater tanks, leading to supply disruptions.
- **Droughts:** Prolonged droughts in 2023 have affected rainwater collection systems, exacerbating water shortages.
- **Tsunamis:** The 2022 tsunami contaminated groundwater sources in southern islands and destroyed coastal water infrastructure.

RESILIENCE GAPS AND CHALLENGES

Despite the ongoing resilience programmes, the water sector faces critical gaps:

- **Funding and Resources:** Many water projects are underfunded, and there is limited access to spare parts and skilled labour for maintenance and repairs.
- **Design Standards:** Infrastructure, such as overhead tanks, often lacks adequate design standards, increasing vulnerability.
- **Lack of Comprehensive Business Continuity Plans:** Current plans for ensuring water supply during disasters are insufficient, particularly at the local level.
- **Limited Data Sharing and Knowledge:** Data on water infrastructure is scattered across different organizations, limiting comprehensive understanding and coordination.

INTERDEPENDENCIES WITH OTHER SECTORS

The water sector in Tonga is heavily dependent on other sectors for its operation, including energy, transport, and health facilities:

- **Transport:** The shipping of essential water asset components into Tonga and outer islands is crucial, making ports and wharves an essential dependency.
- **Energy:** Water pumping stations depend on electricity for operation, with the TWB already taking steps to reduce this reliance through solar projects and backup generators.
- **Health Facilities:** Health centres and evacuation facilities rely on consistent water supply for their functioning, especially during emergencies.

WATER SECTOR RESILIENCE MEASURES

The Ministry of Lands, Survey, and Natural Resources together with the Ministry of Health is collaborating on formalizing the Water Sector and the creation of a Water Security Authority. The aim is to ensure shared responsibility by encouraging stakeholder and community participation in water infrastructure resilience and disaster prevention.

Under the same initiative mentioned above, the Tonga Water Sector Plan is currently in draft form. The Plan focuses on developing and implementing an information system to monitor and regulate water security, thereby enhancing the sector's capacity to better understand and manage interdependencies and design appropriate mitigation and prevention strategies against hazards and threats.

Several resilience measures are in place to address disruptions, though gaps remain:

- Emergency Response Plans: Some response plans are in place, but they are inconsistent across different areas and organizations.
- Desalination Plants: Desalination units have been deployed in some areas to provide alternative water supplies.
- Community Reliance: Communities often rely on untrained individuals to repair infrastructure, leading to delays and potential safety issues.

EXISTING RESILIENCE PROGRAMMES

Several institutions and donors are currently involved in water-related resilience programmes in Tonga, aimed at enhancing water supply systems and their resilience to disasters:

- SPC-R2R IW: Focuses on integrated water resource management, monitoring, and capacity building.
- ADB: Has supported numerous projects, including the Tonga Integrated Urban Resilience Sector Project and the Nuku'alofa Urban Development Sector Project, which aims to improve flood management, piped water networks, and wastewater treatment.
- Ministry of Lands and MFAT: Leading the development of a national Water Sector Plan.
- Community Initiatives: Programmes from organizations like Live & Learn Tonga, CARITAS, and UNICEF focus on water infrastructure vulnerability, rainwater tanks, and sanitation improvements.

RECOMMENDATIONS

Tonga's water sector is essential for the well-being of its communities, yet it remains vulnerable to multiple hazards. Addressing gaps in funding, infrastructure maintenance, disaster preparedness, and sector coordination is critical to building long-term resilience and ensuring water security in the face of increasing climate-related threats.

Based on these findings, several recommendations are proposed to strengthen Tonga's water sector resilience:

- Develop a Comprehensive Asset Registry: A critical water asset registry should be developed to monitor the condition and maintenance needs of infrastructure.
- Improve Water Security on Outer Islands: Water scarcity on outer islands must be addressed through new storage and treatment solutions.
- Strengthen Village Water Committees: A manual of guidance and formal training should be developed for Village Water Committees to improve governance, management, and emergency response capabilities.
- Enhance Coordination Across Sectors: The interdependence of the water sector with other sectors such as transport, ICT, and energy requires more coordinated business continuity and contingency planning.

Resilience Gaps and Recommendations

Table 9. Water sector infrastructure resilience recommendations.

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Lack of formal tariff system to allow for maintenance and replacement of water infrastructure. No standardized equipment and assets, SOPs, and policies. No emergency plans to respond to disasters and water asset failures.	The Water Supply Regulations require each village to establish a Village Water Committee. However, Committee performance is dependent on capacity and capability which are often lacking to improve generation, sanitation and distribution, resulting in poor water accessibility and irregular water distribution. Village Water Committees lack access to guidance and the administrative and engineering skills to efficiently manage village water.	**Develop a Manual of Guidance for village water committees to promote good governance and management, improve water security, access, construction and sanitation.** **Develop generic emergency water response plan for village water committees to adapt for climate and disaster events.** Type: Policy and Regulation, Capacity Building, and Infrastructure management	• Conduct village water committee surveys to assess capacity and capability. • Develop specialized training for Committee members in administration and management of water services.	**Lead:** **Ministry Lands, Survey and Natural Resource** Support: MEIDECC Tonga Water Board Ministry of Health HNWASH Cluster	**High** Timeframe: 8 - 10 months
No water use monitoring system in place for most village water committees. Village water committees have no system to monitor water extraction, or groundwater capacity to meet demand trend.	While water accessibility in Tonga is stated to be almost universal, rural water distribution lacks a water services management system. Hence the majority of VWCs do not have the capability to collect important water data to properly design appropriate water systems to meet current and future water demand. Some data can be found with MLSNR and some with Ministry of Health.	**Develop and establish a data capturing mechanism for Village Water Committees.** Type: Data Capturing, Management and Use, and Capacity Building	• Assess VWC systems • Develop standardized system for all VWCs • Link system to Data repository with NDMRO • Procure necessary hardware for system to operate • Conduct training for VWCs	**Lead:** **Tonga Water Board** Support: MLSNR Ministry of Public Enterprise MORDI HNWASH Cluster	**Medium** Timeframe: 8 – 10 months
Changing rainfall patterns and declining groundwater make outer islands vulnerable to water supply disruptions.	Increasing water scarcity and vulnerability of water supplies, especially in some outer islands.	**Improve water security on outer islands** Type: Policy and Regulation/ Infrastructure Management	• Increase water storage volumes to allow for more water to be stored • Support trials for alternative water supply options - such as hydro panels • Deploy mobile desalination units to the most vulnerable locations and train local people to operate and maintain them	**Lead:** **MLSNR** Support: HNWASH Cluster Ministry of Health Live and Learn MORDI Village Water Committees	**High** Timeframe: 10 – 12 months

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Effective processes to ensure donor projects are appropriately scoped and handed over with relevant data to inform long-term management of assets.	There are a range of disparate existing programmes related to water and resilience already underway in Tonga, initiated by a range of agencies and donors.	**Establish processes for donor project coordination across the water sector.** Type: Policy and Regulation, Governance, Leadership and Collaboration, and Data Capturing, Management and Use	• Development partners and donors to establish a mechanism for information sharing about water sector priorities and projects being funded • Develop a template for water projects to identify relevant spatial data to be collected and handed over to Tongan Government • Integrate findings from Resilient Infrastructure Review in the Water Sector Plan process currently underway	**Lead:** **MLSNR** Support: Ministry of Health MEIDECC (NDRMO) Tonga Water Board Development Partners National Planning (PMO) HN WASH Cluster	**Medium** Timeframe: 4 – 6 months
A comprehensive assessment of water asset exposure to hazards has not been completed.	Water assets in Tonga are exposed to a range of hazards - the hazards impact assets in different ways.	**Complete a comprehensive water sector hazard exposure report, including a review of dependencies on other sectors (especially transport, ICT and energy) and supply chains.** Type: Infrastructure Management/Data Capturing, Management and Use	• Develop a methodology for a water sector hazard exposure assessment • Identify relevant existing GIS data for water assets, and collect additional data where required • Align with Live and Learn tool development process • Complete a comprehensive review (including urban and rural water assets on Tongatapu and outer islands) • Use the results of this assessment to inform a programme of resilience improvement actions for water assets	**Lead:** **MLSNR** Support: MEIDECC (NDRMO) Ministry of Health Tonga Water Board Live and Learn HN WASH Cluster	**High** Timeframe: 6 – 8 months

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Response procedures have not been comprehensively reviewed and tested - considering multiple hazards and all relevant water sector assets.	Procedures for the water sector to respond to disasters are patchy and inconsistent.	**Develop and test business continuity plans and SOPs (standard operating procedures) for all water services (including urban and rural).** Type: Policy and Regulation	• Identify relevant processes in place to respond to water service disruptions • Review to determine if business continuity plans and SOPs are in place • For those where business continuity plans are missing - develop plans • Develop a regular schedule of review for business continuity plans and SOPs • Complete regular reviews, testing and updating of plans	**Lead:** **MLSNR** Support: MEIDECC (NDMRO) Ministry of Health Tonga Water Board Live and Learn HN WASH Cluster Village Water Committees	**High** Timeframe: 6 – 8 months
Water quality from rainwater tanks is uncertain, and testing availability is limited	Rainwater tanks are an essential component of the water sector, but water quality from rainwater tanks is variable during disaster events and in non-disaster times - exposing the community to disruptions in supply and/or poor-quality water.	**Develop programmes to improve water quality and education relating to rainwater tanks.** Type: Governance, Leadership and Collaboration/Policy and Regulation/ Capacity Building	• Ensure a stock of water treatment tablets is available to quickly distribute during disasters • Develop a proactive programme of maintenance and improvements for rainwater harvesting systems - including first flush systems and improvements to gutters • Provide education to water users about water quality and when to use water boiling or water treatment tablets • Consider water treatment retrofits for large rainwater systems supplying multiple homes • Ensure programme links with donor programmes supplying rainwater tanks to communities	**Lead:** **Ministry of Health** Support: MLSNR MEIDECC (NDRMO/ Climate Change Dept.) Live and Learn MORDI HNWASH Cluster Village Water Committees	**High** Timeframe: 6 -8 months

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Management practices to sustain groundwater require additional resourcing.	Groundwater is vulnerable to declining water quality.	**Develop a long-term programme of groundwater management.** Type: Infrastructure Management/Policy and Regulation, and Capacity Building	• Develop and resource a monitoring programme for groundwater resources - covering urban and rural areas in Tongatapu and outer islands • Investigate causes of groundwater quality issues, including salinity and high pathogen content • Develop responses to manage declines in groundwater quality and quantity - including regulation of highly polluting activities on land near groundwater resources	**Lead: MLSNR** Support: Ministry of Health Tonga Water Board Live and Learn MORDI MEIDECC (NDRMO) HNWASH Cluster Village Water Committees	**High** Timeframe: 6 – 8 months

B. ENERGY SECTOR

The energy sector in Tonga includes power operators, fossil-fuel importers and suppliers, and gas. While they were considered as part of the data and information gathered for the analysis, including results from the stress testing, the focus of the assessment is on power (electricity) generation and distribution. Tonga's electricity system is 80% fossil-fuel powered and serves 100% of the population under a single service provider: Tonga Power Limited. The electricity system operates 1 power plant with 11 generator sets, 6 solar farms, and 1 wind farm.

A key feature of the Energy sector is a clear line of communication from policymakers to implementers (owners/operators). The Commission as Regulator, together with MEIDECC, can monitor a small number of operators and owners within the Sector, setting a clear vision and direction through the Energy Roadmap, the Energy and Efficiency Master Plan, and the Low Emission Development Strategy.

Tonga Power has seen substantial improvement in service delivery over the last decade with the assistance of development partners. Tonga Power spearheads the Government's aspiration to achieve 70% electricity generation from renewable energy sources by 2030. In terms of network infrastructure, Tonga Power continues to implement its Village Network Upgrade Project aiming at improving resiliency of power networks throughout the country.

Stakeholders and Regulatory Framework

ENERGY SECTOR	
POLICY MAKERS	Ministry of Energy, Information, Disaster, Environment, and Climate Change (MEIDECC), Ministry of Public Enterprise (MPE)
REGULATORS	Energy Commission
OWNERS	Tonga Power Limited (TPL), Total Energies, Pacific Energy, EM Jones Group
OPERATORS	Tonga Power Limited (TPL), Total Energies, Pacific Energy, EM Jones Group
KEY POLICIES/ LEGISLATIONS	Energy Act, Tonga Energy Roadmap 2021-2035 (TERM Plus), Tonga Energy Efficiency Master Plan 2020 (TEEMP)
CRITICAL ASSETS	Diesel engines, hydro turbines, generators, transformers, solar panels, switching equipment, transmission and distribution lines.[31]

Sectoral Challenges

At the national level, the three key policies mentioned above have been effective in progressing Tonga's development in electricity. The areas that may require greater input and attention are the organizational-level policies and standards of the operators and owners. These should integrate climate change and hazard data into their planning, designs and operations to address not just asset lifecycles but also the resilience phases of preparation, absorption, recovery and adaptation.

The organizational plans including the operations report reviewed in this analysis acknowledge climate change but incorporate limited resilience measures in their planning and operations. For example, recent climate change data has been included in infrastructure design guidelines, but further steps are needed. An example is the effect of ashfall on high voltage overhead cables post-HTHH volcanic eruption which requires costly replacements to the electricity network and very often results in power outages. The study of hazards and climate change is also a necessary input for the sector to consider for future developments.

Sector Vulnerabilities

Power assets especially overhead cables suspended on poles and facilities located within flood-prone areas are exposed to various hazards which are rated as having a high impact on the

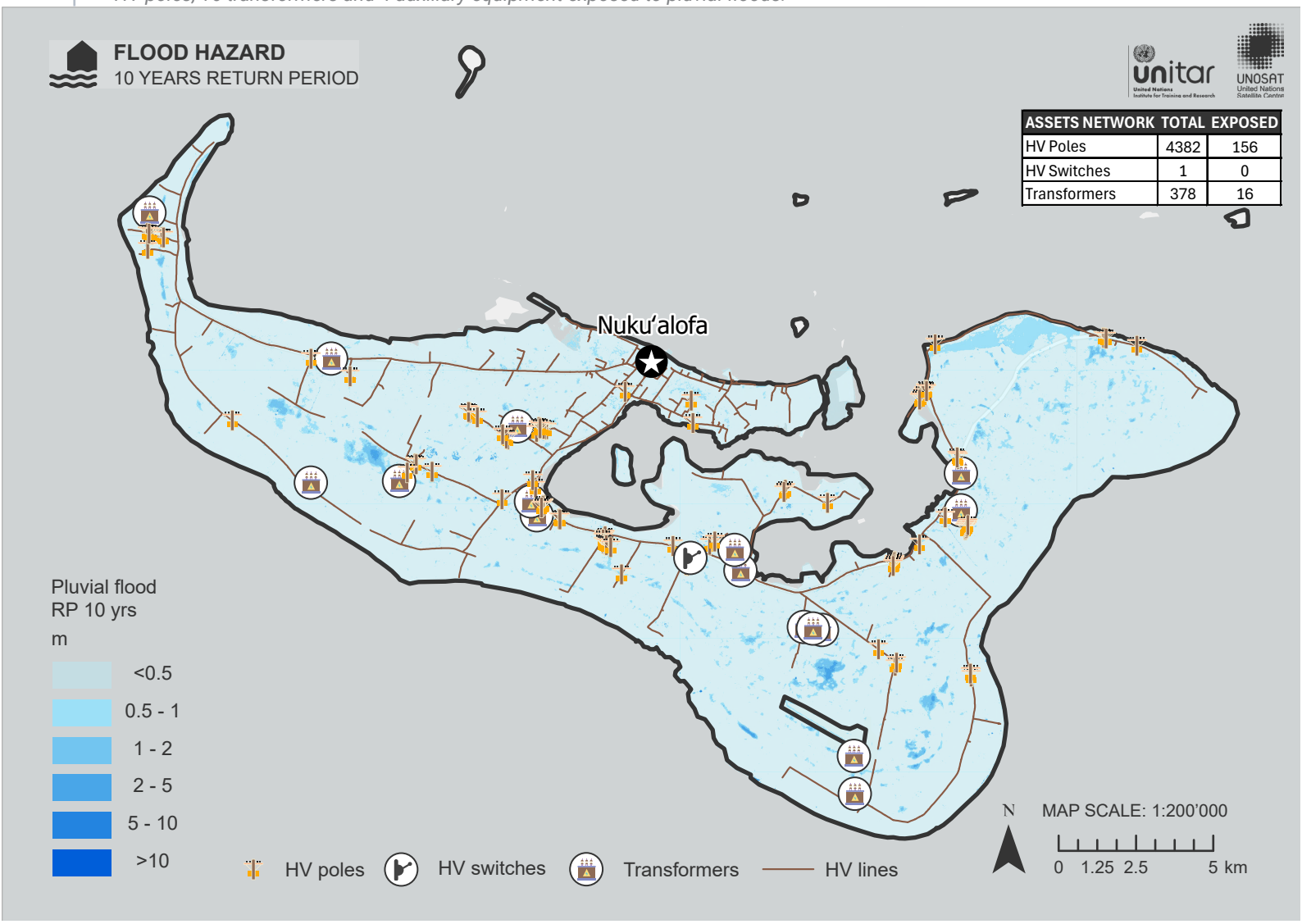
32. *Tonga National Infrastructure Investment Plan 2021 – 2030, https://tinyurl.com/365hts9n*

infrastructure. These include cyclones, volcanic eruptions and ashfall, erosion, flood, sea level rise and cybersecurity breaches. Stress testing results show that while Power has a medium level of risk exposure to these hazards, its vulnerability to failure of other critical functions is low. However, the impact of power disruption on the economy is high. Hence improving resiliency for generating and distributing electricity should focus on hazard- and climate-proofing the systems and assets.

Figure 6 is a map produced by UNOSAT that highlights the extent to which some assets from the energy sector are exposed to flooding in Tongatapu. If flooded, these assets are at risk of falling or malfunctioning. Data from the Multi Hazards Disaster Risk Assessment, ARUP 2021 is depicted in the map.[33]

The power generation and distribution functions were found by the stress-testing exercise to have medium vulnerability and exposure to cybersecurity breaches, with other critical functions having a lower score. This perception is based on the gradual shift of Tonga Power to renewable energy technology and smart grids, prompting questions on whether new infrastructure systems have the necessary local capacity to protect against cybersecurity breaches.

Figure 6. Energy sector assets exposure. Pluvial flood hazard 10-year return period model by ARUP and asset locations from the MHDRA geodatabase. A quantitative GIS analysis of the data shows 156 HV poles, 16 transformers and 4 auxiliary equipment exposed to pluvial floods.



32. ARUP. (2021). Multi Hazard Disaster Risk Assessment, Tongatapu: Hazard Assessment Report - Pluvial Flooding and Coastal Inundation (No. 276779–00). ADB. https://www.adb.org

Interdependencies with other critical infrastructure functions are summarized in the following table:

DEPENDS ON	CRITICAL FUNCTION	IMPACTS
High		**High**
Provide educational services: Generating and distributing electricity requires significant technical capacities that would be impossible to develop without educational services. **Store/maintain fuel:** Electricity in Tonga is heavily reliant on fossil fuels. Disruption of fuel supply will heavily impact power distribution. **Roads:** Power networks are routed along roads using overhead cables and poles. Damage to roads very often damages power assets within the affected area as well. Roads also allow for mobility of power services to communities. **Build/maintain ports, harbours, airports:** Fossil fuel is imported into Tonga requiring ports. Damage to ports will also disrupt the fuel supply chain risking power generator failure.	**GENERATE/ DISTRIBUTE ELECTRICITY**	**Supply/management of water:** Electricity is essential for operating and managing water distribution and treatment facilities. **Build/maintain healthcare facilities:** Water availability and sanitation in hospitals are affected disrupting services. **Build/maintain ports, harbours, airports:** Stable power is crucial; failures disrupt operations and cascade to dependent services. **Safe data connections:** Internet services in Tonga rely on stable power, and outages cause widespread disruptions.
Build and maintain ports, harbours, airports: Fossil fuel is imported into Tonga requiring ports. Damage to ports will also disrupt the fuel storage and reserves. **Build and maintain roads:** Fuel is transported by roads and disruptions can impact storage and reserves. **Generate and distribute electricity:** The operation of fuel storage facilities depend on electricity and disruptions can impact storage capacity **Safe data connection:** A secure data connection is essential for operation, monitoring and management of fuel storage facilities	**STORE FUEL AND MAINTAIN RESERVES**	**Supply water/ water management:** Fuel is essential for operating vehicles and equipment in the water sector. **Build and maintain ports, harbours, airports:** Fuel is critical for airplanes, boats, and vehicles; shortages would halt operations. **Build and maintain roads:** Tonga's fossil-fuel-dependent vehicles require sufficient reserves to build and maintain roads. **Generate and distribute electricity:** With 80% of Tonga's power generation relying on fossil fuels, adequate reserves are crucial. **Safe data connections:** Fuel powers equipment for transmission line maintenance and backup generators for data services. **Build and maintain healthcare facilities:** Fuel supports backup power generation and medical vehicles, critical during outages or emergencies.

DEPENDS ON	CRITICAL FUNCTION	IMPACTS
High		**High**
Build and maintain ports, harbours, airports: Fossil fuel is imported into Tonga requiring ports. Damage to ports will also disrupt the fuel storage and reserves. **Build and maintain roads:** Fuel is transported by roads and disruptions can impact storage and reserves. **Generate and distribute electricity:** The operation of fuel storage facilities depend on electricity and disruptions can impact storage capacity **Safe data connection:** A secure data connection is essential for operation, monitoring and management of fuel storage facilities	**STORE FUEL AND MAINTAIN RESERVES**	**Supply water/ water management:** Fuel is often required to operate the vehicles used in the water sector infrastructure. Additionally some equipment might require fuel to operate. **Build and maintain ports, harbours, airports:** Airplanes, boats, and other vehicles working in the ports require fuel to operate, so not having enough fuel would prevent the ports for working. **Build and maintain roads:** Since most vehicles in Tonga work on fossil fuel, having enough reserves is critical to access roads that require to be build or maintained. **Generate and distribute electricity:** Power generation in Tonga is 80% based on fossil fuels, so having enough reserves is critical for generating electricity. **Safe data connections:** Fuel is required to operate the equipment needed to maintain the transmission lines for data connections. Additionally, fuel could be used in backup electricity generators in multiple assets related to data connections. **Build and maintain healthcare facilities:** Healthcare facilities might use fuel to generate electricity in case of power outages (for instance during an emergency). Additionally, medical vehicles use fuel so this might also be important in the health sector.

Resilience Measurements

Under TERM Plus, the Energy Sector is focusing on developing and implementing resilient infrastructure measures to enhance the adaptive capacity of the overall power generation and supply system.[34] These include ensuring any new generation and distribution infrastructure is resilient to sea-level rise, and continued hardening of transmission and distribution networks.

Measures and interventions to adapt and mitigate risks to Tonga's energy security and resilience are set within TERM Plus which recognizes a shifting energy landscape and changing hazard environment. Key interventions are designed within the Plan to better position Tonga's electricity infrastructure to cope with climate change impacts i.e. infrastructure hardening and flexibility.
While the interventions align with key resilience principles such as disaster risk management assessments, raising essential safety requirements, and designing scalable solutions like micro-grids, these efforts primarily focus on improving preparedness, hazard response, and infrastructure protection.

34. *Government of Tonga. (2021). Tonga Energy Road Map 2021 - 2035. In https://tongaenergyroadmap.gov.to/. https://tongaenergyroadmap.gov.to/*

Resilience Gaps and Recommendations

Table 10. Energy sector infrastructure resilience recommendations

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Integration of climate change and natural hazards in sector and agency planning, design, operations, emergency response and investment planning.	Climate change and natural hazards are and will continue to be the major risks to the energy sector in Tonga. Sector understanding of climate change and hazards is dependent on data and information from Government Ministries that have expertise in climate science. Energy remains the most critical of all infrastructure functions given its cascading effect on other critical functions and the economy.	**Conduct an in-depth study of climate change and hazard risks to power, gas, and fuel systems in Tonga to feed into a Sector Resilience Plan.** Type: Policy and Regulation	• Develop TOR for in-depth study of climate change risks to energy sectors • Submit for endorsement from Energy Commission and NDRMC • Conduct study and present findings to authority • Develop Resilience Plan based on study • Mobilize resources for implementation	**Lead:** **TPL** Support: MEIDECC (NDRMO)	**High** Timeframe: 10 – 12 months
Prevention and mitigation strategies to reduce risk and protect assets located adjacent to shoreline.	Existing power lines located along low coastal shorelines (i.e. Nautoka to Kolonga coastal road, Nuku'alofa area) are exposed to coastal storm surge, sea level rise, and flooding from heavy rainfall combined with chemical and physical degradation, which can lead to corrosion and infrastructure damage. Cost of relocation is costly.	**Establish a pilot programme of nature-based solutions (living shoreline) utilizing vegetation to stabilize the shoreline, reduce erosion, and protect against sea level rise. The pilot programme aligns with existing projects consisting of nature-based solutions under MEIDECC (Dept. of Environment Coastal Protection Programme and Climate Change Dept. for the Hahake coastal area).** Type: Infrastructure Management	• Develop Concept Note for Pilot Programme • Consult with Stakeholders • Seek funding from GCF and GEF allocations	**Lead:** **TPL** Support: MEIDECC	**Medium** Timeframe: 8 – 10 months

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Design tolerances of overhead power lines system to withstand wind loading.	Power distribution relies entirely on overhead lines, vulnerable to damage from Tropical Cyclones, Tonga's most frequent hazard. Category 5 cyclones, with strong wind gusts, often topple trees onto power lines, damaging cables and poles, leading to extended outages. The projected increase in cyclone activity will continue to cause outages, increasing costs for both TPL and consumers.	**Conduct feasibility study for 'selective undergrounding' of certain segments of the network to enhance resilience against wind impact and reduce areas of focus post-hazard allowing deployment of recovery efforts to only those areas with overhead power lines.** Type: Infrastructure Management	• Develop Concept Note for feasibility study • Consult with Stakeholders and development partners • Conduct study • Submit report for consideration by Energy Commission	**Lead: TPL** Support: MEIDECC (Department of Energy) MLSNR MPE	**Medium** Timeframe: 8 – 10 months
Appropriate storm and flood hardening to reduce susceptibility to damage.	The main power plant for Tongatapu is located in a low-lying area surrounded by a body of water exposed to sea level rise, flooding and storm surges. While the compound has installed certain protection measures, it remains vulnerable to projected increased rain and sea level rise. An outage at the main power plant would disrupt all power supply to the main island.	**Conduct an assessment on vulnerability of compound and assets to create a Storm hardening programme for the compound and its critical assets i.e. installation of moats and walls around critical assets.** Type: Infrastructure Management	• Develop Concept Note for feasibility study • Consult with Stakeholders and development partners • Conduct study • Submit report for consideration by Energy Commission	**Lead: TPL** Support: MEIDECC (Energy Dept.) MPE	**Medium** Timeframe: 8 – 10 months

C. TELECOMMUNICATIONS SECTOR

The communications sector drew valuable lessons from the HTHH Volcanic event in terms of infrastructure resilience. The event highlighted the significance of communications to development but also in disaster response. The Communications Department under the Ministry of Meteorology, Energy Information, Disaster Management, Environment, Climate Change and Communications is leading the sector focus towards five key areas for improving resilient ICT infrastructure:

1. Enhancing connectivity
2. Building redundancy
3. Strengthening cybersecurity and measures
4. Implementing a sector disaster recovery plan
5. Promoting ICT skills development.

A monitoring and evaluation framework is being developed to ensure the effectiveness of the strategy and to monitor operators in the sector. Resource mobilization, however, remains the key challenge for the sector.

Stakeholders and Regulatory Framework

TELECOMMUNICATIONS SECTOR	
POLICY MAKERS	Ministry of Energy, Information, Disaster, Environment, and Climate Change (MEIDECC), Ministry of Public Enterprise (MPE)
REGULATORS	Communications Commission
OWNERS	Tonga Cable Limited, Tonga Kacific, Société Européene des Satellites (SES) Communications Corporation, Digicel Tonga, Wantok, Tonga Broadcasting Commission, Nuku'alofa Radio
OPERATORS	Tonga Communications Corporation (TCC), Digicel Tonga, Wantok, Nuku'alofa Radio
KEY POLICIES/ LEGISLATIONS	Communications Act 2016 and Communications Commission Act 2015
CRITICAL ASSETS	Transmission facilities and cables, in-build wiring, switches, Internet cable and landing stations, AM/FM towers[35]

35. *Tonga National Infrastructure Investment Plan 2021 – 2030, https://tinyurl.com/365hts9n*

Sectoral Challenges

As of the end of 2022, Tonga's digital score stood at 53%,[36] reflecting its transition into the expansion phase of its digital economy. This progress is fuelled by enhanced policies and regulations, private sector initiatives to broaden digital services, and ongoing improvements in telecom and digital financial infrastructure. These efforts establish the foundation for future innovation, focusing on building the essential "digital rails"—policy, regulation, infrastructure, and skills—to ensure citizens can access basic digital services, especially in telecommunications and government ministries.[37]

However, despite the Communications Act 2016 outlining governance and administration for the ICT sector, a key body, the Communications Commission, has yet to be established. As a result, many regulatory functions, including policy and standards development, remain unaddressed. Additionally, the National Communications Sector Policy, which would provide a strategic framework for implementation, has not yet been developed.

Sector Vulnerabilities

Results from the stress testing workshop indicate that the function of "safe data collection" demonstrates a high level of resilience, aligned with the Principles for Resilient Infrastructure. However, the sector as a whole faces considerable risk due to the vulnerabilities of its critical supporting functions. This sector, given its role in building, controlling, and operating critical infrastructure, manages vast amounts of sensitive data, further exacerbating the overall risk. Moreover, all sectors analysed show high exposure and susceptibility to cybersecurity breaches, with telecommunications being a primary target.

Interdependencies with other critical infrastructure functions are summarized in the following table:

DEPENDS ON	CRITICAL FUNCTION	IMPACTS
High		**High**
Generate and distribute electricity: Reliable electricity generation and distribution during an emergency is essential for the operation of the radio broadcast in case of emergency. **Store/maintain fuel:** Electricity in Tonga relies heavily on fossil fuels. Disruptions in fuel supply significantly impact the generation and distribution of electricity, particularly during emergencies to feed backup energy generators	**RADIO BROADCAST FOR EMERGENCY**	**Evacuation Centres:** Emergency broadcasts are crucial to direct people to evacuation centres when necessary.

36. *Digital Economy Score (DES), UNCDF, https://ides.uncdf.org/about/scorecard*
37. *INCLUSIVE DIGITAL ECONOMY SCORECARD REPORT, Tonga 2022, https://tinyurl.com/36cwj2k2*

DEPENDS ON	CRITICAL FUNCTION	IMPACTS
High		**High**
Generate and distribute electricity: Reliable electricity generation is essential for the operation of data servers, routers, and other networking equipment. Interruptions in the power supply can lead to system outages, causing data loss or corruption. Therefore, generating and distributing electricity is foundational for ensuring safe and reliable data connections, as any disruptions can significantly impact the performance, security, and availability of data services **Store/maintain fuel:** Electricity in Tonga relies heavily on fossil fuels. Disruptions in fuel supply significantly impact the generation and distribution of electricity, which in turn creates cascading effects on the safety and reliability of data connections.	**SAFE DATA CONNECTION**	**Build and maintain ports, harbors, airports:** Reliable data connections are essential for building and maintaining ports, as they enable real-time communication and coordination among stakeholders. Disruptions in data connectivity can cause operational inefficiencies, delays in cargo handling, and challenges in security measures, ultimately affecting the port's functionality and competitiveness. **Store fuel and maintain reserves:** Reliable data connections are vital for effectively storing and maintaining fuel reserves, as they facilitate real-time monitoring of fuel levels, inventory management, and supply chain coordination. Disruptions in data connectivity can hinder the ability to track fuel supplies, leading to shortages or overstocking, which can disrupt operations and affect overall energy security.
Provide educational services: Maintaining safe data connections in the long run requires people with significant education to use, assess, maintain, fix and improve telecommunications systems. For this reasons, having a safe data connection, and the telecommunications sector more broadly, depend on the provision of educational services.	**SAFE DATA CONNECTION**	**Build and maintain health care facilities:** reliable data connections are crucial for constructing and maintaining healthcare facilities in Tonga, enabling efficient communication and coordination among healthcare professionals. For instance, during the COVID-19 pandemic, health authorities relied heavily on data connections to share critical information regarding patient care and resource allocation across various healthcare facilities. Disruptions in data connectivity can delay project management and hinder access to patient records, which could compromise the quality of care and operational efficiency in facilities like the Vaiola Hospital, the main referral hospital in Tonga. **Provide educational services:** Safe data connections are essential for providing educational services, especially in a digital learning environment. Reliable internet access supports online learning platforms, educational resources, and communication between students and teachers. In Tonga, where educational access can be limited, robust data connections enable remote learning opportunities and enhance the overall learning experience.

Resilience Measures

A number of e-strategies have been developed for the sector. The Tonga Digital Government Strategic Framework 2019-2024 (DGSF) provides a framework for integrated and sustainable digital development for the Government. It offers a set of principles that all technology infrastructure should follow which includes all digital government infrastructure capable of supporting the delivery of e-solutions to all members of the community. Tonga's National Cybersecurity Framework provides key target areas for improvement to ensure the safety of Tonga's infrastructure from cyber threats.

The Tonga E-Commerce Strategy Roadmap 2021 proposes a vision of a transformative economy where most Tongan businesses and consumers actively engage in domestic and cross-border electronic commerce to accelerate Tonga's Digital Transformation through accelerated economic growth that is inclusive and equitable.

The telecommunications sector facilitates access to global markets, fostering a competitive environment. Efforts in policies and strategies are directed towards bridging the connectivity and accessibility gap. However, current assessments indicate that policies and strategies concentrating on the infrastructure resiliency of the sector are insufficient. There is potential to enhance the focus on infrastructure and system resilience by incorporating resilience elements into the National Communications Sector Plan.

Resilience Gaps and Recommendations

Table 11. Telecommunications sector infrastructure resilience recommendations

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Gap in The existing regulatory framework does not require service providers to collect, maintain, and provide critical infrastructure data feeding a Disaster Connectivity Map* when requested from NDRMO/ MEIDECC.	Not all network and service providers conduct vulnerability analyses of their critical infrastructure network based on hazard mapping. This is largely due to asset data not being updated or digitized and hazard maps not being readily available.	**Integrate the requirement for service providers to collect, maintain and share data in the legislation. For example, DRM Regulation and Communications Regulations are both in the pipeline for development. Hazards maps should be made easily available to service providers for planning purposes.** Type: Policy and Regulation, Data Capturing, Management and Use	• Draft provisions for data collection, maintenance and sharing • Consult key stakeholders • Submit for endorsement from NDRMO	**Lead:** **MEIDECC (ITC)** Support: NDRMO ICCC TCC Digicel Wantok	**Medium** Timeframe: 6 – 8 months
The Monitoring and planning function of the Communications Department is not effectively carried out.	The MEIDECC (Communications Department) does not collect data (key indicators for monitoring and planning) like Network coverage area, Network coverage technology, Number of base stations, and Number of exchanges.	**MEIDECC (Communications Department) as Regulator to collect data from service providers and review against indicators on an annual basis. Information should be made readily available to NDRMO.** Type: Policy and Regulation	• Draft data requirement template for operators/owners • Draft supporting policy to implement requirement • Consult with Operators/Owners • Submit to MEIDECC CEO for approval • Distribute for compliance.	**Lead:** **MEIDECC (ITC)** Support: TCC Digicel Wantok ICCC MPE	**Medium** Timeframe: 3 – 4 months

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
No formalized requirement for all operators to have a continuity and contingency plans in place.	Apart from the Telecommunications Cluster whose function is to coordinate service provider activities during a disaster, service providers operate independently throughout the disaster cycle. There is no clear guidance for the Telecommunications Sector on how to operate within the disaster cycle, especially during a disaster.	**Establish specific regulations under the Communications Act or Regulator directive requiring for business continuity and contingency plans during a disaster from Communications Operators.** Type: Policy and Regulation	• Draft requirement provisions • Consult with stakeholders • Submit for approval from Regulator	**Lead:** **MEIDECC (ITC)** Support: TCC Digicel Wantok ICCC	**Medium** Timeframe: 3 – 4 months

***Disaster Connectivity Map (DCM)** – mapping tool that provides real-time information on coverage and quality of telecom connectivity on the ground before, during and after a disaster.*

D. TRANSPORT SECTOR

The Roads Act establishes the Minister of Transport (Infrastructure) as responsible for the building, maintenance, and protection of the integrity of all public roads and road assets. The decision to build a new public road, however, shall be made by the Minister for Land having satisfied there is available land. Classification of roads is the responsibility of the Minister for Transport. The Roads Act further establishes a Road Maintenance Fund specifically for building, maintaining, and protecting the integrity of public roads including road safety. The Fund is managed by the Road Maintenance Fund Steering Committee.

The regulators in the transport sector are supported by established legislation and necessary policies to effectively monitor operator and owner performance. However thin institutional capacities hinder the ability of government institutions to develop their regulatory function; for example, to prepare projects and monitor their effective implementation. With a heavy reliance on fossil-fuel energy for transport, the Government's intent to transition to sustainable transport will require new institutional capacities to implement and sustain these new developments.

Stakeholders and Regulatory Framework

TRANSPORT SECTOR	
POLICY MAKERS	Minister for Infrastructure and Minister for Land
REGULATORS	Civil Aviation Division, Marine and Ports Division, Land Transport Division, Civil Engineering Division
OWNERS	Ports Authority, Tonga Airports Limited, Shipping agencies, International and Domestic Airline, Private transport companies
OPERATORS	Ports Authority, Tonga Airports Limited, Shipping agencies, International and Domestic Airline, Private transport companies
KEY POLICIES/ LEGISLATIONS	Transport Services Act, Roads Act, Ports Management Act and Ports Authority Act, and the Civil Aviation Act
CRITICAL ASSETS	Roads: Earthworks, road pavement, footpaths, traffic signals, guardrails, curbing, roadside drains, bridges, fords, culverts, retaining walls, jetties. Aviation: Runways, taxiways, aprons, navigation aids, runway lighting, weather stations, control systems, fuelling systems, aircraft Maritime: Wharves, jetties, navigation aids, tugs; container yards, cranes, dredges[38]

Sectoral Challenges

Land transport is the dominant mode of transport for people and goods compared to domestic ferries and the national domestic airline. As such roads are a critical infrastructure that contributes to the socio-economic growth of the country. In 2017 there were over 16,000 vehicles (out of approximately 18,200 households) in Tonga with about 87% of them on the main island. Vehicle numbers are estimated to grow at a rate of 1.3% by 2035.[39]

As the highest user of imported petroleum accounting for approximately 90%, TERM Plus and TEEMP strategies integrate transport into their energy roadmaps. The focus however is not the resiliency of roads but the reduction of fossil fuel dependency and gas emissions. TERM Plus however does identify gaps in transport policies highlighting the absence of integrated transport and land use planning, poor quality road infrastructure in terms of design and construction and lack of climate-proofing (poor drainage).

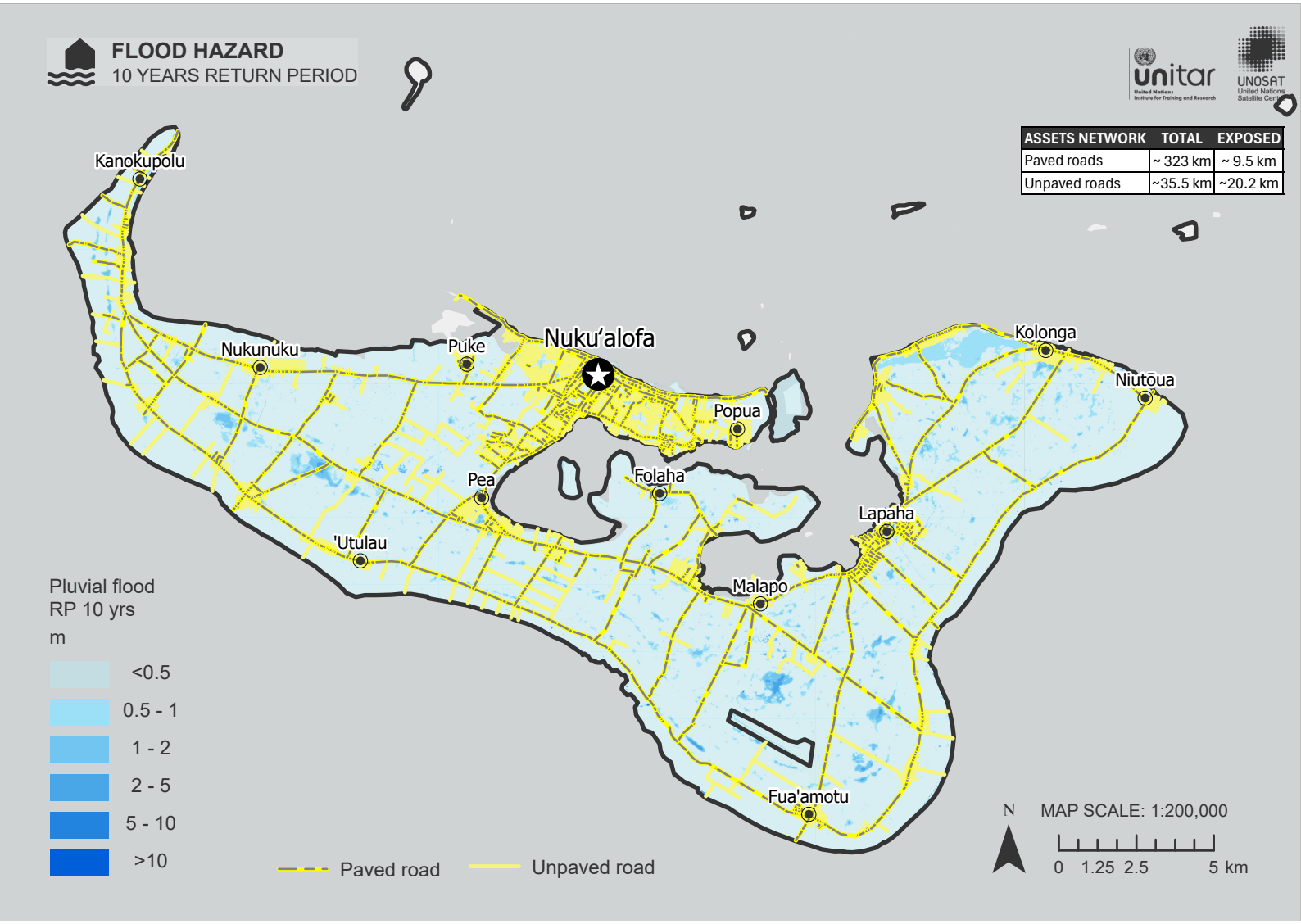
Transport Sector legislation reflects recent developments in DRR in the Tonga context. These legislations were drafted prior to the shifting policy attention towards DRM and DRR. While the Transport Services consolidate all transport in Tonga, it is a complex sector to bring under one overarching national policy document. Reinforcing DRR components into sector policies remains a

38. *Tonga National Infrastructure Investment Plan 2021 – 2030, https://tinyurl.com/365hts9n*

key area for improvement.

Figure 7 is a map produced by UNOSAT that highlights the extent to which assets from the transport sector are exposed to flooding in Tongatapu. If flooded, these assets are at risk of being disrupted. Data from the Multi Hazards Disaster Risk Assessment, ARUP 2021 is depicted in the map.[40]

Figure 7. Transport assets exposure map. Pluvial flood hazard 10-year return period model by ARUP and asset locations from the MHDRA geodatabase. A quantitative GIS analysis of the data results in approximately 9.5 km of paved roads and approximately 20.2 km of unpaved roads exposed to pluvial flood.



39. TERM PLUS Tonga Energy Road Map 2021 - 2035. (2021). In https://tongaenergyroadmap.gov.to/?author=1. Government of Tonga. https://tongaenergyroadmap.gov.to/?author=1
40. ARUP. (2021). Multi Hazard Disaster Risk Assessment, Tongatapu:Hazard Assessment Report - Pluvial Flooding and Coastal Inundation(No. 276779–00). ADB, https://www.adb.org

Sector Vulnerabilities

DEPENDS ON	CRITICAL FUNCTION	IMPACTS
High		**High**
Build and maintain ports, harbours, airports: Serve as the critical entry and exit points for goods and passengers. Goods imported by sea or air are distributed via Tonga's road network to reach markets, businesses, and consumers throughout the islands. Additionally, road transport connects people to airports and harbours for domestic and international travel, making these transport hubs vital for the movement of both freight and passengers.	**ROADS**	**Supply water/water management:** Disruptions in road transport can significantly hinder the supply and management of water in Tonga by delaying the transportation of water supplies, repair materials, and technical personnel needed to maintain or fix water infrastructure. Road transport interruptions may also affect the delivery of clean water to remote or rural areas, exacerbating water scarcity and limiting access to potable water. **Build and maintain ports, harbours, airports**: Disruptions in road transport in Tonga can delay the movement of construction materials, equipment, and personnel essential for building and maintaining ports and harbours. Since ports and harbours rely on regular maintenance and upgrades to ensure operational efficiency and safety, road transport interruptions can slow down these processes, potentially causing delays in port operations. This, in turn, can affect the timely import and export of goods, leading to broader economic impacts, especially for a country heavily dependent on maritime transport. **Generate and distribute electricity:** Disruptions in road transport in Tonga can significantly impact the generation and distribution of electricity by delaying the transport of essential supplies such as fuel (for diesel generators), equipment, and maintenance personnel. Since Tonga's electricity generation is heavily reliant on imported diesel, any road transport interruptionscan hinder the delivery of fuel to power stations. This could lead to power outages or reduced electricity generation, affecting various critical sectors dependent on a reliable power supply. **Evacuation centres:** Disruptions in road transport in Tonga can severely impact access to evacuation centres, especially during emergencies like cyclones or tsunamis. Inaccesible roads delay the movemement of people to safe locations,

	ROADS	disrupt the delivery of essential supplies such as food, water, and medical aid, and hinder the transportation of emergency responders to affected areas. Road blockages caused by flooding or debris can also prevent timely evacuations, increasing the risk for communities in disaster-prone regions. **Store fuel and maintain reserves:** Disruptions in road transport in Tonga can significantly impact the storing and maintaining of fuel reserves. Fuel transportation relies on road networks to move fuel from ports to storage facilities and distribution points across the islands. Any blockage or damage to roads, can delay fuel deliveries, interrupt supply chains, and prevent timely replenishment of reserves. This could lead to shortages, affecting sectors like electricity generation, transportation, and emergency services, all of which depend on a stable fuel supply. **Build and maintain healthcare facilities:** Disruptions in road transport can significantly impact the building and maintenance of healthcare facilities in Tonga by hindering the transportation of essential construction materials, medical supplies, and personnel. In the event of damaged or blocked roads, access to healthcare services becomes limited, affecting the delivery of care and delaying critical infrastructure repairs or upgrades. This can exacerbate health risks, especially in remote or rural areas dependent on timely access to medical services and supplies. **Provide educational services:** Disruptions in road transport in Tonga can severely affect the provision of educational services by limiting access to schools, particularly in rural or remote areas. Students and teachers may face difficulties reaching schools, leading to lower attendance and reduced instructional time. Furthermore, road transport disruptions can delay the delivery of educational materials and resources, impacting the quality of education. During extreme weather events or disasters, damaged roads can isolate communities, preventing students from attending school for extended periods.

DEPENDS ON	CRITICAL FUNCTION	IMPACTS
High		**High**
Roads: Roads are essential for transporting people and goods needed to build and maintain ports, harbours and airports.	**BUILD AND MAINTAIN PORTS, HARBOURS, AIRPORTS**	**Roads:** Ports, harbours and airports serve as the critical entry and exit points for goods and passengers. Goods imported by sea or air are distributed via Tonga's road network to reach markets, businesses, and consumers throughout the islands. Additionally, road transport connects people to airports and harbours for domestic and international travel, making these transport hubs vital for the movement of both freight and passengers.
Generate and distribute electricity: Electricity is needed for the operation, construction and maintenance of all types of ports, so its generation and distribution is essential for this infrastructure function.		**Generate and distribute electricity:** As an island state, Tonga receives equipment and spare parts through its ports, making them essential for maintaining the infrastructure necessary to generate and distribute electricity.
Safe data connection: Ports depend on data connection to coordinate the arrivals and departures so ensuring a safe data connection is critical for the proper work of ports, harbours and airports. Additionally, within the ports, data connections are used to facilitate communication and information sharing which is important for an efficient maintenance of the assets.		**Evacuation centres:** Specially during emergency, Tonga's ports are crucial to receive any kind of assistance, so the evacuation centres require the ports to be working to be able to function properly over time.
Store fuel and maintain reserves: Since ships and airplanes require fuel, having enough reserves is important for the functioning of ports, harbours, and airports. Additionally, vehicles required for the building and maintenance of the ports also require fuel to work, making its availability extremely important.	**BUILD AND MAINTAIN PORTS, HARBOURS, AIRPORTS**	**Store fuel and maintain reserves:** Since all the equipment and spare parts required in the energy sector arrive to Tonga by seaport or airports, these are crucial to store fuel and maintain reserves.
Provide educational services: Building and maintaining complex infrastructures such as ports, harbours and airports requires technical capacities that rely on educational services. For this reason, providing educational services is crucial for this infrastructure function.		**Build and maintain healthcare facilities:** Seaports and airports are critical to receive all kinds of medicines and equipment required to build, maintain and operate healthcare facilities.

Resilience Measures

The Roads Act sets out the governance structure for improved road maintenance and the establishment of a funding pool specifically for road maintenance.

The Transport Services Act brings all transport services under a single administrative umbrella as

regulator for the sector. The Act provides an opportunity for improved coordination within the sector but also a unified approach to setting standards for development.

Tonga Airports Limited (TAL) and Ports Authority of Tonga (PAT) governances are well established and demonstrate effective management and service delivery within the sector. Both report strong financial positions, implementing new policies to drive productivity. TAL and PAT have ongoing infrastructure upgrades supported by development partners to strengthen and improve infrastructure. PAT is working on upgrading its IT infrastructure and expanding the main port in Tongatapu – Queen Salote Wharf. The Vava'u International Airport is set to replace its existing facility with an 8,000m² terminal and cargo facility.

Resilience Gaps and Recommendations

Table 12. Transport sector infrastructure resilience recommendations

GAPS	KEY FINDINGS	RECOMMENDATIONS	ACTIONS	RESPONSIBLE ENTITIES FOR ACTION	PRIORITY / TIMEFRAME
Enhanced road asset management systems based on comprehensive geospatial data infrastructure.	Roads are increasingly exposed to climate hazards especially flooding in low lying areas.	**Improve quality of infrastructure and climate data through an improved Road Asset Management system by creating a programme focused on developing assessments, building technical knowledge and supporting implementation of resilient transport projects.** Type: Data Capturing, Management and Use	• Develop process for conducting geohazard risk assessments to understand which rural and urban roads are exposed to flooding • Produce geohazard maps • Develop mitigation measures based on assessments	**Lead:** **Ministry of Infrastructure** Support: MLSNR MEIDECC (NDRMO)	**Medium** Timeframe: 8 – 10 months
Climate Change vulnerability assessment of critical road infrastructure.	Projected increase in rainfall intensity, tropical cyclone, and flooding for Tonga posing increasing risk to transport infrastructure. Increasing number of road users with limited road networks.	**Integrating climate safety factors in road designs.** Type: Policy and Regulation/ Infrastructure Management	• Develop vulnerability assessment tool • Establish a knowledge management system for MOI to identify, generate, store, and manage knowledge products	**Lead:** **MOI** Support: MLSNR MEIDECC (NDRMO)	**High** Timeframe: 10 – 12 months

THE KINGDOM OF TONGA'S RESILIENT INFRASTRUCTURE PRIORITIES AND NEXT STEPS

As Tonga faces increasing climate-related threats, the protection of critical infrastructure and livelihoods has become a national priority. Strategic investments in resilient infrastructure are now a cornerstone of this effort. The nation remains committed to promoting innovative approaches to infrastructure development that emphasize resilience, sustainability, and inclusivity. By fostering collaborative partnerships with international organizations, development agencies, the private sector, and non-governmental organizations, Tonga aims to harness cutting-edge technologies, global good practices, and local expertise to strengthen its infrastructure networks.

The series of recommendations developed as part of this roadmap were thoroughly discussed by key stakeholders and presented to a group of Chief Executive Officers (CEOs). Following further deliberation, these recommendations were refined and prioritized. The CEOs have committed to moving forward with the following set of prioritized recommendations for implementation.

Cross-sectoral Priority Recommendations:
- Development of a national resilient critical infrastructure strategy
- Establishment of the critical infrastructure working group
- Establish a central disaster data centre

Water Sector Priority Recommendations:
- Develop village water committee manual of guidance
- Develop programmes to improve water quality and education

Energy Sector Priority Recommendations:
- Conduct a study of climate change and hazard risks posed to power, gas and fuel
- Protect power network assets along exposed coastlines using nature-based solutions

Telecommunications Sector Priority Recommendations:
- Collect service provider data and review against set indicators

Transport Sector Priority Recommendation:
- Integrate climate adaptation and resilience measures into road infrastructure design, construction, and operations to minimize exposure to all hazards

A detailed description for each of the recommendations can be found in the Executive Summary under Roadmap Key Priorities.

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Photo credit. NASA Earth Observatory image by Jesse Allen, using Landsat data from the U.S. Geological Survey.

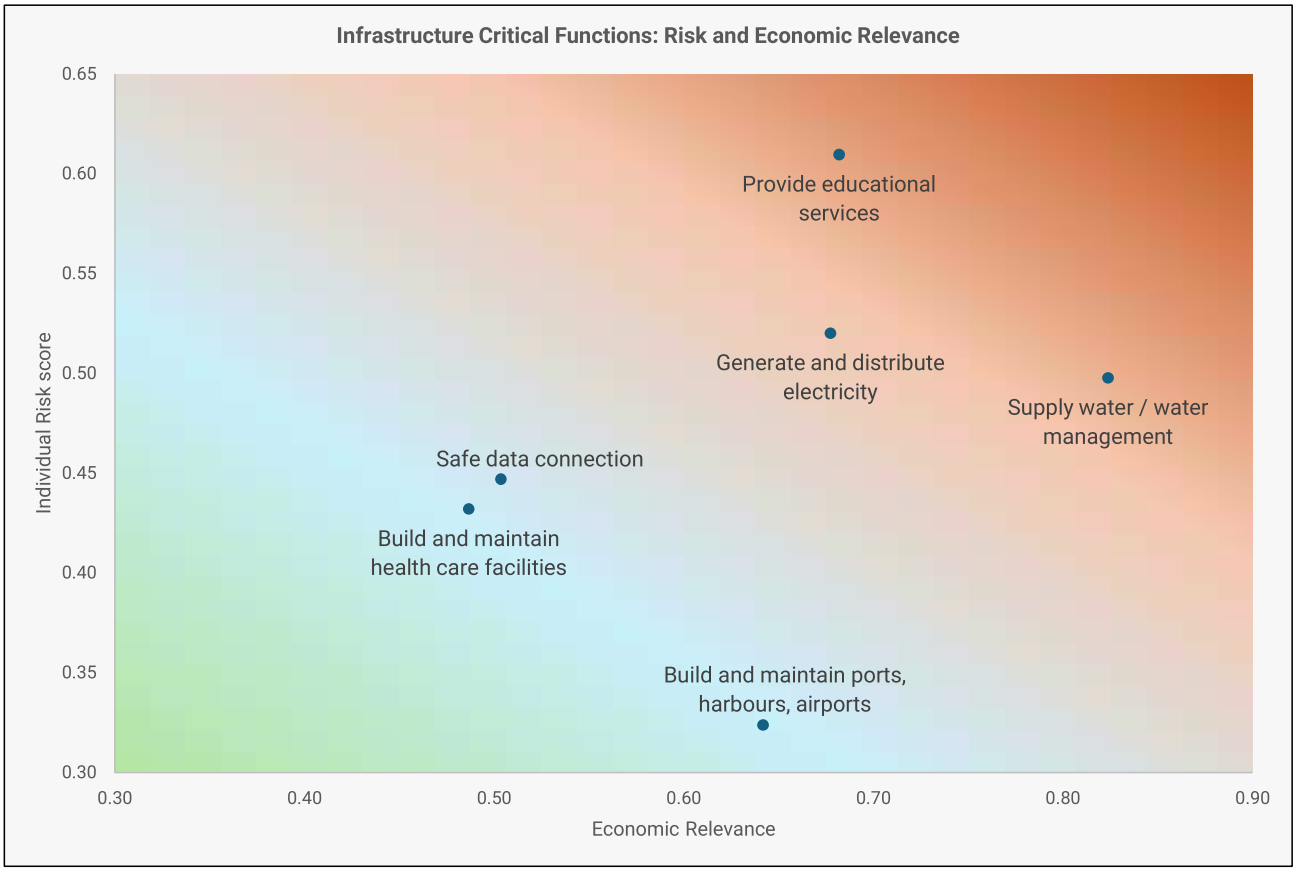
ANNEX I. STRESS-TEST RESULTS

Note: The scores are based on consultations carried out as part of the project and contain a degree of subjectivity by their very nature.

INFRASTRUCTURE CRITICAL FUNCTIONS

The table below assists in prioritizing infrastructure critical functions based on their importance for maintaining the economy in the country and the risks they are exposed to. The Cascading Risk column provides additional information about the risks that an infrastructure function is facing. High cascading risk means that the critical function is vulnerable to disruptions from other functions (as it depends on them).

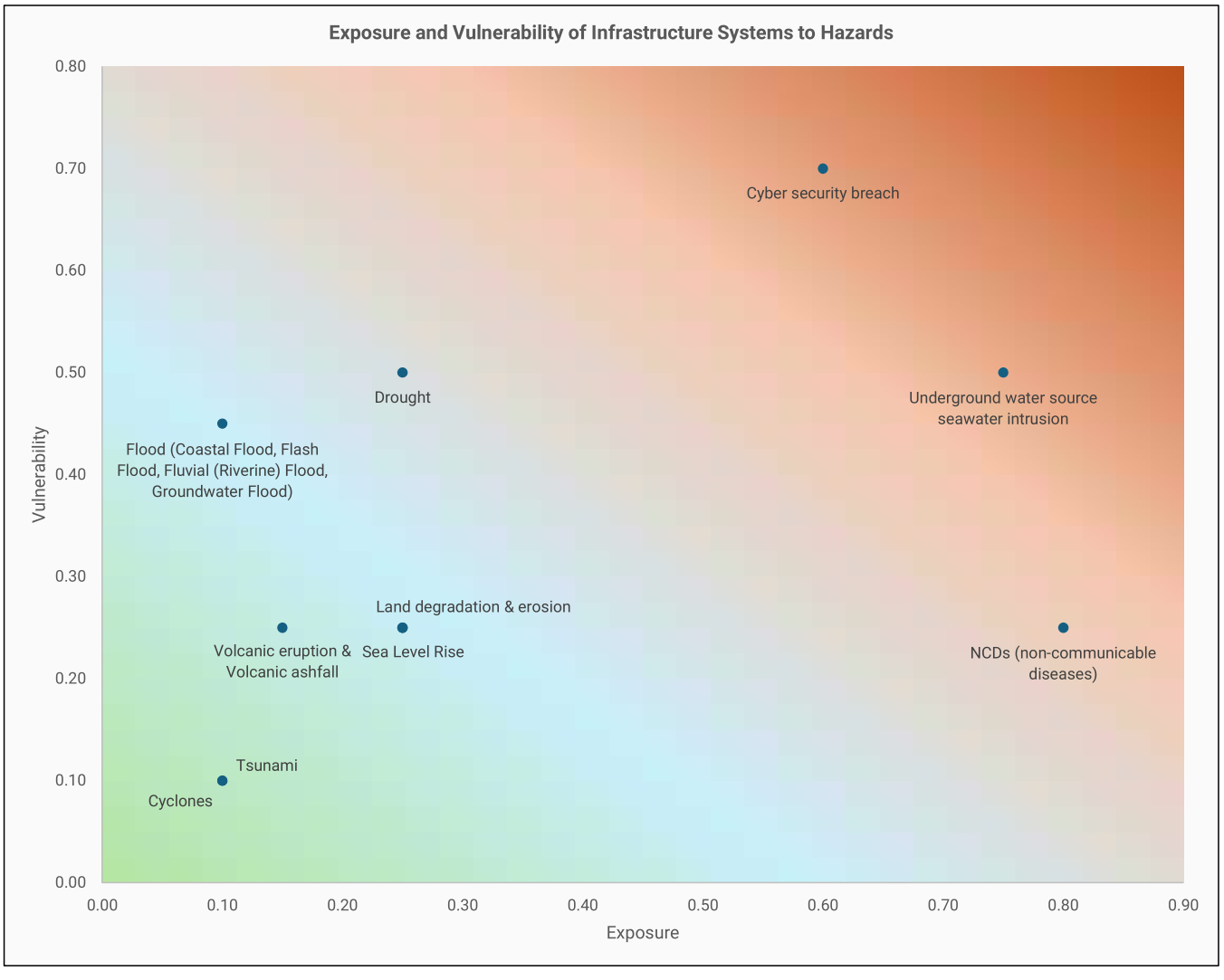
	Importance of the Infrastructure Critical Functions based on their support to the Economic Sectors		*Level of risk of the Infrastructure Critical Functions posed by the selected hazards*	*Cascading risk from dependence between critical functions in disaster scenarios*
INFRASTRUCTURE CRITICAL FUNCTIONS	**IMPACT ON THE ECONOMY**	**CASCADING IMPACT ON THE ECONOMY**	**INDIVIDUAL RISK**	**CASCADING RISK**
Supply water / water management	0.82	0.41	0.50	0.51
Build and maintain ports, harbours, airports	0.64	0.54	0.32	0.53
Build and maintain roads	0.72	0.64	0.27	0.33
Generate and distribute electricity	0.68	0.69	0.52	0.38
Safe data connection	0.50	0.36	0.45	0.51
Radio broadcast for emergency	0.27	0.25	0.13	0.20
Evacuation centres	0.25	0.03	0.18	0.51
Store fuel and maintain reserves	0.74	0.67	0.17	0.44
Build and maintain health care facilities	0.49	0.26	0.43	0.71
Provide educational services	0.68	0.50	0.61	0.41



HAZARDS

The table below assists in prioritizing hazards based on their impacts on critical functions and the economy. The Exposure and Vulnerability columns provide information on the likelihood and potential impacts of each hazard on the overall infrastructure systems, as well as a Risk score (weighted average of the exposure and vulnerability scores).

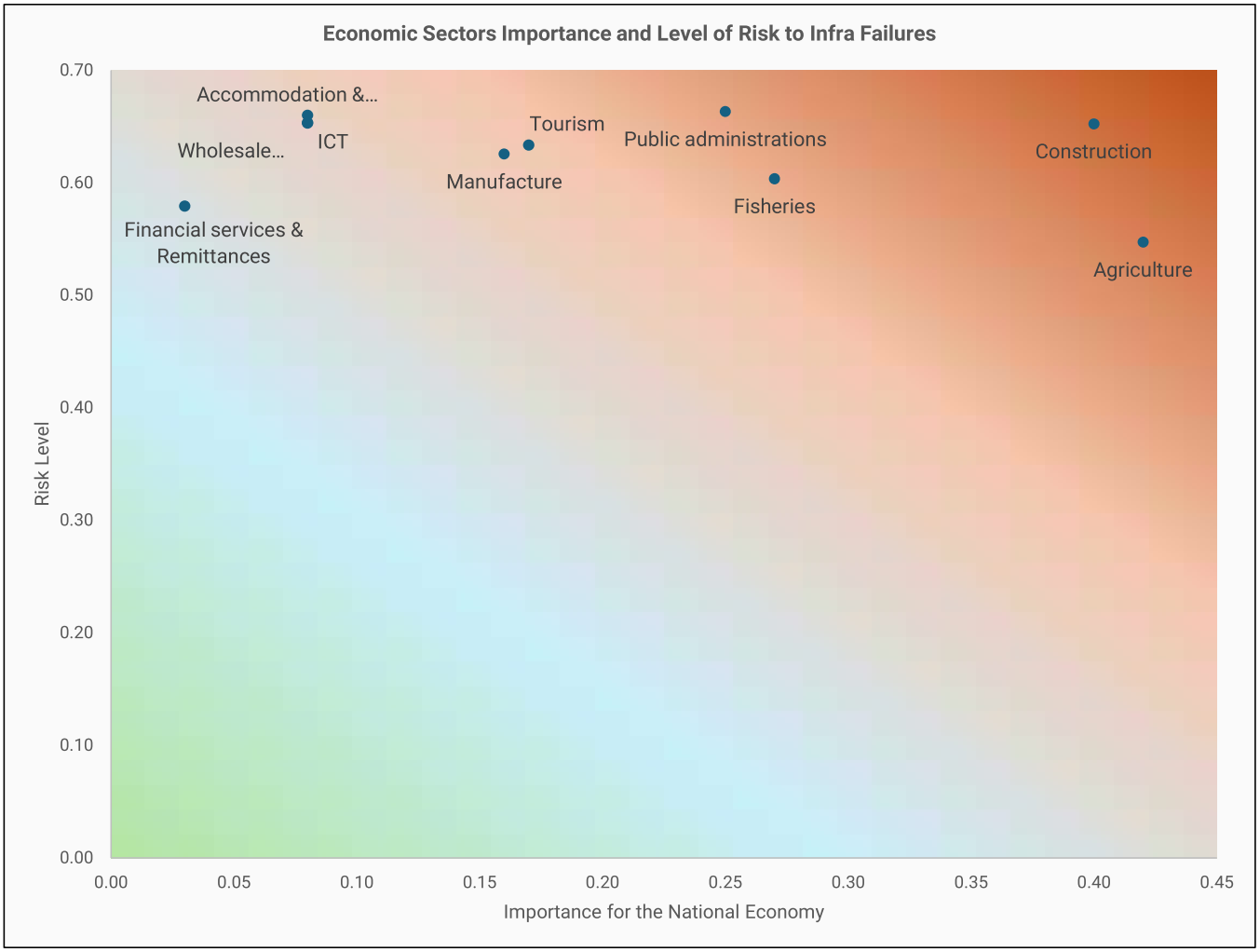
	Relevance of Hazards based on their impact to critical functions and their relevance to the Economic Sectors	EXPOSURE AND VULNERABILITY OF INFRASTRUCTURE SYSTEMS TO SELECTED HAZARDS		
HAZARDS	**IMPACT TO THE ECONOMY**	**EXPOSURE**	**VULNERABILITY**	**RISK SCORE WEIGHTED AVERAGE**
Cyclones	0.53	0.10	0.10	0.10
Drought	0.14	0.25	0.50	0.38
Underground water source seawater intrusion	0.48	0.75	0.50	0.63
Tsunami	0.63	0.10	0.10	0.10
Volcanic eruption & Volcanic ashfall	0.64	0.15	0.25	0.20
NCDs (non-communicable diseases)	0.20	0.80	0.25	0.53
Land degradation & erosion	0.36	0.25	0.25	0.25
Flood (Coastal Flood, Flash Flood, Fluvial (Riverine) Flood, Groundwater Flood)	0.60	0.10	0.45	0.28
Sea Level Rise	0.62	0.25	0.25	0.25
Cybersecurity breach	0.26	0.60	0.70	0.65

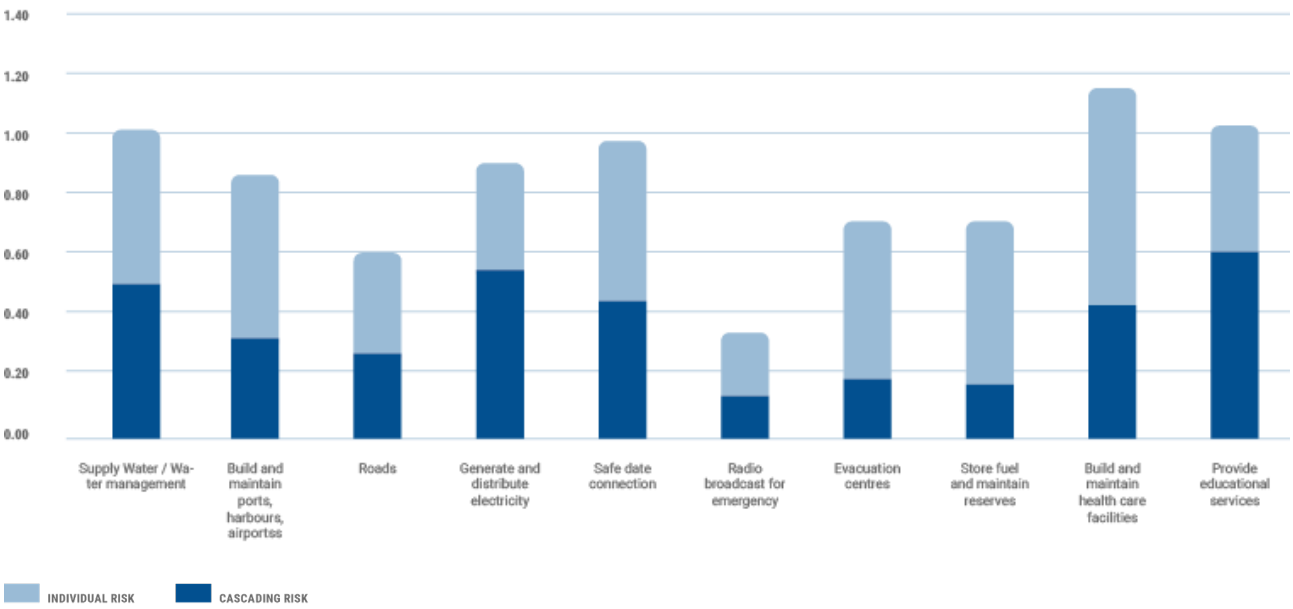


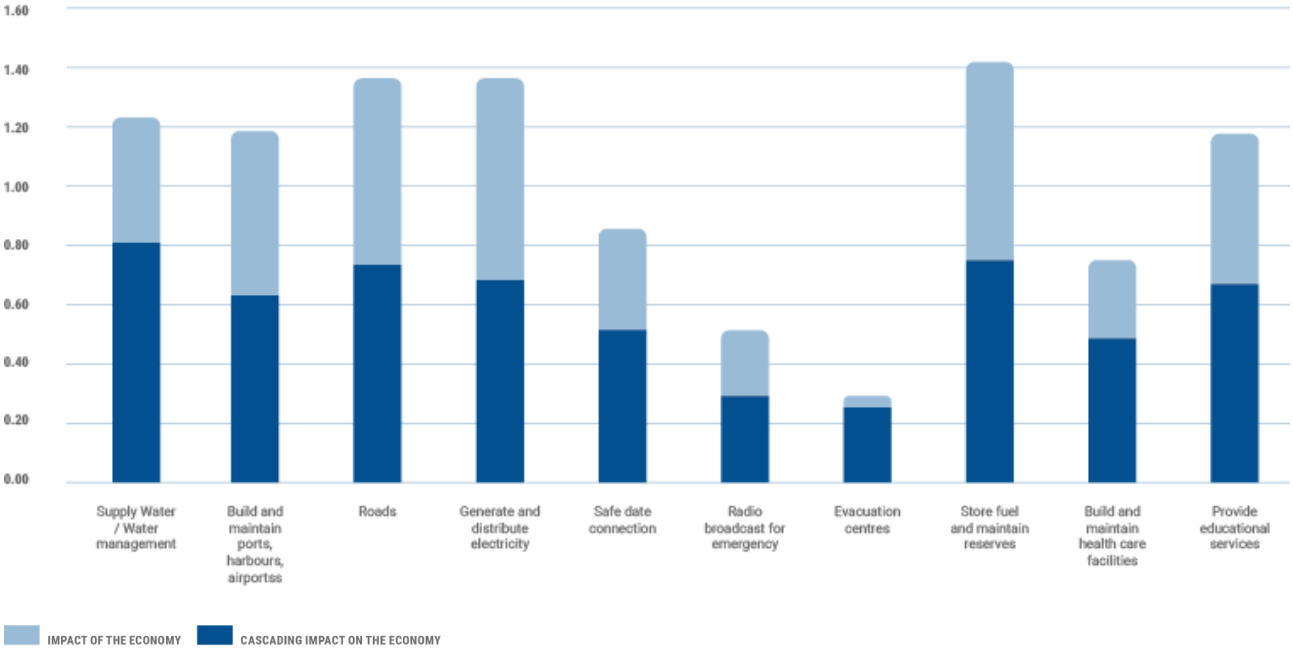
ECONOMIC SECTORS

The table below assists in prioritizing economic sectors based on a) their contribution to the GDP and to the creation of jobs (average between the two); b) the level of risk posed to the economic sectors due to possible failures of the critical functions on which they depend.

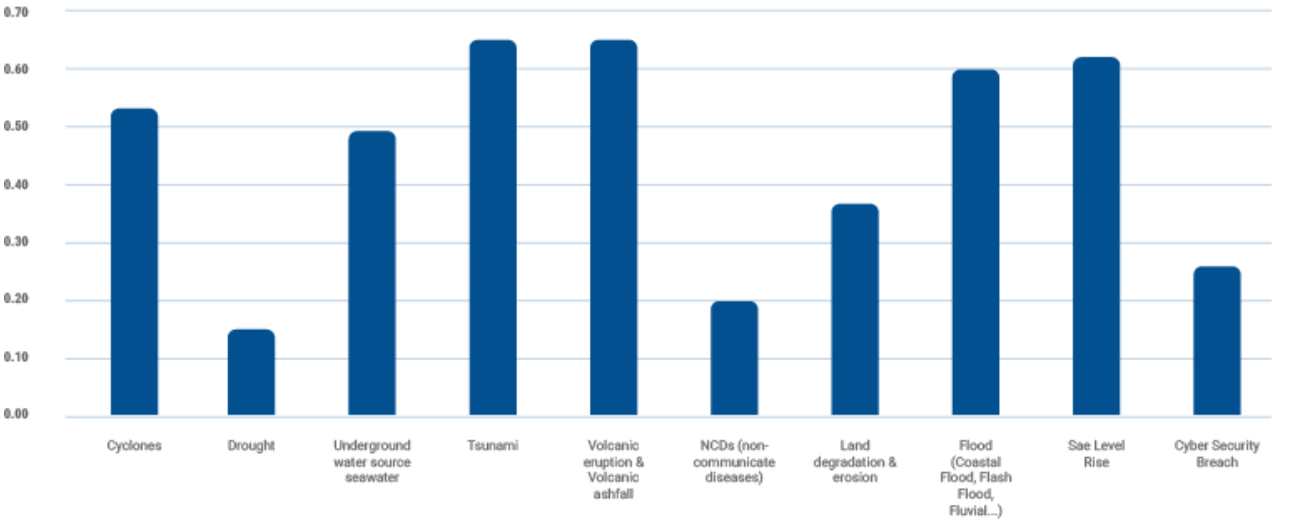
ECONOMIC SECTORS	IMPORTANCE OF ECONOMIC SECTOR TO ECONOMY *Importance of Economic Sector based on its contribution to jobs and GDP*	RISK OF ECONOMIC SECTORS *Level of risk of the Economic Sectors based on the risk of the Critical Functions on which they depend*
Agriculture	0.42	0.55
Fisheries	0.27	0.60
ICT	0.08	0.66
Construction	0.40	0.65
Wholesale and Retails	0.08	0.65
Tourism	0.17	0.63
Accommodation & Restaurants / bars / café	0.08	0.65
Financial services & Remittances	0.03	0.58
Manufacturing	0.16	0.63
Public administrations	0.25	0.66







IMPACT TO THE ECONOMY THROUGH THE DISRUPTION OF CRITICAL INFRASTRUCTURE FUNCTIONS



ANNEX II. REVIEW OF POLICIES AND INTEGRATION OF THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE

FINDINGS OF THE POLICY AND REGULATORY REVIEW

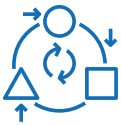
DOCUMENT TITLE	HOW IS THIS RELEVANT FOR DRR / RESILIENCE	LINK TO THE PRINCIPLES					
		P1	P2	P3	P4	P5	P6
CROSS-CUTTING							
Tonga's Strategic Development Framework 2015-2025 (TSDF II)	The overarching framework for Tonga's development which identifies the significance of reliable, safe, and affordable infrastructure to its growth and improved national and community resilience to climate change.	N	N	N	N	N	N
Government Priority Agenda and Budget 2020-2023	Outlines key focus areas of the present Government which include improved Infrastructure resilience, and resilience capability towards climate change and disasters.	N	N	N	N	N	N
Tonga Climate Change Policy 2016	Focus on building a resilient Tonga by 2035. It is intended to provide an overarching context and guiding framework for multi-sector holistic coordination.	N	N	N	N	N	N
Joint National Action Plan 2 on Climate Change and Disaster Risk Management (JNAP2) 2018-2028	Sets six policy objectives for Tonga to achieve its vision of a resilient Tonga by 2035. Identifies the necessity of critical infrastructure security and its resiliency.	Y	Y	N	N	N	Y
Disaster Risk Management Act 2021	Establishes a coherent legal, institutional, and regulatory framework for – (a) planning and management of disaster risk reduction and preparedness activities before a disaster occurs; (b) coordinating emergency response during a disaster; and (c) facilitating disaster recovery work following a disaster.	Y	N	N	N	N	N
National Disaster Risk Management Policy	Provides a detailed list of policy objectives in cross-cutting areas such as governance, finance and disaster risk data contributing to building disaster resilience in Tonga.	Y	Y	N	N	N	N
Disaster Risk Financing Strategy 2021	Sets the Government's layered approach to post-disaster financing and calls for investments in risk reduction for more proactive DRM.	Y	Y	N	N	N	N
National Infrastructure Investment Plan 2013-2023	Government document that links infrastructure planning and development to the TSDF II objectives ensuring cross-sector prioritization.	Y	Y	Y	N	N	N
Building Control and Standards Act & Regulations	The basic objective of the Code is to ensure that acceptable standards of structural sufficiency, fire safety, health and amenities, are maintained for the benefit of the community. The Code sets down the Performance Requirements and corresponding Deemed-to-Satisfy Provisions which apply to the construction of buildings for all Classes of occupancy.	N	N	N	N	N	N
National Spatial Planning and Management Act	Establishes governance and framework for land use and development planning and policy integrating environmental, social, cultural, economic, conservation and resource management issues at all levels. The established Authority is responsible for assisting the coordination of provision of infrastructure and services by ministries and public authorities for the benefit of the community.	N	N	N	N	N	N

ENERGY							
Energy Act 2021	Provides the regulatory framework for the management, planning and coordination of energy and provides for the development of standards and regulations of the energy sector.	Y	Y	N	N	Y	Y
Tonga Energy Roadmap 2021-2035 (TERM PLUS)	Built around consistent set of quantifiable targets for energy supply, renewable energy and introduces transportation and resiliency among other focus areas. Requires investment in new infrastructure and technology.	Y	Y	Y	Y	Y	Y
Government of Tonga Energy Efficiency Master Plan 2020	The TEEMP encompasses electricity use and ground transportation and complements the approach of the 2009 Tonga Energy Road Map 2010-2020 (TERM) focusing on lowering Tonga's fossil fuel dependence and improving national energy security. TEEMP recognizes Tonga's vulnerability to climate change and considers improvements in power and transport sectors to support resiliency in terms of the ability of the two sectors to recover and withstand disasters.	N	N	N	N	N	N
TRANSPORT							
Tonga Energy Roadmap 2021-2035 (TERM PLUS)	Built around consistent set of quantifiable targets for energy supply, renewable energy and introduces transportation and resiliency among other focus areas.	Y	Y	Y	Y	Y	Y
Roads Act 2020	Provides governance and establishes the Maintenance Fund to provide for construction and maintenance of public roads.	N	N	N	N	N	N
Transport Services Act 2008	Integrates the administration of land, sea, and air transport sectors in Tonga.	N	N	N	N	N	N
ICT							
Communications Act	Establishes the National Communications Sector Policy (not yet drafted) which includes policy objectives that focus on maximizing availability of communications infrastructure, and communications infrastructure to support new industry investment.	N	Y	N	N	Y	N
Tonga National Cybersecurity Framework	Establishes objectives to help guide the often complex requirements to develop and safely manage the data and information systems used for improving government services. Provides framework and suggests actions for building cyber resiliency for Tonga through a risk management approach.	N	Y	N	Y	Y	Y
Tonga E-Commerce Strategy Roadmap 2021	Provides a basic analysis of Tonga's current e-commerce environment, identifies key constraints both internal and external, assesses current strengths, weaknesses, gaps and opportunities and provides recommendations on key actions in terms of legislation and policy framework changes, institutional reforms and capacity development to address seven relevant areas. Strategy shifts trade and business towards digitization and digitalization which in turn requires resilient infrastructure investment.	N	N	N	Y	N	N

WATER AND WASTEWATER							
Water Resources Act 2020	Provides for sustainable management of water resources in Tonga and regulates the infrastructure used for taking and use of water.	N	Y	Y	Y	Y	Y
Tonga Water Board Act 2000	Establishes the Tonga Water Board as regulator of water supply services.	N	N	N	N	N	N
National Water Resources Policy 2019	Provides a framework for leadership and coordinated action in the supply of safe, adequate and financially, technically and environmentally sustainable water services to rural and urban communities in Tonga. Provides for policy objectives to improve planning and management of water supply systems.	N	N	N	Y	N	Y
Hydrology and Water Resources Division Strategic Plan 2020 - 2030	Sets out the goals, objectives, strategies, actions, planned outcomes and outputs and an implementation schedule for the Hydrology and Water Resources Division (HWRD) of MLNR. Guides responsibilities identified in the WRA to sustainably manage, conserve and protect the Kingdom's water resources now, and in the future under changing climate conditions and increasing extreme events	N	N	N	Y	N	Y
National Water Resources Implementation Plan 2019	The NWRIP is a key Government strategy for ensuring provision of safe, adequate and financially, technically and environmentally sustainable water services to rural and urban communities in Tonga and for the protection, conservation, sustainable use and efficient management of Tonga's water resources	N	Y	Y	Y	N	Y

PRINCIPLES SCORECARD ASSESSMENT OF WATER SECTOR RESILIENCE

PRINCIPLE FOR RESILIENT INFRASTRUCTURE	FINDINGS FOR TONGA WATER SECTOR – KEY RESILIENCE GAPS	RECOMMENDATIONS IN IMPLEMENTATION PLAN
CONTINUOUSLY LEARNING 	Monitoring information about water quality, quantity and infrastructure is patchy and not properly used to inform decisions for water sector management. Information is held by various entities with limited data sharing. Formal training for Village Water Committees is limited.	Develop a Manual of Guidance for village water committees to promote good governance, management, improve water security, access, construction and sanitation. Develop a generic emergency water response plan for village water committees to adapt for climate and disaster events. Develop and establish a data-capturing mechanism for Village Water Committees.
PROACTIVELY PROTECTED 	Water sector infrastructure is exposed to a range of hazards (including floods, storms, sea level rise, volcanoes, tsunamis). Limited assessment of hazard exposure of critical assets has been completed. Responses to emergencies have not been properly embedded into business continuity plans, while maintenance and asset management budgets are insufficient.	Develop a water critical assets registry to monitor maintenance and replacement needs. Improve water security on outer islands.

ENVIRONMENTALLY INTEGRATED 	Water sources are not properly protected from land-based activities and subsequent pollution, nor is the sustainable yield of water sources properly understood. Wastewater systems are likely a source of water pollution and public health impacts.	Develop a long-term programme of groundwater management.
SOCIALLY ENGAGED 	The water sector involves a range of stakeholders – from government, utilities, NGOs, and communities, with different stakeholders playing a role in the management and delivery of water functions to community members. However, gaps exist in terms of effective communication of water-related messaging to community members at the right time to ensure their safe and reliable access to water.	Develop programmes to improve water quality and education relating to rainwater tanks.
SHARED RESPONSIBILITY 	A range of water-related working groups and projects exist, however there are limited experienced resources in Tonga available to contribute. Data sharing across organizations appears to be ad hoc, and while it may be shared if the right people connect, it is not routinely available to others who could use it to improve water sector resilience. The water sector is dependent on the energy and transport sectors to function. Processes to work across sectors and develop contingencies are currently limited.	Establish processes for donor project coordination across the water sector. Review the TOR for the WASH sector cluster. Develop and test business continuity plans and SOPs (standard operating procedures) for all water services (including urban and rural).
ADAPTIVELY TRANSFORMING 	Water sector infrastructure in Tonga has experienced a range of disruptions due to exposure and vulnerability to a range of natural hazards. A focus on recovery from these events, and information gaps about exposure of assets to hazards has limited the ability of the sector to coordinate and build capacity for transformation. Some initial adaptive projects are being completed – such as increasing renewable energy generation by Tonga Water Board.	Complete a comprehensive water sector hazard exposure report, including a review of dependencies on other sectors (especially transport, ICT and energy) and supply chains.

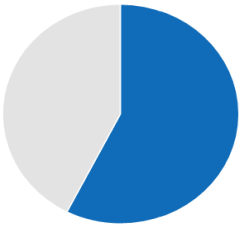
PRINCIPLES SCORECARD ASSESSMENT OF ALL SECTORS, WORKSHOP RESULTS

Current state of infrastructure resilience

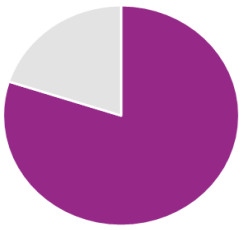
The following charts provide an aggregated view of the implementation of each principle (i.e. average score by principle based on the inputs provided for each action

Principle 1: Continuously Learning

Principle 2: Proactively Protected



Principle 3: Environmentally integrated



Principle 4: Socially Engaged

Principle 5: Shared Responsibility

Principle 6: Adaptively Transforming

ANNEX III. CURRENT RESILIENCE PRACTICES - DASHBOARD

PRINCIPLE 1 **Continuously learning** *Understand and manage the interdependencies and correlations in an infrastructure network*	**KPI QUESTIONS**	**KPI RESPONSE**	**CURRENT SCORE**	**NEED / AMBITION FOR IMPROVEMENT**	**RATIONALE FOR SELECTED RESPONSE (CURRENT STATE & PRIORITY)**
P1.1 EXPOSE AND VALIDATE ASSUMPTIONS	Are threat and hazard modelling assumptions, which are used in plans and operating systems, tested and checked for quality and reviewed after disruptions?	1 - Modelling assumptions used for making decisions for infrastructure resilience are tested and reviewed but not reported nor published.	**1**	**High Priority**	Are threat and hazard modelling assumptions, which are used in plans and operating systems, tested and checked for quality and reviewed after disruptions?
P1.2 MONITOR AND INTERVENE APPROPRIATELY	Do you have monitoring/data systems in place to intervene in real time in your infrastructure?	3 – Monitoring of some infrastructure systems and hazards but not for most or not with enough frequency, and there are not enough well-trained operators to test and implement all of the corresponding interventions for preventing critical service interruptions.	**3**	**High Priority**	Telecommunications, water and energy are between 4 and 5. Other sectors are between 1 and 2.
P1.3 ANALYZE, LEARN, AND FORMULATE IMPROVEMENTS	Do you have formal mechanisms for disseminating/ embedding lessons learned from past disruptions/ disasters?	3 – The need to learn is acknowledged and there are some attempts to share lessons, but it is not systematic and not regularly considered in future resilience strategies.	**3**	**Medium Priority**	The cluster system is at 3. Civil society is at 0. Public enterprise is at 4. Government is at 3.
P1.4 CONDUCT STRESS TESTS	Do you carry out network risk/ scenario/stress-testing analysis for existing systems?	1 – Ad hoc partial stress tests – not all scenarios incorporated and tested, not realistic, and implemented according to informal guidelines at local or project level.	**1**	**High Priority**	
PRINCIPLE 2 **Proactively Protected** *Determine and increase the level of hazard/ threat preparedness and response*	**KPI QUESTIONS**	**KPI RESPONSE**	**CURRENT SCORE**	**NEED / AMBITION FOR IMPROVEMENT**	**RATIONALE FOR SELECTED RESPONSE (CURRENT STATE & PRIORITY)**

P2.1 RAISE ESSENTIAL SAFETY REQUIREMENTS	Do new infrastructure systems and upgrades to existing infrastructure account for extreme but plausible lifecycle hazard scenarios and do they adopt elevated baselines for essential safety requirements?	5 – All the new infrastructure programmes dedicated to resilience in the last year considered lifecycle hazards and recommend safety-baseline increases or improvements.	**5**	**Low Priority**	
P2.2 EXCEED BASIC REQUIREMENTS FOR CRITICAL COMPONENTS	Do critical components of national infrastructure exceed basic reliability and durability requirements?	3 – Some critical components of national infrastructure in ASCE (American Society of Civil Engineers) risk category IV or national equivalent.	**3**	**Mediun Priority**	
P2.3 CONSIDER COMPLEX INTERDEPENDENCIES OF CONNECTED NETWORKS	Are there alternative networks available to deliver the same or similar critical services?	3 – Limited interruption in some infrastructure services due to the availability of alternate routes or modes to deliver the same critical services.	**3**	**Medium Priority**	
P2.4 EMBED EMERGENCY MANAGEMENT	Are emergency management plans and responses properly funded, adequately resourced and frequently tested with appropriate stakeholders?	4 – Mature and regularly tested emergency-management plans with some limitations on resources or governance.	**4**	**Medium Priority**	
P2. 5 DESIGN INFRASTRUCTURE TO FAIL SAFELY	Is critical infrastructure designed and operated to fail safely to protect occupants/exposed populations by maintaining critical life-support conditions or passive survivability?	4 – Deliver safe-to-fail solutions in the worst case of failure for most critical infrastructure assets.	**4**	**No Priority**	

P2.6 DESIGN FOR MULTIPLE SCALES	Is there sufficient cross-scale redundancy (national/regional/ local) in the infrastructure network to maintain critical services? For example, water-storage tanks at community centres to provide back-up supply in the event of a disruption in the water systems at regional or national level.	3- Some infrastructure systems have sufficiently cross-scale redundancy to maintain service objectives in the event of a primary failure.	**3**	**Medium Priority**	
P2.7 COMMIT TO MAINTENANCE	Are maintenance and preventative-maintenance programs effective and adequately funded?	2 - Limited maintenance budgets and preventative-maintenance investment for critical infrastructure but only marginally-funded maintenance budget for non-critical infrastructure.	**2**	**High Priority**	
P2.8 DEVISE LONG-TERM INVESTMENTS	Are investments in infrastructure focused on the long-term with appropriate investment in sustaining resilience over the whole lifecycle of infrastructure components (asset or sub-system)?	2- Limited investment in increasing the lifespan of infrastructure components and rehabilitating or refurbishing those reaching end of life, which just meets short-term needs of infrastructure.	**2**	**High Priority**	
PRINCIPLE 3: ENVIRONMENTALLY INTEGRATED *Integrate natural environment implications into infrastructure planning and management*	**KPI QUESTIONS**	**KPI RESPONSE**	**CURRENT SCORE**	**NEED / AMBITION FOR IMPROVEMENT**	**RATIONALE FOR SELECTED RESPONSE (CURRENT STATE & PRIORITY)**
P 3.1 MINIMIZE ENVIRONMENTAL IMPACT	Are adverse effects of infrastructure projects and operations on the ecosystem minimized? Are there good practices in place for environmental impact	5- Obligations and legislation for environmental-impact assessments of all infrastructure projects are in place, in line with international good practices, and enforced.	**5**	**No Priority**	

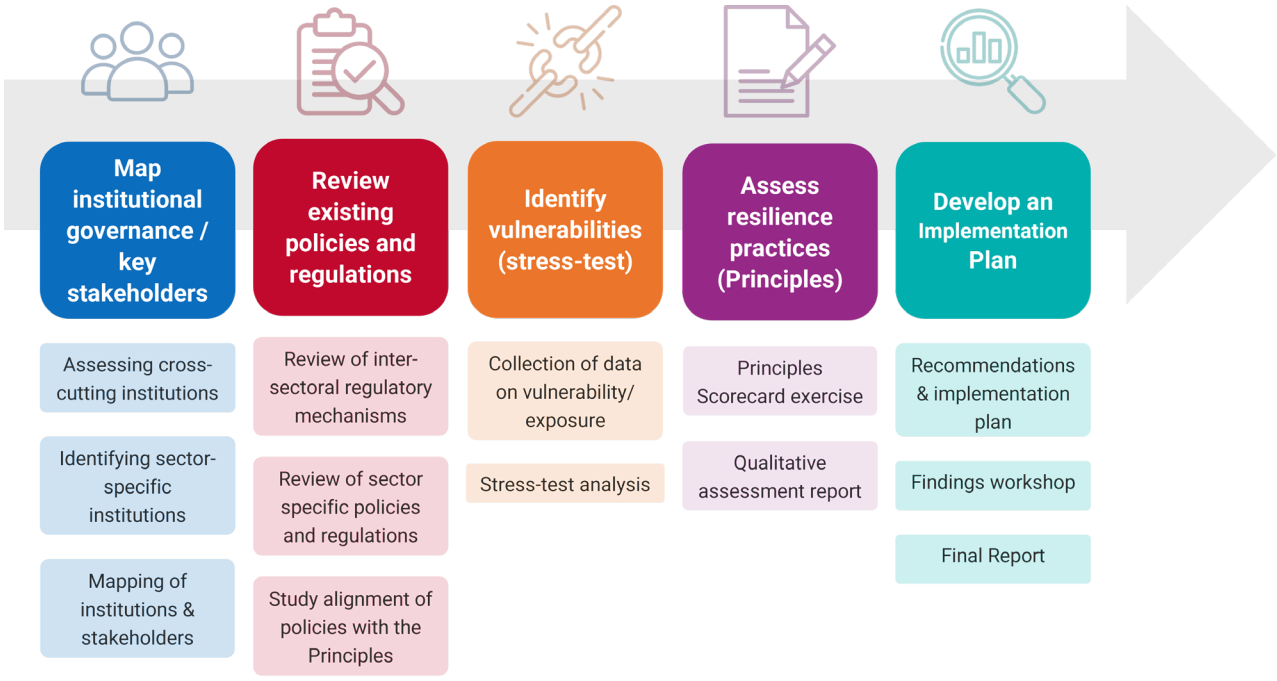
P 3.2 USE ENVIRONMENTAL SOLUTIONS	Are environmental assets and nature-based solutions that can/could improve resilience considered as an option and valued accordingly when assessing infrastructure development (e.g., through natural-capital accounting)?	3 – Ecosystems assets and services are sometimes considered as an option when assessing infrastructure development and their contributions to resilience are valued.	**3**	**Medium Priority**	
P3.3 INTEGRATE ECOSYSTEM INFORMATION	Is information about ecosystems integrated into decision-making in the planning and design of infrastructure?	3 - Environment information, including findings from environmental assessment, is incorporated into the planning process of some infrastructure projects.	**3**	**Medium Priority**	
P3.4 MAINTAIN THE NATURAL ENVIRONMENT	Are regulations and policies in place for maintaining the surrounding natural environment by infrastructure?	4 - Adequate regulatory provisions for maintaining the surrounding natural environment by infrastructure operators are in place and enforced for critical sector infrastructure.	**4**	**High Priority**	
P3.5 USE LOCAL SUSTAINABLE RESOURCES	Is sustainable procurement a standard practice and are locally available resources prioritized where possible?	2 - Sustainable procurement requirements exist for infrastructure projects, but are only partially enforced.	**2**	**Medium Priority**	
PRINCIPLE 4: SOCIALLY ENGAGED *Empower communities to participate in infrastructure resilience and disaster prevention*	**KPI QUESTIONS**	**KPI RESPONSE**	**CURRENT SCORE**	**NEED / AMBITION FOR IMPROVEMENT**	**RATIONALE FOR SELECTED RESPONSE (CURRENT STATE & PRIORITY)**
P4.1 INFORM PEOPLE ABOUT DISRUPTIONS	Are users of critical services informed about expected or ongoing disruptions so they can proactively adjust their usage?	4 – The literacy level used in all emergency messages can be read by most of the target community and can be accessed by communication channels available to most of the community.	**4**	**Low Priority**	

P4.2 RAISE RESILIENCE LITERACY	Are education initiatives designed to build awareness around how communities can contribute to infrastructure resilience?	3- optional infrastructure resilience training and activities to most children (above 11 years) and adults, which are provided by teachers with training in infrastructure resilience.	**3**	**High Priority**	
P4.3 INCENTIVIZE DEMAND BEHAVIOUR	How effective are incentive programs aimed at reducing demand-based (excessive demand) critical services disruptions?	2- Above half of all interruptions are because of excessive demand.	**2**	**Medium Priority**	
P4.4 ENCOURAGE COMMUNITY PARTICIPATION	Are exposed communities appropriately engaged on infrastructure decisions to improve sense of ownership and trust in infrastructure resilience?	4 - Most of the people in the target community are participating and contributing to shaping resilience outcomes.	**4**	**Medium Priority**	
PRINCIPLE 5: SHARED RESPONSIBILITY *Empower communities to participate in infrastructure resilience and disaster prevention*	**KPI QUESTIONS**	**KPI RESPONSE**	**CURRENT SCORE**	**NEED / AMBITION FOR IMPROVEMENT**	**RATIONALE FOR SELECTED RESPONSE (CURRENT STATE & PRIORITY)**
P5.1 HARMONIZE OPEN STANDARDS	Are harmonized open-data standards that improve overall resilience by enabling collaboration between different stakeholders, including governments, private organizations and the public being used?	3 – Infrastructure projects are subject to informal, national-level information-sharing guidelines.	**3**	**High Priority**	
P5.2 CULTIVATE COLLABORATIVE MANAGEMENT	Is there open communication within and between sectors on resilience activities that provide opportunities for learning and improvement in infrastructure resilience?	2 – A limited variety of organizations are involved in a cross-sector partnership designed to identify and address vulnerabilities in critical infrastructure systems. Meetings are held at least once a year.	**2**	**High Priority**	

P5.3 ESTABLISH SHARED RESPONSIBILITIES	Is there clear accountability and understanding of roles and responsibilities for relevant stakeholders in responding to threats, hazards and/or failure events?	5 – Infrastructure projects are subject to formal, national-level accountability standards during pre-operational, operational and post-operational stages.	**5**	**No Priority**	
P5.4 ENHANCE CONNECTIVITY FOR INFORMATION SHARING	Is data being shared between the sectors, sector infrastructure and relevant organizations?	1 – Data sharing capacity and platforms are non-existent and project data has been shared with a stewardship institution but not refreshed, OR project has assigned its own data steward within the operational team.	**1**	**High Priority**	
P5.5 ASSURE DATA SAFETY TO DEVELOP TRUST	Are there robust data-sharing security practices and programs in place?	1 - Infrastructure projects set out their own data security policy	**1**	**High Priority**	
P5.6 SHARE RISK AND RETURN INFORMATION	Is infrastructure risk information publicly available where appropriate to promote risk-informed investment?	1- Risk reporting by infrastructure operators or owners is scarce.	**1**	**High Priority**	
PRINCIPLE 6: ADAPTIVELY TRANSFORMING *Critical assets are designed to operate comfortably in hazardous conditions and during extreme disruption events*	**KPI QUESTIONS**	**KPI RESPONSE**	**CURRENT SCORE**	**NEED / AMBITION FOR IMPROVEMENT**	**RATIONALE FOR SELECTED RESPONSE (CURRENT STATE & PRIORITY)**
P6.1 CHOOSE MANAGEABLE SOLUTIONS	Are infrastructure solutions in terms of complexity and modularity considered and aligned to the skills and resources available in local environments where possible?	4 – Modularity is used wherever suitable for the given service. Repair services are on site or within an hour of the site and parts are easily available and accessible.	**4**	**Low Priority**	

P6.2 CREATE ADAPTIVE CAPACITY	Is adaptive capacity built into infrastructure systems at all lifecycle stages to allow flexibility in decision making and problem solving?	4 – Capacity (of data storage, service and supply chain) is known. Demand is monitored. There is some scope to adjust capacity. Alternative suppliers have been identified and relationships established.	**4**	**Medium Priority**	
P6.3 DEVELOP FLEXIBLE MANAGEMENT	Is there a culture of dynamic management within infrastructure operators where there are feedback loops between management, staff and community that facilitates and improves effectiveness of disaster response?	3 – Disaster-management training is available for employees. There are formal reporting and whistleblowing procedures in place for employees and informal communication channels for community engagement. Operators are subject to infrequent assessment.	**3**	**High Priority**	
P6.4 ENABLE CAPACITY FOR TRANSFORMATION	Is there planned and deliberate capacity in critical infrastructure assets to adapt beyond primary purposes to provide overlapping redundancy and ability to redistribute stress?	4 – Component connections mapped and vital components identified. Most critical services have redundancy. Plan in place in case of vital component failure. Neighbouring services identified and failure plan in place that involves utilizing capacity of neighbouring services. Operational processes and failure plans assessed somewhat frequently and formal or informal reporting procedure in place for employees.	**4**	**Medium Priority**	
P6.5 ALLOW FOR HUMAN DISCRETION	Is there sufficient and appropriate provisions for human discretion and intervention in standard operating practices for flexibility in unexpected situations?	3 – Formal training is available for some employees wishing to learn how to operate equipment or learn emergency skills. A defined percentage of employees are required to have received resilience, safety, override and emergency training at a level that ensures redundancy in most emergency roles or operators for specific pieces of equipment. Somewhat frequent emergency drills (every 12 to 24 months).	**4**	**High Priority**	

ANNEX IV. ACTIVITIES AND CONSULTATIONS



Step 1: Map institutional governance and identify key stakeholders
The first step involved mapping the key stakeholders in infrastructure development, such as ministries, regulators, and operators, who play a pivotal role in strengthening infrastructure resilience. In addition to identifying those responsible for Disaster Risk Reduction (DRR) and broader infrastructure initiatives, this step engaged stakeholders across critical sectors—energy, transport, information and communication technologies (ICT), and water. Initial findings from this step were gathered through a desk study of relevant national literature and subsequently presented to stakeholders for validation during the kick-off meeting held in Nuku'alofa, Tonga, on 30 August 2023.

Step 2: Review existing policies and regulations
The next step focuses on understanding how policy and regulatory frameworks shape the resilience of infrastructure and ensure the continuity of essential services. Since disasters often trigger cascading effects across multiple sectors, it's important to have cross-cutting policies and intersectoral regulatory mechanisms in place. This phase involves assessing whether sector-specific policies and strategies adequately address Disaster Risk Reduction (DRR) considerations. The goal here is to identify the key policies and regulations that influence infrastructure resilience, along with their crucial DRR components. Initial findings from this step were gathered through a desk study of relevant national literature and subsequently presented to stakeholders for validation during the kick-off meeting held in Nuku'alofa, Tonga, on 30 August 2023.

Step 3: Detect vulnerabilities through a stress-testing analysis
The third step of the methodology helps users conduct multi-hazard stress testing on infrastructure systems. The goal was to assist Tonga in gaining a deeper understanding of infrastructure vulnerabilities and system interdependencies, enabling them to prioritize actions and allocate resources more effectively, while also assessing the condition of critical infrastructure at the national level. To support the stress testing process, data on the vulnerability and exposure of infrastructure systems was collected. Preliminary results from this step were presented to stakeholders and experts in a workshop held in Nuku'alofa, Tonga, on 28 November 2023 to consider the impact of various stressors.

Step 4: Assess current resilience through the Principles for Resilient Infrastructure
In this step, the analysis evaluated whether current infrastructure practices are sufficient to achieve resilience. The assessment took place through a workshop held in Nuku'alofa, Tonga, on 29 November 2023 involving key stakeholders identified in step 2, allowing participants to become familiar with the Principles for Resilient Infrastructure. The evaluation was conducted using a scorecard tool developed by UNDRR. It required interactive discussions with the workshop participants. The results, combined with the analysis from previous steps, were then used to prioritize key interventions and to shape the recommendations developed in step 5.

Step 5: Develop an implementation plan and produce a final report

As a final step, results from steps 1 to 4 were consolidated into a comprehensive final report including the analyses from previous steps, and data gathered from workshops. The main findings and recommendations were also shared and discussed with relevant stakeholders during a validation workshop held in Nuku'alofa, Tonga, on 29 May 2024 and further on 30 May 2024, shared with potential donors and development partners active in the region to discuss and encourage financing of the implementation plan.

A Validation Workshop was conducted with representatives from Tonga's critical infrastructure sectors—including technical officers, practitioners, and experts—to assess the identified gaps from the assessment process. During the workshop, stakeholders further assessed and validated recommendations that they agreed would address these gaps.

The recommendations were presented to a group of Chief Executive Officers and/or their representatives for their final feedback. As part of the validation process, stakeholders selected 9 recommendations as priorities for implementation. These recommendations were selected based on their short-term implementation timeframe, cost and impact on resilience.

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