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List of abbreviations

ADB	Asian Development Bank
AFL	Assets Fiji Pte Limited
AR5	The 5th Assessment Report of the Intergovernmental Panel on Climate Change
AR6	The 6th Assessment Report of the Intergovernmental Panel on Climate Change
AusAID	Australian Agency for International Development
BCP	Business Continuity Plan
BH	Borehole
BOR	Berth Occupancy Ratio
CAAV	the Civil Aviation Authority of Vanuatu
CCECC	China Civil Engineering Construction Corporation Limited
CD	Chart Datum
CDL	Chart Datum Level
CDM	Cement Deep Mixing
CFS	Container Freight Station
CMIP5	Coupled Model Intercomparison Project - Phase 5
COVID-19	Coronavirus disease 2019
d4PDF	database for Policy Decision making for Future climate change
DL	Datum Level
DSA	Debt Sustainability Analysis
DWT	Deadweight Tonnage
Fiji	Republic of Fiji
FIRR	Financial Internal Rate of Return
FNPF	Fiji National Provident Fund
FPCL	Fiji Port Corporation Limited
FPTL	Fiji Ports Terminals Limited
FSHIL	Fiji Ship and Heavy Industries Limited
GDP	Gross Domestic Product
GRT	Gross Register Tonnage
GT	Gross Tonnage
HP	Homepage
IMF	International Monetary Fund
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPDS	Ifira Ports & Development Services
Is	Islands
JICA	Japan International Cooperation Agency
LDC	Least Developed Country
LOA	Length overall

LPG	Liquid Petroleum Gas
MHDPP	Multi-hazard Disaster Preparedness Plan
MHWS	Mean Hight Water Spring
MICRO	Maritime Investment in Climate Resilient Operations
MIH	Maximum Inundation Height of Tsunami
MIPU	Ministry of Infrastructure and Public Utilities in Vanuatu
MLWS	Mean Low Water Spring
MOI	Ministry of Infrastructure in Tonga
MT	Metric Ton
MTECI	Ministry of Transport, energy, communication and innovation in Tuvalu
NCDs	Non-Communicable Diseases
NDMO	Vanuatu National Disaster Management Office
NFD	National Fisheries Developments Limited in Solomon Islands
NISCOL	Northern Islands Stevedoring Company Limited in Vanuatu
NTP	National Transport Plan 2017-2036 in Solomon Islands
NZ	New Zealand
NZSEE	New Zealand Society for Earthquake Engineering
OCDI	The Overseas Coastal area Development Institute of Japan
ODA	Official Development Assistance
PAT	Ports Authority Tonga
PCCC	Pacific Climate Change Centre
PGA	Peak Ground Acceleration of Earthquake
PIANC	Permanent International Association of Navigation Congresses
PIANC guide	"CLIMATE CHANGE ADAPTION PLANNING FOR PORTS AND INLAND WATERWAYS" (PIANC, EnviCom WG Report No. 178-2020)
PLC	Public Limited Company
PMD	Ports and Marine Department in Vanuatu
PPE	Personal Protective Equipment
PRIF	Pacific Region Infrastructure Facility
PWD	Public Works Department in Vanuatu
RCP	Representative Concentration Pathways
RL	Reduced Level (in surveying)
RORO	Roll on Roll off
RTG	Rubber Tyred Gantry crane
SBD	Solomon Islands Dollar
SIIP	Solomon Islands Infrastructure Program
SIPA	Solomon Islands Ports Authority
SOLTUNA	SolTuna Limited in Solomon Islands
SPA	Samoa Ports Authority
SPC	the Pacific Community

SPMA	Sea Ports Management Act 2005 in Fiji
SPREP	Secretariat of the Pacific Regional Environment Programme
SPT	Standard Penetration Test (geotechnical)
SSP	Shared Socioeconomic Pathways
SWL	Safe Working Load
TEU	Twenty-foot equivalent unit
TMPI	Tonga Maritime Polytechnical Institute
UDL	Uniformly Distributed Load
UNESCO	United Nations Educational, Scientific and Cultural Organization.
USD	United States dollar
VISSP	the Vanuatu inter-Island Shipping Support Project
VMGD	the Vanuatu Meteorological and Geohazards Department
VT	the Vatu, the currency of Vanuatu
WACOP	the Changing Waves and Coasts in the Pacific project
WG	Working Group

1. Project Overview

1.1 Basic Policy for Implementation

1.1.1 Project Background

The Pacific region is vulnerable to the effects of climate change, such as sea level rise and larger cyclones, and is also at risk from earthquakes and tsunamis. For Pacific Island countries surrounded by the ocean, ports and harbors, which serve as the gateway for daily commodities and trade goods, play an important role as the foundation of economic and social activities, and are required to support recovery and reconstruction activities from disaster damage by ensuring that port functions are maintained or can be quickly restored in the event of a disaster.

Based on this role of ports in Pacific Island countries, in 2019, the Pacific Community (hereinafter referred to as "SPC") established long-term goals and indicators for port resilience, and proposed a concrete approach to promote the implementation of such measures, entitled "PACIFIC PORTS VISION 2030-2050 RECOGNITION FRAMEWORK," which sets long-term goals and indicators for port resilience and lays out concrete measures for making progress. However, many Pacific Island countries have small populations, making it difficult for them to implement appropriate port maintenance and management measures on their own, and thus there is a high need for support in this area.

In light of this situation, the Government of Fiji has requested JICA to dispatch a Port Operation and Maintenance Advisor to SPC to evaluate and support the implementation of port resilience measures and port maintenance management measures at major ports in the Pacific Island countries. In response to this request, the advisory team will carry out this work with the aim of promoting the development of port resilience measures and maintenance management measures as well as the establishment of a sustainable maritime system in the Pacific region.

1.1.2 Project Objectives

(1) Project Goals

The main objective is to establish a sustainable maritime transportation system in the Pacific region by advancing measures for improving port resilience and port maintenance management.

(2) Project Outcome

1) Issues related to the maintenance and management of key ports and harbors in the Pacific Island countries will be identified.
2) A strategy for the resilience of key ports and harbors in the Pacific Island countries will be formulated.

(3) Main Activities

1) Setting of target ports
2) Review of issues related to port maintenance and management
3) Identification of the scale of natural disasters (earthquakes, tsunamis, volcano eruptions, storm surges, cyclones) that can be expected at the target ports
4) Review of the current status of natural disaster adaptation, climate change adaptation, and emergency response
5) Assessment of natural disaster adaptation, climate change adaptation, and emergency response
6) Formulation of Port Resilience Strategy
7) Holding of seminars on port resilience and maintenance management

(4) Implementation Period

From July 2023 to June 2025

(5) Target Countries/ Ports

The target of support for this project will be selected based on the current situation in the Pacific island countries, requests from SPCs, and JICA's track record of support. In the initial contract, 11 target ports were identified, including Betio Port in Kiribati. However, Betio Port has since been excluded, and Ohonua Port in Tonga has been added. In Vanuatu, a survey of Luganville Port was initially planned. However, Air Vanuatu, the state-owned airline, began bankruptcy proceedings, and flights between Port Vila and Luganville were suspended. Therefore, after discussions with SPC, the focus shifted to Port Vila Port, where both the Lapetasi International Wharf and the Main Wharf were surveyed instead.

Table 1.1-1 Target Countries and Target Ports for this Project

Target Countries	Target Ports
Fiji	Suva, Levuka
Tuvalu	Funafuti
Vanuatu	Port Vila Lapetasi International Wharf, Port Vila Main Wharf
Tonga	Nuku'alofa, Neiafu, Ohonua
Solomon Islands	Honiara, Noro
Samoa	Apia

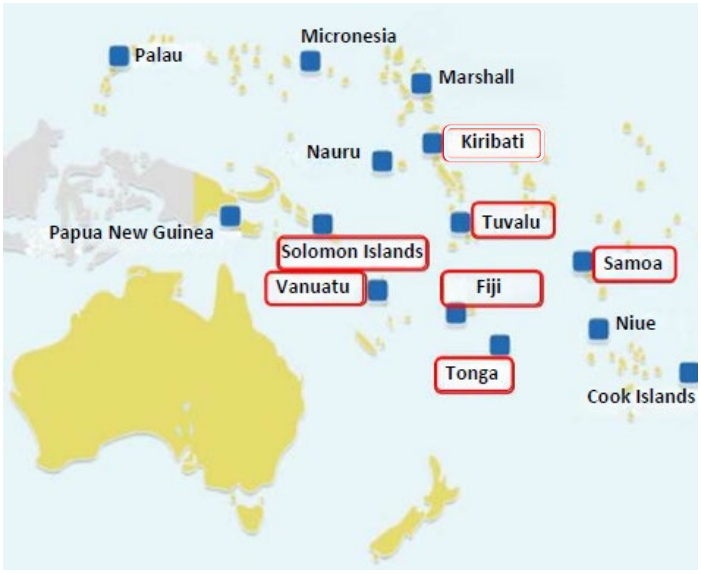


Figure 1.1-1 Location map of the assumed target ports (Tentative) [1]

(6) Institute to be assigned

Pacific Community (SPC)

1.1.3 Project Implementation Structure

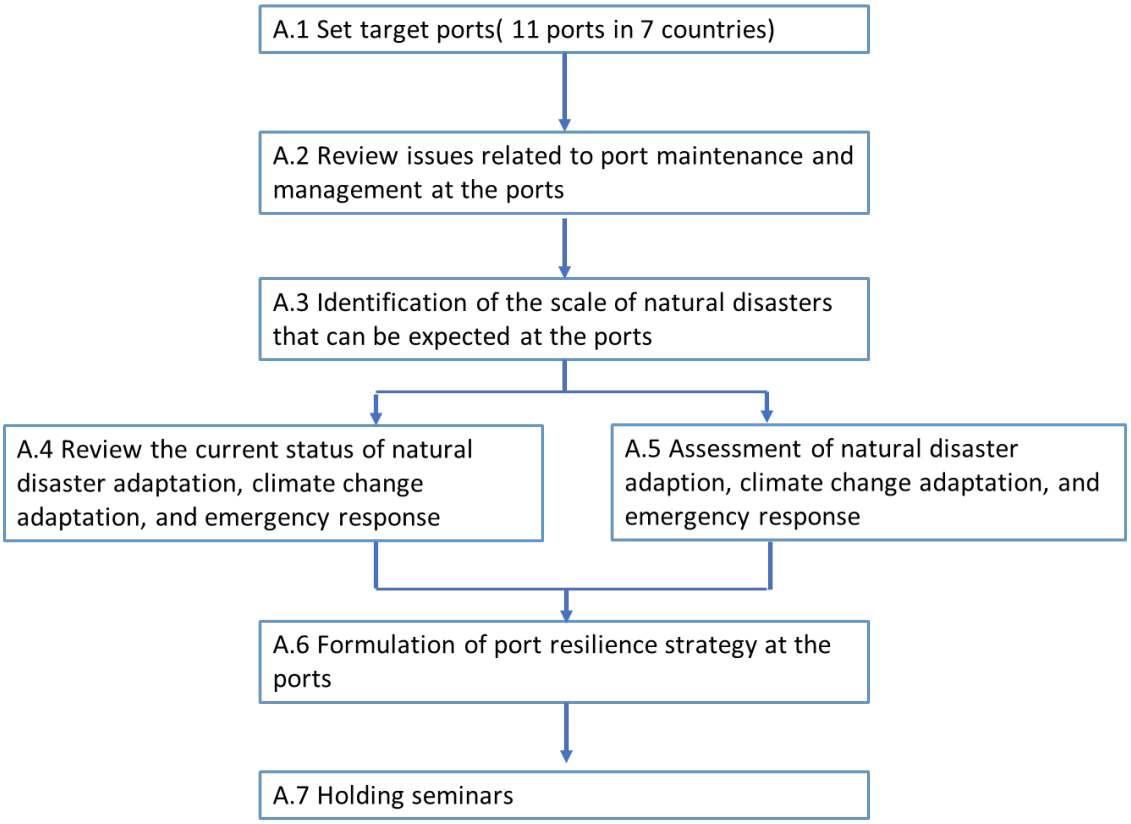
Since JICA has not concluded a technical cooperation agreement with the SPC or other regional cooperation organizations, JICA will dispatch JICA experts to such organizations based on a written request from the government of the country where the organization is located (in the case of this project, the government of Fiji). The dispatch of experts to target countries other than Fiji will be carried out under liaison and coordination with the respective countries by SPC.

1.2 Project Implementation Method

1.2.1 Project Flowchart

A flowchart of the work is shown below.

[1] https://www.mofa.go.jp/mofaj/gaiko/oda/region/pacific/index.html



The dispatch schedule of experts is shown in Figure 1.2-1.
The expert dispatch schedule is shown on the next page.

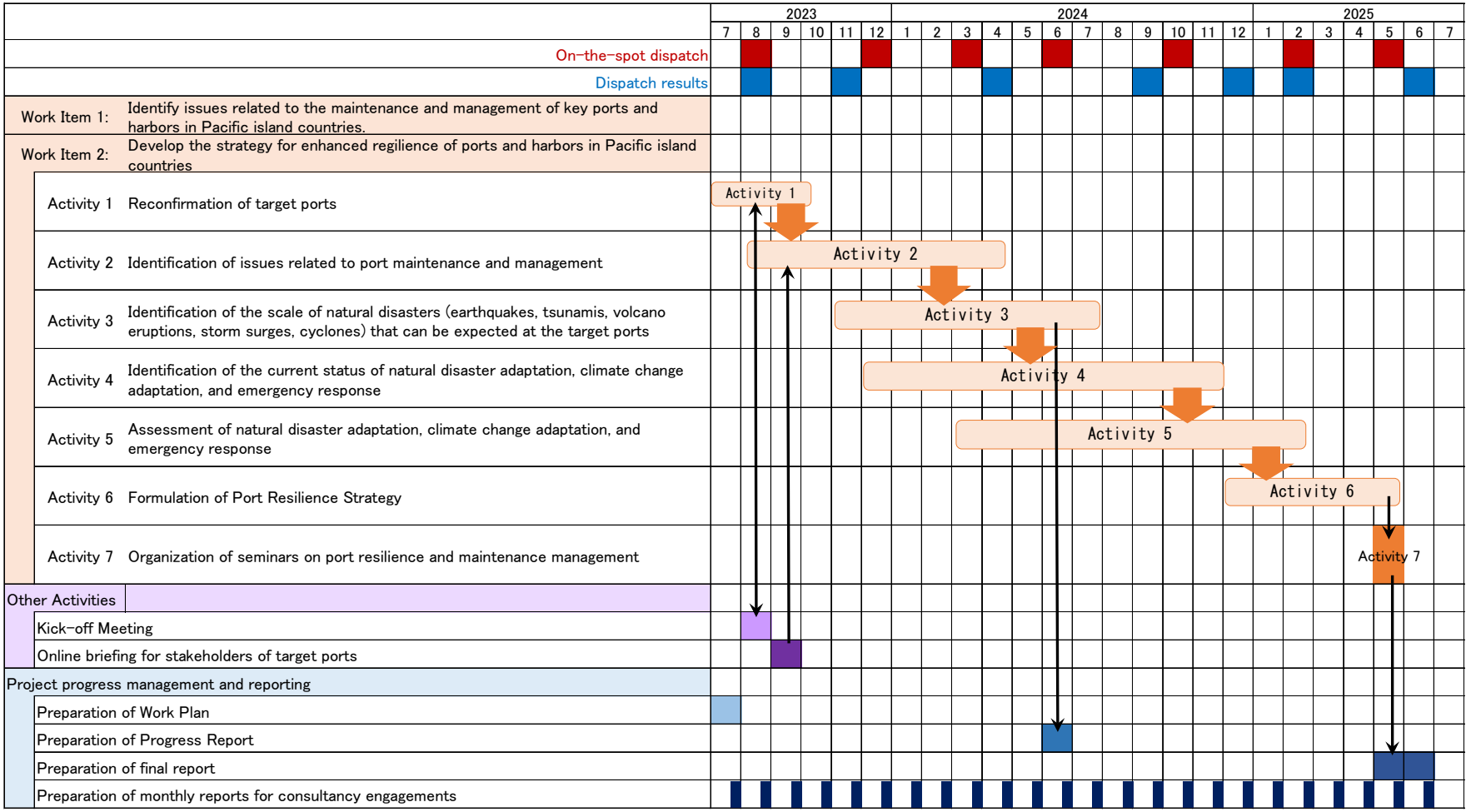


Figure 1.2-1 Workflow Chart

1.2.2 Project Implementation Method

(1) Preparation of a work plan

The advisory team analyzed and reviewed existing relevant materials and information to obtain an overall picture of the project. At the same time, the advisory team prepared a work plan after examining the project implementation policy and methods. The work plan was then submitted to JICA and revised as necessary based on their comments.

(2) Kick-off meeting with SPC

The advisory team prepared an English version of the work plan and briefing material outlining the activities of this project. The implementation policy was explained to SPC, and their approval was sought.

(3) On-line briefing for target port stakeholders

The advisory team conducted an online briefing for the target country parties based on the English version of the presentation materials and solicited input from SPCs and port administrators in the target countries (see Picture 1.2-1).



Picture 1.2-1 August 18, 2024 - Online Briefing (at SPC Office)

(4) Set target ports

Based on the current situation in the Pacific Island countries, requests from SPC, and JICA's track record of support, the advisory team will, through discussions with SPC, reconfirmed the ports to be considered for this project and grasp the importance and issues of the target ports.
As part of this process, Betio Port was excluded, and Ohonua Port in Tonga was newly added. In the case of Vanuatu, due to the suspension of domestic flights, it was agreed through consultations with SPC to conduct the survey not in Luganville but instead at both the Lapetasi International

Wharf in Port Vila and the Main Wharf, which serves domestic vessels.

1) **Establishment of indicators of the importance of the target ports**

Possible indicators of the importance of the subject port included the port's location, cargo handling volume, and forecast demand. In addition to these indicators, the advisory team added and set additional indicators that it considered important for the subject ports based on requests and opinions from SPC and the subject countries.

As a result, the original plan to survey 11 international ports was revised to exclude Betio Port in Kiribati and Luganville Port in Vanuatu, and instead include Ohonua Port in Tonga and the Main Wharf in Port Vila, Vanuatu. Furthermore, considering the importance to the public and the **location of the ports**, the survey was also conducted at Mulifanua Port and Salelologa in Samoa, in addition to Apia Port.

2) **Identification of issues at the target ports**

At the target ports, the advisory team interviewed SPC and port stakeholders in the target countries from the perspectives of port resilience and port maintenance management, respectively, and identified any issues.

Possible measures to be taken related to port resilience were considered not only to ensure resilience to existing disasters, but also to take into account the perspective of adaptability to climate change based on the "CLIMATE CHANGE ADAPTION PLANNING FOR PORTS AND INLAND WATERWAYS" (PIANC, EnviCom WG Report No. 178-2020) (hereinafter referred to as the PIANC guide). The advisory team analyzed and identified specific issues related to port maintenance and management using the methodology described in the following section.

(5) Review issues related to port maintenance and management

The advisory team collected information on the structure, maintenance status, maintenance management, and daily inspections of the target ports through interviews with related parties, review of design documents, and on-site inspections, etc., to identify issues related to port maintenance management at each target port. The specific methods used to identify issues were as follows.

1) **Collection and organization of design documents from the viewpoint of maintenance and management**

Prior to the on-site inspection of the target ports, the advisory team collected information on the natural conditions and maintenance concerns that were taken into account when designing port facilities at each target port, as well as structural types based on the design documents. In collecting design documents, in addition to the materials available at the JICA library, the advisory team requested design documents at the time of interviews with relevant parties in the target countries.

2) **Assessing the current situation through on-site inspections**

Based on the results of interviews with related parties and the collection and confirmation of information on the target ports based on the design documents, the advisory team conducted on-site inspections of each target port in this project to inspect and diagnose the deformation of port facilities from the start of service to the present time. The advisory team referred to the "Guidelines for Inspection and Diagnosis of Port Facilities, July 2014 (Port and Harbor Bureau, Ministry of Land, Infrastructure, Transport and Tourism)" for the items of inspection and diagnosis to be conducted. The inspection covered the following items.

a. Are there any significant changes in the usage conditions (cargo usage patterns, heavy vehicles, etc.) assumed at the time of design?
b. Are there any signs or reports of impact from ships or other objects?
c. Are there any significant deviations from the normal line or large steps in the joints?
d. Are there any signs of settlement or sinking in the apron pavement?
e. Are there any abnormal sounds or vibrations from the port facilities?
f. Are there any abnormalities in the ancillary facilities?
g. re there any reports of any problems with the use of the port facilities?

Based on the results of the inspection and diagnosis during the on-site inspection, the advisory team organized the items and frequency of inspection and diagnosis that were considered necessary for the maintenance and management of port facilities at each target port as future issues. The advisory team also flew a drone for the on-site inspection, capturing images from the seaward side of areas that could not be checked from land (e.g., the front of the wharf) to qualitatively assess the degree of deterioration of the facility.

During the site surveys, port authorities accompanied the team, and opinion exchanges were conducted on facility resilience and maintenance methods through explanations of the survey methods and interviews.

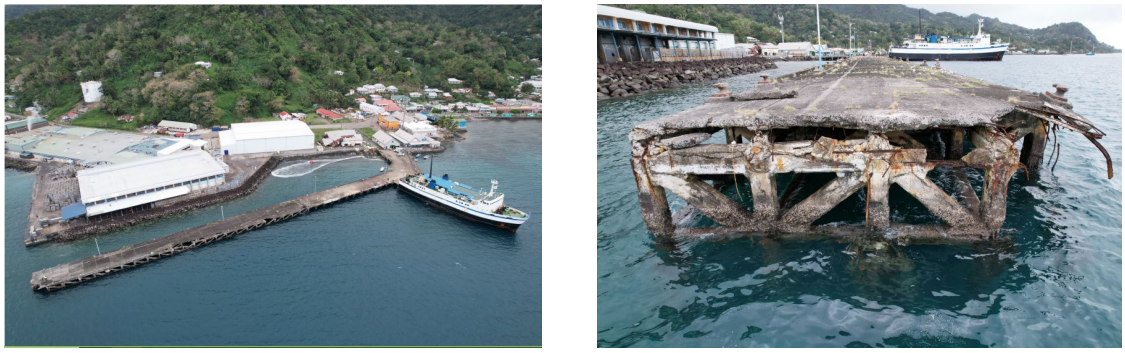


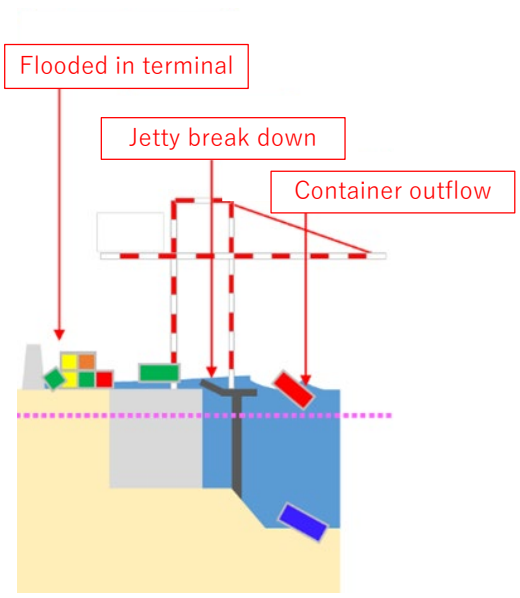
Figure 1.2-2 Capturing the current status of a structure by a drone (Example: the Port of Levuka)

(6) Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at the target ports

The advisory team collected information on natural disasters that the target ports had experienced, as well as information on damage forecasts and hazard maps prepared by research institutes, to indicate, port by port, what scale of natural disaster should be assumed. For storm surges and cyclones, the scale of the storm surge/cyclone was estimated in addition to the case of no climate change impact.

1) **Collection of data on damage caused by past natural disasters**

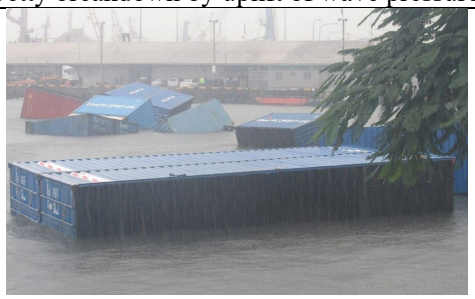
The advisory team focused on the categories of natural disasters that the target ports had experienced, the scale of the disasters, and the human and material damage, and collected data and records related to previous natural disasters over time. The advisory team requested the provision of meteorological and oceanographic data, which were indicators of the scale of natural disasters, from local meteorological agencies and neighboring countries. In particular, the future trends of cyclones were analyzed in detail, as the frequency and size of cyclones were expected to increase.



Concept of major damage caused by storm surge



Jetty breakdown by uplift of wave pressure



Drifting containers by storm surge. The drifting containers block-shipping routes

Figure 1.2-3 Examples of Damage at Port Facilities [2] [3]

2) **Organization of external force conditions at the design of the existing facilities**

Based on the design documents of the port facilities at the subject port (JICA report and materials provided by the subject port stakeholders), the advisory team summarized the following external

[2] Source: Ministry of Land, Infrastructure, Transport and Tourism, Port and Harbor Bureau

[3] https://www.rnz.co.nz/international/pacific-news/330212/containers-floating-in-fiji-harbour-after-ship-sinks

force conditions that were set during the design of the existing facilities.

Table 1.2-1 Items for external force conditions (Draft)

Port facilities	External force condition
Breakwater	Water depth, waves, tide level, soil condition
Mooring facilities	Target vessels, water depth, berthing velocity, tide level, soil condition, seismic force

3) **Estimation of the magnitude of future natural disasters**

The advisory team identified natural disasters to watch out for (from among earthquakes, tsunamis, volcano eruptions, storm surges, cyclones, etc.) by port, based on records or interviews with port officials on climate change, signs of global environmental change, and disaster information. The estimated scale of the identified natural disaster was determined as accurately as possible.

Table 1.2-2 Methodology for Identifying Natural Disasters and their Scales (Example: the Port of Suva)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Could not be confirmed.	Not applicable	Estimate earthquake waves by considering the scale of past earthquakes and taking into account the distance from the epicenter and ground conditions.
Tsunami	Could not be confirmed.	Not applicable	Estimate the loads acting on structures by assuming tsunami heights and flow velocities based on past maximum tsunamis.
Volcano	Could not be confirmed.	Not applicable	Estimate the impact of volcanic eruptions and ashfall on ports based on records of volcanic eruptions in neighboring countries and past volcanic disasters.
Storm Surge	Could not be confirmed. Existing wharves use previous average tide levels. The effects of high tides seem not to be included.	Flood disasters increase due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	Could not be confirmed. The effects of the intensification of waves caused by cyclones do not seem to have been considered for existing wharves	Increase in high waves due to cyclone intensification.	Consider the increase in waves caused by cyclone intensification objectively. The recent research results, such as future predictions using d4PDF described later can be used.

4) **Estimation of the magnitude of sea level rise and wave power by climate change**

There are two possible impacts of climate change: one is the mean sea level rise and the other is the intensification of cyclones' power. For the mean sea level rise, the advisory team estimated the amount of future rise and distribution characteristics in the ocean areas of the Pacific Island countries based on the projections of the Intergovernmental Panel on Climate Change (IPCC). [4]

As for the intensification of cyclones' power, two effects, the "suction effect" due to low pressure (1 hPa drop = 1 cm sea level rise) and the "blow-in effect" due to wind, increase wave height and contribute to inundation of coastal areas. Therefore, when a cyclone becomes more powerful,

[4] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

storm surge and wave power are expected to increase due to these effects. In estimating the magnitude of water level and wave conditions (offshore waves) considering climate change, time series data on wind speeds during past cyclone events were not available. Therefore, the advisory team only introduced the estimation method.

(7) Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

For natural disaster adaptation, the time range is divided into "medium- to long-term preventive adaptation" and "emergency response" (see Table 1.2-3). For "medium- to long-term preventive adaptation," it is necessary to take into account not only the previous natural disaster but also recent climate change. On the other hand, "emergency response" should be prepared for maintaining and restoring port functions immediately after a natural disaster.

Based on the conceptual arrangement in the table below, the survey team collected design documents of the ports and examined the structural characteristics and maintenance conditions of the facilities in the target ports. In addition, the survey team interviewed officials in port authorities to confirm whether they had prepared natural disaster adaptation plans and their operational status.

Table 1.2-3 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The survey confirmed the structure and maintenance status of existing facilities at the target port through interviews with the port management agency and the review of available design documents. It also confirmed the existence and implementation status of natural disaster response plans for each port facility.

From December 9, 2024 to January 2025, the survey team conducted a questionnaire survey targeting port authorities in the respective countries. The survey covered four areas: maintenance and management, natural disaster response, emergency response, and climate change adaptation.

The questionnaire asked whether plans existed and whether monitoring surveys were being implemented for each of the four areas.

The summary table of the questionnaire results and the table showing the implementation status evaluated on a four-level scale are presented below. No responses were received from Tuvalu and Vanuatu.

Table 1.2-4 Summary Table of Questionnaire Survey Results

Questions		Fiji	Tonga (MOI)	Tonga (PAT)	Solomon Islands	Samoa
Maintenance and management	Do you have a maintenance management plan?	✓	—	✓	✓	✓
	Do you have an inspection manual?	✓	✓	✓	✓*	✓
	Do you regularly inspect port facilities' condition?	✓	✓	✓	✓	✓
	How often do you conduct inspections?	3	3	4	2	3
Countermeasures against natural disasters	Do you have hazard maps for natural disasters in your port?	✓	✓	✓	✓	—
	Do you have any measures in place to deal with natural disasters?	✓	—	✓	✓*	✓
	The current situation at your port in terms of dealing with natural disasters.	4	1	3	2	4
	Do you have any plans to deal with natural disasters?	✓	✓	✓	✓	✓
Emergency response	Has a port BCP (business continuity plan) been formulated?	✓	—	✓	—	✓
	Regarding emergency response, the current situation at your port.	4	3	3	2	4
	Do you have any plans to take action in the event of an emergency?	✓	✓	✓	✓	✓
Climate change adaptation	Are any measures being implemented at the port to deal with the effects of climate change?	✓	—	✓	✓	✓
	The current situation at your port in relation to climate change adaptation.	3	1	3	2	3
	Do you have any plans to deal with natural disasters?	✓	✓	✓	✓	✓

*But not adequate

(8) Assessment of adaptation plans for natural disasters, climate change, and emergency response

1) **Confirmation and evaluation by key resilience indicators**

In order to assess the current state of disaster preparedness of each port, the advisory team identified each port's resilience level based on the KEY RESILIENCE INDICATORS as indicated in the "PACIFIC PORT VISION 2030-2050 RECOGNITION FRAMEWORK." Table 1.2-6 shows the confirmation results for the evaluation indicators of each port.

Table 1.2-5 Key Resilience Indicators and Requirements [5]

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

[5] 「PACIFIC PORT VISION 2030-2050 RECOGNITION FRAMEWORK」"4.5 KEY RESILIENCE INDICATORS"

Table 1.2-6 Confirmation Results of Resilience Indicators

Country	Port Name	Natural Disaster Adaptation	Climate Change Adaptation	Emergency Response
Fiji	the Port of Suva	Engaged	Engaged	Highly engaged
Fiji	the Port ofLevuka	Unengaged	Unengaged	Engaged
Tuvalu	Funafuti Port	Unengaged	Unengaged	Unengaged
Tonga	Neiafu Port	Unengaged	Unengaged	Highly engaged
Tonga	Nuku'alofa Port	Highly engaged	Highly engaged	Highly engaged
Tonga	Ohonua Port (Nafanua Wharf)	Unengaged	Unengaged	Highly engaged
Solomon Islands	Honiara Port	Engaged	Engaged	Highly engaged
Solomon Islands	Noro Port	Unengaged	Unengaged	Engaged
Samoa	Apia Port	Engaged	Engaged	Engaged
Vanuatu	Lapetasi International Wharf	Engaged	Engaged	Highly engaged
Vanuatu	Main Wharf	Unengaged	Unengaged	Engaged

The key resilience indicators for "Climate change adaptation" are based on the PIANC guide, which identifies four stages of progress: Stage 1 is to set the goals of the measures, Stage 2 is to collect and analyze climate change-related information for analysis, Stage 3 is to assess the vulnerability and risks of the facility due to climate change, and Stage 4 is to adapt the measures. Therefore, based on this, the status of climate change adaptation was positioned as a resilience indicator after confirming and evaluating the progress.

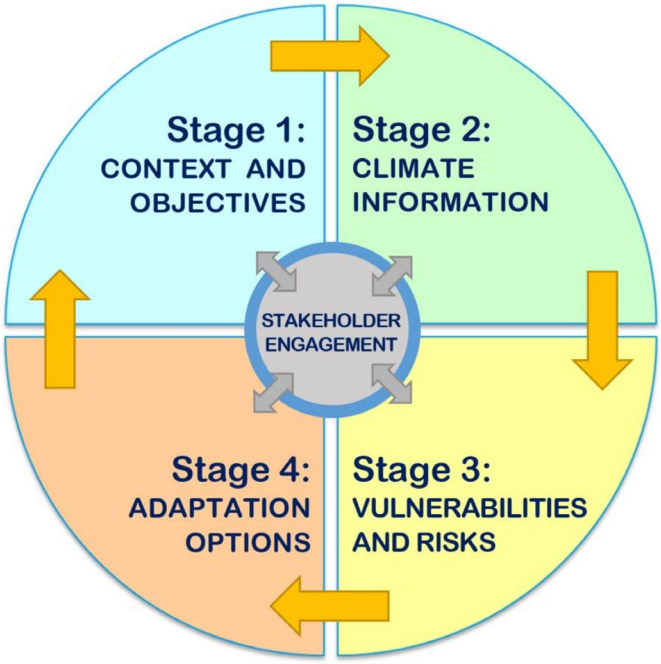


Figure 1.2-4 Climate change adaptation planning process [6]

2) **Impact assessment of possible natural disasters**

The advisory team summarized the impact of natural disasters on port facilities, management systems, and operations for each type of natural disaster as listed in sub-section (6).

[6] CLIMATE CHANGE ADAPTION PLANNING FOR PORTS AND INLAND WATERWAYS」（PIANC, EnviCom WG Report No. 178-2020）

Table 1.2-7 Assessment of Impacts of Natural Disasters (Example: the Port of Suva)

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	The Port of Suva was constructed in 1963, with a sheet pile retaining wall behind it. The prestressed concrete piles of the foundation and the concrete deck slabs of the superstructure are deteriorating. Significant damage from an earthquakes possible. There is also a risk that the entire retaining wall could suffer circular slip failure due to seismic motion.	The collapse of offices and injuries due to an earthquake could affect management systems. Damage to port facilities such as piers is expected to have a significant impact on port operations. Damage to the Port of Suva is expected to have a significant impact on the stable supply of food and other daily necessities to Fiji and neighboring countries.	Earthquakes may cause human casualties that could affect operations. Damage to port facilities and loss of power may affect port calls. Damage to cargo handling equipment may also affect cargo handling activities.
Tsunami	Although the Republic of Fiji is not at high risk of tsunami disasters, there is a possibility of damage to ships due to collisions or damage caused by tsunamis, as well as the loss of container cargo. In addition, damage such as the overturning of cargo-handling machinery, including mobile harbor cranes, and loss of power supply is also a concern.	The tsunami is expected to cause injuries and other human casualties, which could affect management systems. Damage to port facilities and the loss of cargo due to the tsunami could have a significant impact on the stable supply of food and other essential goods to Fiji and neighboring countries.	Human casualties caused by tsunamis may affect operations. Damage to port facilities and loss of power may affect the port calls. Collisions and sinking of ships caused by tsunamis may prevent ships from arriving.
Volcano	The Republic of Fiji is located between Tonga and Vanuatu and is one of the countries with a high risk of volcanic disasters. There are concerns about the potential for volcanic eruptions and ashfall to cause significant damage to port facilities and cargo handling equipment, as well as the closure of shipping lanes.	Human casualties caused by volcanic eruptions may affect management systems. Damage to port facilities and disruption of land transportation caused by volcanic eruptions could have a significant impact on the stable supply of food and other essential goods to Fiji and neighboring countries.	Human casualties such as injuries caused by volcanic eruptions may affect operations. Volcanic ejecta and ashfall may render port facilities and container yards unusable.
Storm Surge	There is concern that high tides will cause flooding of port facilities and container yards behind the port. There is also concern that high tides will cause ships to run aground and container cargo to spill out.	High tides may cause injuries and other human casualties, which could affect management systems. Damage to port facilities and the loss of cargo due to high tides could have a significant impact on the stable supply of food and other goods to Fiji and neighboring countries.	Human casualties caused by high tides may affect operations. Damage to port facilities and loss of power may affect port calls.
Cyclone	The strong winds from cyclones could cause damage to office buildings and warehouses, as well as lead to the collapse of stacked containers and lighting equipment,	Cyclones may result in casualties and other human damage, which could affect management systems. Strong winds could damage land	Cyclones may cause injuries and other human casualties that could affect operations. Strong winds may halt land

	and the overturning of cargo handling machinery. High waves from cyclones may also cause flooding of port facilities, ships to run aground or collide containers to spill out, and power outages.	facilities and close roads, halting land transportation, while high waves could damage port facilities and cause cargo to spill, severely affecting the stable supply of food and other goods to Fiji and neighboring countries.	transportation, which could affect operations. High waves may damage port facilities and cause cargo to spill, which could also affect operations.

(9) Formulation of Port Resilience Strategy

The advisory team clarified the reasons why the indicators identified in sub-section (8) remained at the current level, provided specific directions on what needed to be done to improve the indicators, and compiled a strategy for port resilience, including natural disaster risk reduction measures and port facility maintenance and management measures.

1) **Confirmation of the reasons for staying with the current resilience indicators**

After presenting the advisory team's approach to setting resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response for each port, the team confirmed with port managers the reasons why they were staying with those indicators, the obstacles they faced, and whether or not they intended to work on improvements.

2) **Consideration of measures to advance key resilience indicators one level higher**

In order to advance the current indicators for each target port one level higher, the advisory team exchanged opinions with port administrators and stakeholders on the following perspectives, and compiled measures that could be undertaken jointly by all parties concerned.

a. Introduction of disaster risk if no measures are taken by the advisory team,
b. Listing of possible measures and the feasibility of each measure,
c. The effectiveness of the measures taken in reducing disaster risks and their costs, as well as the work-sharing between the public and private sectors, and
d. Fostering momentum for the sustainability of measures and joint participation of all parties involved.

3) **Examples of countermeasures**

Examples of measures introducing climate change adaptation and efficient maintenance and management methods were presented.

a. Design and renovation of port facilities in consideration of climate change

In Japan, the concept of design considering the effects of climate change on port facilities has been studied and reflected in the technical standards for port facilities. The conventional approach (Figure 1.2-5 left) is to assume that the effects on port facilities during the design service period are constant, and to set the bearing capacity of the facilities for design purposes. The new approach

(Figure 1.2-5 right) requires that the performance of the structure be secured against changes in action (due to climate change) during the design service period.

In the future, when changes in tidal levels, waves, and other effects due to climate change are quantitatively understood, measures such as those shown in Figure 1.2-6 (raising the wharf and installing seawalls) can be considered for existing container terminals.

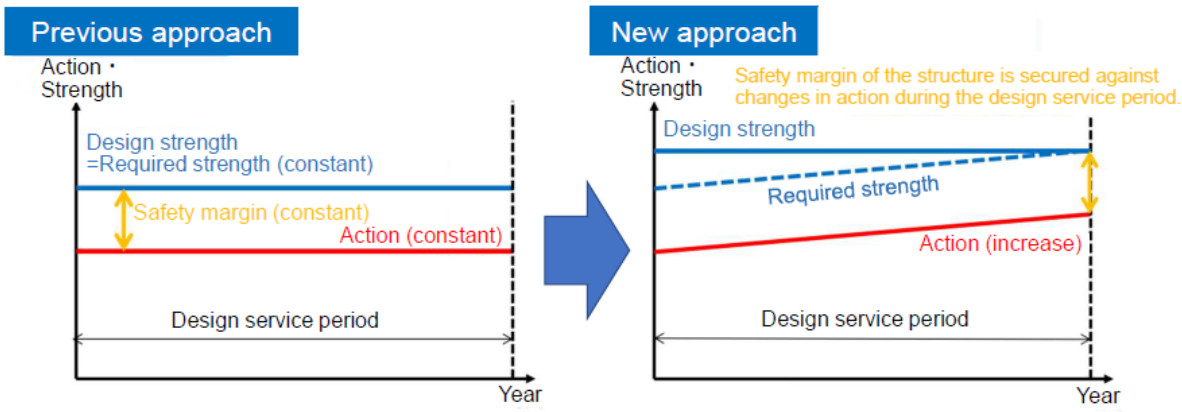


Figure 1.2-5 Design Approach for Climate Change [7]

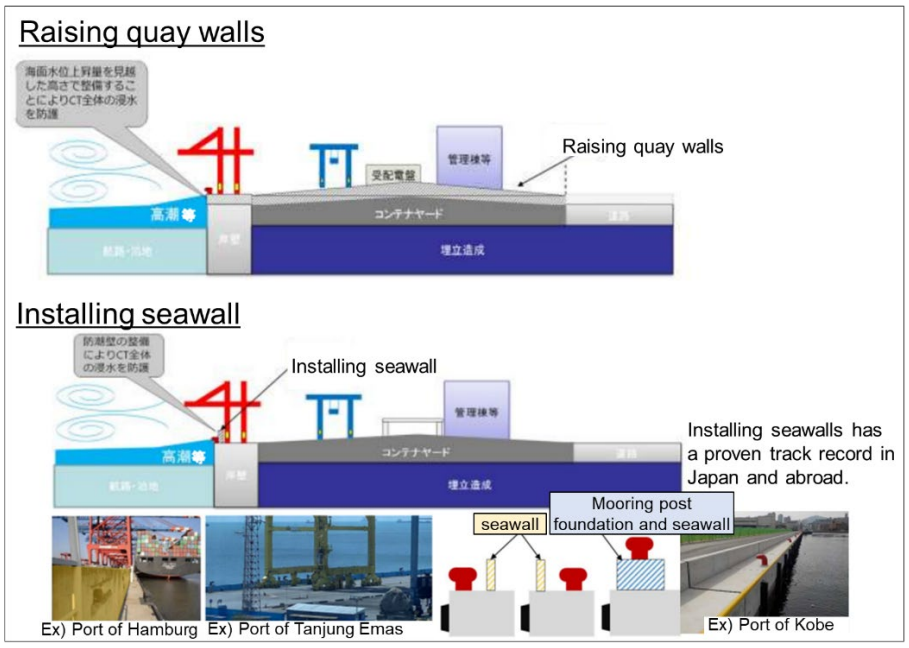


Figure 1.2-6 Diagram of proposed countermeasures against sea level rise [8]

[7] https://www.mlit.go.jp/kowan/content/001595012.pdf
[8] https://www.mlit.go.jp/kowan/content/001595016.pdf

b. Extending the service life of facilities (preventive maintenance)

While the number of deteriorated facilities will increase rapidly in the future, there is a limit to the financial resources that can be allocated for maintenance, renewal, and repair. Therefore, preventive maintenance plans will be formulated taking into consideration the status of deterioration, utilization, and priority of facilities, and based on these plans, efficient improvement works will be carried out to extend the service life of facilities while controlling maintenance and management costs.

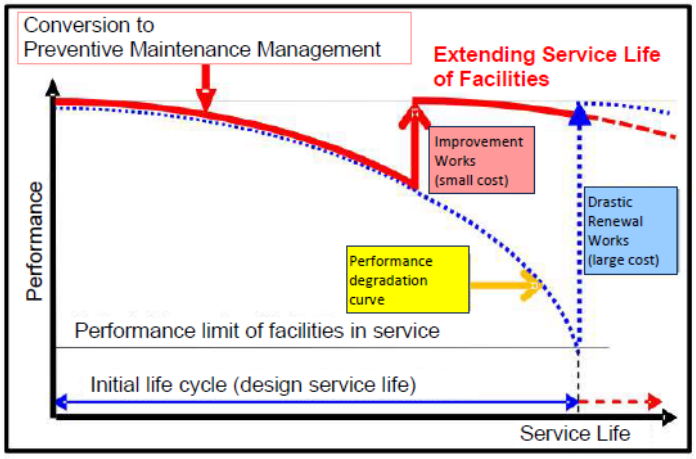


Figure 1.2-7 Preventive maintenance [9]

c. Resilient breakwater

In future plans for rehabilitation or reconstruction of the breakwater, it is essential to adopt a resilient structure. This is especially important for facilities with high importance, where damage could lead to serious consequences for human life, property, and socioeconomic activities.

To ensure the breakwater remains stable even under extreme tsunami forces, the proposed approach includes increasing the crest height, modifying the crest shape, and placing revetment support structures on the landward side. These measures are intended to prevent scouring caused by overflow and to reduce the risk of significant displacement or collapse of the structure.

[9] https://www.cdit.or.jp/english/news/20230525.html

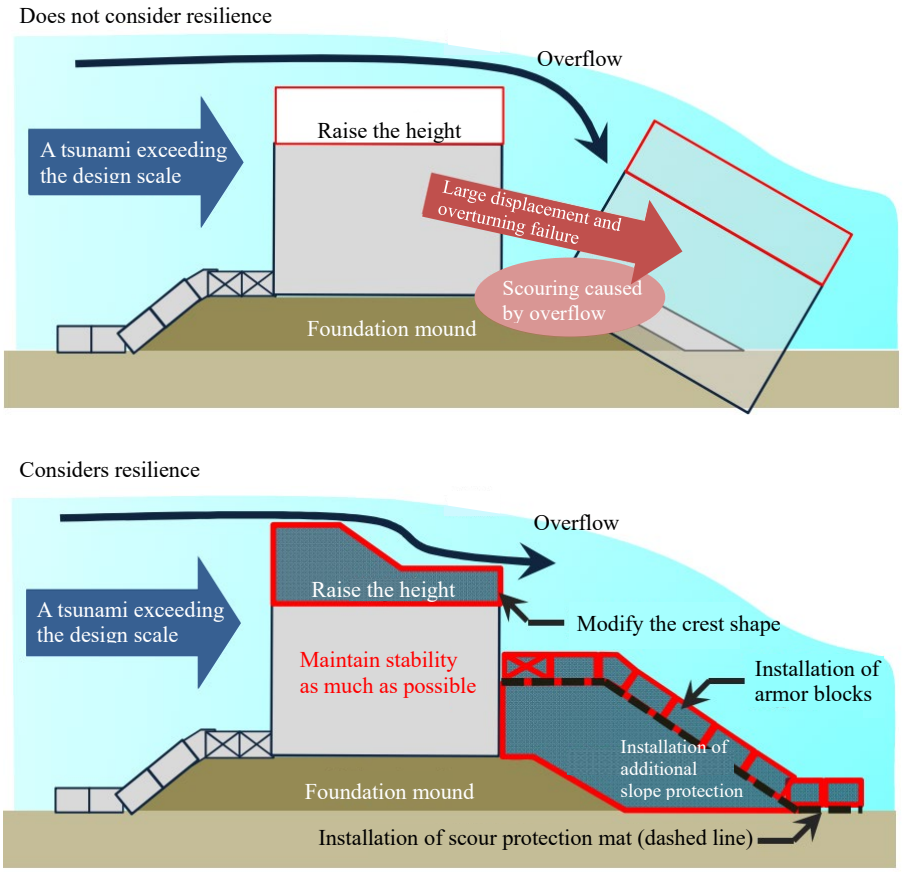


Figure 1.2-8 Resilient breakwater [10]

d. Introduction of steel structures considering seismic resistance and ease of maintenance

Port steel structures, which use steel pipes, steel sheet piles, and other main materials, can reduce the structural weight compared to concrete structures, thereby reducing lateral earthquake forces. Additionally, these structures exhibit a more flexible response to berthing forces from vessels, allowing for a more rational and economical design.

Steel structures need to be properly protected from corrosion due to the harsh corrosive environment in which they are often installed. This requires the use of corrosion protection methods such as electrical corrosion protection or coating protection techniques.

Concrete structures were widely used in island nations due to limitations in construction capabilities at the time and difficulties in securing steel materials. However, many concrete structures have suffered significant structural damage, likely caused by salt damage or the impact of large vessels berthing.

[10] https://www.mlit.go.jp/common/001102317.pdf

Therefore, fundamental renovation should be considered, such as transitioning to a steel pipe pile structure that can elastically respond to ship impacts and earthquakes and reducing the weight of the deck slab to account for seismic considerations.

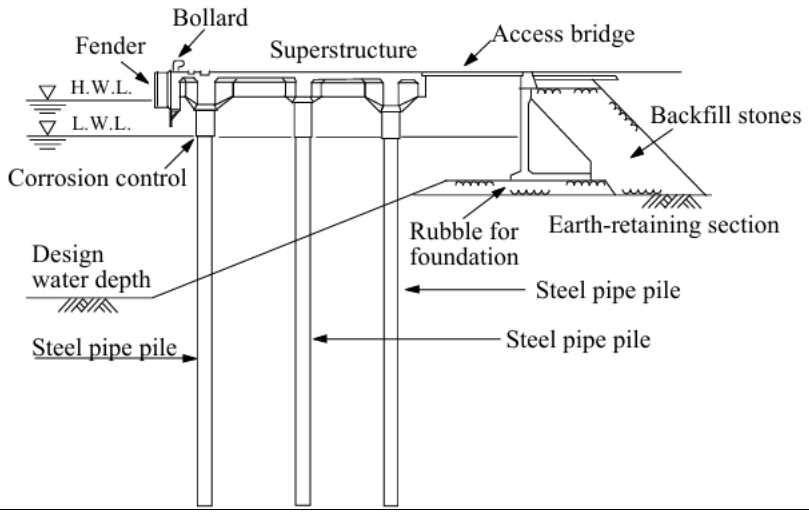


Figure 1.2-9 Cross-sectional diagram of a quay wall with steel pipe piles[11].

4) **Compilation of Port Resilience Strategy**

Based on the results of the study of measures in sub-sections 2) and 3) for each port, the advisory team summarized the requirements, policies to satisfy those requirements, and proposed measures to achieve a higher level of resilience indicator.

For example, as shown in Figure 1.2-10, after identifying the reasons that the current indicator status remained as "Unengaged", specific policies and proposed measures to satisfy the requirements for improving to "Engaged" indicator, which is one level above the "Unengaged" indicator, will be examined.

[11] Technical standards and explanations for port facilities (English version) (2020)

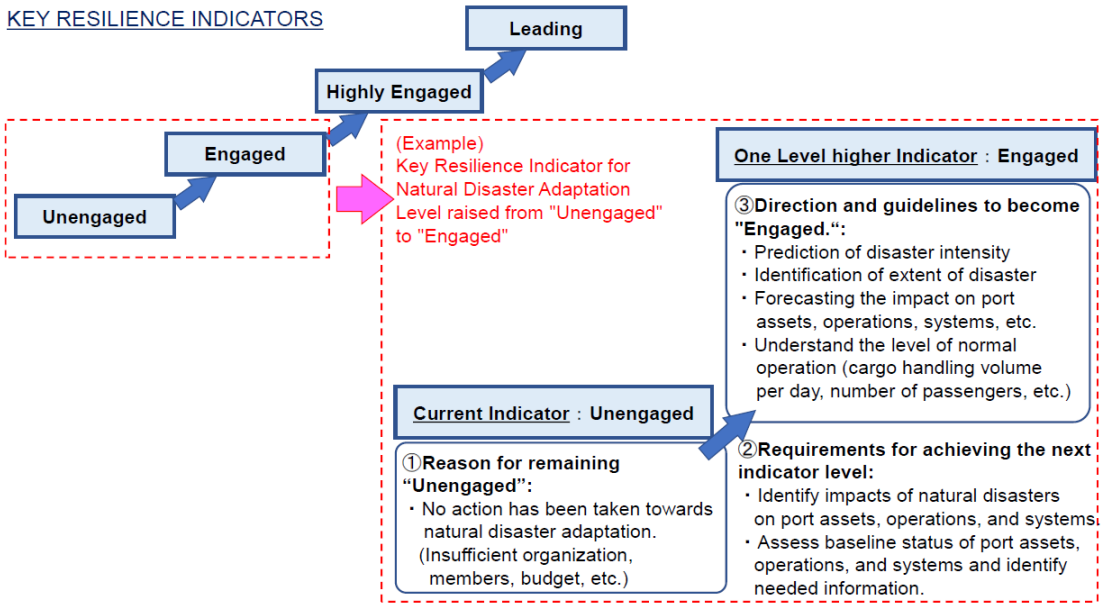


Figure 1.2-10 Process for moving up to the next key resilience indicators

Next, vulnerable facilities at each port were identified, and resilience enhancement projects were proposed.

Table 1.2-8 Identification of Vulnerable Areas and Proposal of Resilience Projects at Each Port

Target Country	Island Name	Port Name	Proposed Resilience Project	Total Cost (million USD)
Fiji	Viti Levu Is	Suva	The container terminal at the Port of Suva is significantly deteriorated, and there is a strong need to enhance its functionality. Development that considers seismic resistance and global warming, including the possible relocation of the container terminal, is required.	N/A
Fiji	Ovalau Is	Levuka	Although it is the only port on the island, the current jetty is severely deteriorated. Rehabilitation of the jetty, taking into account seismic resistance and global warming, is necessary.	6.6
Tuvalu	Funafuti atol	Funafuti	Although it is Tuvalu's only international trade port, there is only one usable jetty, resulting in unstable vessel operations. In conjunction with the removal of the deteriorated jetty, rehabilitation of the jetty that takes global warming into account is necessary.	12.9
Solomon Islands	Guadalcanal Is	Honiara	Although it is an international trade port of the Solomon Islands, there is no dedicated bulk terminal, resulting in unstable handling of bulk cargo such as energy imports and coconut oil exports. Construction of a dedicated bulk terminal that considers seismic resistance and climate change measures is necessary.	30.9
Tonga	‘Eua Is	Ohonua (Nafanua Wharf)	Ohonua Port(Nafanua Wharf), the only port on ‘Eua Island, was damaged by a tsunami, resulting in the loss of its breakwater. As a result, the safe berthing	N/A

			and unberthing of ferries has become difficult. Therefore, reconstruction of the breakwater is necessary, taking into account tsunami countermeasures and climate change adaptation.	
Tonga	Vava'u Is	Neiafu	Neiafu Port, the main gateway to the Vava'u Islands, is significantly deteriorated, and the existing quay is too short for the vessels that call at the port, making safe cargo handling difficult. Therefore, reconstruction and extension of the deteriorated quay, as well as improvement of the access channel, are necessary.	N/A
Tonga	Tongatapu Is	Nuku'alofa Port	The old port area has experienced significant land subsidence, and the water area is also limited. Therefore, expansion of the domestic shipping terminal is required in line with the enhancement of domestic routes. In doing so, tsunami countermeasures and climate change adaptation must be taken into account.	N/A
Samoa	Upolu	Apia	Although the transportation of goods to Savai'i Island relies on ferries from Salelologa, cargo is currently transferred from containers to trucks, resulting in high transportation costs and concerns about potential damage to the cargo. By expanding the container terminal at Salelologa and the transshipment yard at Apia Port, it will be possible to introduce domestic container vessel services.	10.0 (Assuming 150 yen per USD)
	Savai'i	Salelologa		13.3 (Assuming 150 yen per USD)

(10) Seminars

Two seminars on port resilience strategies were held for stakeholders of the target ports.

(a) First Seminar

A seminar on port resilience strategies was held for stakeholders of the target ports. The seminar was conducted in an online format.

Table 1.2-9 First Seminar Outline

Date and Time	February 25, 2025, 14:00 – 17:00 (Fiji Time)
Target Organizations	Port management authorities of all target ports
Participants	Disaster risk reduction and crisis management officers of the target organizations
Contents	・Interim results of the study ・Guidelines for maintenance and repair of port facilities ・Technical standards for port facilities in response to climate change ・Technical standards related to earthquakes

(b) Second Seminar

Stakeholders from the target ports were invited to Fiji, and a seminar on port resilience strategies was held. The seminar took place in a conference room owned by SPC and was conducted in a hybrid format, combining both in-person and online participation.

Table 1.2-10 Second Seminar Outline

Date and Time	June 10 and 11, 2025, 11:00–15:00 (Fiji Time)
Target Organizations and Companies	Port authorities, operators, cargo handling and warehouse companies of all target ports
Participants	Disaster risk reduction and crisis management officers of the relevant organizations and companies
Contents	・Overview of the survey results ・Resilience of port structures against earthquakes and tsunamis ・Port design in response to climate change ・Challenges in Pacific island countries - small and geographically dispersed oceanic islands

2. Republic of Fiji

2.1 Overview of the country and its major ports and external relations

2.1.1 Country Overview

The Republic of Fiji (hereinafter referred to as "Fiji") is an island nation consisting of 330 islands located at a strategic point in the South Pacific Ocean. With a population of approximately 925,000, Fiji is a multi-ethnic nation, although indigenous Fijians and Indo-Fijians are the largest ethnic groups.



Source: https://www.pinterest.com/pin/316377942582760780/, (accessed: January 2024)

Figure 2.1-1 Location Map of Republic of Fiji

2.1.2 Economic and Social Conditions

The country is blessed with mineral resources such as gold, copper and bauxite, as well as forest and marine resources, and its warm climate and natural resources such as coral reefs have also made it a popular tourist destination. Since gaining independence in 1970, it has shown a strong presence as a regional hub. On the other hand, there are still issues based on traditional values, such as a low level of gender equality awareness. In addition, in urban areas in particular, the existing infrastructure is unable to keep up with the ever-increasing demand, and many of these existing infrastructures are also aging, so there is a need for systematic infrastructure development

and renewal.

After recording a negative 6.6% economic growth rate in 2007, immediately following the December 2006 coup d'état, the rate improved to 0.2% in 2008, but in 2009 the economic growth rate fell to a negative 3% due to the decline of the sugar industry and the impact of the global economic crisis. In particular, the sugar industry, which has supported the Fiji economy for many years, is facing problems such as aging machinery. Since 2011, the Fiji economy has been generally stable, maintaining growth in the 2% to 5% range. However, rapid economic development has led to an increase in the number of non-communicable diseases (NCDs) and a shortage of workers with advanced skills and knowledge, as well as other new issues, due to changes in lifestyle and industrial structure, as well as the widening gap between urban and rural areas as a result of the influx of population into urban areas. Since 2020, the COVID-19 pandemic has had a severe impact on the economy, particularly on the tourism industry, which accounts for 35% of GDP. However, the economy began to recover in 2023, led by the tourism industry, and is expected to grow at a rate of more than 3% in 2024.

2.1.3 Overview of Port Administration

(1) Port Administration Organization

Fiji's port management organization is a publicly owned organization, unlike port management organizations in other Pacific states. In Fiji, the government has partially divested ownership in many institutions, including ports and airports, to establish public/ private agencies. Fiji Ports Corporation Limited (FPCL) was established in 2013 through the corporatization of the Fiji Port Authority. The shares of FPCL were divested in 2015 and distributed between the Government (41%), FNPF (39%) and Aitken Spence PLC (20%) - a Sri Lankan entity experienced in operations of seaports globally.

Fiji Ports Terminals Limited (FPTL) is an affiliated company of FPCL, with 51% owned by Aitken Spence PLC and 49% by FPCL. Fiji Ship and Heavy Industries Limited (FSHIL) is a subsidiary of FPCL and is 100% owned by FPCL.

After the public incorporation in 2013, the Fiji government transferred ownership of the port to Assets Fiji Pte Limited, a government agency, which leases the port property back to FPCL. The ownership is classified into three categories. The core assets are such as wharves and loading/unloading machinery, which are clearly considered port property. The intermediate assets are such as warehouses and factory sites, and the other assets are those with little or no connection to the ports, such as hotels. Asset Fiji has been examining these assets carefully and leasing those assets that are closely related to the port to FPCL. In addition to ports, the Fiji government has adopted the same scheme for the establishment of public corporations for the airports and the electricity as well.

(2) Organization

Fiji Ports Corporation Pte Limited (FPCL) is the Port Management Company of Fiji appointed under the Sea Ports Management Act 2005 (SPMA). It solely owns Fiji Ships & Heavy Industries Limited (FSHIL) and has 49% shares in the Ports Terminal Operator – Fiji Ports Terminal Limited.

(3) Overview of Major Ports

Fiji's four major ports are Suva, Lautoka, Levuka, and Malau, as shown in Figure 2.1-2. These four ports are managed by the FPCL.



Source: http://geo.d51498.com/SilkRoad-Lake/2917/syometsu/rotuma.html

Figure 2.1-2 Location Map of Major Ports in Fiji

(a) The Port of Suva

Suva port is located in Suva, the capital city of Fiji, and has the largest international container terminal in Fiji. The port is managed by FPCL, and cargo handling is carried out by FPTL. Suva port was constructed in 1880s as a timber jetty and wharf. In 1912, the original King's wharf was constructed including major reclamation. The King's wharf has been reconstructed as container multipurpose facility in 1963. The wharf has been developed to handle containers with ADB loan in 1980s, and extended wharf deck and container yard capacity in 2006. This port has three wharves: King's Wharf (container cargo, liquid bulk, cruise ships), Princess Wharf (international fishing vessels), and Walu Bay Wharf (dry bulk).

(b) The Port of Lautoka

Lautoka Port is located on the northwest coast of Viti Levu and handles bulk cargo such as sugar,

wood chips, molasses, LPG, natural gas, and petroleum. The annual handling volume is over 1.2 million tons, and more than 100 cargo ships come and go from the port.

(c) The Port of Levuka

Levuka Port is located on the east coast of Ovalau Island, about 20km east of the largest island in the archipelago, Viti Levu. Levuka was once the capital of Fiji, and the original wharf was constructed in 1886 as a timber superstructure on concrete piles. In the 1920s, the Port of Levuka was renovated as a concrete superstructure on concrete piles with a depth of approximately 10 meters and a length of 180 meters, which could accommodate 10 fishing boats. In 1980, the section from the first 70 meters was rehabilitated, and this section is still in use today. After deliberations at the 37th World Heritage Committee in 2013, the Beach Street and surrounding area were registered on the UNESCO World Heritage List as “Levuka Historical Port Town”. It is the first World Heritage Site in Fiji.

(d) The Port of Malau

The Port of Malau is located in the northwest of Vanua Levu Island and is the main port for handling molasses. The port contributes to the sugar industry of the country, centered on the town of Labasa, and handles about 140,000 tons of cargo per year. The port is also owned by the Fiji Sugar Corporation, but it is under the jurisdiction of FPCL based on the Port Management Act.

2.1.4 Cargo handling volume

The total volume of international general cargo handled in the ports of Suva, Lautoka and Levuka recorded at 2,684,540 tons in 2019. Although the impact of the coronavirus pandemic, the number was dropped in 2020. The total volume of international containers recorded at 180,989 TEU in 2018 and dropped to 148,488 TEU in 2020. The number is increasing 192,540 TEU in 2022. The breakdown cargo volume for the three ports is not available.

Table 2.1-1 Annual cargo handling volume in the ports of Suva, Lautoka and Levuka

General Cargo

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023
Import (ton)	1,406,040	1,613,286	1,622,651	1,129,573	1,550,201	1,076,495	1,107,637	1,346,314	1,521,935
Export (ton)	552,128	1,057,054	876,127	755,081	1,134,339	803,508	848,919	623,188	780,951
Total (ton)	1,958,168	2,670,340	2,498,778	1,884,654	2,684,540	1,880,004	1,956,556	1,969,502	2,302,886

Containerized Cargo

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023
Laden (TEU)	92,761	101,082	109,343	112,464	104,050	96,646	106,656	122,428	115,783
Empty (TEU)	47,201	54,294	65,396	68,525	63,389	51,842	60,671	70,112	70,984
Total (TEU)	139,962	155,376	174,739	180,989	167,439	148,488	167,327	192,540	186,767

Source: courtesy of FPCL (sum of three ports: Suva, Lautoka, and Levuka).

Table 2.1-2 shows the number of vessel-calls at the port of Suva in 2023 by vessel type and the average size of the arriving vessels. The total number of vessel-calls for the year was 1,057. Container ships, general cargo ships, and roll-on/roll-off (RO/RO) ships accounted for a combined 366 arrivals, followed by fishing vessels and trawlers with a combined 291 arrivals. Additionally, liquefied petroleum gas (LPG) carriers, chemical tankers, and product tankers accounted for a combined 68 arrivals, while cruise ships recorded 31 arrivals.

Table 2.1-2 Number of Vessel Calls by Type and Size in the Port of Suva

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
Bulk carrier	10	21	690,292	422,887	32,871	20,137
Buoy ship	2	7	6,024	2,060	861	294
Cable ship	1	2	11,940	28,264	5,970	14,132
Chemical tanker	1	1	7,717	5,991	7,717	5,991
Combined chemical and oil tanker	12	24	652,715	384,919	27,196	16,038
Fishing (general)	121	284	27,056	83,208	95	293
Fully cellular containership	31	208	4,349,161	3,431,304	20,909	16,497
General cargo	2	2	9,106	7,460	4,553	3,730
General cargo with container capacity	17	89	1,123,767	925,661	12,627	10,401
Liquified Petroleum Gas Carrier	4	12	53,324	50,062	4,444	4,172
Meteorological research	2	6	55,188	110,442	9,198	18,407
Naval Vessel	3	5	20,494	34,530	4,099	6,906
Oceanographic research	2	2	636	5,109	318	2,555
Passenger (cruise)	20	31	229,014	2,406,757	7,388	77,637
Patrol ship	2	3	0	2,453	0	818
Pilot ship	2	137	0	0	0	0
Product tanker	13	31	1,496,352	893,142	48,269	28,811
Research	2	2	1,458	1,489	729	745
Roll on roll off with container capacity	2	12	217,410	217,200	18,118	18,100
Supply	1	2	5,600	9,046	2,800	4,523
Trawler (All types)	2	7	12,150	17,270	1,736	2,467
Tug	5	126	86,260	59,408	685	471
Vehicle carrier	19	29	447,879	1,460,286	15,444	50,355
Vessel Type (unspecified)	6	9	0	0	0	0
Yacht	2	5	720	3,519	144	704
Total	284	1,057	9,504,263	10,562,467	8,992	9,993

Source: Lloyd's List Intelligence Sea searcher data (2023) analyzed by OCDI

As a result of preliminary discussions with FPCL and SPC, the two ports selected for this project in Fiji are the Port of Suva and the Port of Levuka.

2.2 The Port of Suva

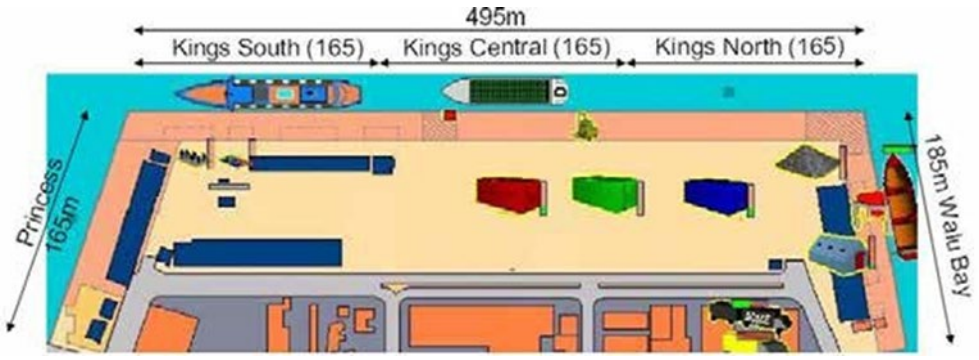
2.2.1 Review issues related to port maintenance and management

(1) Status of Port facilities

The Port of Suva is located on the southeast coast of Viti Levu Island, the main island of Fiji. The Port of Suva has five berths: Kings South, Kings Central, Kings North, Walu Bay, and Princess, with a total length of 845 meters and a water depth of 12 meters. The container terminal has a storage capacity of up to 100,000 TEUs. The main cargoes handled include minerals, vegetable

oils, LPG, general cargo, and various other cargoes. Approximately 757,000 tons of cargo are imported, and over 184,000 tons are exported. Port facilities include mobile harbor cranes with a lifting capacity of 15 TEU per hour, and all facilities are managed and operated by Fiji Ports Terminal Limited (FPTL).

(a) Port Plan



Source: JICA Report on Information Collection and Verification Survey on Vein Logistics in the Pacific Region (2013)

Figure 2.2-1 Plan for the Port of Suva Terminal

Table 2.2-1 Specifications of the Port of Suva Terminal

Wharf	No.	Length	Depth	Fender Type
Kings Wharf	No. 1	492m	10m	Cone
Walu Bay Berth	No. 2	189m	7m	Tubular
Princess Wharf	No. 3	163m	5m	Tyre

Source: FPCL HP: https://fijiports.com.fj/port-of-suva/
(accessed in October, 2023)

(b) Port cross-section (survey photos, drone photos)



Figure 2.2-2 Panoramic view of Kings Wharf in the Port of Suva **(courtesy of FPCL)** (Cargo handling by mobile harbor cranes.)

(c) Assessing the current situation through on-site inspections

Kings Wharf is the largest wharf in the Port of Suva with 492 meters in berth length. Approximately 300 meters of the north side of the wharf was reinforced in 2005 by the support of ADB to enable mobile harbor cranes to quickly handle cargo to cope with efficient cargo handling operations. However, this reinforcement work was insufficient to bear any containers or cranes operation on the yards. Load restrictions remained even after the reinforcement work. Therefore, deterioration of the facility might be accelerated due to loads over the period even though the load was within the restriction range.

After having surveyed the aging condition of the wharf, FPCL is carrying out a rehabilitation plan to extend facility life for 10 or 15 years. The first rehabilitation work was carried out in 2005. This work rehabilitated the northern and the center parts of the wharf to enable them to accommodate container vessels. Since the 15 years have passed after the rehabilitation, FPCL conducted a survey again in 2019 to evaluate the aging condition of the wharf and established a new rehabilitation plan. The FPCL survey identified concrete peeling of the pile head and that of underside of the deck pier due to aging.

In addition, JICA expert team's visual observation, no misalignment of the quay wall or joints was observed. However, they identified the damage to the chains and bolts of the marine fender's attachment and cracks on the aged concrete apron. During the visual observation survey, FPCL accompanied the team and exchanged opinions about strengthening port facilities and maintenance methods through introduction of survey methods and interviews. The photos taken during the exchange of opinions are shown in Figure 2.2-3.



Figure 2.2-3 Photo during the exchange of opinions

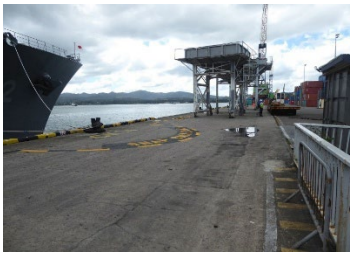
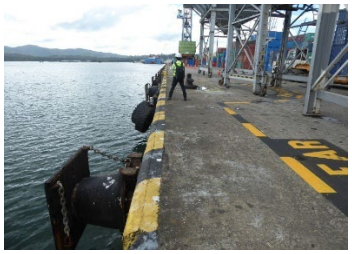
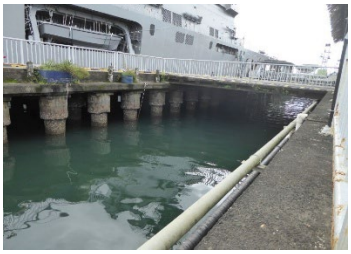
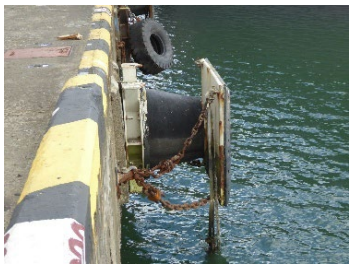
 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)
No.1- Suva, Pier Status 1	No.2- Suva, Pier Status 2	No.3- Suva, Pier Status 3
 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)
No.4- Suva, Pier Status 4	No.5- Suva, Pier Status 5	No.6- Suva, Pier Status 6
 (Photo by Survey team, 2023)	 (Source: report from FPCL)	 (Source: report from FPCL)
No.7- Suva, Damaged Fender	No.8- Suva, Deterioration of pile head 1	No.9- Suva, Deterioration of pile head 2
 (Source: report from FPCL)	 (Source: report from FPCL)	 (Source: report from FPCL)
No.10- Suva, Deterioration of slab -1	No.11- Suva, Deterioration of slab -2	No.12- Suva, Deterioration of slab -3

Figure 2.2-4 Site investigation photos

(d) Collection and organization of design documents from the viewpoint of maintenance and management

FPCL is a port operating company responsible for the maintenance and management of core port infrastructure facilities and navigation aids. FPCL's real estate assets was transferred to Assets Fiji Pte Limited (AFL) and leased back to FPCL; however, some of these transactions are still pending completion. For the maintenance and management of such state-owned facilities, and/or major repair works, maintenance dredging, relocation plans, and other projects related to the future asset management plans in Fiji are subject to the judgment of the Ministry of Public Works and Transport. FPCL is following these matters through the Management Committee.

FPCL keeps the original design drawings and the drawings and reports for the repair works for facilities in Suva port and is working on organizing and digitizing the hard copy documents. In addition, survey reports, design documents, and drawings related to recent rehabilitation plans are also stored in its database. These documents are basically treated as internal FPCL documents but can be reviewed by relevant parties as needed.

(2) Implementation Department responsible for Port Management

FPCL is a port management company established in Fiji under the Sea Port Management Act (SPMA) of 2005. FPCL is responsible for managing ports and approaches to ports designated under the SPMA. The main port are the port of Suva and the port of Lautoka, with other ports including the port of Levuka, the port of Malau, the port of Buda, the port of Rotuma, and the port of Wailiki. FPCL also serves as a regulatory oversight body under the SPMA, regulating port activities including monitoring environmental violations within port boundaries.

(3) Status of Existing Facility and Future Plans

Rehabilitation projects aimed at extending the service life of existing wharves are planned and partially underway in Suva port. In addition, Suva port relocation plan is in the pipelines with the support of ADB. As the current port is located in the center city, its container yard is limited and no space for expansion in the current location. Land prices are high, and traffic congestion is severe. Therefore, the study is searching for a new site including land for attracting businesses behind the port. As of August 2024, three sites have been narrowed down from 12 candidates, and a comprehensive decision will be made through further detailed evaluations.

2.2.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at the Port of Suva

(1) Collection of data on damage caused by past natural disasters

In this section, we will collect reports on the disasters, and compile information on natural disasters that affected the port of Suva over the years. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss.

(a) Sea level rise, cyclone and high wave

First, we will review the natural disaster risks across Oceania based on "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[12]". AR6 reports that the occurrence proportion of strong tropical cyclones (categories 3 to 5) among all tropical cyclones globally has increased in the last 40 years, with a moderate level of confidence. AR6 indicates low confidence in the long-term trends of the increasing frequency of tropical cyclones across all categories. In addition, AR6 mentions that the global mean sea level has been rising more rapidly since 1900 than at any other 100-year time in the past 3,000 years, with high confidence.

Next, we will show the major cyclones that have caused critical damage to Fiji in chronological order of their occurrence. Fiji is frequently hit by tropical cyclones and coastal floods associated with weather fronts. In 2016, Cyclone "*Winston*", the strongest cyclone ever recorded in the Southern Hemisphere, struck the country, resulting in 44 deaths and economic losses totaling 1,990 million Fijian dollars (source: Post-Disaster Needs Assessment. 1 Fijian dollar ≈ 50 yen). In 2020, Cyclones "*Harold*" and "*Yasa*" caused damage in multiple Pacific Island nations, including Fiji, with particularly severe impacts in Fiji, resulting in the collapse of homes, damage to infrastructure, and significant losses to crops.

(b) Earthquake, tsunami and volcanic activity

World Bank reported that Oceania was exposed to high risk of tsunamis, earthquakes, and volcanic activity[13] as shown in **Figure 2.2-5** to **Figure 2.2-7**. The earthquake peak ground acceleration in Fiji falls in the range of 100.1 to 250 cm/s^2, indicating a high seismic hazard (see Figure 2.2-6). Tsunami maximum inundation height (MIH) for a to-year return period in Suva Port area falls from 1.51 to 2.00-meter range (see Figure 2.2-5). On the other hand, the risk from volcanic activity may be considered low (see Figure 2.2-7).

[12] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[13] Pacific Maritime Transport Systems Hazard Exposure Technical Note, World Bank. 2023.

This region has been affected by seismic disasters such as the 1953 Suva earthquake and the 2018 Fiji earthquake, as well as tsunami disasters caused by earthquakes, and it also faces a risk of tsunami occurrence. Measures against earthquakes and tsunamis should be urgently introduced. The expert team requested FPCL to provide meteorological and oceanographic data which are indicators of the scale of natural disasters. However, the data could not be obtained.

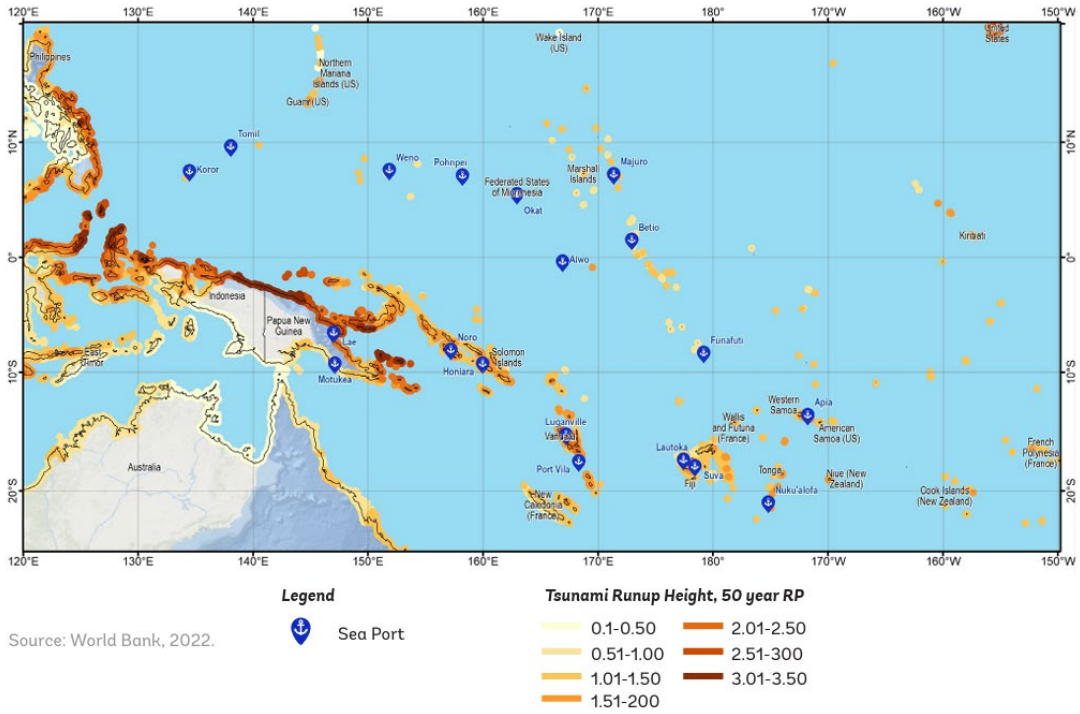


Figure 2.2-5 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

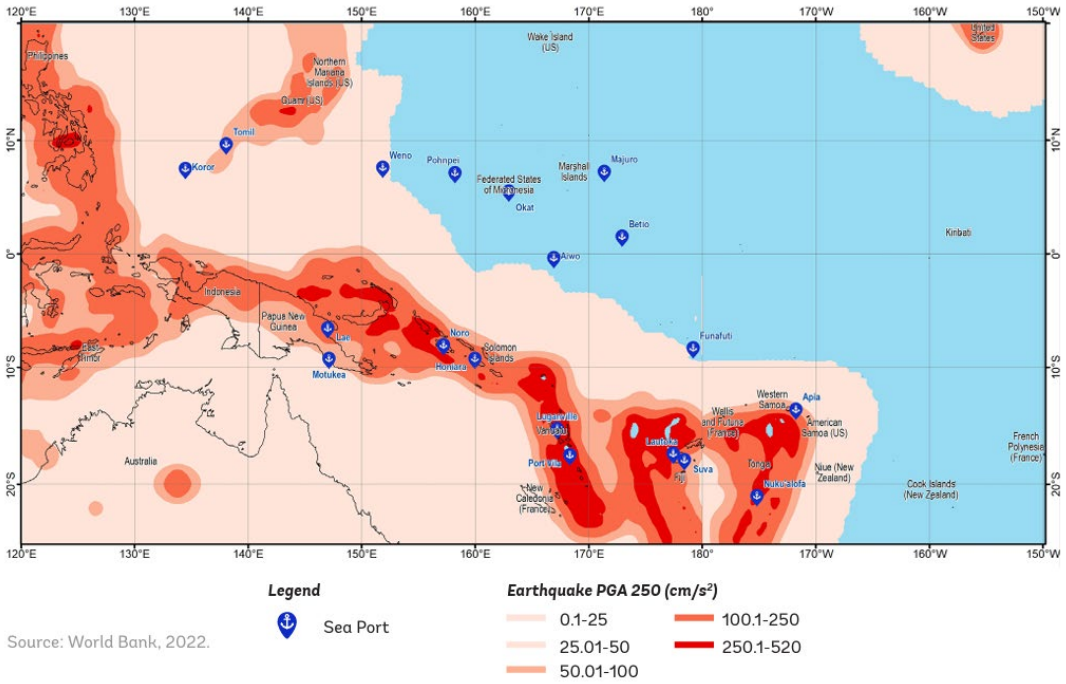


Figure 2.2-6 Earthquake peak ground acceleration (PGA) in cm/s2 for a 250-year return period

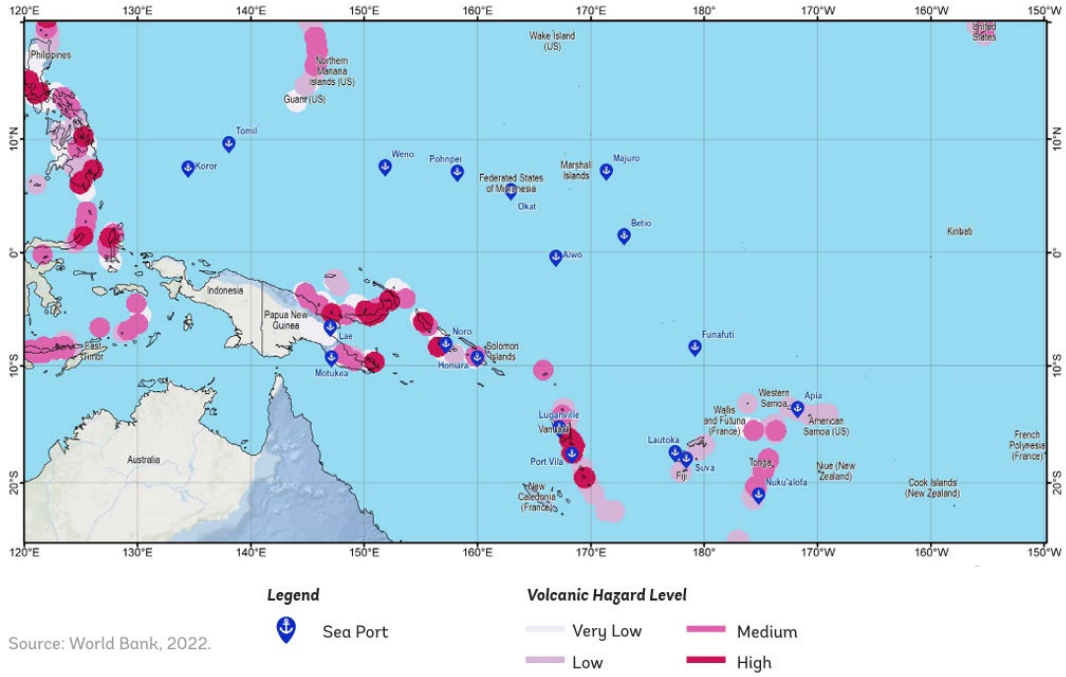


Figure 2.2-7 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in the port of Suva and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters. The design conditions such as natural conditions, design loads, etc. at the time of construction of the existing facilities at the Port of Suva have been confirmed referring to the information provided by FPCL.

Deck Level: RL+3.40 m
Tide Level:
Mean High Water Spring: (MHWS) RL+1.46 m
Mean Low Water Spring: (MLWS) RL 0.0 m

Water depth: RL-10.0m

Design vessels: unknown (not shown in the document)
Geotechnical Conditions: unknown (not shown in the document)
Seismic condition: unknown (not shown in the document)

(The above information was confirmed based on the as-built drawings which are part of the design documents from the time of construction, held by FPCL.)

2.2.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in the port of Suva based on the research papers and past records of natural disasters.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*[14]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for the Port of Suva. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

Referring to Table 2.2-2, the risk of coastal flooding due to storm surges is classified high around the Port of Suva in Fiji. Additionally, the risk from cyclones and associated waves, high waves during regional storms, and earthquakes is rated as medium. On the other hand, the risk from tsunamis and volcanoes is rated as low.

[14] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

Fiji is located on the "Pacific Ring of Fire," which stretches approximately 40,000 km around the Pacific Ocean. Here, the Pacific Plate collides with several surrounding continental plates, causing repeated earthquakes.

One of the main islands of Fiji, Viti Levu, is highly vulnerable to earthquakes because it is located within the Fiji Platform. Most visitors spend time on this most developed island, which is also home to Fiji's main international airport. Viti Levu's capital city, Suva, a hub of cultural and shopping centers, has been struck by major earthquakes and tsunami warnings in the past. The area around Suva Port on Viti Levu has been assessed as having a medium risk. The Peak Ground Acceleration (PGA) of the earthquake to be considered in Suva Port is estimated to be 0.28. It is essential in Suva Port to take adaptation measures against earthquake disaster.

Tsunamis are caused by earthquakes or other seismic eruptions on ground of an oceans. It can cause massive tidal waves, which run with enormous force on land, causing great devastation. Even relatively small flood waves can lead to high losses and financial damage. Tsunami has rarely occurred in Fiji and the risk at Suva Port has been assessed as low. The maximum inundation height (MIH) of tsunamis around Suva is estimated to be 1.3 meters. While tsunami disasters in Fiji are infrequent, they are a definite possibility, and appropriate measures must be taken to address them.

Taveuni is the third-largest island in the Fiji Group and is home to around 15,000 people. The island is the surface expression of a large volcano, 40 km long and up to 12 km wide. Recent geological surveys indicated that it has erupted at least 36 times since people inhabited the island. Given the continual nature of eruptive activity on Taveuni since 9500 BC, the probability of activity within the next 100 years is high. The risk of volcanic disasters in Fiji has been assessed as low. But the volcano has the potential to cause damage in Fiji.

Fiji's location in the South Pacific Ocean exposes the country to tropical cyclones, which are the most frequent hazard process to occur in Fiji and result in the most damage. On average, Fiji experiences 10 to 15 tropical cyclones per decade, of which 2 to 4 results in severe damage. Tropical cyclones in Fiji affect an average of 28,837 people per event. The recent tropical cyclone Category V (Winston, 2016) affected 540,000 people and killed 44. Cyclone (Ami, 2003) affected 30,000 people and killed 17. The risk of cyclone disasters in Fiji has been assessed as medium. The wave height with cyclone is estimated at 6.4 meters. The appropriate measures must be taken to address them.

Table 2.2-2 Multi-hazard Heat Map Port Exposure (Republic of Fiji)

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High Medium Low Very Low Not applicable

Source: "A Blue Transformation for Pacific Maritime Transport" (World Bank. 2023. A Blue Transformation for Pacific Maritime Transport. World Bank, Washington, DC. © World Bank.)

Table 2.2-3 Methodology for Identifying Natural Disasters and their Scales (the Port of Suva)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Could not be confirmed.	Not applicable	Estimate earthquake waves by considering the scale of past earthquakes and taking into account the distance from the epicenter and ground conditions.
Tsunami	Could not be confirmed.	Not applicable	Estimate the loads acting on structures by assuming tsunami heights and flow velocities based on past maximum tsunamis.
Volcano	Could not be confirmed.	Not applicable	Estimate the impact of volcanic eruptions and ashfall on ports based on records of volcanic eruptions in neighboring countries and past volcanic disasters.
Storm Surge	Could not be confirmed. Existing wharves use previous average tide levels. The effects of high tides seem not be included.	Flood disasters increase due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	Could not be confirmed. Existing wharves seem not to be considered the effects of the intensification of waves caused by cyclones.	Increase in high waves due to cyclone intensification	Consider the increase in waves caused by cyclone intensification objectively. The recent research results, such as future predictions using d4PDF described later can be used.

(2) Measures against sea level rise and wave power due to climate change

The effects of sea level rise and waves caused by climate change can be taken into consideration by applying the adaptation measures against climate change described in Japan's "Technical Standards and Commentaries for Port and Harbour Facilities in Japan" (English version, 2025). The concept of adaptation measures against climate change is as shown below.

"Japanese port and harbor design standards" explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately determined using the latest research findings and scientific knowledge. **Figure 2.2-8** illustrates two conceptual approaches for setting structural strength while considering changes in external

forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as “Proactive adaptation.” On the other hand, “Adaptive adaptation” refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life but implementing physical upgrades progressively at appropriate times during the period, depending on material and structural characteristics.

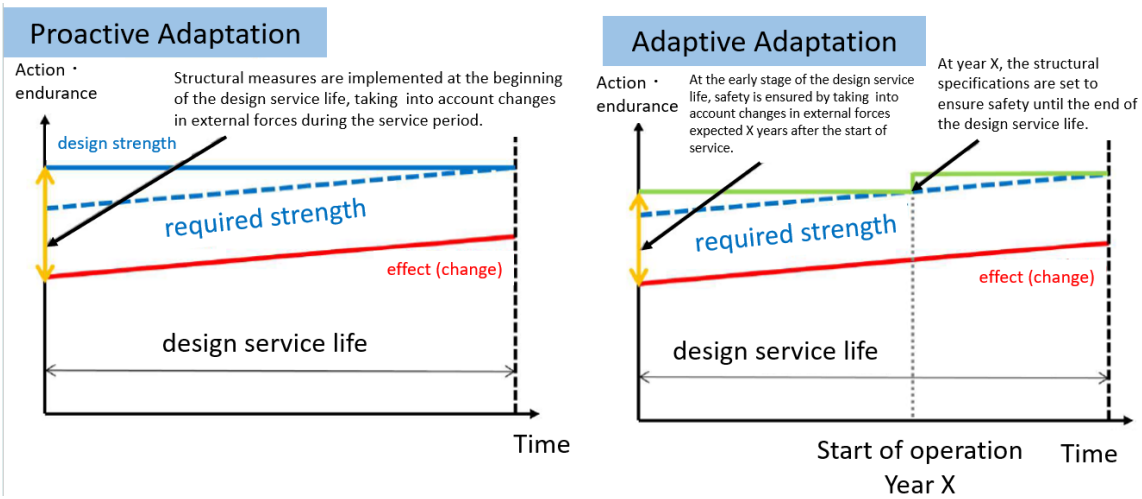


Figure 2.2-8 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

Due to the many uncertainties surrounding climate change, a range of scenarios has been discussed. For example, “The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[15]” presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to “holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C.” In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[16] as a basis when considering the impacts of climate change in port facility design. RCP2.6

[15] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

[16] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. Figure 2.2-9 shows the projected median regional sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [17].

The projected sea level rise in Fiji is shown in Figure 2.2-10. Sea level rise in Fiji by 2050 is projected to be 0.26 meters under the 2°C warming scenario (SSP1-2.6). Under the 4°C warming scenario (SSP5-8.5), it is projected to be 0.29 meters, with a small difference between the two scenarios. However, by 2100, the difference becomes significant, with 0.57 meters under the 2°C warming scenario (SSP1-2.6) and 0.93 meters under the 4°C warming scenario (SSP5-8.5). Therefore, depending on the scenario selected, the value of projected sea level rise differs, and this must be considered when setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

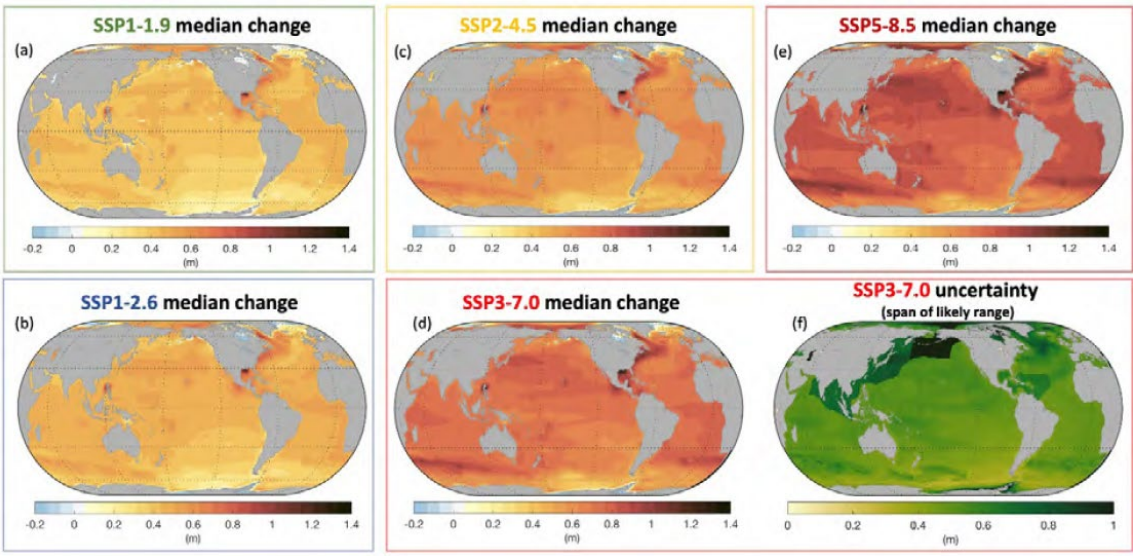


Figure 2.2-9 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

[17] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

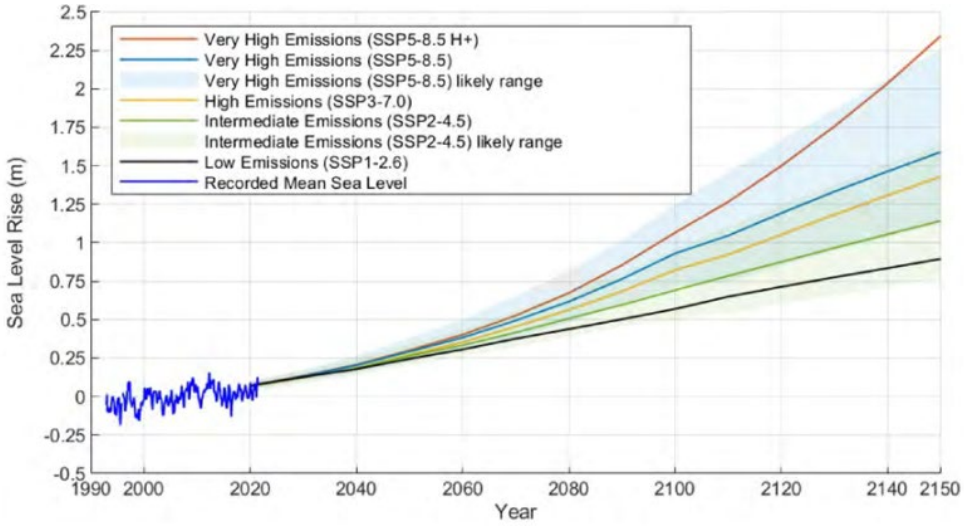


Figure 2.2-10 Sea Level Rise Projections to 2150 for Fiji Relative to 1995–2014 Mean Sea Level

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the "Database for Policy Decision-Making for Future Climate Change" (d4PDF, Mizuta et al.[18]. To predict future changes in extreme weather events such as typhoons due to climate change, a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing Waves and Coasts in the Pacific" (WACOP) project[19]. This project uses four climate models that

[18] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita, M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.

[19] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html (Accessed in July, 2024)

participated in CMIP5. When considering storm surges and high waves, it is essential to incorporate research findings or wave simulations using these future climate models.

2.2.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize FPCL's current disaster mitigation plans in terms of time frames and types of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". Natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in **Table 2.2-4**.

Table 2.2-4 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The expert team confirmed the structure of existing facilities and maintenance status of the target port through hearings with FPCL and confirmation of available design documents. The existence and implementation status of natural disaster response plans for the respective port facilities were also confirmed. The expert team sent questionnaires to each port authority to examine if the disaster mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change.
The responses from FPCL are summarized below.

(2) Results of Questionary Survey

(a) Maintenance and Management

FPCL has created a maintenance plan and inspection manual for maintenance and management. Regular inspections of port facilities are conducted approximately once a month, and additional inspections are conducted as necessary after cyclones, earthquakes, etc.

(b) Countermeasures against Natural Disasters

FPCL has created hazard maps for tsunamis and earthquakes as natural disasters and organizes and analyzes the impact of natural disasters

FPCL has identified and documented assets, operations, and systems that may be affected by natural disasters and has identified the information necessary to establish baseline conditions.

FPCL has conducted risk assessments related to natural disaster adaptation, formulates natural disaster adaptation plans, and has promoted their implementation. FPCL has conducted verification through annual audits.

(c) Emergency Response

FPCL has established an emergency response plan based on the following conditions, which is verified through annual audits.

(i) Ensure the protection and safety of all personnel involved

(ii) Minimize the impact on assets

(iii) Take remedial actions

(d) Climate Change Adaptation

FPCL is implementing measures such as elevating critical infrastructure, improving drainage systems to mitigate flood risk, and conducting periodic assessments of sea level and wave height trends.

Additional measures include upgrading port facilities to be more resistant to storm surges and wave actions and introducing green initiatives to reduce carbon emissions alignment with climate change adaptation goals.

FPCL is conducting risk assessments related to climate change adaptation and developing plans to deal with natural disaster risks and disasters.

FPCL has developed a business continuity plan (BCP) to ensure operational resilience during natural disasters. The plan includes pre-disaster risk assessments, evacuation procedures, emergency response drills, and post-disaster recovery protocols. FPCL also collaborates with national disaster management authorities to align their preparedness and response strategies.

FPCL has formulated and implemented a comprehensive plan covering all port facilities under its jurisdiction for natural disaster response, climate change response, and emergency response. In this survey, the status of each response for the port facilities at the target ports of the Port of Suva and the Port of Levuka are confirmed.

2.2.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by examining the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*" [20] (hereinafter referred to as 'Pacific Ports Vision') shown in Table 2.2-5. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[20] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 2.2-5 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities in the Port of Suva are shown below.

(a) Natural disaster adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at the Port of Suva to respond to natural disasters at existing facilities.

The Port of Suva was constructed in 1963 and has undergone two rehabilitation plans, but no review of natural conditions since construction has been conducted, and current information on natural disasters is not reflected in the plans of those rehabilitation. However, assessments of the

impact of natural disasters have been conducted and are being incorporated into future plan.

(b) Climate change adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at the Port of Suva to address climate change in existing facilities. The existing wharf at the Port of Suva remains unchanged since its construction in 1963 and does not take into account the effects of sea level rise due to climate change. However, the impact of climate change has been assessed and incorporated into future plan.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in the Port of Suva. The relevant plans and documents are as shown below.

- NATIONAL DISASTER MANAGEMENT PLAN 2018[21]
- CLIMATE SMART COMMUNITY-BASED DISASTER RISK MANAGEMENT TRAINING MANUAL[22]
- Emergency Preparedness: Operational Logistics Contingency Plan[23]

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in the Port of Suva in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

[21] NATIONAL DISASTER MANAGEMENT PLAN 2018; Fiji National Disaster Management Plan – NDMO

[22] CLIMATE SMART COMMUNITY-BASED DISASTER RISK MANAGEMENT TRAINING MANUAL ; CBDRM – NDMO

[23] Emergency Preparedness: Operational Logistics Contingency Plan ; Fiji Emergency Preparedness: Operational Logistics Contingency Plan Part 1 – Risk Profile & Disaster Management, February – April 2012 - Fiji | ReliefWeb

Table 2.2-6 Assessment of Impacts of Natural Disasters for the Port of Suva

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	The Port of Suva is a wharf on the vertical piles constructed in 1963, with a sheet pile retaining wall behind it. The prestressed concrete piles of the foundation and the concrete deck slabs of the superstructure are deteriorating. Significant damage from earthquake is anticipated. There is also a risk that the entire retaining wall could suffer circular slip failure due to seismic motion.	The collapse of offices and injuries due to an earthquake may affect management systems. Damage to port facilities such as piers is expected to have a significant impact on port operations. Damage to the Port of Suva is expected to have a significant impact on the stable supply of food and other daily necessities to Fiji and neighboring countries.	Earthquakes may cause human casualties that could affect operations. Damage to port facilities and loss of power may affect port calls. Damage to cargo handling equipment may also affect cargo handling activities.
Tsunami	Although the Republic of Fiji is not at high risk of tsunami disasters, there is a possibility of damage to ships due to collisions or damage caused by tsunamis, as well as the loss of container cargo. In addition, damage such as the overturning of cargo-handling machinery, including mobile harbor cranes, and loss of power supply is also a concern.	Tsunami could cause injuries and other human casualties, which may affect management systems. Damage to port facilities and the loss of cargo due to the tsunami could have a significant impact on the stable supply of food and other essential goods to Fiji and neighboring countries.	Human casualties caused by tsunamis may affect operations. Damage to port facilities and loss of power may affect the port calls. Collisions and sinking of ships caused by tsunamis may prevent ships from arriving.
Volcano	The Republic of Fiji is located between Tonga and Vanuatu and is one of the countries with a high risk of volcanic disasters. There are concerns about the potential for volcanic eruptions and ashfall to cause significant damage to port facilities and cargo handling equipment, as well as the closure of shipping lanes.	Human casualties caused by volcanic eruptions may affect management systems. Damage to port facilities and disruption of land transportation caused by volcanic eruptions could have a significant impact on the stable supply of food and other essential goods to Fiji and neighboring countries.	Human casualties such as injuries caused by volcanic eruptions may affect operations. Volcanic ejecta and ashfall may render port facilities and container yards unusable.
Storm Surge	There is concern that high tides will cause flooding of port facilities and container yards behind the port. There is also concern that high tides will cause ships to run aground and container cargo to spill out.	High tides may cause injuries and other human casualties, which could affect management systems. Damage to port facilities and the loss of cargo due to high tides could have a significant impact on the stable supply of food and other goods to Fiji and neighboring countries.	Human casualties caused by high tides may affect operations. Damage to port facilities and loss of power may affect port calls.
Cyclone	The strong winds from the cyclone are expected to cause damage to office buildings and warehouses, as well as the collapse of stacked containers and lighting equipment,	Cyclones could cause casualties and other human damage, which may affect management systems. Strong winds could damage land	Cyclones could cause injuries and other human casualties that may affect operations. Strong winds may halt land

	and the overturning of cargo handling machinery. High waves from the cyclone may also cause flooding of port facilities, ships running aground or colliding, the spill of container cargo, and power outages.	facilities and close roads, halting land transportation, while high waves could damage port facilities and cause cargo to spill, severely affecting the stable supply of food and other goods to Fiji and neighboring countries.	transportation, which could affect operations. High waves may damage port facilities and cause cargo to spill, which could also affect operations.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in the Port of Suva. Figure 2.2-11 illustrates the natural disaster risks and resulting damage to the port.

The Port of Suva is a wharf on the vertical piles constructed in 1963, and a sheet pile retaining wall behind it. The prestressed concrete piles and the concrete deck slabs are deteriorating. An earthquake may cause critical damage to them. Piles of containers could be fallen. The building and warehouse could be damaged. Tsunami may flow over coral reef and mass of water may cause damage to port facilities. Containers in the yard may be washed away into the sea. This could disrupt the vessel entering. Seawater from the ocean side may flood into the port area like cyclone “Winston” in 2016 due to sea level rise.

Natural disaster damages to the Port of Suva could have a significant impact on the stable supply of food and other daily necessities to Fiji and neighboring countries.

The results of the survey in this project confirmed that King's Wharf in the Port of Suva is extremely vulnerable to natural disasters such as earthquakes.

Therefore, the advisory team proposes a preliminary plan for the strengthening of existing facilities at Kings Wharf prepared.

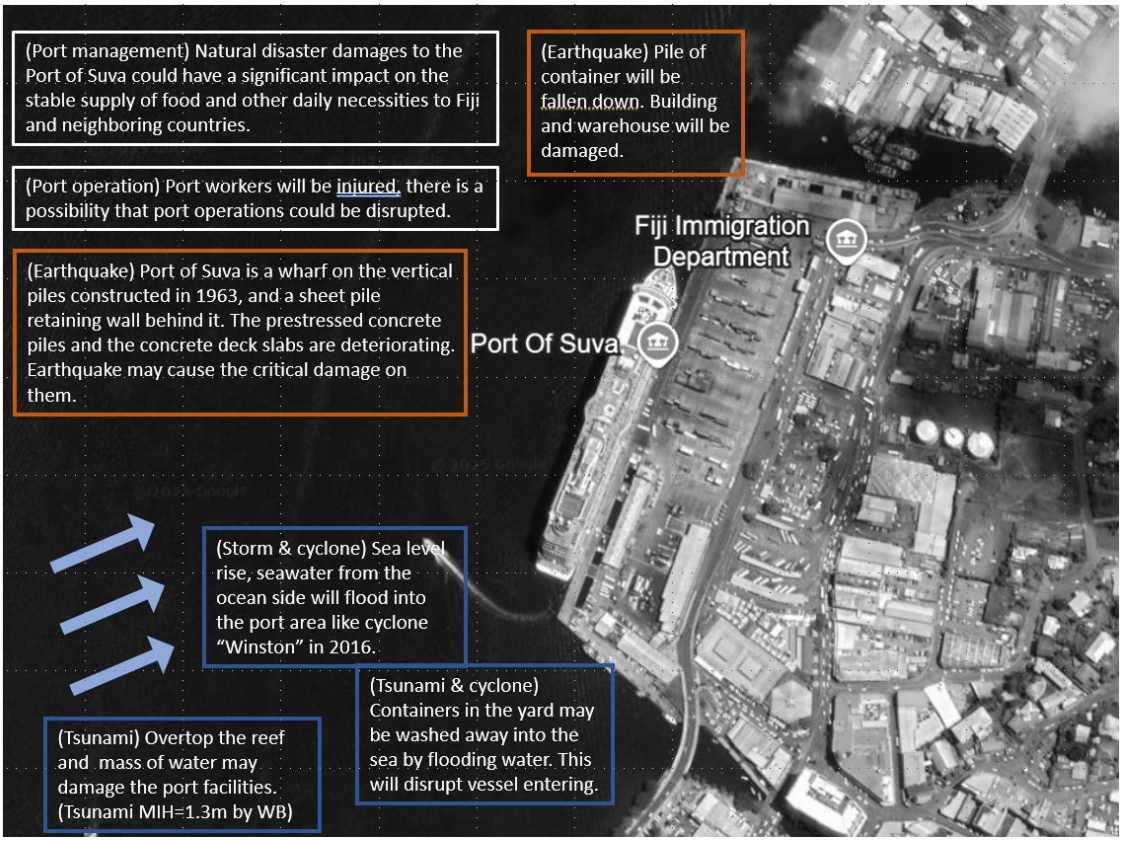


Figure 2.2-11 Geographical characteristics of natural disasters

2.2.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans.

(1) Confirmation of the reasons for staying with the current resilience indicators

In Section 2.2.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for the Port of Suva. The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in "*CLIMATE CHANGE ADAPTATION PLANNING FOR PORTS AND INLAND WATERWAYS*" (PIANC, EnviCom WG Report No. 178-2020) (hereinafter referred to as the PIANC guide).
The results are presented below.

(a) Natural disaster adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at the Port of Suva to respond to the natural disasters at existing

facilities.

- The goal(s), planning horizon and objectives of the natural disaster adaptation initiative have been established and agreed at the Port of Suva.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has been completed, and the potential impacts of natural disasters on each have been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the natural disaster adaptation process.

(b) Climate change adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at the Port of Suva to address climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed at the Port of Suva.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has been complete, and the potential impacts of climate changes on each have been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate change is in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in the Port of Suva.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at the Port of Suva for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

Measures to make the Port of Suva one level higher on the resilience indicators

(a) Natural disaster adaptation

- Reconfirm the goal(s), planning horizon and objectives of the natural disaster adaptation initiative established and agreed at the Port of Suva.
- Reconfirm the potential impacts of critical assets, operations and systems including interdependencies that could be affected by natural disasters identified.
- Grasp the status of the baseline for port assets, operations, and systems, and reconfirm that necessary information is being provided appropriately.
- Check the information collected on natural disaster intensity forecasts and confirm the severity of the identified disasters.
- Grasp normal operating conditions (daily cargo volume, passenger numbers, etc.) and confirm the predicted impact of disasters.
- Conduct a natural disaster risk assessment and formulate a natural disaster adaptation plan for the Port of Suva.

(b) Climate change adaptation

- Confirm the climate parameters and processes relevant to the critical assets, operations and systems identified.
- Collate the existing baseline data including information on extreme events for each relevant climate parameter or process and instigate monitoring to enhance local knowledge or fill gaps.
- Depending on the planning horizon for the adaptation strategy, agree on the climate change scenarios, and collate the climate change projections for relevant parameters and processes.
- Analize Data to confirm baseline conditions, to identify existing patterns and trends, and to determine what changes are expected under each scenario. Consider both slow onset changes and expected changes in the frequency or severity of extreme meteorological, oceanographic or hydrological events. Acknowledge the limitations of the data.
- Conduct a climate change risk assessment and develop a climate change adaptation plan for the Port of Suva.

(c) Disasters and Emergency Response

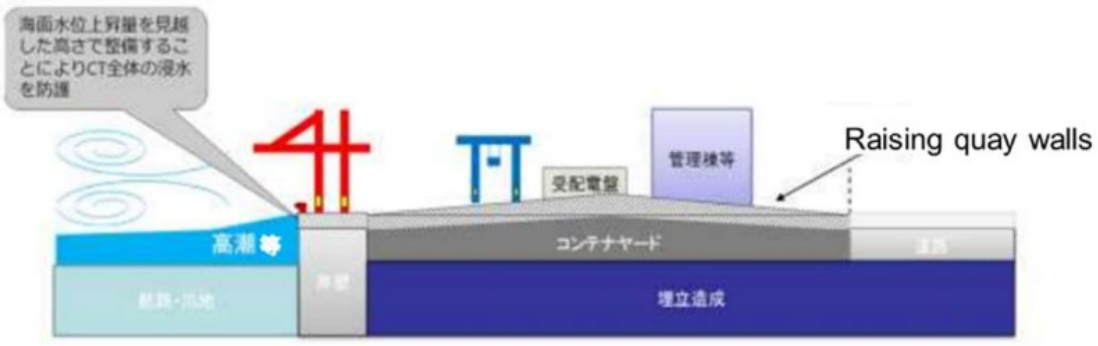
- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans for the Port of Suva.

- Maintain emergency response plans for natural disasters at existing facilities in the Port of Suva and verify them through annual audits.

(3) Examples of countermeasures

The Port of Suva was constructed in 1963 and has undergone two rehabilitation plans, but no review of natural conditions since construction has been conducted, and current information on natural disasters is not reflected in the plans of those rehabilitation. When assessments of the impact of natural disasters are being incorporated into future plan, the following example is one of the countermeasures against storm surges and cyclones for the facilities in the Port of Suva.

- **Raising quay walls**

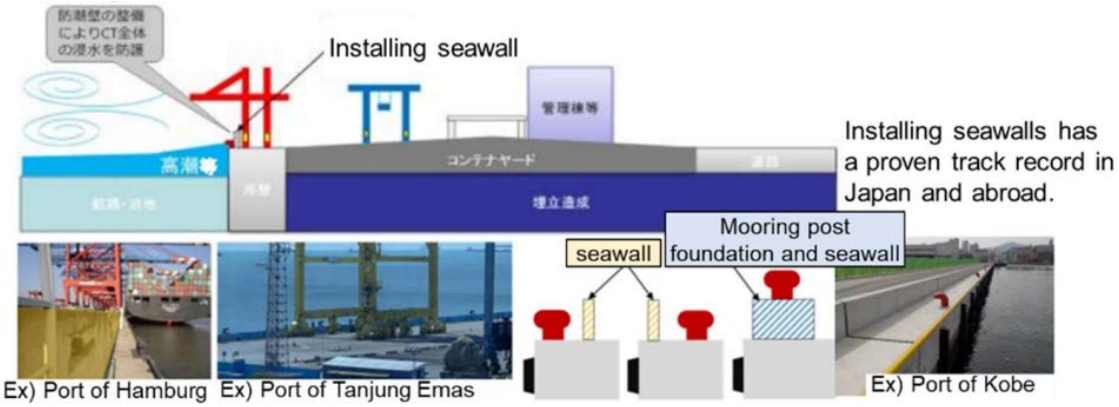


(The concept is to raise the height of new or existing wharves to a level that takes into account the effects of storm surges and sea level rise, and to plan or renovate the structure so that it can withstand the resulting increase in load.)

Relocation plans are currently under consideration for the Port of Suva. In the design of the new wharf, it is expected that the appropriate wharf elevation will be adopted by raising up from the elevation of existing facilities.

The following example is also effective as one of the countermeasures against storm surges and cyclones at existing facilities such as other domestic ports in Fiji.

➢ **Installing seawall**



(The concept is to install additional flood walls on existing wharves to prepare for the effects of high tides and sea level rise. Flood walls are sometimes installed in front of or behind mooring posts (bollards) on wharves for mooring and cargo handling operations. In cases where mooring posts can be relocated or newly constructed, a design integrating the flood walls with the foundations of mooring posts is also considered.)

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for the Port of Suva are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in the Port of Suva is evaluated as "Engaged."

In order to achieve the next level of resilience indicator, it is necessary to reconfirm the goal(s), planning horizon, and objectives of natural disaster adaptation, formulate natural disaster adaptation plans for existing facilities in the Port of Suva, and obtain agreement among stakeholders.

It is recommended to reconfirm the impact of natural disasters on port assets, operations, and systems, identify the baseline situation, conduct risk assessments, and formulate plans for the Port of Suva.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in the Port of Suva is evaluated as "Engaged."

In order to achieve the next level of resilience indicator, it is necessary to reconfirm the goal(s), planning horizon, and objectives of climate change adaptation, formulate climate change

adaptation plans for existing facilities in the Port of Suva, and obtain agreement among stakeholders.

It is recommended to implement the following actions and develop a plan for the Port of Suva:

- Collect baseline data that includes information on extreme weather events.
- Begin monitoring relevant climate parameters.
- Select climate change scenarios in accordance with the planning horizon for climate change response and collect information on climate change projections.

(c) Disasters and Emergency Response

The resilience indicator outlined in the "*Pacific Port Vision*" for emergency response in the Port of Suva is evaluated as "Highly Engaged." To achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and verify that these plans are maintained through annual audits.

FPCL has formulated and implemented a comprehensive plan covering all port facilities under its jurisdiction for natural disaster adaptation, climate change adaptation, and emergency response. In this survey, we attempted to evaluate the plans and implementation status for the Port of Suva, which is the target port; however, we were unable to confirm specific details, resulting in the above evaluation results. This conclusion does not apply if it is confirmed that the Port of Suva has its own adaptation plan that has been formulated and implemented.

(d) Introduction of the Draft Plan for Port Resilience

(i) Proposal for the Port of Suva Strengthening Plan (Draft Conceptual Design)

The results of the survey in this project confirmed that King's Wharf in the Port of Suva is extremely vulnerable to natural disasters such as earthquakes. Therefore, a preliminary plan for the strengthening of existing facilities at Kings Wharf is prepared and submitted to FPCL.

In developing the strengthening plan for King's Wharf in the Port of Suva, the future cargo demand, the berthing of emergency supply vessels during disasters, ensuring seismic resistance during earthquakes, etc. are taken into consideration based on the information of the existing wharf. The effect of tsunami, future changes in wave and tidal levels, etc. are necessary to be considered in the basic design stage to plan facilities that provide sufficient safety and business continuity against natural disasters such as cyclones.

Since the soft soil layer extends to a depth of 40 meters or more, it is considered important to evaluate the structural capacity of the wharf and soil foundation during an earthquake based on the past design documents and existing evaluation report for residual strength.



Figure 2.2-12 Plan view of the Port of Suva (created by Survey team based on Google Earth)

(ii) Capacity of container terminal at the Port of Suva

Based on ship arrival records and container handling volume at the Port of Suva, 1) the container handling volume in 2050, 2) the cargo handling capacity at berth, and 3) the cargo handling capacity at yard, are estimated. It is also estimated whether there will be sufficient handling capacity to meet future demand.

1) Estimated cargo handling volume

The estimated containerized cargo handling volume at the Port of Suva in 2050 is 307,000 TEUs in 2050, up from 126,000 TEUs in 2023.

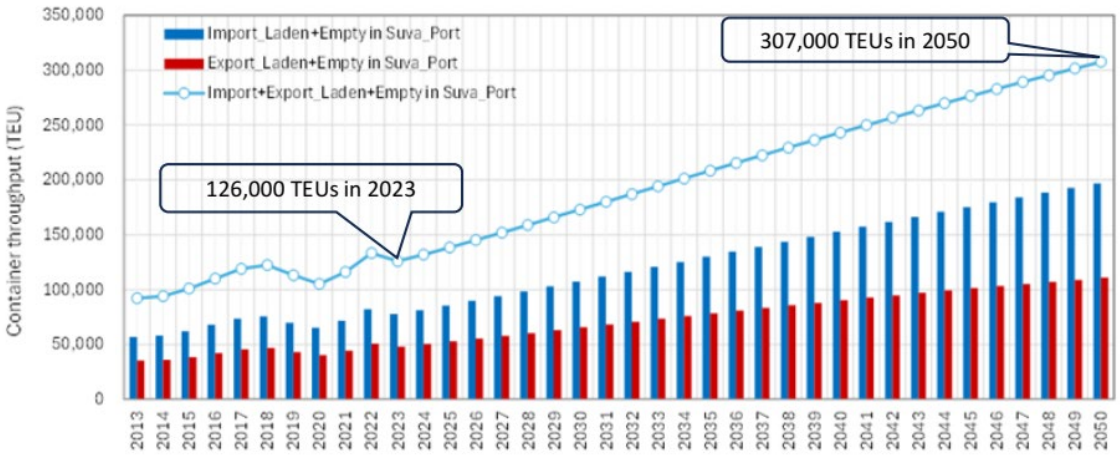


Figure 2.2-13 Container handling volume forecast for the Port of Suva (based on data from FPCL, compiled by Survey team)

GDP elasticity is assumed to be 1.5 for both exports and imports based on an analysis of historical GDP and container handling volumes; GDP values are assumed to asymptote from 3.15% in 2029 to 2.0% in 2050.

As a result, container throughput in Suva and Lautoka is assumed to increase from 180,000 TEU in 2023 to 439,000 TEU in 2050. The share between the ports of Suva and Lautoka is assumed to be 7:3, and the container handling volume for the port of Suva in 2050 is calculated.

2) Cargo handling capacity at Berth

Based on the actual container cargo handling volume in 2021 and the estimated results for 2050, the number of container vessels entering the port and the berth occupancy ratio expected in 2050 will increase from 44.5% to 116.6%, which cannot be handled. Therefore, if a gantry crane is installed in place of the existing mobile harbor crane, the BOR will be 38.9%, which is a significant improvement.

Table 2.2-7 Cargo handling volume at the Port of Suva (comparison between 2021 and 2050)

Year	unit	2021	2050	2050
Containerized Cargo	TEU	117,129	**307,000**	**307,000**
Type of crane	-	Mobile Harbor Crane	**Mobile Harbor Crane**	**Gantry Crane**
Container handing volume per hour	box/hour	5	**5**	**15**
Port Stay (Berth occupancy time)	hours	7,772	**20,371**	**6,790**
Berth Occupancy Ratio (BOR)	%	44.5%	**116.6%**	**38.9%**

Note 1: Port stay (berth occupancy time) in 2050 is obtained from the ratio of container cargo handling volume and berth occupancy time in 2021, multiplied by the volume to be handled in 2050.

Note 2: The hourly handling volume of containerized cargo is assumed to be 5 units per hour for the existing mobile harbor cranes and 15 units per hour for the gantry cranes.

Based on the vessel arrivals at the Port of Suva, the number of vessels and port stay (occupied hours) of container vessels in 2021 were as shown in the table below.

Table 2.2-8 Number of container vessels arriving at the Port of Suva (2021)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Port Stay (hrs)	328.4	612.8	832.9	740.7	466.2	500.6	1281.9	668.8	339.3	681.6	619.8	698.9	**7,772**
Vessel no. (vessel)	8	12	9	15	8	10	16	13	8	11	19	12	**141**
Ave. (hrs/vessel)	41.1	51.1	92.5	49.4	58.3	50.1	80.1	51.4	42.4	62.0	32.6	58.2	**55.1**

From this data, the berth occupancy ratio BOR for the port of Suva in 2021 would be calculated,
(Note: Berth Occupancy Ratio, BOR: BOR > 65%: High, BOR < 50%: Low)

$$BOR = \frac{\text{Port Stay (hrs)}}{\text{Total Working Time per berth (hrs/berth) x No. of Berth (berth)}} \times 100$$

$$= \frac{7{,}772}{24 \times 364 \times 2} \times 100 = 44.5\%$$

Compared to the 65% that is generally considered high occupancy, the Port of Suva has a generous berth window.

3） Cargo handling capacity at Yard

The container handling capacity of a yard can be calculated using the following formula.

Container handling volume calculation formula

$$My = \frac{Ns \times Dy \times H \times \alpha}{Dt \times P}$$

My : Annual (Monthly) Handling Volume (TEU)
Ns : Number of ground slots (TEU)
: Number of ground spaces where containers can be stored
P : Peak rate : Ratio of annual (monthly) maximum daily container handling volume to annual (monthly) average daily container handling volume

$$\text{Peak rate} = \left(\frac{\text{Maximum daily container handling volume (TEU/day)}}{\text{Average daily container handling volume (TEU/day)}}\right)^2$$

α : Effective coefficient : Ratio of effective use of container stacking space

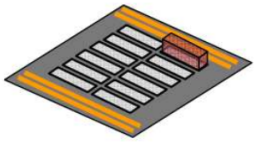
H : Maximum number of container stacking tiers (tier)
Dt : Average container dwell time in the container yard (day)

$$\left(Dt = \frac{\text{Volume of annual (monthly) container dwell time (TEU*day)}}{\text{annual (monthly) container handling volume (TEU)}}\right)$$

Dy Number of working days per year (month) (day)

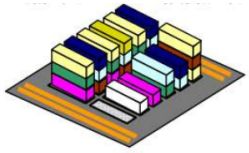
Concept of each coefficient of the calculation formula

Ns: Number of ground slots
(Number of ground spaces where containers can be stored)



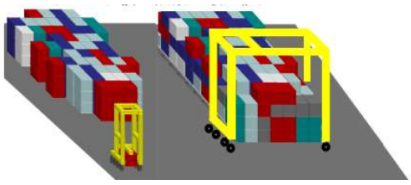
Ex. In the above figure, Ns = 12

α : Effective coefficient
(Ratio of effective use of container stacking space)



Ex. In the above figure, α = 0.75
(27 TEUs for a maximum of 36 TEUs (3 tiers))

H : Maximum number of container tiers (tier)
(Maximum number of container stacking tiers)



Straddle carrier
3 tiers with cargo,
4 tiers empty

Transfer crane
4 tiers with cargo,
5 tiers empty

The number of ground slots at the Port of Suva was calculated from the number of slots within the blue line in the drawing below.

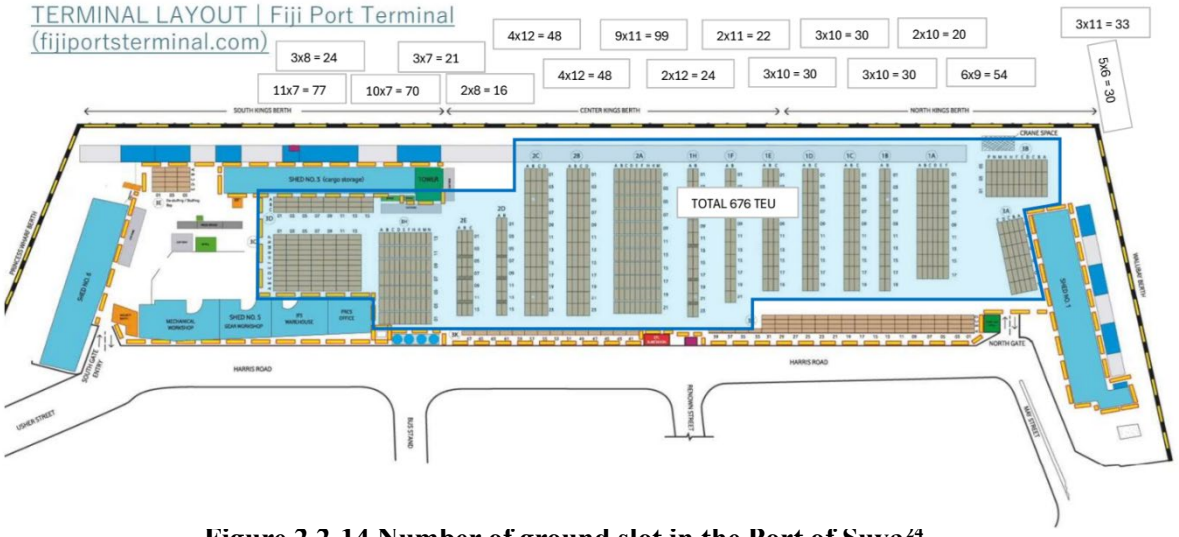


Figure 2.2-14 Number of ground slot in the Port of Suva[24]
(based on FPTL data compiled by Survey team)

[24] Fiji Port Terminal Layout; TERMINAL LAYOUT | Fiji Port Terminal

The total number of ground slots is 676. The maximum cargo handling volume is calculated assuming 376 of these slots are for laden containers and 300 are for empty containers.

Assuming a peak rate of P = 1.3 and an effective coefficient of α = 0.75, and assuming that the maximum number of container tiers is 4 for laden and 5 for empty, and that the average number of
storage days is 4 for laden and 8 for empty, for an annual working day of 364 days, we obtain 118,335
TEU, which is close to the handling volume of 117,129 TEU in 2021.

Container handling volume calculation formula

$$My = \frac{Ns \times Dy \times H \times \alpha}{Dt \times P}$$

		Assumption of Current Status		
			Laden	Empty
My	: Annual (Monthly) Handling Volume (TEU)			
Ns	: Number of ground slots (TEU)	Ns =	376 (TEU)	300 (TEU)
	: Number of ground spaces where containers can be stored			
P	: Peak rate : Ratio of annual (monthly) maximum daily container handling volume to annual (monthly) average daily container handling volume	P =	1.3	1.3
	$\text{Peak rate} = \left(\frac{\text{Maximum daily container handling volume (TEU/day)}}{\text{Average daily container handling volume (TEU/day)}}\right)^2$			
α	: Effective coefficient : Ratio of effective use of container stacking space	α =	0.75	0.75
H	: Maximum number of container stacking tiers (tier)	H =	4 (tiers)	5 (tiers)
Dt	: Average container dwell time in the container yard (day)	Dt =	4 (days)	8 (days)
Dy	Number of working days per year (month) (day)	Dy =	364 (days)	364 (days)

Annual handling volume (Laden containers)

$$My = \frac{Ns \times Dy \times H \times \alpha}{Dt \times P} = \frac{376 \times 364 \times 4 \times 0.75}{4 \times 1.3} = 78{,}960 \text{ (TEU/year)}$$

Annual handling volume (Empty containers)

$$My = \frac{Ns \times Dy \times H \times \alpha}{Dt \times P} = \frac{300 \times 364 \times 5 \times 0.75}{8 \times 1.3} = 39{,}375 \text{ (TEU/year)}$$

Annual handling volume (Laden + Empty) = 118,335 (TEU/year)

In order to secure handling volume of 307,000 TEUs in 2050, 315,560 TEUs, which is close to 307,000 TEUs, can be obtained by reducing the average container dwell time (days) in storage from 4 days for laden containers and 8 days for empty containers, to 1.5 days for laden and 3 days for empty.

Container handling volume calculation formula

$$My = \frac{Ns \times Dy \times H \times \alpha}{Dt \times P}$$

		Assumption of Demand Forcast in 2050		
			Laden	Empty
My	: Annual (Monthly) Handling Volume (TEU)			
Ns	: Number of ground slots (TEU)	Ns =	376 (TEU)	300 (TEU)
	: Number of ground spaces where containers can be stored			
P	: Peak rate : Ratio of annual (monthly) maximum daily container handling volume to annual (monthly) average daily container handling volume	P =	1.3	1.3
	$\text{Peak rate} = \left(\frac{\text{Maximum daily container handling volume (TEU/day)}}{\text{Average daily container handling volume (TEU/day)}}\right)^2$			
α	: Effective coefficient : Ratio of effective use of container stacking space	α =	0.75	0.75
H	: Maximum number of container stacking tiers (tier)	H =	4 (tiers)	5 (tiers)
Dt	: Average container dwell time in the container yard (day)	Dt =	1.5 (days)	3 (days)
Dy	Number of working days per year (month) (day)	Dy =	364 (days)	364 (days)

Annual handling volume (Laden containers)

$$My = \frac{Ns \times Dy \times H \times \alpha}{Dt \times P} = \frac{376 \times 364 \times 4 \times 0.75}{1.5 \times 1.3} = 210{,}560 \text{ (TEU/year)}$$

Annual handling volume (Empty containers)

$$My = \frac{Ns \times Dy \times H \times \alpha}{Dt \times P} = \frac{300 \times 364 \times 5 \times 0.75}{3 \times 1.3} = 105{,}000 \text{ (TEU/year)}$$

Annual handling volume (Laden + Empty) = 315,560 (TEU/year)

The results are summarized as shown below.

	2021	2050
# of ground slot(slot)	L(Laden) 376 E(Empty) 300	L(Laden) 376 E(Empty) 300
P:Peak rate	1.3	1.3
A:effective coefficient	0.75	0.75
H:Maximum number of stacking tier	L 4 E 5	L 4 E 5
Dt: Average container dwell time(days)	L 4 E 8	L 1.5 E 3
DY: Number of working days(days)	364	364
Annual handling Capacity(TEU/year)	L 78,960 E 39,375 Total 118,335	L 210,560 E 105,000 Total 315,560

4) Consideration of cargo handling capacity at the Port of Suva

- The Port of Suva handled 117,129 TEUs of cargo annually in 2021. It is expected to increase to 307,000 TEUs by 2050 based on the future GDP growth and the correlation between GDP growth and past container throughputs.
- Our team examined whether Kings Wharf could handle 307,000TEUs in 2050. The berth occupancy ratio (BOR) of vessels entering the port was 44.5% in 2021 and will exceed 100% (116.6%) by 2050. As a measure to increase BOR, the existing mobile harbor cranes can be replaced with gantry cranes to increase handling capacity, thereby reducing the occupancy ratio to 38.9%.
- The present cargo handling capacity at yard in the King's Wharf is calculated to be 118,335 TEUs, equivalent to the total volume handled in 2021 of 117,129 TEUs, assuming an average storage period of 4 days for laden containers and 8 days for empty containers.
- In order to handle the total 307,000 TEUs in 2050, the handling volume of 315,560 TEUs can be achieved by reducing the average container dwell time (days) to 1.5 days for laden containers and 3 days for empty containers.
- By taking measures to strengthen existing container terminals, increasing crane capacity, and reducing the average container dwell time, we believe that the handling volume of containerized cargo expected in 2050 can be handled

(iii) Assumed specifications of vessels entering the Port of Suva

1) Container vessels

When investigating the DWT of container vessels and semi-container vessels entering the Port of Suva, the maximum DWT is 37,882 DWT, equivalent to 40,000 DWT. Based on this, the LOA

derived from technical standards is 228 meters. The draft at full load is 11.9 meters (required water depth 13 meters). An average container vessel has a DWT of 20,000 and an LOA of 175 meters. Currently, there is one weekly service, but as demand increases, two ships will need to berth simultaneously. Therefore, to accommodate future demand, the berthing layout plan is made to enable two vessels berthing, one 40,000 DWT and one 20,000 DWT, to berth simultaneously.

Table 2.2-9 Assumed specifications of container vessels

Target Vessels	DWT	LOA (m)	Breadth (m)	Draft (m)	Required Wharf Length (m)
Average Vessel	20,000DWT	175	27	10.2	229
Largest Vessel	40,000DWT	228	31.8	11.9	291.6

2） Cruise ships

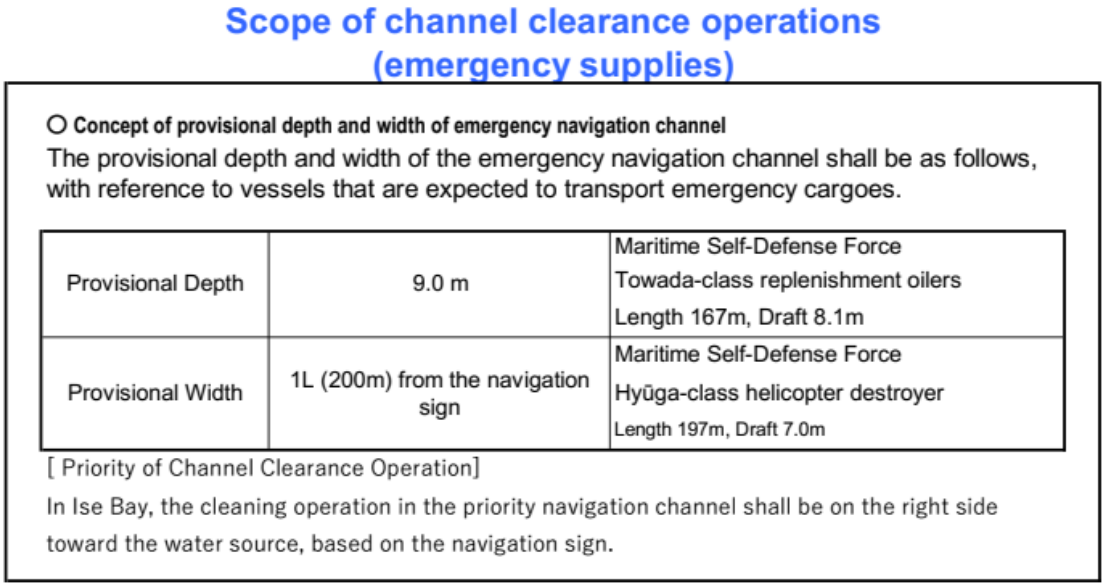
The assumption is based on a cruise ship owned by P&O Australia operating in Pacific Islands countries. With container ships arriving almost daily, the berthing layout plan is to enable simultaneous berthing with 20,000 DWT class container vessels.

Table 2.2-10 Assumed specifications of cruise ships

	Pacific Adventure	Pacific Explorer
GT (ton)	109,000.0	7,741.0
DWT (ton)	8,418.0	8,293.0
Length (m)	290.0	261.0
Beam (m)	36.0	32.2
Draught (m)	8.1	8.2

3) Emergency transport vessels

The berthing of Japanese escort vessels is assumed to enable international relief activities in the event of a disaster. During the Tonga undersea volcanic eruption disaster (January 2022), the escort vessel Oosumi (length 178 m, draft 6.0 m) participated in international emergency relief activities and provided support such as drinking water. In the event of a disaster, the berthing is assumed at earthquake-resistant wharves.



Scope of channel clearance operations
(emergency supplies)

○ Concept of provisional depth and width of emergency navigation channel

The provisional depth and width of the emergency navigation channel shall be as follows, with reference to vessels that are expected to transport emergency cargoes.

Provisional Depth	9.0 m	Maritime Self-Defense Force Towada-class replenishment oilers Length 167m, Draft 8.1m
Provisional Width	1L (200m) from the navigation sign	Maritime Self-Defense Force Hyūga-class helicopter destroyer Length 197m, Draft 7.0m

[Priority of Channel Clearance Operation]

In Ise Bay, the cleaning operation in the priority navigation channel shall be on the right side toward the water source, based on the navigation sign.

(source: https://www.pa.cbr.mlit.go.jp/file/content/file/topics-isewan_bcp-pdf-kaigi_leaflet.pdf)

Figure 2.2-15 Assumed vessels for transporting emergency supplies

(iv) Assumed berthing layout based on the port call patterns

Currently there are 6.5 container vessel calls per week or roughly one vessel calls per day. The following four patterns of berthing are assumed for future demand growth.

Note: The current number of container ship calls is calculated based on the number of calls for container-related vessels in Table 2.1-2 “Number of Vessel Calls by Type and Size in the Port of Suva”. The total number of calls for “Fully cellular containership,” “General cargo,” “General cargo with container capacity,” “Roll on roll off with container capacity,” and “Vessel Type (unspecified)” is 320. Based on 1 year = 52 weeks, this was calculated as 6.2 vessels per week and rounded to 6.5 vessels per week.

1) Pattern A assumes the simultaneous arrival of two vessels, one 40,000 DWT and one 20,000 DWT class vessel, to meet future demand.
2) Pattern B assumes that a cruise ship (a medium-sized Pacific Explorer class) and a 20,000 DWT class container ship can simultaneously berth at the port
3) Pattern C assumes that a larger Pacific Adventure class cruise ship and a 20,000 DWT class container ship can simultaneously berth at the same time.
4) Pattern D is designed to allow for the simultaneous berthing of a Maritime Self-Defense Force emergency supply transport vessel (Hyuga class) and a 20,000 DWT class container ship in the event of a disaster.

The berthing layouts for each of the above calling patterns required to the wharf strengthening

plan is as follows.

Pattern A	DWT	LOA(m)	Breadth(m	Required berth length(m)
Container (average size)	20,000	175	27	202
Container(max size)	40,000	228	31.8	260
			Total	462

Pattern B	DWT	LOA(m)	Breadth(m	Required berth length(m)
Cruiser(Pacific Explorer)	8,293	261	32.2	293
Container (average size)	20,000	175	27	202
			Total	495

Pattern C	DWT	LOA(m)	Breadth(m	Required berth length(m)
Cruiser(Pacific Adventer)	8,418	290	36	326
Container (average size)	20,000	175	27	202
			Total	528

Pattern D	DWT	LOA(m)	Breadth(m	Required berth length(m)
Rescue vessel(HYUGA)		197	33	230
Container (average size)	20,000	175	27	202
			Total	432

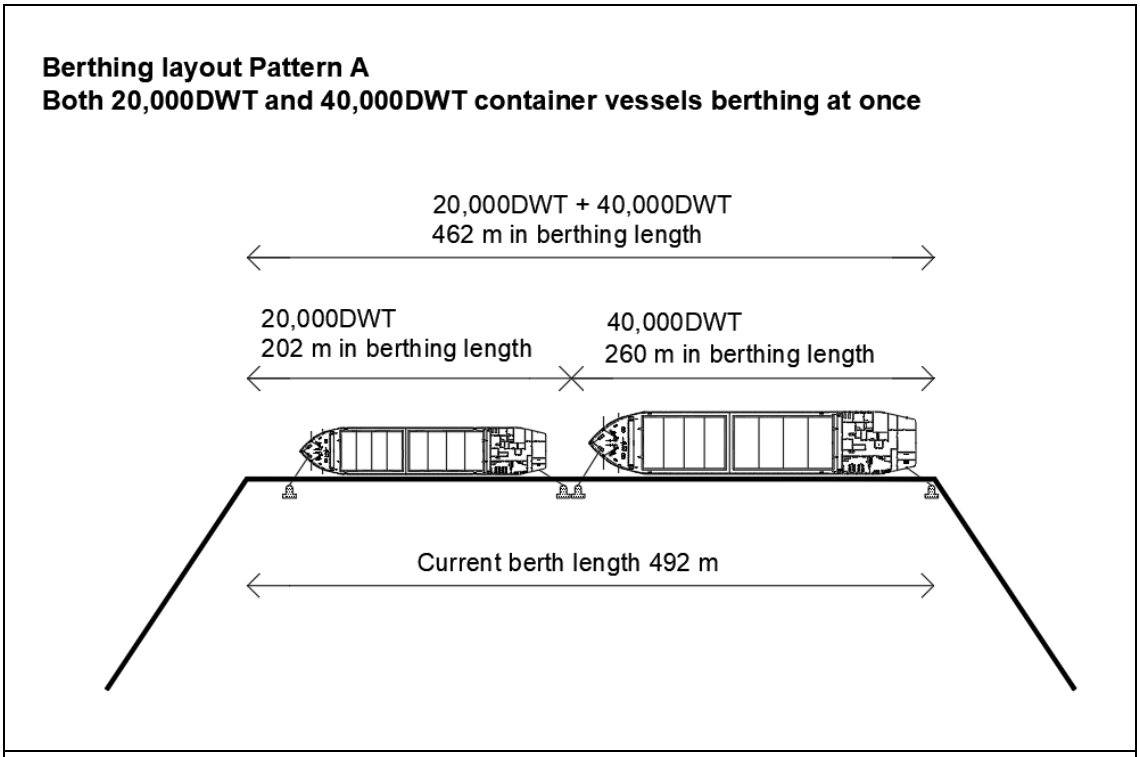


Figure 2.2-16 Assumed berthing layout diagram (Pattern A)

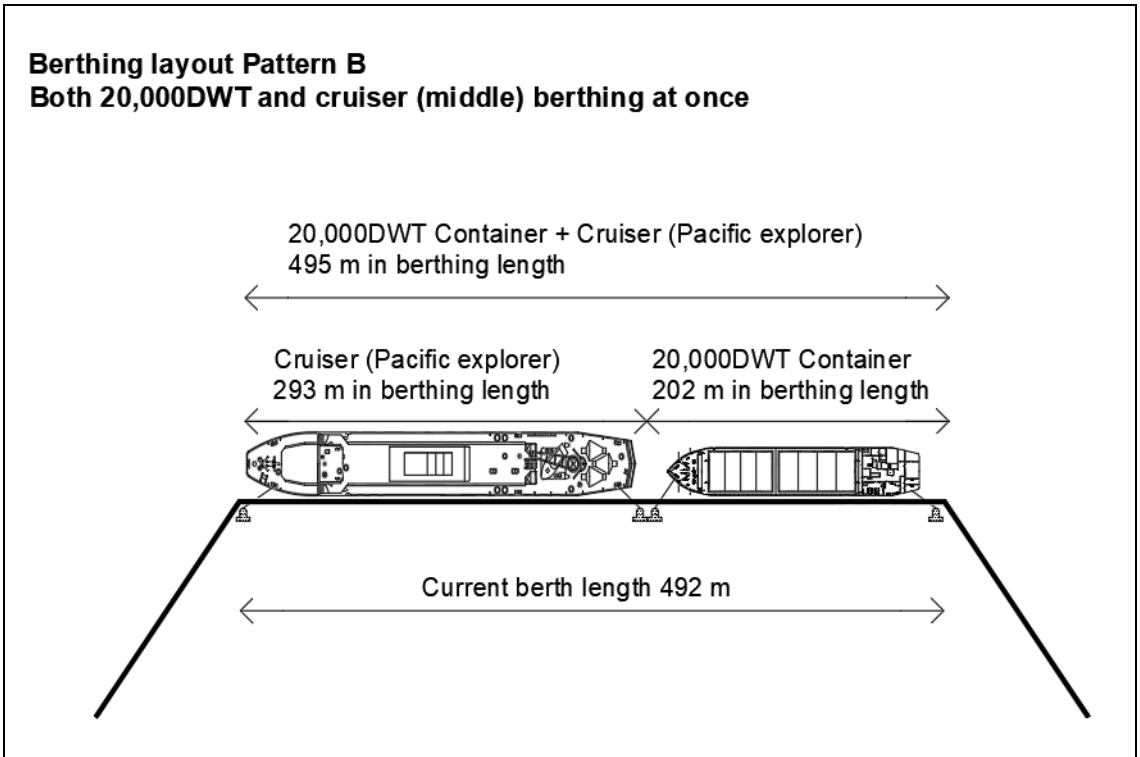


Figure 2.2-17 Assumed berthing layout diagram (Pattern B)

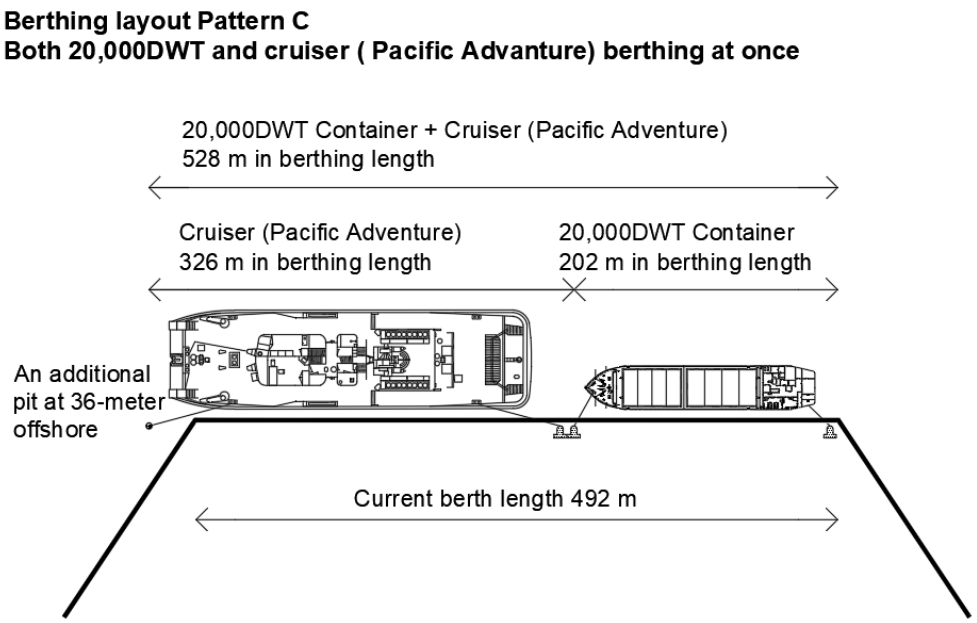


Figure 2.2-18 Assumed berthing layout diagram (Pattern C)

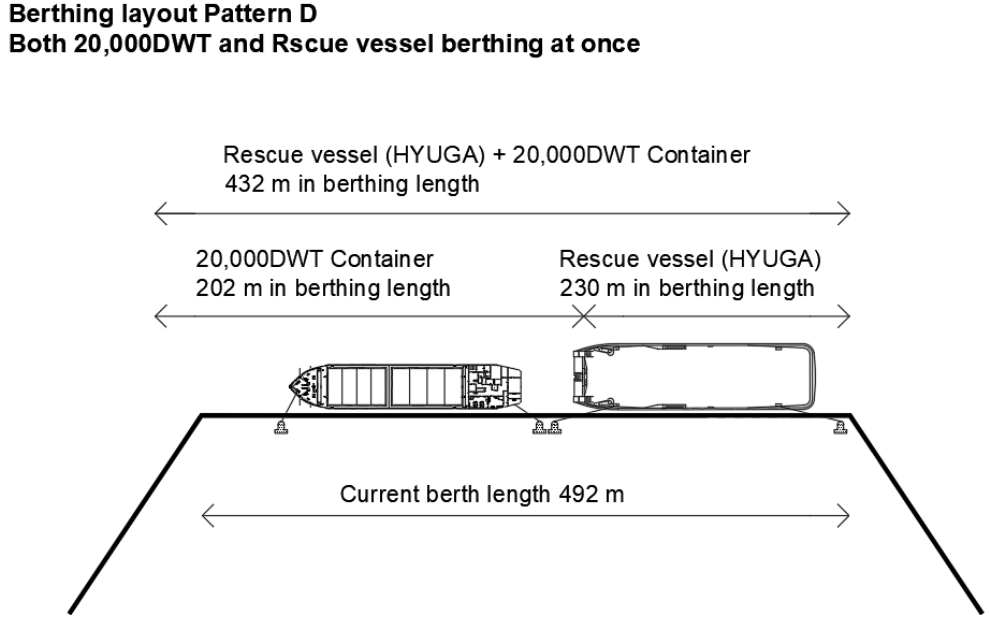


Figure 2.2-19 Assumed berthing layout diagram (Pattern D)

The details of the draft conceptual design for the Port of Suva strengthening plan derived from these berthing patterns are as follows.

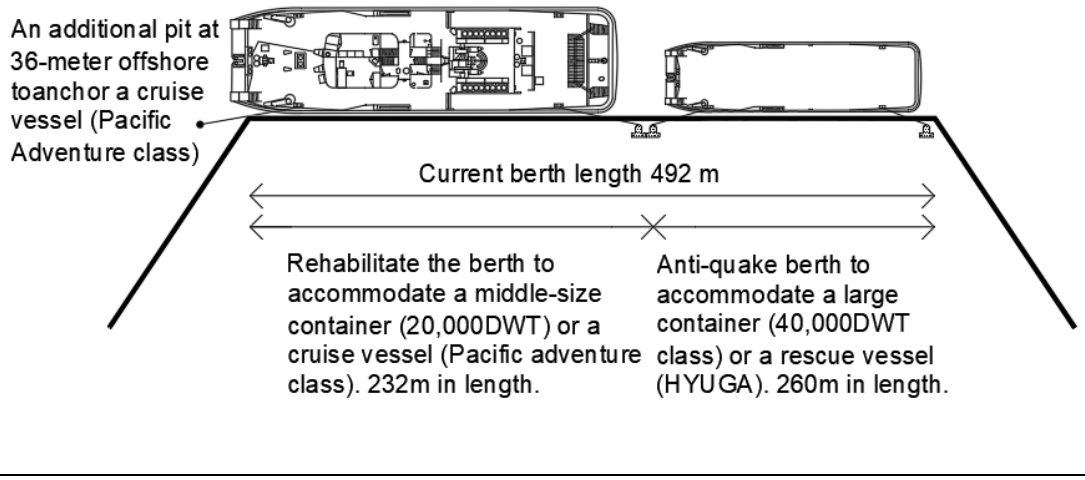


Figure 2.2-20 Assumed berthing layout

(v) Assumed design conditions

As a schematic study of the strengthening plan for the Port of Suva, a conceptual design proposal is prepared using steel pipe sheet pile quay wall system.
By installing steel pipe sheet piles in front of the existing wharf and backfilling behind the steel pipe sheet piles, it is possible to ensure the required functions of the quay without relying on the remaining load-bearing capacity of the pile foundations and superstructure of the existing wharf, which has deteriorated due to aging.

A schematic study of a steel pipe sheet pile quay wall (vertical pile anchor type) was conducted as a strengthening plan for the existing wharf.
The design study conforms to the Port and Harbor Standard (H30 version).

[References]

- "Suva Harbour – Kings Wharf Survey", Apr-May 2020,
- "Geotechnical Engineering (Interpretive Report), Geotechnical Investigation for the Proposed Kings Wharf Sheet Pile Wall", 02 June 2023, ENTEC PTE LIMITED

1). Top elevation of the wharf: +3.40mCD

The top elevation of the wharf shall be +3.40m CD in accordance with the existing pier.

2). Water depth: -15ｍCD

The design water depth in front of the steel pipe sheet pile shall be -15 m CD, referring to the design vessel specifications and the reference data from the local bathymetry survey.

3). Tide level:

Referring to the Fiji Roads Authority's Design Guide and FIJI PORTS MARINE FACT SHEET, the following tidal levels officially adopted in the Port of Suba after 2019 shall be applied.

Tidal planes are documented in the Fiji Nautical Almanac 2019. The almanac documents tidal planes at Suva Harbour and documents the tidal differences at secondary harbours around Fiji.

The following are the tidal planes at Suva Harbour (as provided in the Fiji Nautical Almanac 2019).

Table 5: Fiji Tidal Planes at Suva Harbour

Tide	Tidal Plane	Level Relative to Tidal Levels at Suva Harbour	Occurrence
HAT	Highest Astronomical Tide		Occurs on average about once or twice per year
MHWS	Mean High Water Springs	1.8m	Occurs over a few tides every fortnight
MHWN	Mean High Water Neaps	1.6m	
MSL	Mean Sea Level	1.1m	Average water level
MLWN	Mean Low Water Neaps	0.6m	
MLWS	Mean Low Water Springs	0.4m	Occurs over a few tidal cycles each fortnight.
LAT	Lowest Astronomical Data (Chart Datum, CD)	0.1m	Occurs about once or twice per year. Used for preparation of hydrographic charts

4). Soil conditions

Soil conditions were set based on the reference soil investigation data from "Geotechnical Engineering (Interpretive Report), Geotechnical Investigation for the Proposed Kings Wharf Sheet Pile Wall", 02 June 2023, ENTEC PTE LIMITED. A summary of the data is attached on the next page.

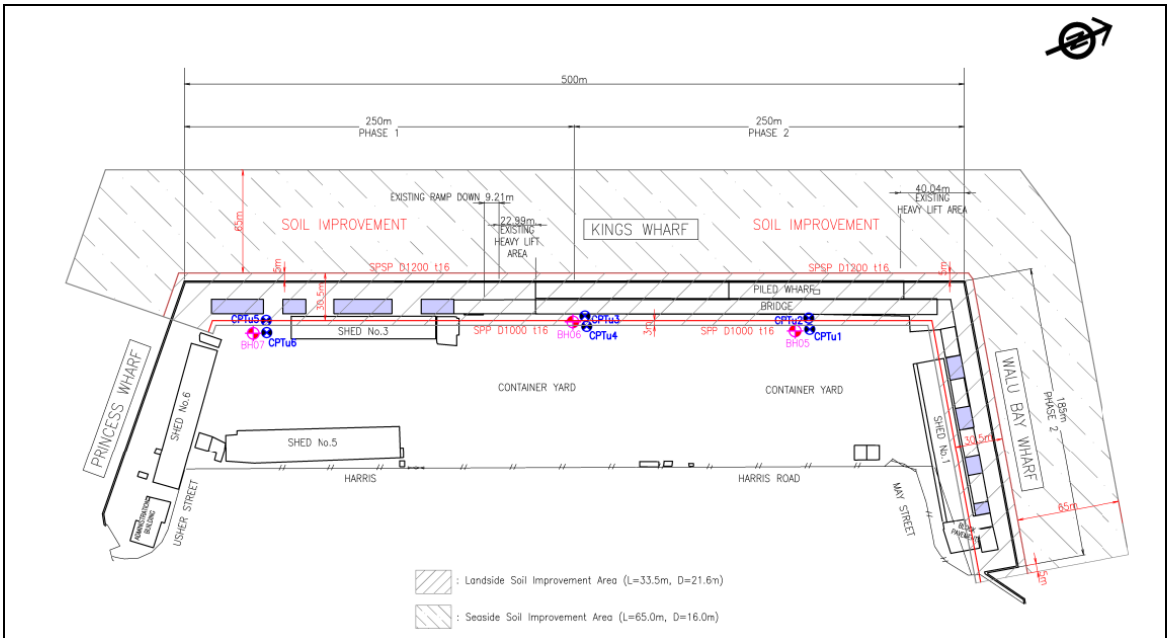


Figure 2.2-21 Layout of King's Wharf (location of existing borehole data)

Referring to existing soil investigation records, the investigation was conducted approximately 10 meters landward from the existing retaining sheet piles and approximately 30 meters landward from the front face of the wharf. Additionally, among the three borehole survey results, BH05 differs from BH06 and BH07 in that ground improvement work was previously carried out, but the details of the improvement method and the exact scope are unclear. On the other hand, BH06 and BH07 exhibit relatively similar characteristics of soft soil.

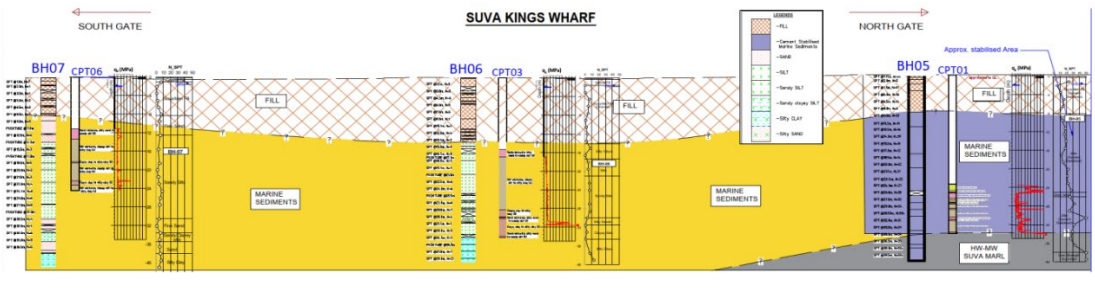


Figure 2.2-22 Cross section of soil layer estimation (excerpt)

The overview of each BH is as follows.

Borehole BH05
Borehole BH05, drilled within the bentonite stabilized block encountered approximately 8m of cement and possibly bentonite stabilized material (SPT N = 5 - 23) over cement and possibly bentonite stabilized Marine sediments (SPT N = 9 - 50+) over highly weathered to moderately weathered, very low strength Suva Marl rock, which was encountered at 38.0m below the wharf deck level.

Borehole BH06
Borehole BH06 encountered approximately 14m of un-stabilized fill (SPT N = 0 - 6) over Marine sediments (SPT N = 0 - 13) to the termination depth of 40.0m. Suva Marl rock was not intercepted within the termination depth of 40.0m.

Borehole BH07
Borehole BH07 encountered approximately 8.3m of un-stabilized fill (SPT N = 1 - 7), over Marine sediments (SPT N = 1 - 8) to the termination depth of 41.0m. Suva Marl rock was not encountered within the termination depth of 41.0m.

According to the soil investigation report, soil investigations have been conducted to a depth of approximately 40 m below the ground surface, but no information on depths deeper than this has been obtained. Therefore, the soil strength at depths deeper than the soil investigation data is assumed to be proportional to the effective stress increasing in the direction of depth and is calculated by the following equation.

Shear strength of soil deeper than the depth of investigation, (Su) = Su’ + 0.25 x 7.9 x Hi (kN/m2)

Where,

Su’：Soil strength at the bottom level of the survey (kN/m2)

Hi：Depth from survey bottom level (m)

As a result of examining the structural analysis of sheet pile cross-sections for soil data BH05, BH06, and BH07, it was found that the structure could not be established under the conditions of BH06 and BH07, except for BH05, due to the soft soil layer. Therefore, it is necessary to adopt ground improvement method below seabed behind the sheet piles.

5). Bollard Specifications: 100 t (1000kN) Bollard
100tonnes (1000kN) is adopted in accordance with the mooring bollard of the existing pier.

6). Design Load: 25kN/m2
The uniformly distributed load (UDL) is considered to be 25 kN/m^2.

7). Horizontal seismic intensity: kh=0.15
The design horizontal seismic intensity was determined to be kh=0.15 based on "Recent Seismic Hazard Studies in SE Asia, Pacific, and USA" (P.H. Nguyen, 2015 NZSEE Conference) and the Design Guide of the Fiji Roads Authority.

(vi) Summary of draft plan

Based on the results of the above schematic study, the overall plan and basic cross section of the proposed steel pipe sheet pile quay wall (vertical pile anchor-type) are shown below.
According to existing soil data, there is a soft soil layer extending more than 40 meters below King's Wharf to the bearing layer. Based on the stability analyses by survey team, it is real possibility that circular slip failure could be occurred around the wharf. Therefore, measures to prevent circular slip failure (CDM soil improvement method or equivalent) are required to the wharf area.

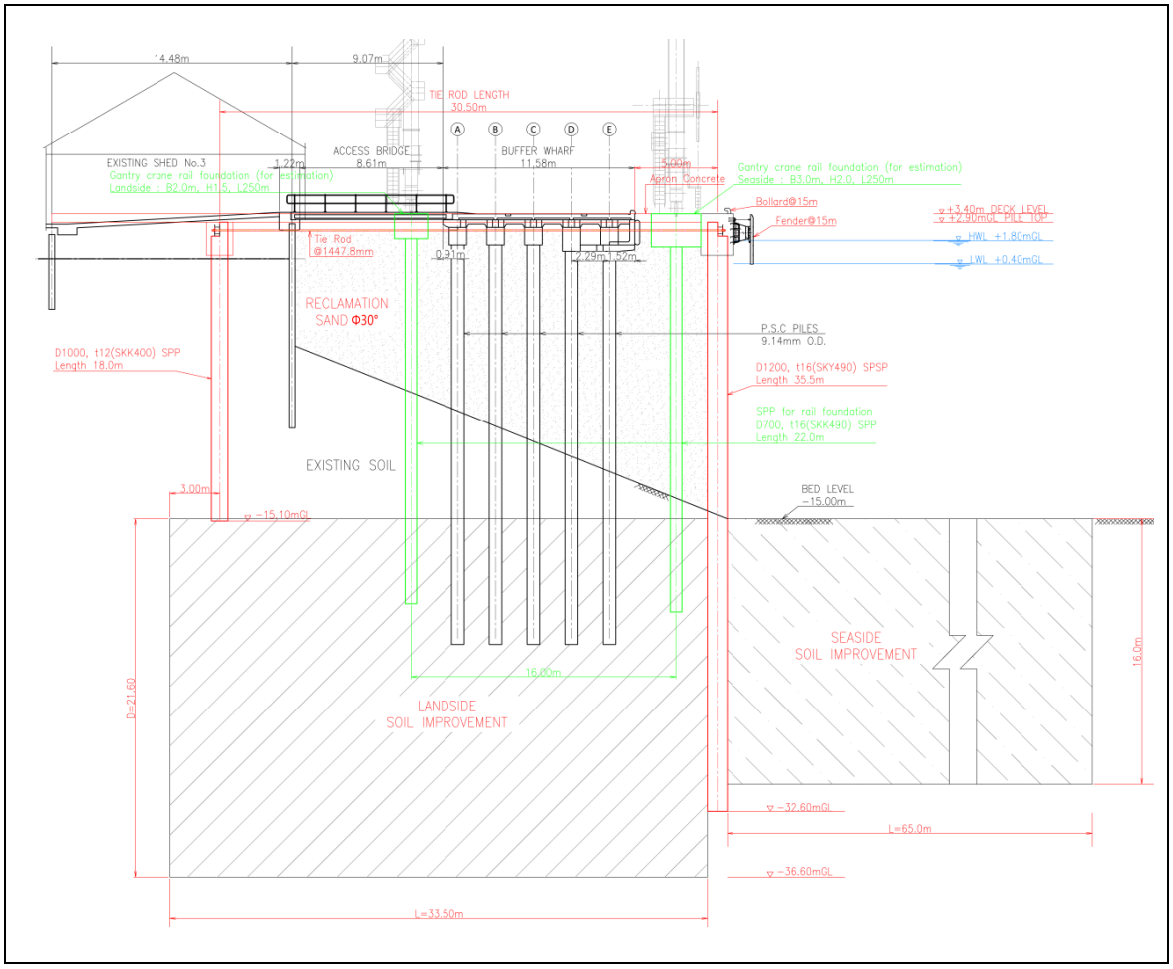


Figure 2.2-23 King's wharf typical cross-section

Table 2.2-11 Estimated Cost Calculation Results for the Port of Suva Strengthening Plan (Draft Conceptual Design)

		Cost per meter	Kings Wharf (South)	Kings Wharf (North)	Walu Bay Wharf	Total
Length(m)		-	280	250	185	715
Cost (US$)	50-year service period	323,000	80,174,377	97,884,266	52,972,357	231,031,000

If the renovation of King's Wharf and Walu Bay Berth totaling 715 meters is assumed, the construction cost will be approximately 231 million US dollars (including three sets of cargo handling machinery at 26.3 million US dollars).
(The construction unit price per meter is 323,000 dollars.)

According to financial analysis estimates, Fiji's interest rate has ranged from 0.25% to 2.5% from 2010 to 2024 (Fiji Interest Rate (tradingeconomics.com)), resulting in a FIRR of 19.7% for the

renovation project. This is higher than the previous real interest rate in Fiji. Therefore, this project is feasible.

Table 2.2-12 FIRR calculation results of the Port of Suva Strengthening Plan (Draft Conceptual Design)

Service period	Container Volume (TEU)	Total Vessel (GT)	Total Revenue				Total Cost				FIRR
			Wharfage (US$)	Marine Service (US$)	Stevedoring (US$)	Container Handling (US$)	Investment (US$)	Maintenance (US$)	Management (US$)	operation (US$)	
40 years	12,959,908	363,982,978	173,401,979	104,146,292	1,620,192,976	319,412,979	231,031,000	94,722,710	172,200,000	52,691,668	19.7%
			2,217,154,226				550,645,378				

Note: This calculation result is based on the following conditions.

1. The container volume is based on the demand forecast results up to 2070. The growth rate of the total GT was set at two-thirds of the growth rate of the container volume.
2. Revenue was derived from wharfage, marine service, stevedoring, and container handling, and calculated based on the tariffs.
3. Costs were derived from investment, maintenance, management, and operation expenses. The investment is assumed to cover a 5-year construction period, with maintenance costs assumed to be 1% of the construction cost each year.
4. The management cost covers the expense of employing 200 full-time staff. It was calculated based on the annual salary of truck drivers in Suva.
5. The operation cost was calculated based on the average fuel and electricity consumption of container terminal in Japan.

(vii) Notes and issues in draft plan

These schematic design and study are based on the following conditions: Further study is highly needed.

1. Demand forecast and terminal capacity: Our survey is based on limited operational information. It is highly needed to carry out a detailed and precise study on demand forecast and operational efficiency.
2. Limited natural condition data: the two borehole boring data prepared by FPCL that do not reach the solid strata. It is highly needed to investigate ground condition as well as facility condition if a detailed design will be carried out.
3. Cost estimation is based on the Japanese cost estimation standard that might be more expensive than that in Fiji. It is necessary to check the construction material cost, machine chartering and labor cost in Fiji.
4. Seismic data is not available at present. If this data is available, it will be possible to develop a proper and reasonable design for the appropriate service period of the King's Wharf.
5. In addition, this ground improvement can be updated if further usage of the facility is needed in the future.
6. A detailed wharf use plan for the King's Wharf is needed if the cost of rehabilitation is limited.
7. The estimated cost of procuring three sets of machines (one gantry crane and three RTGs as one set) and constructing the crane foundation is estimated at USD 26.3mil. (Note that the gantry crane and RTGs are refurbished pre-owned products.)

2.3 The Port of Levuka

2.3.1 Review issues related to port maintenance and management

(1) Status of Port facilities

The port town of Levuka is located on Ovalau Island, 20 kilometers east of Viti Levu, the main island of Fiji. With a population of 9,100 (2014) and an area of 106 hectares, it is a small island. As the first European settlement in the Pacific, it was designated a UNESCO World Heritage Site as the "Historic Port Town of Levuka" in 2013.

A reef is formed off the coast of the island. The Port of Levuka, managed by FPCL, is located on the east coast, which is the center of the island. The Port of Buresala, a private port, is located on the west coast.

The Port of Levuka is a pier with a depth of 11.5 meters and a length of 180 meters. It was originally constructed in the 1920s as a reinforced concrete structure. Only the first 70 meters of the pier was repaired in 1980, and it is still in use today.

According to the report "FPCL Levuka Wharf Condition Assessment Report" conducted by FPCL in 2023, field tests results such as concrete carbonation tests and chloride ion tests revealed that "structural strength has been lost, and the wharf is unfit for use." Visual inspections conducted by the JICA survey team also confirmed the findings of the FPCL survey.

(a) Port Plan



(Photo by Survey team, November 2023)

Figure 2.3-1 Panoramic view of The Port of Levuka

Table 2.3-1 Specifications of the Port of Levuka

Main International Wharf	Quantity	Length (m)	Maximum Draft (m)
Conventional Berth	1	180	7.5
Berthing Tugs	N/A	-	-

(b) Port cross-section (survey photos, drone photos)



(Photo by Survey team, November 2023)

Figure 2.3-2 The Port of Levuka from the side face of the pier

(c) Assessing the current situation through on-site inspections

The section from the first 70 meters was repaired in 1980 and is currently used by a ferry that arrives seven times a week (New Wharf). The subsequent 110-meter section remains in its original condition from the 1920s and is currently unused (Old Wharf). The superstructure of reinforced concrete in 1920s, including the concrete and steel bars, has completely deteriorated. The rebars are not the deformed bars in present but square-section bars, retaining traces of their historical construction materials. In the first 70-meter section, all fender materials have replaced with used tires suspended by chains and are used as a substitute. Based on structural strength evaluations conducted by FPCL, the load capacity is restricted to 3 tons or less, equivalent to the weight of a small truck.

During the on-site survey, FPCL accompanied the team and exchanged opinions about strengthening port facilities and maintenance methods through introduction of the survey methods and interviews. Thje photos taken during the survey are shown in **Figure 2.3-3** and **Figure 2.3-4**.



Figure 2.3-3 Photos during the filed survey

 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)
No.1- Levuka, Pier Status 1	No.2- Levuka, Pier Status 2	No.3- Levuka, Pier Status 3

 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)	 (Photo by Survey team, 2023)
No.4- Levuka, Pier Status 4	No.5- Levuka, Pier Status 5	No.6- Levuka, Bollard Status

 (Source: report from FPCL)	 (Source: report from FPCL)	 (Photo by Survey team, 2023)
No.7- Levuka, Deterioration below slab -1	No.8- Levuka, Deterioration below slab -2	No.9- Levuka, Fender Status

Figure 2.3-4 Site investigation photos

(d) Collection and organization of design documents from the viewpoint of maintenance and management

FPCL is a port operating company responsible for the maintenance and management of core port infrastructure facilities and navigation aids. Fiji government's real estate assets have been transferred to Assets Fiji Pte Limited (AFL) and leased back to FPCL. However, some of these transactions are still pending completion. For the maintenance and management of such state-owned facilities where procedures are incomplete, and/or major repair works, maintenance dredging, relocation plans, and other projects related to the future plans in Fiji are subject to the judgment of the Ministry of Public Works and Transport. And FPCL is addressing these matters through the Management Committee.

FPCL keeps the original construction drawings and the drawings and reports for the repair works for the Port of Levuka facilities. They are working on organizing and digitizing the hard copy documents. In addition, survey reports, design documents, and drawings related to recent rehabilitation plans are also managed in a database. These documents are basically treated as internal FPCL documents but can be viewed by relevant parties as needed.

(2) Implementation Department responsible for Port Management

The management of the Port of Levuka is the responsibility of FPCL, as is the case with the Port of Suva.
FPCL also serves as a regulatory agency under the Sea Port Management Act (SPMA), regulating various port activities, including monitoring environmental violations within the port boundaries.

(3) Status of Existing Facility and Future Plans

FPCL conducted a field survey in 2023 to assess the condition of the wharf at the Port of Levuka, taking into account that the wharf is over 100 years old. Based on the results of this survey, FPCL plans to evaluate the port facilities at the Port of Levuka and determine the optimal rehabilitation methods. FPCL is currently exploring funding options to manage infrastructure and promote sustainable development in line with national priorities in Fiji.

2.3.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at the Port of Levuka

(1) Collection of data on damage caused by past natural disasters

We collected reports on the disasters and compiled information on natural disasters that affected the Port of Levuka over the years in the previous section 2.2.2. Please refer to section 2.2.2 for details.

(a) Sea level rise, cyclone and high wave

Fiji is frequently hit by tropical cyclones and coastal floods associated with weather fronts. In 2016, Cyclone Winston, the strongest cyclone ever recorded in the Southern Hemisphere, struck the country, resulting in 44 deaths and economic losses totaling 1,990 million Fijian dollars (source: Post-Disaster Needs Assessment. 1 Fijian dollar ≈ 50 yen). In 2020, Cyclones Harold and Yasa caused damage in multiple Pacific Island nations, including Fiji, with particularly severe

impacts in Fiji, resulting in the collapse of homes, damage to infrastructure, and significant losses to crops.

(b) Earthquake, tsunami and volcanic activity

Due to its geographical location on the Pacific Ring of Fire, Fiji experiences frequent earthquakes in the surrounding waters. This region has been affected by seismic disasters such as the 1953 Suva earthquake and the 2018 Fiji earthquake, as well as tsunami disasters caused by earthquakes, and it also faces a risk of tsunami occurrence.

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in the Port of Levuka and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters.
The design conditions such as natural conditions, design loads, etc. at the time of construction of the existing facilities at the Port of Levuka have been confirmed referring to the information provided by FPCL.

Deck Level: RL+3.40 m
Tide Level:
Mean High Water Spring: (MHWS) RL+1.5 m
Mean Low Water Spring: (MLWS) RL 0.3 m
Water depth: RL-9.50m

Design vessels: unknown (not shown in the document)
Geotechnical Conditions: unknown (not shown in the document)
Seismic condition: unknown (not shown in the document)

Design load: unknown (not shown in the document)
However, the loading on pier is currently restricted as follows.
Old Wharf: No vehicles or pedestrians allowed.
New Wharf: Use restricted to passenger cars and light trucks (maximum 3 tons).
(Completely closed in areas with severe deterioration.)

2.3.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in the Port of Levuka based on the research papers and past records of natural disasters.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for the Port of Suva. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

The Port of Levuka is located on the east coast of Ovalau Island, approximately 20 km east of Viti Levu Island, where the Port of Suva is located. Therefore, the natural disasters and their magnitude that should be considered for the Port of Levuka are applied the same as those for the Port of Suva.
The Multi-hazard Heat Map Port Exposure for Suva Port in Fiji is shown in Table 2.3-2.
Referring to Table 2.3-2, the risk of coastal flooding due to storm surges is classified high around Suva Port in Fiji. Additionally, the risk from cyclones and associated waves, high waves during regional storms, and earthquakes is rated as medium. On the other hand, the risk from tsunamis and volcanoes is rated as low.

Table 2.3-2 Multi-hazard Heat Map Port Exposure (Republic of Fiji)

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High Medium Low Very Low Not applicable

Source: "A Blue Transformation for Pacific Maritime Transport" (World Bank. 2023. A Blue Transformation for Pacific Maritime Transport. World Bank, Washington, DC. © World Bank.)

Table 2.3-3 Methodology for Identifying Natural Disasters and their Scales (the Port of Levuka)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Could not be confirmed.	Not applicable	Estimate earthquake waves by considering the scale of past earthquakes and taking into account the distance from the epicenter and ground conditions.
Tsunami	Could not be confirmed.	Not applicable	Estimate the loads acting on structures by assuming tsunami heights and flow velocities based on past maximum tsunamis.
Volcano	Could not be confirmed.	Not applicable	Estimate the impact of volcanic eruptions and ashfall on ports based on records of volcanic eruptions in neighboring countries and past volcanic disasters.
Storm Surge	Could not be confirmed.	Flood disasters increases due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	Could not be confirmed.	Increase in high waves due to cyclone intensification	Consider the increase in waves caused by cyclone intensification objectively. Recent research results, such as future predictions using d4PDF described later can be used.

(2) Measures against sea level rise and wave power by climate change

The adaptation measures against sea level rise and wave power by climate change was described in the previous section 2.2.3 (2). Please see section 2.2.3 (2) for details.

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

The projected sea level rise in Fiji by 2050 is projected to be 0.26 meters under the 2°C warming scenario (SSP1-2.6). Under the 4°C warming scenario (SSP5-8.5), it is projected to be 0.29 meters, with a small difference between the two scenarios. However, by 2100, the difference becomes significant, with 0.57 meters under the 2°C warming scenario (SSP1-2.6) and 0.93 meters under the 4°C warming scenario (SSP5-8.5). Therefore, depending on the scenario selected, the value of projected sea level rise differs, and this must be considered when setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

2.3.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing analysis on port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize FPCL's current disaster mitigation plans in terms of time frames and types of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". Natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 2.3-4.

Table 2.3-4 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The expert team confirmed the structure of existing facilities and maintenance status of the target port through discussions with FPCL and confirmation of available design documents. The existence and implementation status of natural disaster response plans for the respective port facilities were also confirmed. The expert team sent questionnaires to each port authority to examine if the disaster mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change.
The responses from FPCL are summarized in 2.2.4.

(2) Results of Questionary Survey

Please refer to the responses from FPCL summarized in 2.2.4.

FPCL has formulated and implemented a comprehensive plan covering all port facilities under its jurisdiction for natural disaster response, climate change response, and emergency response. In this survey, the status of each response for the port facilities at the target ports of the Port of Suva and the Port of Levuka are confirmed.

2.3.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by examining the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*" [25] (hereinafter referred to as 'Pacific Ports
Vision') shown in Table 2.3-5. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[25] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 2.3-5 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities in the Port of Levuka are shown below.

(a) Natural disaster adaptation – Resilience indicator: **Unengaged**

Reason: The Port of Levuka began operating in the 1920s. Subsequently, in the 1970s, the connecting bridge and about 70 meters of the pier were renovated, and the port began operating again in 1980 and has been in use ever since. Current information on natural disasters is not reflected on the existing structures.

(b) Climate change adaptation - Resilience Indicators: Unengaged

Reason: The Port of Levuka began operating in the 1920s. Subsequently, in the 1970s, the connecting bridge and about 70 meters of the pier were renovated, and the port began operating again in 1980 and has been in use ever since. The effects of climate change, such as sea level rise are not reflected on the existing structures.

(c) Emergency response - Resilience indicator: Engaged

Reason: The Port of Levuka has a comprehensive emergency response plan for natural disasters. The relevant plans and documents are as shown below.

- NATIONAL DISASTER MANAGEMENT PLAN 2018[26]
- CLIMATE SMART COMMUNITY-BASED DISASTER RISK MANAGEMENT TRAINING MANUAL[27]
- Emergency Preparedness: Operational Logistics Contingency Plan[28]

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in the Port of Levuka in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

[26] NATIONAL DISASTER MANAGEMENT PLAN 2018; Fiji National Disaster Management Plan – NDMO

[27] CLIMATE SMART COMMUNITY-BASED DISASTER RISK MANAGEMENT TRAINING MANUAL; CBDRM – NDMO

[28] Emergency Preparedness: Operational Logistics Contingency Plan; Fiji Emergency Preparedness: Operational Logistics Contingency Plan Part 1 – Risk Profile & Disaster Management, February – April 2012 - Fiji | ReliefWeb

Table 2.3-6 Assessment of Impacts of Natural Disasters for the Port of Levuka

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	The Port of Levuka is located on the east coast of Ovalau Island and is a pile-supported pier constructed in the 1920s. Although the first 70 meters of the pier was renovated in 1980, the concrete piles of the foundation and the concrete deck of the superstructure have deteriorated significantly, raising concerns about severe damage from earthquakes.	An earthquake could affect the management system due to human casualties such as injuries. The damage to the pier is expected to have a significant impact on port functions. The damage to the Port of Levuka is expected to have a significant impact on the stable supply of food and other daily necessities to Ovalau Island and on the tourism industry.	An Earthquake could cause human casualties that may affect operations. Damage to piers and loss of power may affect port calls.
Tsunami	Although the Republic of Fiji is not at high risk of tsunami disasters, there is a possibility of damage to aging piers, damage to ships, and spill of cargo due to tsunamis. There is also a possibility of damage such as loss of power.	Tsunami could cause injuries and other human casualties, which may affect the management system. Damage to piers and the loss of cargo due to the tsunami will have a significant impact on the stable supply of food and other necessities to Ovalau Island and on the tourism industry.	Human casualties due to tsunamis may affect operations. Damage to piers and loss of power may affect port calls
Volcano	The Republic of Fiji is located between Tonga and Vanuatu and is one of the countries with a high risk of volcanic disasters. There are concerns about the potential for volcanic eruptions and ashfall to cause severe damage to piers and adjacent port cities, as well as the closure of shipping lanes.	Human casualties due to volcanic eruptions may affect management systems. Damage to piers and disruption of land transportation caused by volcanic eruptions could have a significant impact on the stable supply of food and other necessities to Ovalau Island.	Human casualties, such as injuries due to volcanic eruptions may affect operations. Volcanic ejecta and ashfall may cause road closures in and around the pier.
Storm Surge	There are possibilities that flooding and damage to piers due to high tides, flooding of adjacent port cities, and other effects. There is also a possibility that the effects of ships running aground and cargo spillage are also possible.	Human casualties due to storm surges may affect management systems. Damage to piers and loss of cargo due to storm surges may have a significant impact on the stable supply of food and other necessities to Ovalau Island.	Human casualties due to high tides may affect operations. Damage to piers and loss of power may affect port calls.
Cyclone	The strong winds from the cyclone are expected to affect office buildings and the adjacent port town. High waves caused by the cyclone may also cause flooding of piers and surrounding areas, ships running aground or colliding, and loss of power.	Cyclones could cause injuries and other human casualties, which may affect management systems. Strong winds may damage office buildings and close roads, halting land transportation, while high waves may damage piers, severely affecting the stable supply of food and other necessities to Ovalau Island.	Human casualties due to cyclones may affect operations. Strong winds may cause land transportation to stop, which may affect operations, and high waves may damage piers, which may also affect operations.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in the Port of Levuka. Figure 2.3-5 illustrates the risks of natural disasters and resulting damage to the port.

The Port of Levuka is a pile-supported pier constructed in the 1920s. Although the first 70 meters of the pier was renovated in 1980, concrete piles of foundation and concrete deck of superstructure deteriorated significantly, raising concerns about critical damage from earthquakes. Tsunami may flow over the coral reef and a mass of water may damage the port facilities. Tsunami may affect damage to aging pier, damage to ships and spill of cargo. Loss of power supply are also concern. Seawater from the ocean side will flood into the port area like cyclone “Winston” in 2016due to sea level rise. A Cyclone may affect office buildings and adjacent port town.

The Port of Levuka is the only public port on Ovalau. Damage to the Port of Levuka may have a significant impact on the stable supply of food and other daily necessities to Ovalau Island and on the tourism industry.

Therefore, the advisory team proposes a draft plan to construct a new wharf by renovating the existing pier at the Port of Levuka.

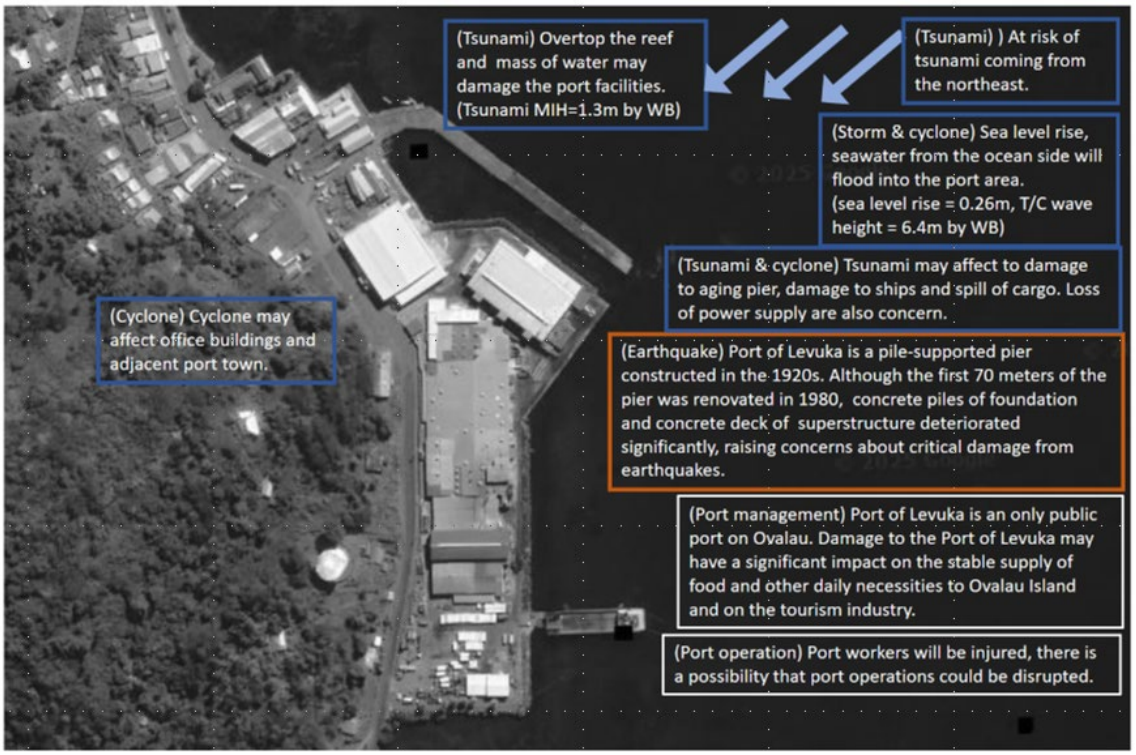


Figure 2.3-5 Geographical characteristics of natural disasters

2.3.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans.

(1) Confirmation of the reasons for staying with the current resilience indicators

In Section 2.3.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for the Port of Levuka. The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in "*CLIMATE CHANGE ADAPTATION PLANNING FOR PORTS AND INLAND WATERWAYS*" (PIANC, EnviCom WG Report No. 178-2020) (hereinafter referred to as the PIANC guide).
The results are presented below.

(a) Natural disaster adaptation – Resilience indicator: **Unengaged**

Reason: Actions are not taken at the Port of Levuka to respond to the natural disasters at existing facilities.

- The goal(s), planning horizon, and objectives for natural disaster adaptation have not been established and agreed at the Port of Levuka.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has not been complete, and the potential impacts of natural disasters on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the natural disaster adaptation process for the Port of Levuka.

(b) Climate change adaptation - Resilience Indicators: Unengaged

Reason: Actions are not taken at the Port of Levuka to address the climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed at the Port of Levuka.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has not been complete, and the potential impacts of climate changes on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate changes is not in place, along with a fit-for-purpose data management system.

- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response - Resilience indicator: Engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in the Port of Levuka.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at the Port of Levuka for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

Measures to make the Port of Levuka one level higher on the resilience indicators

(a) Natural disaster adaptation

- Establish goal(s), planning horizon and objectives for natural disaster adaptation at existing facilities in the Port of Levuka.
- Identify the impact of natural disasters on port assets, operations, and systems in the Port of Levuka.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information related to natural disaster intensity predictions and determine the extent of the natural disaster.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(b) Climate change adaptation

- Establish goal(s), planning horizon and objectives for climate change adaptation at existing facilities in the Port of Levuka.
- Identify the impact of climate changes on port assets, operations, and systems in the Port of Levuka.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information on natural disaster intensity forecasts including the effects of climate change and identify the extent of natural disasters with climate change impacts.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and

predict the impact of disasters under normal circumstances.

(c) Emergency response

- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans.
- Fully develop emergency response plans for natural disasters at existing facilities in the Port of Levuka and communicate them to stakeholders.

(3) Examples of countermeasures

The Port of Levuka began operating in the 1920s. Subsequently, in the 1970s, the connecting bridge and about 70 meters of the pier were renovated, and the port began operating again in 1980 and has been in use ever since. The current information on natural disasters is not reflected in the existing structures. When assessments of the impact of natural disasters are being incorporated into future plan, the following example is one of the countermeasures against storm surge and cyclones for the facilities in the Port of Levuka.

- **Raising quay walls**



(The concept is to raise the height of new or existing wharves to a level that takes into account the effects of storm surges and sea level rise, and to plan or renovate the structure so that it can withstand the resulting increase in load.)

The existing pier at the Port of Levuka is aging and causing operational problems. Therefore, it is necessary to plan and implement fundamental renovation plans that take into account future natural disasters and climate change, such as raising the height of the quays in addition to structural rehabilitation.

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for the Port of Levuka are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in the Port of Levuka is evaluated as "Unengaged."
In order to achieve a higher level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for existing facilities at the Port of Levuka in terms of their natural disaster adaptation.
It is recommended to identify the impact of natural disasters on port assets, operations, and systems at existing facilities in the Port of Levuka, collecting information necessary to understand the baseline situation, and specifying information necessary for natural disaster risk assessment in order to prepare for the formulation of a natural disaster adaptation plan.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in the Port of Levuka is evaluated as "Unengaged."
In order to achieve the next level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for climate change adaptation.
It is recommended to collect information on natural disaster intensity forecasts that include the impact of climate change in order to identify the impact of climate change on the port assets, operations, and systems of the Port of Levuka and to understand the baseline situation.

(c) Disasters and Emergency Response

The resilience indicator outlined in the "*Pacific Port Vision*" for emergency response in the Port of Levuka is evaluated as "Engaged."
In order to achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and that emergency response plans for natural disasters at existing facilities in the Port of Levuka be fully developed and communicated to stakeholders.

FPCL has formulated and implemented a comprehensive plan covering all port facilities under its jurisdiction for natural disaster adaptation, climate change adaptation, and emergency response. In this survey, we attempted to evaluate the plans and implementation status for the Port of Levuka, which is the target port; however, we were unable to confirm specific details, resulting in the above evaluation results. This conclusion does not apply if it is confirmed that the Port of Levuka

has its own adaptation plan that has been formulated and implemented.

(d) Introduction of the Draft Plan for Port Resilience

(i) Proposal for the Port of Levuka Strengthening Plan (Draft Concept)

The Old Wharf, which was constructed in the 1920s, is severely deteriorated and has been unused. Although the New Wharf, which was reconstructed in 1980, is used by seven ferry services per week, it has weight restrictions on cargo and trucks due to its deterioration. For this reason, a draft plan is proposed to construct a new wharf by renovating the existing pier.

(ii) Assumed conditions

The renovation of this pier will enable 1,000-ton ferries and 1,500-ton ships to dock simultaneously. The base of the pier has sufficient space for 40-foot container trailers to turn around, allowing general cargo vehicles to wait and passengers to board and disembark safely.

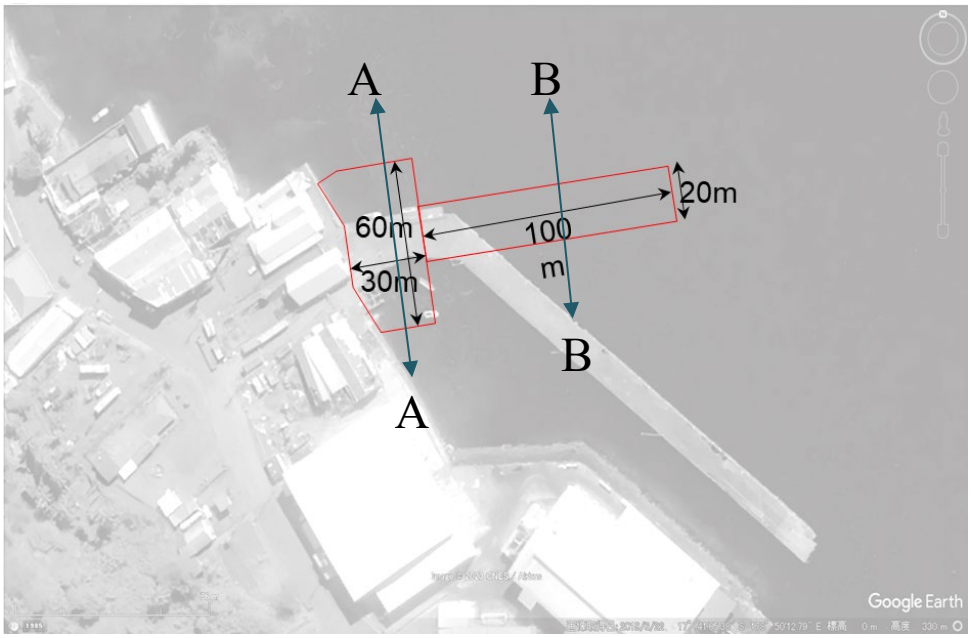


Figure 2.3-6 Draft layout of the new pier

(iii) Summary of draft plan

Figure 2.3-7 shows the plan view of the new pier, **Figure 2.3-8** shows the cross-sectional view of the berth area, and **Figure 2.3-9** shows the cross-sectional view of the pier area. The construction cost is estimated to be approximately 6.6 million USD.

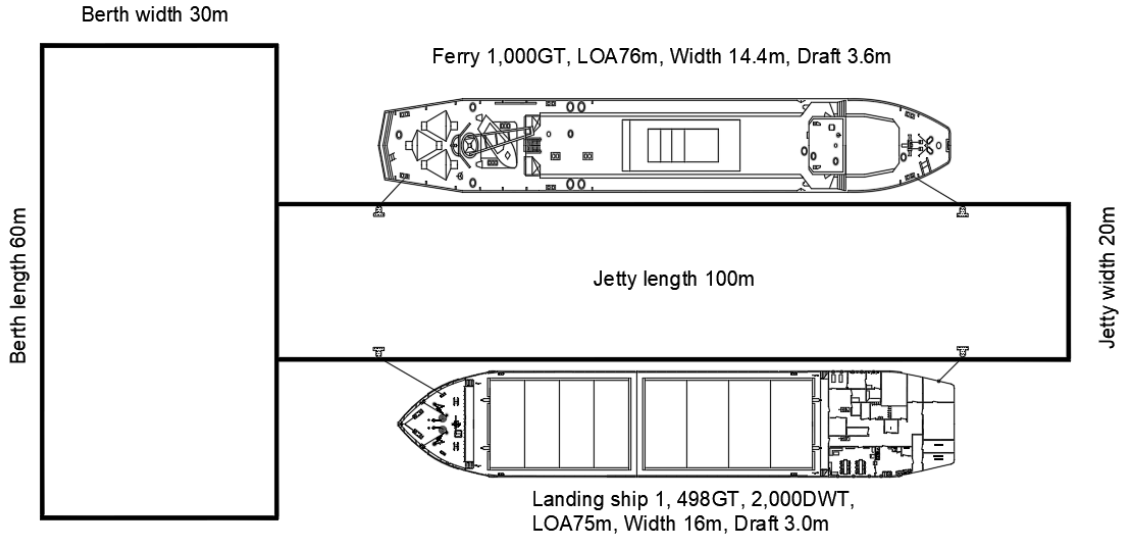


Figure 2.3-7 The Port of Levuka Strengthening Plan (Draft)

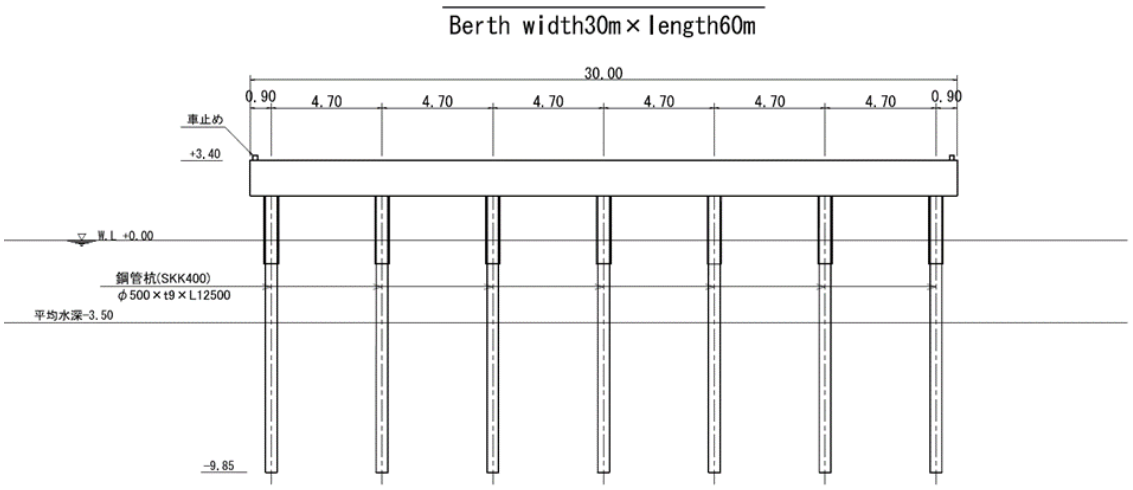


Figure 2.3-8 Cross-section of the new pier (berthing area)

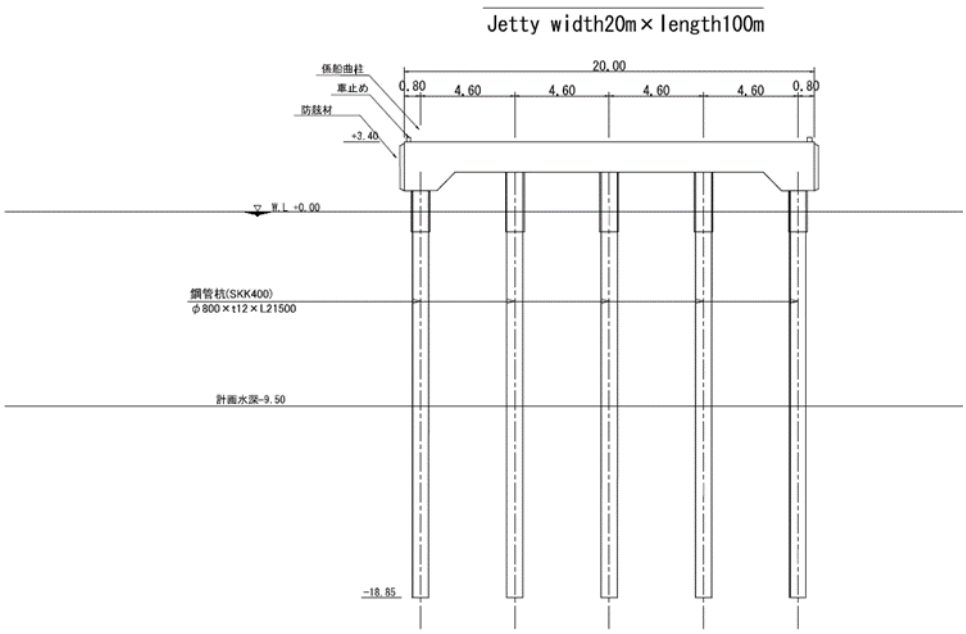


Figure 2.3-9 Cross-section of the new pier (pier section)

(iv) Notes and issues in draft plan

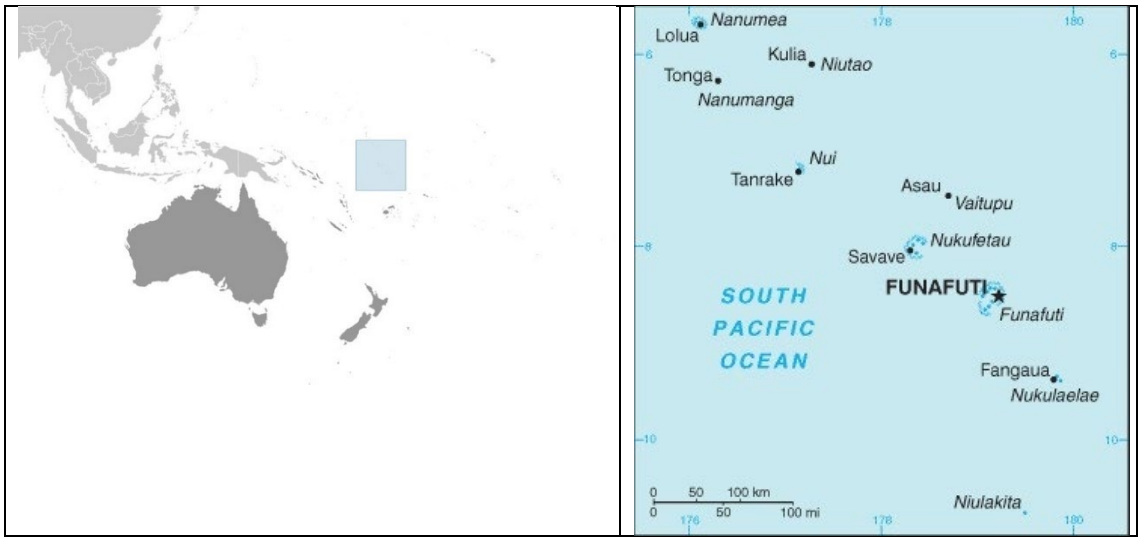
When conducting the basic design survey for this Port of Levuka strengthening plan, it is necessary to conduct a site survey of the existing pier facilities to thoroughly confirm the condition of the pier pile foundations, superstructure concrete, and the condition of the revetment behind the pier, and to reflect those information in the demolition and construction plans. We recommend conducting geotechnical surveys of the area around the pier and reevaluating the meteorological and oceanographic conditions as necessary for the renovation plan and implementing the basic design appropriately.

3. Tuvalu

3.1 Overview of the country and its major ports and external relations

3.1.1 Country Overview

Tuvalu is the westernmost part of Polynesia, consisting of nine islands. Tuvalu has a land area of 26 km^2 and a population of approximately 11,000. The Funafuti Atoll, where the capital is located, is situated about 950 km south of the equator and about 1,000 km north of Fiji. Tuvalu consists of islands scattered over a distance of 676 km from northwest to southeast. These islands are all at low elevations, with the highest points being only about 5 meters above sea level. Rising sea levels due to climate change is a major concern of the people of Tuvalu.



Source: CIA HP、https://www.cia.gov/the-world-factbook/countries/tuvalu/(accessed: August 2024)

Figure 3.1-1 Location Map of Tuvalu

3.1.2 Economic and Social Conditions

Tuvalu, lacking natural resources, relies primarily on fishing license fees and remittances from overseas workers, such as seafarers on foreign fishing vessels, for national revenue. Consequently, the fiscal deficit has been supplemented by earnings from the Tuvalu Trust Fund (established in 1987 with contributions from Tuvalu, the UK, Australia, and New Zealand). Although the Trust Fund has been managed soundly, in 2001, it faced a real negative return due to the U.S. economic slowdown, decline in the U.S. stock market, depreciation of the Australian dollar against the U.S. dollar, and the downturn in the Australian economy.

Tuvalu has been receiving royalties from the lease of its internet domain code ".tv" to an American internet company since 1999, but the income from this source is highly variable each year. Consequently, managing the limited income remains a challenge. Given these constraints on major national revenue sources, the government is making efforts to significantly reduce fiscal

expenditures, including government subsidies and special development expenses, and to improve fiscal transparency. Tuvalu is classified as an LDC (Least Developed Country).

3.1.3 Overview of Port Administration

The Ministry of Transport, Energy, Communication and Innovation (MTECI) oversees port administration. The MTECI was previously known as the Ministry of Transport, Energy and Tourism. The Ministry was reorganized under the new cabinet formed by Prime Minister Feleti Teo in February 2024. Due to Tuvalu's small population, government ministries often change depending on the administration in power.

(1) Overview of Major Ports

Tuvalu is divided into nine islands (atolls). The main port is Funafuti port, located on Funafuti Atoll, the largest in Tuvalu. Funafuti port is situated in the atoll, so the waters are relatively calm. The right image of Figure 3.1-2 shows the location of Funafuti port. Funafuti port has two wharves: the Old Wharf and the New Wharf. The Old Wharf was constructed in 1980 with financial assistance from Australia. The New Wharf was developed in 2009 through Japan's grant aid program (total contribution: 932 million yen). Although port facilities exist on the other eight islands as well, they are limited to small-scale domestic operations.

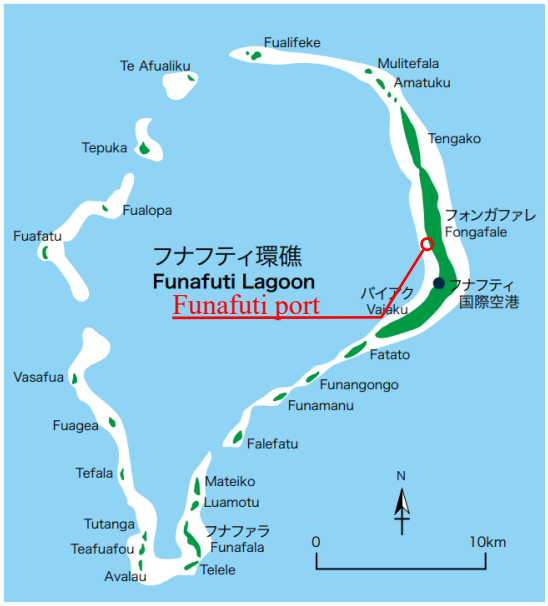


Figure 3.1-2 Location of major ports in Tuvalu

3.1.4 Number of port calls by vessel type and the average size of vessels calling

Table 3.1-1 shows the number of port calls by vessel type and the average size of vessels calling at Funafuti port in 2023. A total of 168 vessels called at the port during the year. Passenger vessels (cruise ships) accounted for the most calls at 46. Fourteen general cargo vessels with container-handling capacity and 10 fully cellular containerships also called.

Table 3.1-1 Number of Vessel Calls by Type and Size in Funafuti port

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
Combined chemical and oil tanker	1	8	45,648	31,832	5,706	3,979
Fishing (general)	1	1	1,784	1,850	1,784	1,850
Fully cellular containership	2	10	74,906	73,909	7,491	7,391
General cargo with container capacity	2	14	123,080	97,039	8,791	6,931
Passenger (cruise)	1	46	26,588	61,502	578	1,337
Reefer	1	1	4,218	3,475	4,218	3,475
Research	1	2	0	784	0	392
Tug	5	25	2,954	4,100	118	164
Vessel Type (unspecified)	1	13	0	0	0	0
Yacht	5	48	180	855	4	18
Total	20	168	9,504,263	275,346	1,663	1,639

Source: Lloyd's List Intelligence Seasearcher data（2023）analyzed by OCDI

3.2 Funafuti port

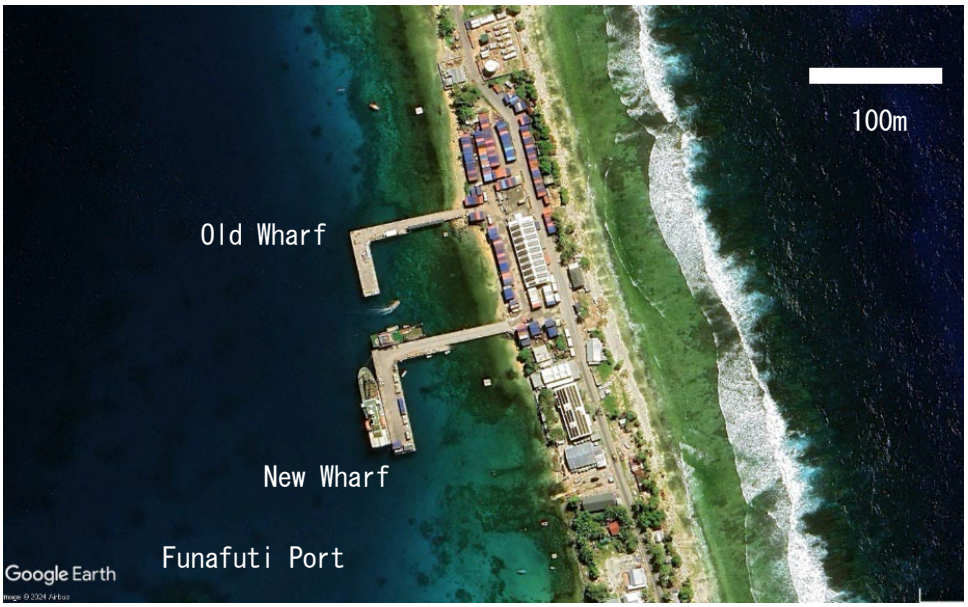
After the preliminary discussions with MTECI and SPC, Funafuti port was selected as the target port in Tuvalu.

3.2.1 Review of issues related to port maintenance and management

(a) Status of port facilities

The layout of Funafuti port is shown in Figure 3.2-1. The port has two L-shaped piers. The pier on the north side is called the Old Wharf, while the one on the south side is the New Wharf. The specifications for each wharf are shown in Table 3.2-1. The Old Wharf is an L-shaped pier with steel pipe piles, constructed in 1980 with financial assistance from Australia. The structure of the Old Wharf is considered to be reinforced concrete based on its appearance during the site survey. The details have not been confirmed. The wharf was originally designed to accommodate container ships. Currently, the wharf is severely deteriorated and has lost its structural integrity. It is no longer capable of handling heavy cargo, and it is considered dangerous for vessels to berth at the wharf. The New Wharf is also an L-shaped pier with steel pipe piles, developed in 2009 by Japan’s grant aid program, with a total contribution of 932 million yen. This wharf is in good condition. However, the container yard behind it is narrow and unpaved. In addition, a public road runs through the container yard. This creates a very dangerous situation where container

handling operations, general vehicle traffic, and pedestrian traffic intermingle in the same area.



Source: Google Earth with annotations by the JICA study team

Figure 3.2-1 Layout of Funafuti port

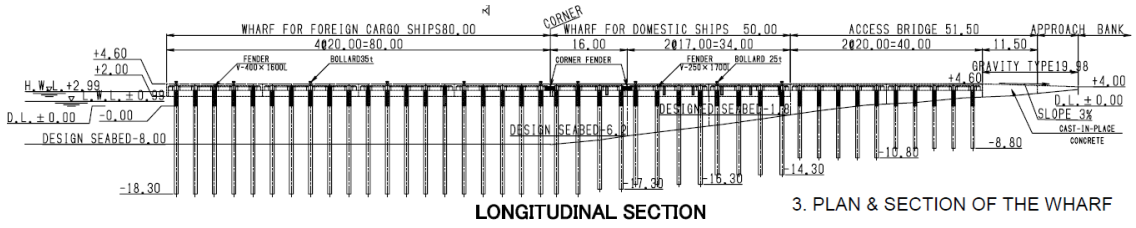
Table 3.2-1 Specifications of Funafuti port[29]

Wharf Name	Berth	Length (m)	Depth (m)	Description
Old Wharf	West Berth	50	8	Container vessels
	North Berth	39	5	Inter-island vessels,cargo ships
	East Berth	40	5.5	Patrol boats
New Wharf	West Berth	80	8	Container vessels, international cargo ships, inter-island vessels
	North Berth	50	2-8	inter-island vessels
	East Berth	68	5	Patrol boats
	South Berth	34	0-6	Small fishing boats

(b) Port cross-section

The Study team obtained the design drawings of the New Wharf[30] (see Figure 3.2-2). The cross-section drawing indicated that the wharf was composed of three sections: an international berth for foreign cargo vessels (80 meters in length and 12 meters in width), a berth for domestic vessels (50 meters in length and 10 m in width), and a 51-meter-long access bridge. It is a sheet pipe pile structure. The length of pile is around 22 meters or so. The splash zone of the pile was covered with corrosion proofing. The slab is reinforced-concrete structure.

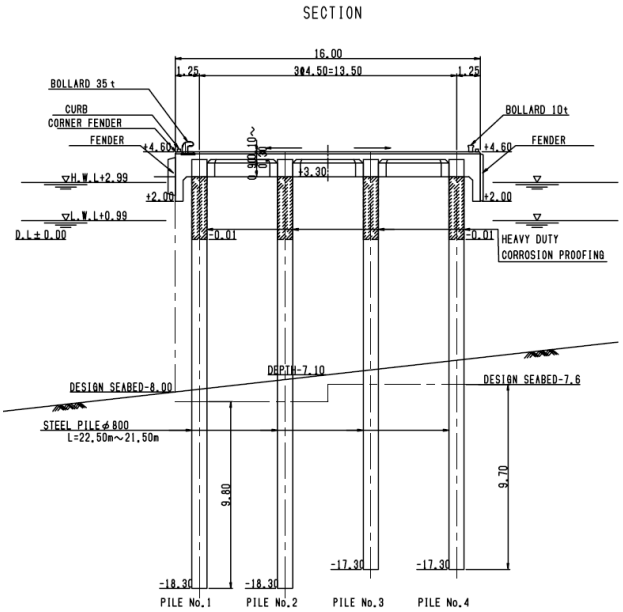
[29] "Basic Design Study Report on the Project for Improvement of Funafuti port in Tuvalu", JICA, 2007. https://libopac.jica.go.jp/images/report/11852365_01.pdf
[30] "Basic Design Study Report on The Project for Improvement of Funafuti Port in Tuvalu", JICA, 2007. https://libopac.jica.go.jp/images/report/11852365_01.pdf



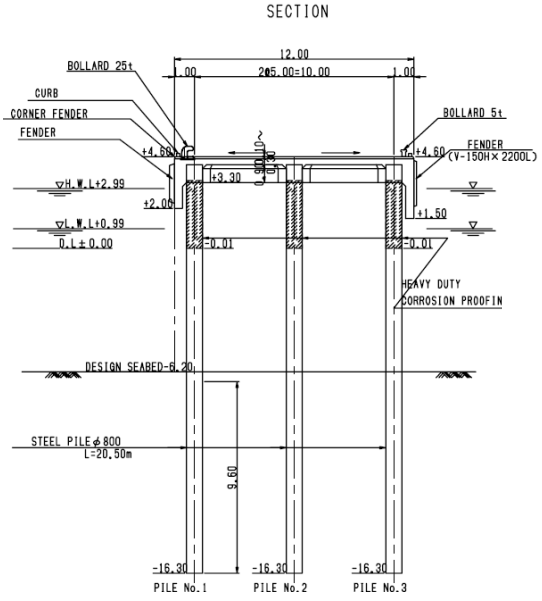
LONGITUDINAL SECTION

3. PLAN & SECTION OF THE WHARF

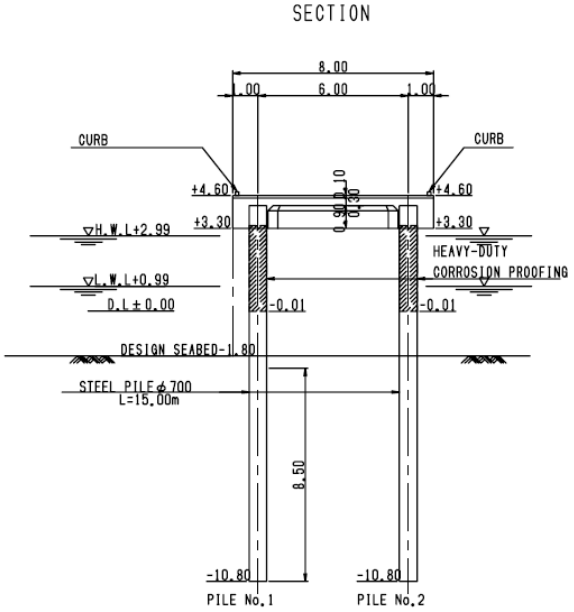
LONGITUDINAL SECTION OF THE WHARF



SECTION OF THE WAHRF FOR FOREIGN CARGO SHIPS



SECTION OF THE WHARF FOR DOMESTIC SHIPS



SECTION OF ACCESS BRIDGE

Figure 3.2-2 Cross-Section of the New Wharf

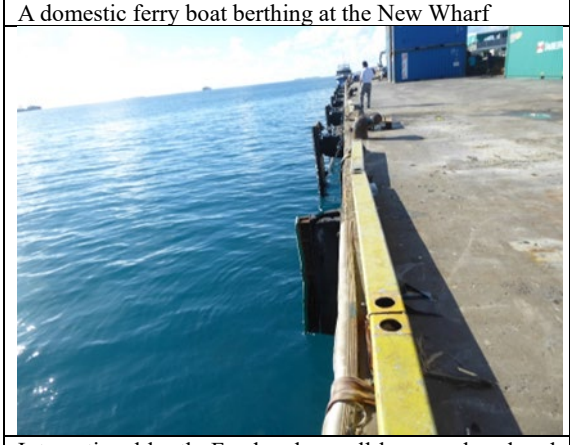
	
A domestic ferry boat berthing at the New Wharf	View of domestic berth from the access bridge
	
International berth. Fenders have all been replaced and surface of berth is in good condition.	Inner harbor area, Back side of international berth is also well maintained.

Figure 3.2-3 Survey photos of the New Wharf（taken by expert team in 2024）

Old wharf design documents could not be obtained from MTEC. The expert team conducted a site survey (photos are shown in the Figure below.) Drone photography was not allowed as Funafuti port is located near the airport.



View of the Old wharf from the New Wharf



Cargo devanning work from a container inthe yard. The yard is unpaved. Cargo is placed on the muddy ground.



Seaside view from the base of Old wharf. The surface condition is reasonably good. Only a patrol boat is berthed.



Landside view from the Old wharf. No heavy cargo is stacked on the wharf.

Figure 3.2-4 Survey photos of the Old Wharf（taken by expert team in 2024）

(c) Assessing the current situation through on-site inspections

The JICA expert team conducted a site inspection with officers of MTECI on April 18, 2024. The current berthing vessel type and size is the same as the original design purpose. No damage signs of impact from vessels are observed. No subsidence or signs of collapse in the apron pavement, and no abnormal noise or vibrations were observed. Accordingly, the wharf is in sound condition.

On the other hand, the Old wharf is in poor condition. Damage caused by the impact of berthing vessels was observed on the upper surface of the deck. Critical concrete spalling and detachment, as well as exposure and corrosion of the reinforcing steel, had progressed underneath the deck. The Old Wharf has lost its original structural integrity and is currently unable to accommodate

any heavy cargo or cargo vessels.

In addition, the container yard at Funafuti port remains unpaved and is not in a suitable condition for container storage. Figure 3.2-5 presents a series of photographs showing the container yard behind the wharf and the deterioration condition of the Old Wharf. Due to insufficient yard space, containers are being stacked along both sides of the commuter road just behind the wharves. A project to pave the yard by the World Bank is currently underway. MTECI officers closely worked together with JICA experts on the site survey. During the site survey, MTECI explained the current facility's physical condition and berth allocation on the wharves. JICA experts identified the important check points of the facilities during the site survey.

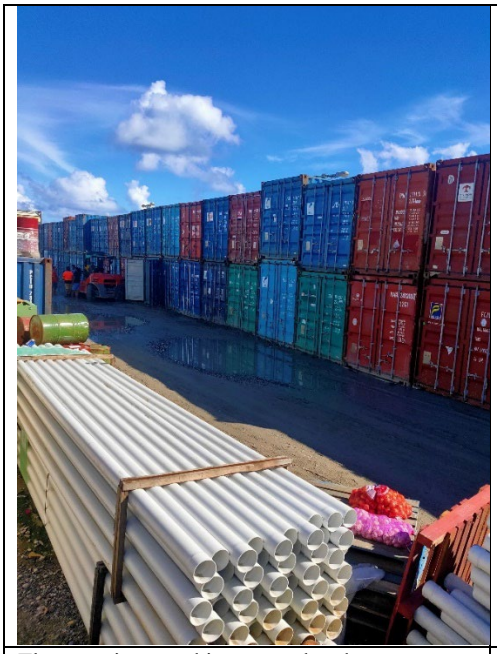
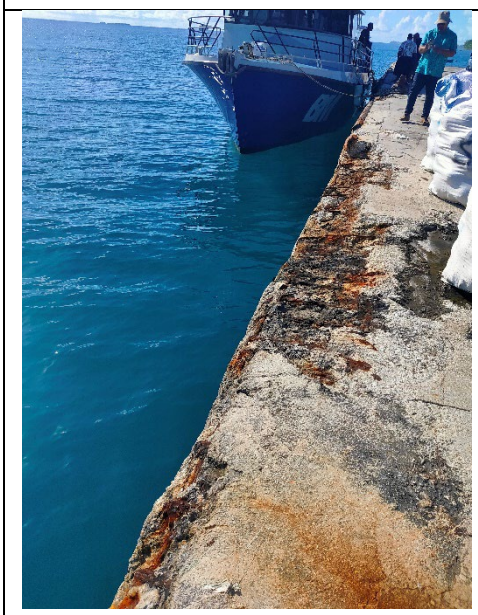
	
The container yard is unpaved and uneven, making it unsuitable for container storage.	The container yard is extremely dangerous for the loading/unloading works, and operation of container handling equipment.
	
The surface of the deck of the Old Wharf is severely deteriorated due to the impact from berthing ships.	The underside of the deck of the Old Wharf has peeling and falling concrete, with exposed and corroded rebar. Structural integrity has been lost.

Figure 3.2-5 Deterioration of the Old wharf in Funafuti port

3.2.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) at Funafuti port

(1) Collection of data on damage caused by past natural disasters

In this section, we will collect reports on the disasters, and compile information on natural disasters that affected Funafuti port over the years. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss.

(a) Sea level rise, cyclone and high wave

First, we will review the natural disaster risks across Oceania based on "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[31]". AR6 reports that the occurrence proportion of strong tropical cyclones (categories 3 to 5) among all tropical cyclones globally has increased in the last 40 years, with a moderate level of confidence. AR6 indicates low confidence in the long-term trends of the increasing frequency of tropical cyclones across all categories. In addition, AR6 mentions that the global mean sea level has been rising more rapidly since 1900 than at any other 100-year time in the past 3,000 years, with high confidence.

Next, we will list the major cyclones that have caused critical damage to Tuvalu in chronological order of their occurrence. Tuvalu has repeatedly suffered significant damage from cyclones. Cyclone *Bebe*, which struck in 1972, is considered one of the worst disasters in recent history and reportedly caused six fatalities. In 1997, Tuvalu was devastated by three cyclones—*Gavin, Hina,* and *Keli*. Approximately 40% of homes and the runway were submerged in 2004 and 2006. Cyclone *Pam*, which occurred in 2015, damaged real estate, household appliances, plantations, and livestock, resulting in an estimated loss equivalent to nearly 20% of the country's GDP. At Funafuti port, coastal erosion occurred, part of the warehouse roof was damaged, and both fenders and navigation lights required replacement. Cyclone *Tino*, which hit in 2020, caused storm surges, flooding, and inundation, forcing many residents living near the western coastline to evacuate inland. In coastal areas, flooding and inundation have damaged crops.

(b) Earthquake, Tsunami and volcanic activity

World Bank reported that Oceania was exposed to high risk of tsunamis, earthquakes, and volcanic activity[32]as shown in Figure 3.2-6 to Figure 3.2-8. Tuvalu is in the "Pacific ring of fire" and exposed to earthquakes and tsunamis. The risk from volcanic activity may be considered minimal due to its considerable distance from volcanic sources. However, the earthquake peak ground acceleration in Tuvalu falls in the range of 0.1 to 25 cm/s² or less, indicating a low but

[31] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[32] Pacific Maritime Transport Systems Hazard Exposure Technical Note, World Bank. 2023.

non-negligible seismic hazard. (see Figure 3.2-7). Tsunami maximum inundation height (MIH) for a 50-year return period in Tuvalu falls in the 0.1 to 0.50 meter range (see Figure 3.2-6). However, as the country is surrounded by tectonic plate boundaries, it remains at risk of being affected by tsunamis generated by distant earthquakes. In fact, a tsunami reached Tuvalu following an earthquake that struck Papua New Guinea in 1899. Measures against earthquakes and tsunamis should be urgently introduced. The expert team requested MTECI to provide meteorological and oceanographic data which are indicators of the scale of natural disasters. However, the data could not be obtained.

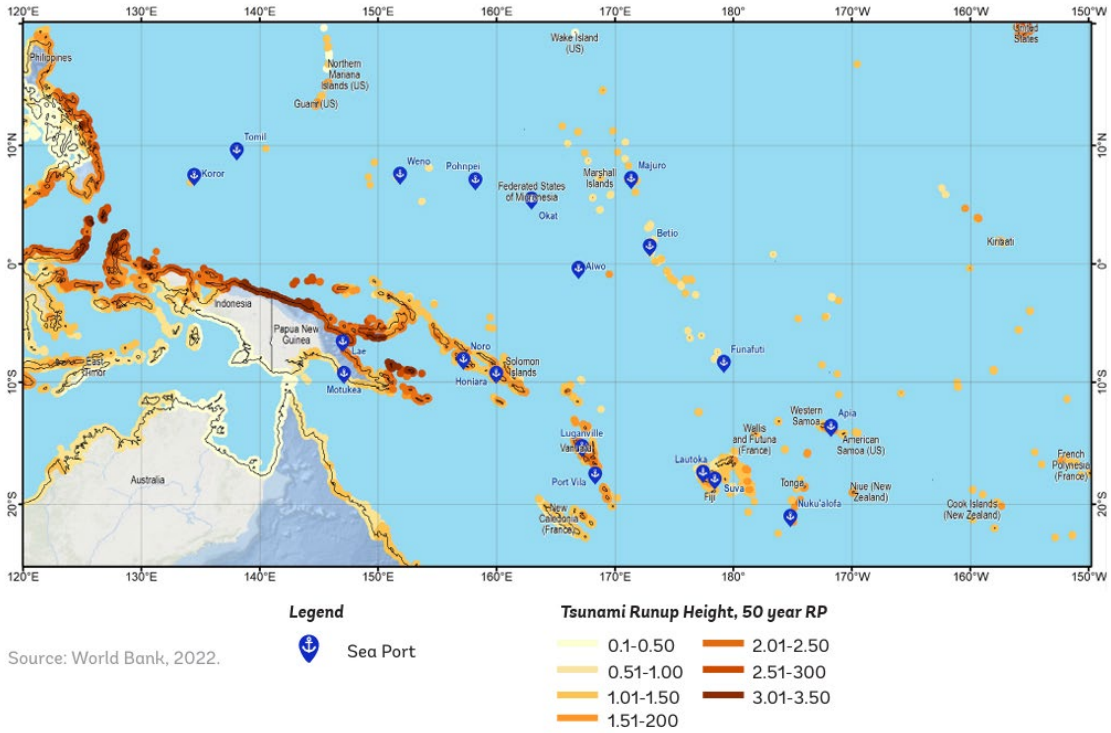


Figure 3.2-6 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

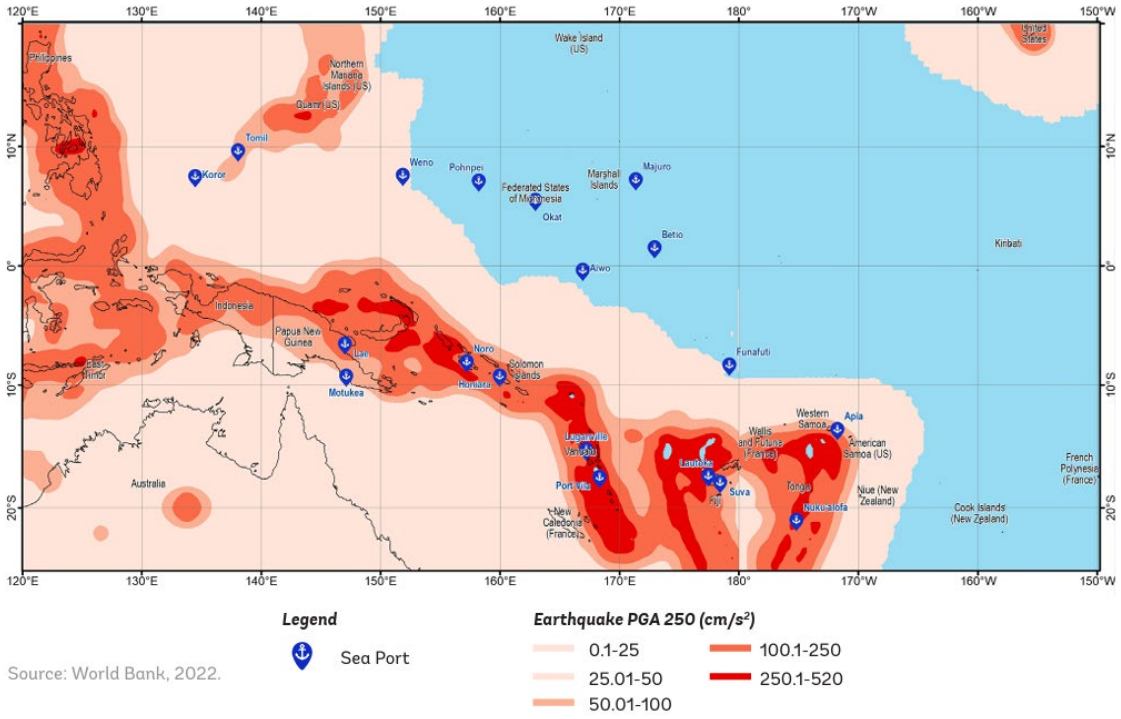


Figure 3.2-7 Earthquake peak ground acceleration (PGA) in cm/s2 for a 250-year return period

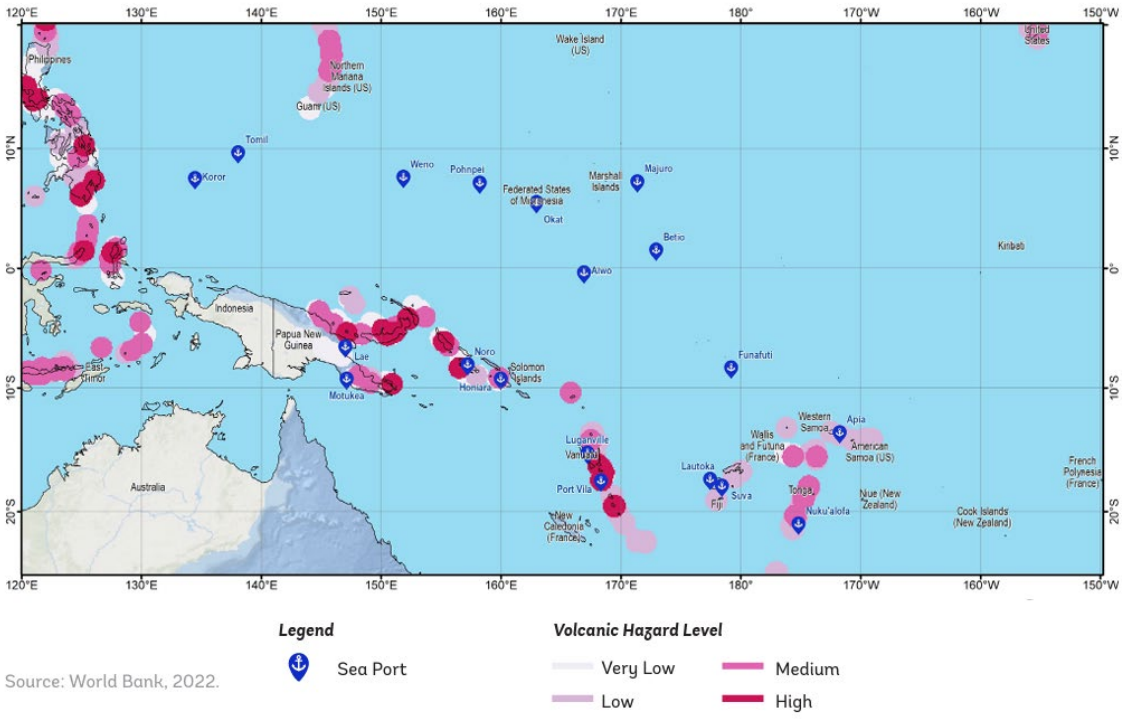


Figure 3.2-8 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

(2) Organization of external force conditions in the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in Funafuti and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters. The design conditions, including natural conditions and design loads, at the time of construction of the existing facilities at Funafuti port have been obtained by referring to JICA's *Basic Design Study Report on the Project for the Improvement of Funafuti port in Tuvalu*[33] (2007).

Deck Level: DL+4.60 m
- Tide Level:
  - Highest high water level (H.H.W.L) D.L.+3.26 m
  - High water level (H.W.L) D.L. +2.99 m
  - Low water level (L.W.L) D.L. +0.99 m
- Wave Force:
  - Design wave height $H_{1/3}$=2.1m Period T=5.6sec
  - Maximum wave height H_{max}=3.8m Period T=5.6sec
- Water depth: -8.0m to -1.5m
- Design vessels:
  - Length overall = 100 m
  - Full load draught dmax = 6.7 m
  - Displacement tonnage 3,000 tons
  - Tractional force 350 kN
  - Approaching velocity v = 0.15 m/s
- Live load conditions
  - Surcharge Jetty: 20kN/m^2
- Geotechnical Conditions: Coral rock 6.1-27.9MPa (16.5MPa on average)
- Seismic condition: No earthquakes have been recorded in Tuvalu, and seismic forces are not considered in structural calculations for architecture and civil engineering within the country.

The JICA study report also states that the top elevation of the Old Wharf quay is DL +4.6 m.

3.2.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in Funafuti port based on the research papers and past records of natural disasters.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*[34]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for Funafuti port. This process will determine if the current port design fails to

[33] Basic Design Study Report on the Project for the Improvement of Funafuti port in Tuvalu, 2007. https://libopac.jica.go.jp/images/report/11852365_01.pdf
[34] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

account for important natural disasters or underestimates the risk of natural hazards.
According to Table 3.2-2, the area around Funafuti port in Tuvalu is surrounded by coral reefs, which limits the fetch required for wave development. However, due to the low elevation of the land, the risk of inundation caused by storm surges and high waves during regional storm events is assessed as moderate. In contrast, the risk levels for maximum tsunami run-up height and for earthquakes are considered low, and the wave height associated with tropical cyclones is rated even lower. Although sea level rise itself does not pose an immediate threat of direct damage, it may increase the risks associated with storm surges, cyclones, and high waves. Additionally, since there are no volcanoes in the vicinity of the Funafuti Atoll, volcanic hazards are not considered a relevant risk.

According to the classification, earthquakes are less frequent and of smaller magnitude compared to other pacific countries. However, tsunami height is classified as 1.1 meters and thus presents a risk for a low ground level island country such as Tuvalu. The country is surrounded by tectonic plate boundaries, and it remains at risk of being affected by tsunamis generated by distant earthquakes. In fact, a tsunami reached Tuvalu following an earthquake that struck Papua New Guinea in 1899. It is important to prepare for a potential future earthquake and tsunami. The current port facilities were designed without considering the critical damage which a tsunami could inflict on the port and economy. Countermeasures to mitigate the damage to port facilities in the event of a tsunami should be examined as soon as possible. For example, cargo could flow out of the yard into the sea due to a tsunami, making it difficult for rescue boats and/or commercial ships to enter the port. In addition, continuous tsunami flow will scour the front and back side of facilities base and make the facility unstable.

According to the classification, the risk associated with volcanoes is “not applicable”. Since there are no volcanoes in the vicinity of Funafuti Atoll, volcanic hazards are not considered a relevant risk.

The risk of high waves from cyclones around Funafuti port is “very low” among the pacific ports. Additionally, the risk of regional storm wave height and coastal flooding is “medium”. The sea level rise is 0.27 meters in 2050. This figure is one of the highest numbers in the Pacific. Recent records also indicate that several strong cyclones attacked Tuvalu and caused serious damage. Due to the low elevation of the land, it is important to monitor the effect of cyclones and storm surges on port facilities. In addition, available research on the magnitude of sea level rise and wave power due to climate change will be examined and measures to prevent waves from overflowing into the yard will be introduced if deemed necessary.

Table 3.2-2 Multi-hazard Heat Map Port Exposure (Tuvalu)

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5. 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High | Medium | Low | Very Low | Not applicable

Table 3.2-3 Methodology for Identifying Natural Disasters and their Scales (Funafuti port)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Not considered in the design	Not applicable	Although Funafuti is located far from major seismic sources, tsunamis can propagate over a wide area. Therefore, tsunamis triggered by earthquakes should be objectively assessed.
Tsunami	Not considered in the design	Not applicable	Although Funafuti is located far from major seismic sources, tsunamis can propagate over a wide area. Therefore, tsunamis triggered by earthquakes should be objectively assessed.
Volcano	Not applicable (No active volcanoes are found around Tuvalu.)	Not applicable (No active volcanoes are found around Tuvalu.)	Not applicable (No active volcanoes are found around Tuvalu.)
Storm Surge	Highest high water level (H.H.W.L) : D.L.+3.26m High water level (H.W.L) : D.L. +2.99 m	Flood disasters increase due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later, can be used as one of the methods.
Cyclone	$H_{1/3}$=2.1m、$T_{1/3}$=5.6sec The 50-year return period wave estimated using wind data observed at Funafuti Airport from 1949 to 2006 and the fetch length within the lagoon.	Increase in high waves due to cyclone intensification.	Consider the increase in waves caused by cyclone intensification objectively. Recent research results, such as future predictions using d4PDF described later, can be used.

(2) Measures against sea level rise and wave power due to climate change

"Japanese port and harbor design standards" explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately determined using the latest research findings and scientific knowledge. Figure 3.2-9 illustrates two conceptual approaches for setting structural strength while considering changes in external forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as "Proactive adaptation." On the other hand, "Adaptive adaptation" refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life, but implementing physical upgrades progressively at appropriate times during the period, depending on material and structural characteristics.

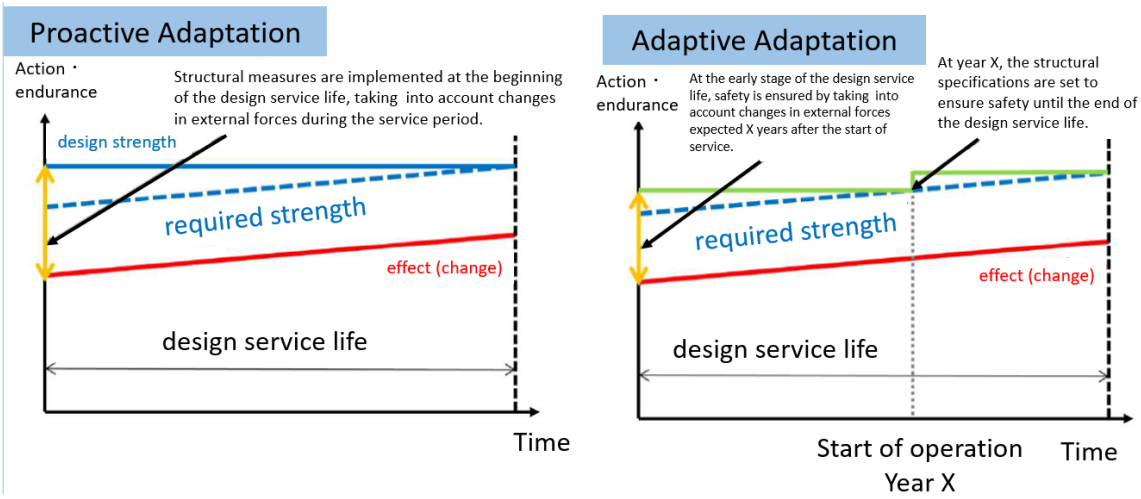


Figure 3.2-9 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

Due to the many uncertainties surrounding climate change, a range of scenarios has been discussed. For example, "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[35]" presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to

[35] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

"holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[36] as a basis when considering the impacts of climate change in port facility design. RCP2.6 corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. Figure 3.2-10 shows the projected median regional sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [37].

The projected sea level rise in Tuvalu is shown in Figure 3.2-11. By 2050, sea level rise in Tuvalu is projected to be 0.25 m under the 2°C scenario (SSP1-2.6) and 0.29 m under the 4°C scenario (SSP5-8.5), with a small difference of 0.04 m. On the other hand, by 2100, sea level rise is expected to reach 0.61 m under the 2°C scenario (SSP1-2.6) and 0.91 m under the 4°C scenario (SSP5-8.5), showing a larger difference of 0.30 m. Therefore, attention must be paid to the correspondence with the design service life. Additionally, since future projections contain uncertainties, it is necessary to understand the range of possible future outcomes.

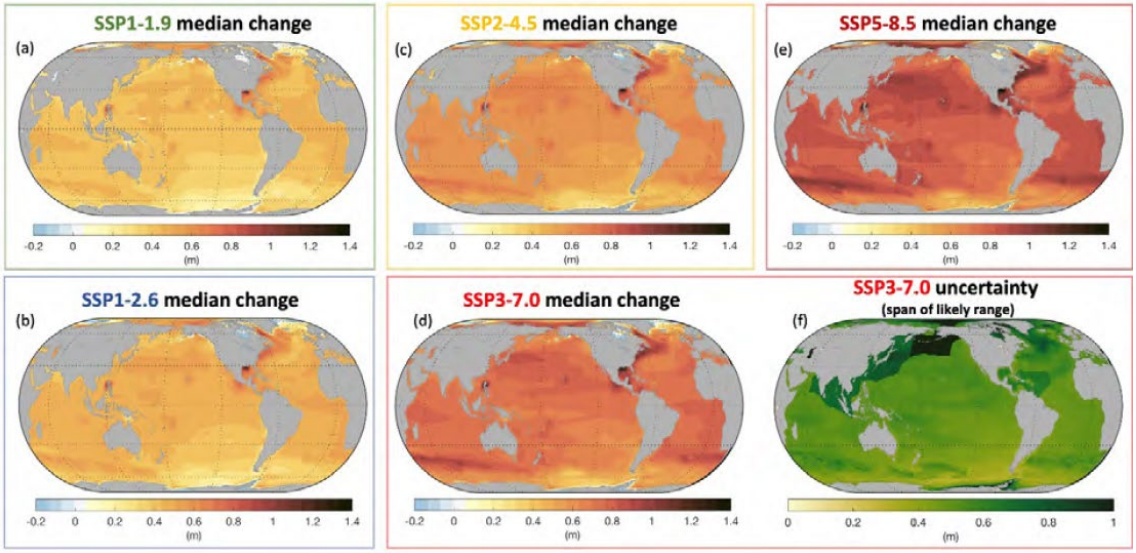


Figure 3.2-10 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

[36] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
[37] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

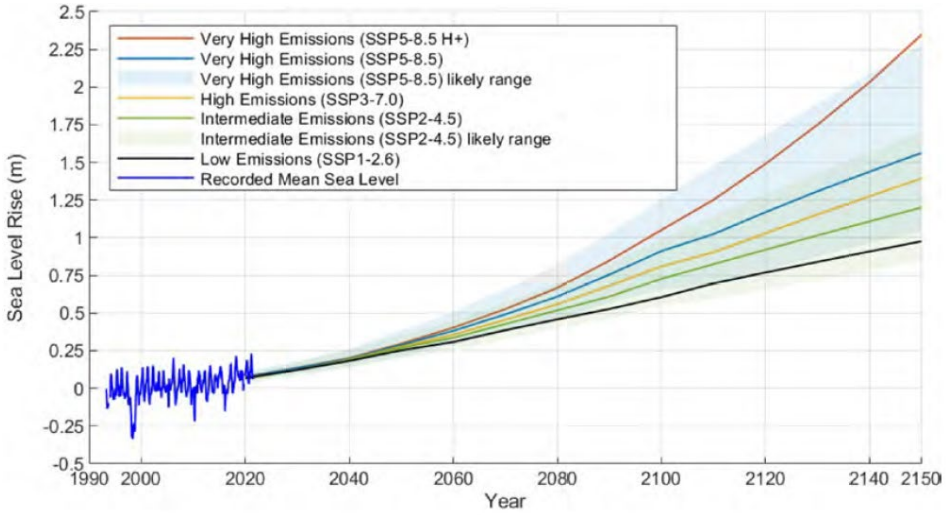


Figure 3.2-11 Sea Level Rise Projections to 2150 for Tuvalu Relative to 1995–2014 Mean Sea Level

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the “Database for Policy Decision-Making for Future Climate Change” (d4PDF, Mizuta et al. [38]). To predict future changes in extreme weather events such as typhoons due to climate change, a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing Waves and Coasts in the Pacific" (WACOP) project[39]. This project uses four climate models that participated in CMIP5. When considering storm surges and high waves, it is essential to

[38] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita, M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.
[39] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html(Accessed in July, 2024)

incorporate research findings, such as conducting wave simulations using these future climate models.

3.2.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing analysis on port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize MTECI's current disaster mitigation plans in terms of time frames and types of disasters.

(1) Classification of responses according to phase

In organizing the time frames for responding to disasters and climate change, we divided the time frames into "Medium- to long-term preventive measures" and "emergency response measures". The natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 3.2-4.

Table 3.2-4 Classification of adaptations and responses according to natural disasters

Type of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✔	—	✔
Tsunami	✔	—	✔
Volcano Eruption	Not applicable	—	Not applicable
Storm Surge	✔	✔	✔
Cyclone	✔	✔	✔

Through interviews with each port authority and the review of available design documents, the structure and development status of each target port, as well as the existence and operational status of disaster response plans, were examined. The design documents for the New Wharf were available, although they did not include any considerations for earthquakes or tsunamis.

JICA expert team sent questionnaires to each port authority to examine if disaster prevention or mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. Unfortunately, the expert team could not obtain any further detail information on disaster prevention or mitigation plans in Tuvalu.

3.2.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "Pacific Ports Vision 2030-2050 Recognition Framework"[40] shown in Table 3.2-5. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[40] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 3.2-5 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

Due to the limited survey period, JICA expert team could not obtain substantial data to evaluate the level of resilience indicators. Accordingly, the scores are low, however, we are ready to reevaluate them if reliable information is obtained.

(a) Natural disaster adaptation – Resilience indicator: Unengaged

The Old Wharf, constructed in 1980, is no longer usable due to age and deterioration. The New Wharf was constructed in 2009. High waves and tsunamis were considered in its design but the design should be reevaluated based on the current data on storm surge and high waves. Yard pavement and revetment in the back of the wharves are in the pipeline under the World Bank's

"Maritime Investment in Climate Resilient Operations" [41, 42] (hereinafter referred to as MICRO). Detailed information related to the national disaster conditions could not be obtained during our survey. Therefore, natural disaster adaptation is assessed as Unengaged.

(b) Climate change adaptation – Resilience indicator: Unengaged

The Old Wharf, constructed in 1980, is no longer usable due to age and deterioration. The New Wharf was constructed in 2009. Although high waves and tsunamis were considered in its design, the future impact of global warming was ignored. Consequently, the deck level of the New wharf is the same as that of the Old one. The design needs should be reevaluated based on the current data on storm surge and high waves. On the other hand, as mentioned above, yard pavement and revetment in the back of the wharves are in the pipeline under the World Bank's MICRO project. "Detailed information related to climate change adaptation could not be obtained during our survey. Therefore, climate change adaptation is assessed as Unengaged.

(c) Emergency response – Resilience indicator: Unengaged

World Bank's MICRO project is being carried out to support emergency response in Tuvalu. Under this project, an Emergency Action Plan (EAP) to ensure the functionality of port infrastructure and facilitate rapid recovery from a disaster at Funafuti port will be developed. The plan clearly defines the response procedures and responsibilities to be followed in the event of a disaster. However, the plan does not yet exist. Therefore, the resilience indicator is assessed as Unengaged.

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in Funafuti port in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

[41] https://projects.worldbank.org/en/projects-operations/project-detail/P161540 (accessed April 2025)
[42] https://projects.worldbank.org/en/projects-operations/procurement-detail/OP00310650 (accessed April 2025)

Table 3.2-6 Assessment of Impacts of Natural Disasters for Funafuti port

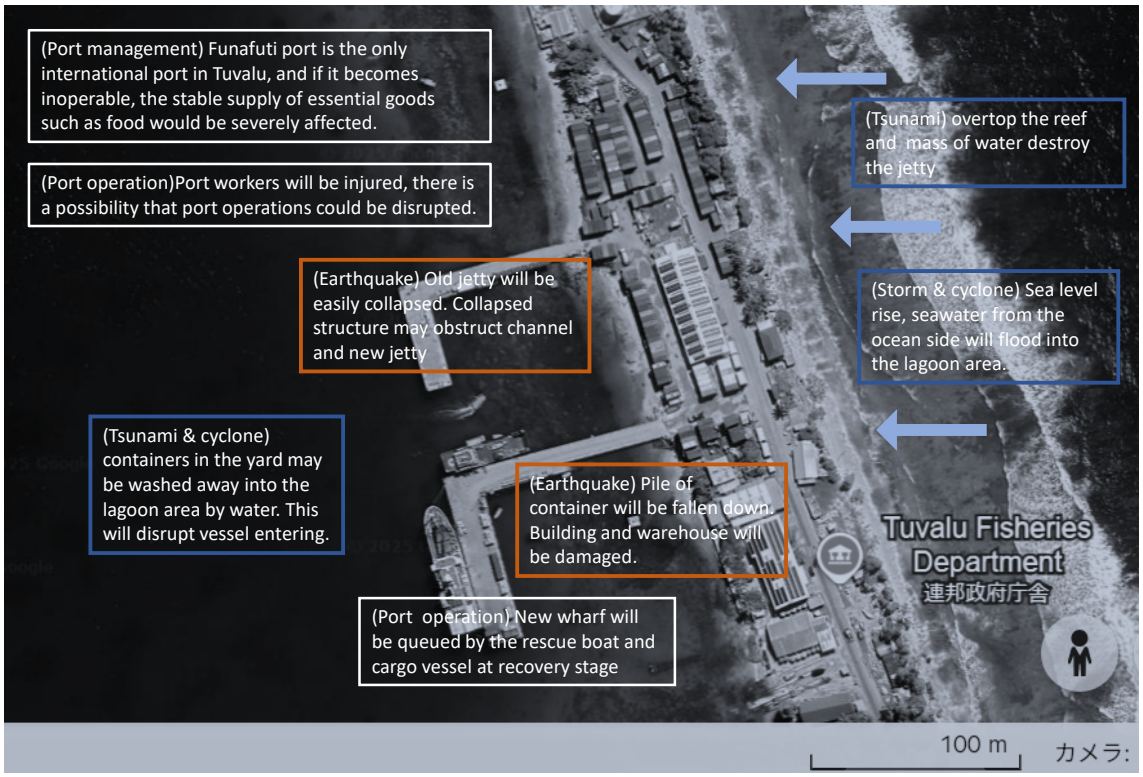
Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	Both the Old Wharf and the New Wharf at Funafuti port are of pier-type structure, and in the event of a earthquake, damage such as the destruction of pile heads and superstructure failure could occur. The Old Wharf is so deteriorated that it is no longer suitable for regular use. There is concern that the collapse of this structure during an earthquake could obstruct the approach channel and berth area of the New Wharf.	Funafuti port is the only international port in Tuvalu, and if it becomes inoperable, the stable supply of essential goods such as food would be severely affected. Tuvalu relies on inter-island ferries that operate on a regular basis, and a major earthquake could disrupt these transport links, making inter-island mobility difficult. The Old Wharf has structural capacity issues, making it difficult to maintain cargo handling functions for emergency relief supplies in the event of an earthquake.	Tuvalu has a small population, and the number of personnel involved in port operations at Funafuti port is limited. Therefore, if an earthquake causes injuries to the workers, there is a possibility that port operations could be disrupted.
Tsunami	Funafuti port is located within an atoll, and there is a possibility that a tsunami approaching from outside the atoll could overtop the reef and enter the lagoon. In such a case, the overtopping water mass may cause scouring around the foundation of the pier structure. In addition, the Old Wharf is so deteriorated that it is no longer suitable for regular use. If a tsunami enters from the ocean side, there is concern that containers may be	Funafuti port is located inside an atoll, and there is a possibility that a tsunami surging from the ocean side could enter the lagoon. In such a case, containers stored in the yard may be washed away into the lagoon area. The Old Wharf has structural capacity issues, making it difficult to maintain cargo handling	Tuvalu has a small population, and the number of personnel involved in port operations at Funafuti port is limited. Therefore, if a tsunami causes injuries to the workers, there is a possibility that port operations could be disrupted.

	washed away and that the backflow of waves could lead to structural failure. This, in turn, could result in blockage of the approach channel and berth area of the New Wharf.	functions for emergency relief supplies in the event of a tsunami.	
Volcano	No active volcanoes are present near Tuvalu, and therefore, volcanic activity poses no threat.	No active volcanoes are present near Tuvalu, and therefore, volcanic activity poses no threat.	No active volcanoes are present near Tuvalu, and therefore, volcanic activity poses no threat.
Storm Surge	Funafuti port is located in an open water area, so the impact of storm surge caused by wind setup is relatively limited. The port is located near the end of cyclone tracks, meaning that cyclones approaching the area are often in a weakened state. As a result, the central pressure tends not to drop significantly, and the suction effect of depression is generally minimal. The yard and backland areas of Funafuti port have low ground elevation and are therefore highly susceptible to sea level rise caused by climate change. During storm surges, there is a high possibility that seawater from the ocean side will flood into the lagoon area.	Funafuti port is located inside an atoll, and there is a possibility that a storm surge rising from the ocean side could enter the lagoon. In such a case, containers stored in the yard may be washed away into the lagoon area.	Tuvalu has a small population, and the number of personnel involved in port operations at Funafuti port is limited. Therefore, if a storm surge causes injuries to the workers, there is a possibility that port operations could be disrupted.
Cyclone	Funafuti port is located near the end of typical cyclone tracks, where approaching cyclones are often in a weakened state. Since the port is located inside an atoll, waves generated within the lagoon during cyclone events may directly impact port facilities.	Funafuti port is located inside an atoll, and there is a possibility that wave overtopping from the ocean side could enter the lagoon. In such a case, containers stored in the yard may be washed away into the lagoon area.	Tuvalu has a small population, and the number of personnel involved in port operations at Funafuti port is limited. Therefore, if a cyclone causes injuries to the workers, there is a possibility that port

	When waves act directly on the structures, there is a risk that the superstructure may be damaged due to uplift. The yard and backland areas of Funafuti port have low ground elevation and are therefore susceptible to sea level rise caused by climate change. There is a high possibility that large waves generated by cyclones may overtop the reef from the ocean side and allow seawater to inundate the port area.		operations could be disrupted.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in Funafuti port. Figure 3.2-12 illustrates the natural disaster risks and resulting damage in the port. Containers may be washed into the lagoon by tsunamis or cyclones, potentially obstructing vessel entry. Tsunamis entering through the reef from the open ocean could destroy the Old Wharf. In the event of an earthquake, the Old Wharf is likely to collapse easily, and the resulting debris may block the navigation channel and impede operations at the New Wharf. Funafuti port is Tuvalu's only international port. If port operations are disrupted, the stable supply of emergency goods, daily goods, energy supplies would be jeopardized.

Therefore, the advisory team proposes to rehabilitate the Old Wharf to enhance resilience capacity of the port. Our proposal could eliminate the risk of the old wharf collapsing and enhance the port backup function in case either wharf becomes unusable. In addition, this proposal also addresses the issue of berth congestion.



(Source: Google Earth with annotations by the JICA advisory team)

Figure 3.2-12 Geographical Assessment of Impacts of Natural Disasters for Funafuti port

3.2.6 Formulation of Port Resilience Strategy

In this sub-section, we will try to identify the reason why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans in Funafuti port.

(1) Confirmation of the reasons for staying with the current resilience indicators

The status of countermeasures against natural disasters, climate change adaptation, and emergency response, each evaluated using resilience indicators in Section 3.2.5, was reviewed and assessed based on the perspectives presented in the *Climate Change Adaptation Planning for Ports and Inland Waterways*[43] (hereinafter referred to as the PIANC Guide). The findings are presented below.

[43] Climate Change Adaptation Planning for Ports and Inland Waterways, PIANC, EnviCom WG Report No. 178-2020

(a) Natural disaster adaptation – Resilience indicators: Unengaged

Reason: Actions are not taken at Funafuti port to respond to the natural disasters at existing facilities.

- The goal(s), planning horizon, and objectives for natural disaster adaptation have not been established and agreed at Funafuti port.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has not been complete, and the potential impacts of natural disasters on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the natural disaster adaptation process for Funafuti port.

(b) Climate change adaptation – Resilience indicators: Unengaged

Reason: Actions are not taken at Funafuti port to address the climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed at Funafuti port.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has not been complete, and the potential impacts of climate changes on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate changes is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response – Resilience indicator: Unengaged

Reason: Stakeholders and relevant authorities have not been identified, and engagement for the development of an emergency response plan has not progressed.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at Funafuti port for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

(a) Natural disaster adaptation

- Establish goal(s), planning horizon and objectives for natural disaster adaptation at existing facilities in Funafuti port.
- Identify the impact of natural disasters on port assets, operations, and systems in Funafuti port.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information related to natural disaster intensity predictions and determine the extent of the natural disaster.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(b) Climate change adaptation

- facilities in Funafuti port.
- Identify the impact of climate changes on port assets, operations, and systems in Funafuti port.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information on natural disaster intensity forecasts including the effects of climate change and identify the extent of natural disasters with climate change impacts.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(c) Disasters and Emergency Response

Identify relevant internal and external stakeholders and take actions to engage them in the development of emergency response plans.

(3) Examples of countermeasures

The New Wharf at Funafuti port is currently in sound condition and remains in use without any issues. MTECI has replaced the rubber fenders by itself to secure the safety of berthing vessels. The surface of the berth pavement is well maintained. In contrast, the Old Wharf has already deteriorated significantly. Given the limited financial resources, proper maintenance must be carried out by developing a preventive maintenance plan that considers the condition of deterioration, usage status, and priority of each facility. By implementing improvement works in a planned and efficient manner based on such a maintenance plan, it will be possible to reduce maintenance costs and extend the service life of the facilities.

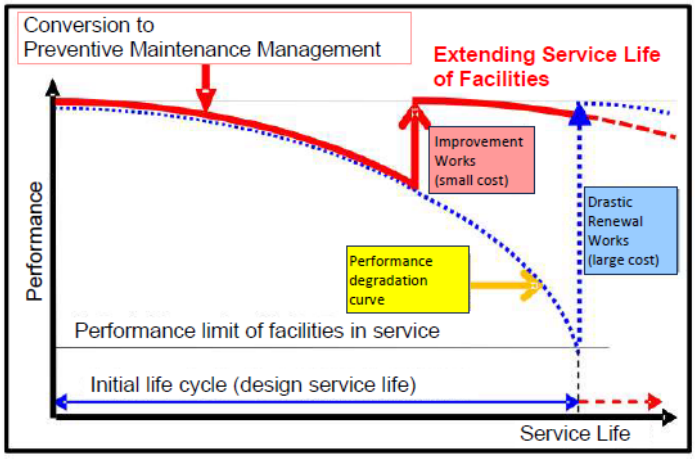


Figure 3.2-13 Preventive maintenance [44]

[44] https://www.cdit.or.jp/english/news/20230525.html

(4) Summary of Port Resilience Strategy in Funafuti port

The key measures to be considered in the port resilience strategy for Funafuti port are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in Funafuti port is evaluated as "Unengaged."
In order to achieve a higher level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for existing facilities at Funafuti port in terms of their natural disaster adaptation.
It is recommended to identify the impact of natural disasters on port assets, operations, and systems at existing facilities Funafuti port, collecting information necessary to understand the baseline situation, and specifying information necessary for natural disaster risk assessment in order to prepare for the formulation of a natural disaster adaptation plan.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in Funafuti port is evaluated as "Unengaged."
In order to achieve the next level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for climate change adaptation.
It is recommended to collect information on natural disaster intensity forecasts that include the impact of climate change in order to identify the impact of climate change on the port assets, operations, and systems of Funafuti port and to understand the baseline situation.

(c) Disasters and Emergency Response

The resilience indicator (KEY RESILIENCE INDICATOR) outlined in the "PACIFIC PORT VISION 2030-2050 RECOGNITION FRAMEWORK" for emergency response in Funafuti port is evaluated as "Unengaged."
In order to achieve the next level of resilience indicator, it is recommended to develop an emergency response plan for natural disasters at the existing facilities of Funafuti Port and to take actions to engage relevant stakeholders in the planning process.

(d) Port resilience measures in Funafuti port

(i) The Old Wharf Rehabilitation Plan for Port Resilience

Even though Funafuti port is Tuvalu's only international port and serves as a domestic hub port for remote islands, only the New Wharf is currently in operation. Due to the insufficient berth window, vessels sometimes must wait for a berth to become available, disrupting vessel schedules and cargo handling. Domestic vessels are often forced to give priority to international vessels. In

addition, the Old Wharf cannot currently be used for cargo handling operations. The redundancy of port functions is highly needed in case of emergencies or disasters to ensure a stable supply of emergency goods. Therefore, JICA experts will propose the rehabilitation of the Old Wharf.

(ii) Assumed Specifications of Entering Vessels

At the coral reef area, the actual water depth is 12 meters, but the vessel draft is limited to 10 meters or less for safety reasons. In addition, the water depth in front of the quay is between 7 and 8 meters. If a quay depth of 12 m can be secured, transport efficiency will improve. MTECI requested a movable ramp for RORO ships, berth space for oil tankers, and extending a pile-supported yard between the New Wharf and the existing facility. The average specifications of vessels entering Funafuti port, estimated from their DWT, are 102 meters in length and 6.4 meters in draft for tankers, and 137 meters in length and 8.2 meters in draft for cargo ships. While future vessel trends need to be considered, for now, it is necessary to ensure sufficient quay length and depth to accommodate these vessels.

Table 3.2-7 Specifications of Vessels Entering Funafuti port

Ship Type	Number of Ships	Number of Calls	Total DWT	Average DWT	Standard LOA (m)	Standard Draft(m)
Combined chemical and oil tanker	1	8	45,648	5,706	102	6.4
Fully cellular containership	2	10	74,906	7,491	N/A	N/A
General cargo with container capacity	2	14	123,080	8,791	137	8.2

(iii) Assumed conditions

JICA expert team proposes a pile-type pier structure, the same as the New Wharf. The current water depth in front of the New Wharf is approximately 7 to 8 meters. If a water depth of 12 meters can be secured in front of the pier, vessels with a draught of 10 meters would be able to berth, which could contribute to improved transport efficiency. Accordingly, the JICA team plans an I-shaped pier with a total length of 190 meters rather than the existing L-shaped pier, which enables two vessels with a draught of 10 meters to berth on both sides. To ensure safe cargo handling operations on the pier, the pier width is set at 20 meters. In addition, a yard with a pier-type structure measuring 30 meters in length and 80 meters in width is planned for the storage of cargo and containers. The proposed plan is shown in Figure 3.2-14.

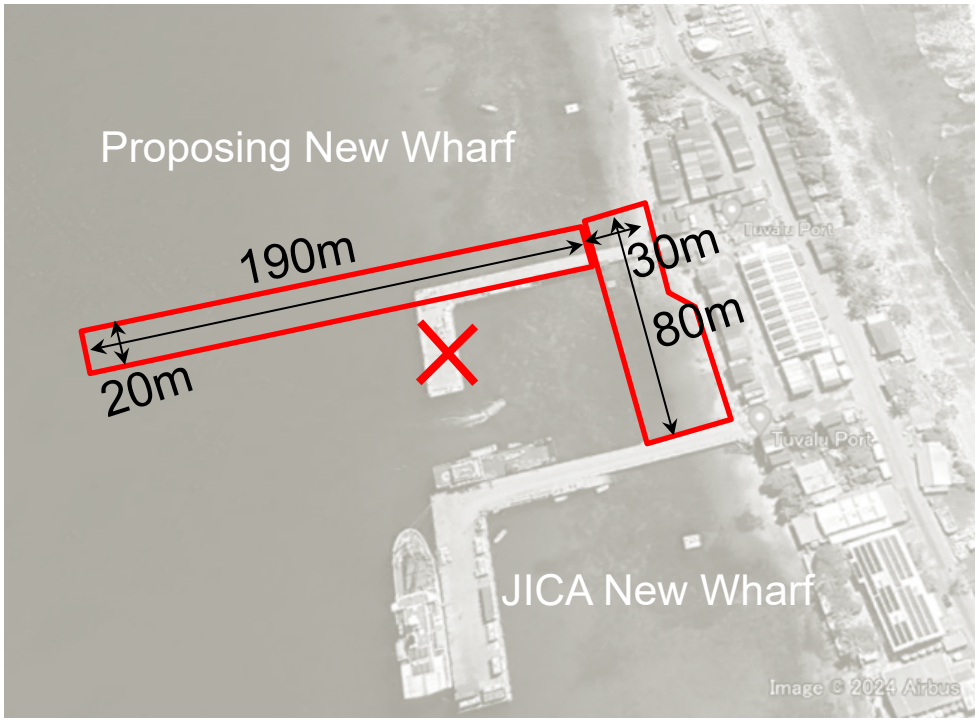


Figure 3.2-14 Plan on Old Wharf rehabilitation (draft)

(iv) Summary of draft plan

The conceptual cross-sectional views of the jetty section and yard section are shown in Figure 3.2-15 and Figure 3.2-16, respectively. The construction quantities for the rehabilitation work are presented in Table 3.2-8 and Table 3.2-9. The preliminary construction cost for both the jetty section and the yard section amounted to 12.9 million USD (approximately 1.94 billion JPY). The exchange rate used for the estimation was 150 JPY per USD. It should be noted that this cost does not include the removal of the existing Old Wharf.

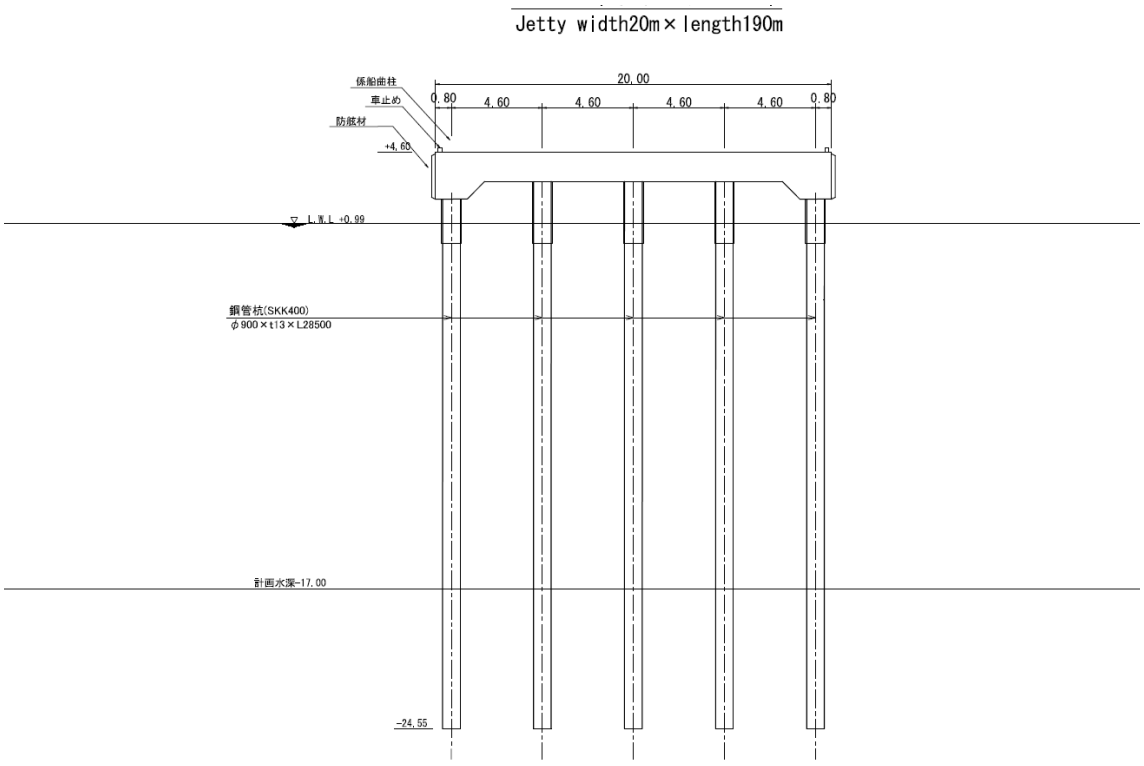


Figure 3.2-15 Cross-section of the new pier (jetty section)

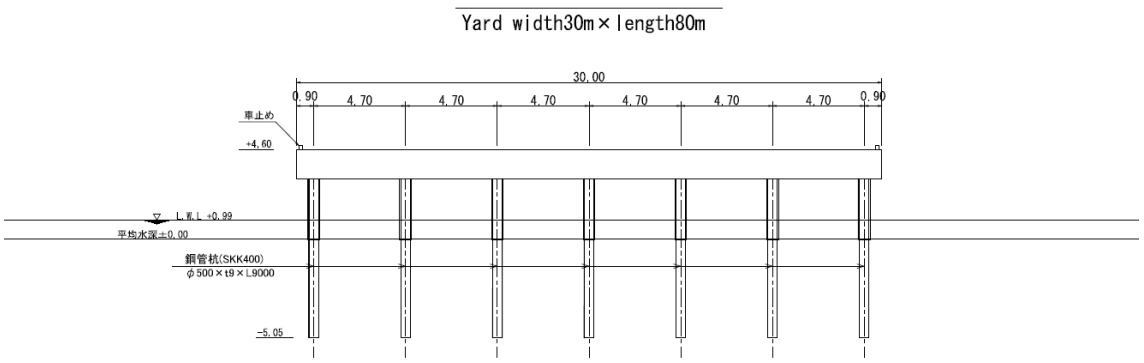


Figure 3.2-16 Cross-section of the new pier (yard section)

Table 3.2-8 Estimated Construction Cost for Jetty Section Rehabilitation

Rough Estimate for Jetty

Description	Unit	Quantity	Unit Price	Total Amount	Remarks
Steel Pipe Pile	ls	1.00		2,890,500	per meter of Jetty
Pile guide installation and removal	m	4.00	62,000	248,000	
Steel Pipe Pile φ900×t13×L28.5m(SKK400)	nos	1.25	1,714,000	2,142,500	
Driving of Steel Pipe Pile φ900×t13×L28.5m	nos	1.25	400,000	500,000	
Cast in Place Concrete	ls	1.00		1,585,200	per meter of Jetty
Concrete Pouring 240-12-25	cu.m	13.30	44,000	585,200	
Formworks and Temporary supoport installation and removal	sq.m	20.00	50,000	1,000,000	
Fenders and Bollards	ls	1.00		560,000	per meter of Jetty
Supply and Installation	ls	1.00	560,000	560,000	
Cathodic Protection	ls	1.00		387,500	per meter of Jetty
Supply and Installation Aluminum Anode, 3A, Lifetime 50 years	nos	1.25	310,000	387,500	
Subtotal				5,423,200	per meter of Jetty
Expenses (50%)	ls	1.00		2,711,600	per meter of Jetty
Unit Price per meter of Jetty	**m**	**1.00**		**8,134,800**	
Total Amount **Berth Length L=190m**	**m**	**190.00**	**8,134,800**	**1,545,612,000**	JPY
				10,304,080	US$

Table 3.2-9 Estimated Construction Cost for Yard Section Rehabilitation

Rough Estimate for Yard

Description	Unit	Quantity	Unit Price	Total Amount	Remarks
Steel Pipe Pile	ls	1.00		1,124,750	per meter of Berth
Pile guide installation and removal	m	4.00	62,000	248,000	
Steel Pipe Pile φ500×t9×L9.0m(SKK400)	nos	1.75	221,000	386,750	
Driving of Steel Pipe Pile φ500×t9×L9.0m	nos	1.75	280,000	490,000	
Cast in Place Concrete	ls	1.00		1,800,175	per meter of Berth
Concrete Pouring 240-12-25	cu.m	17.03	47,000	800,175	
Formworks and Temporary supoport installation and removal	sq.m	20.00	50,000	1,000,000	
Fenders and Bollards	ls	1.00		0	per meter of Berth
Supply and Installation	ls	0.00	0	0	
Cathodic Protection	ls	1.00		358,750	per meter of Berth
Supply and Installation Aluminum Anode, 2A, Lifetime 50 years	nos	1.75	205,000	358,750	
Subtotal				3,283,675	per meter of Berth
Expenses (50%)	ls	1.00		1,641,838	per meter of Berth
Unit Price per meter of Berth	**m**	**1.00**		**4,925,513**	
Total Amount **Berth Length L=80m**	**m**	**80.00**	**4,925,513**	**394,041,000**	JPY
				2,626,940	US$

(vi) **Notes and issues in draft plan**

It should be noted that the preliminary study conducted in this survey is based on the following assumptions, and further detailed study will be necessary in the design stage.

1. Demand Forecast and Terminal Capacity: this preliminary study was carried out based on limited operational information. Therefore, a more detailed and accurate analysis is required regarding future demand forecasts and the operational efficiency of terminal functions.
2. Limited Design Conditions: the design conditions in this study were set based on the 2007 design documents[45] for the New Wharf. However, in the basic design stage, it will be necessary to properly investigate, assess, and evaluate geotechnical and natural conditions to determine appropriate cross-sectional designs.
3. Assumptions for Cost Estimation: the current cost estimate includes assumed impacts of exchange rate fluctuations and inflation. Nevertheless, the basic design study must confirm local unit prices around Funafuti port, including construction material costs, machinery rental rates, and labor costs.
4. Exclusion of Existing Wharf Removal Costs: the removal cost of the existing Old Wharf has not been included in the current estimate. The basic design study should assess appropriate removal methods and validate the associated removal costs.

[45] Basic Design Study Report on The Project for Improvement of Funafuti Port in Tuvalu, JICA, 2007

4. Kingdom of Tonga

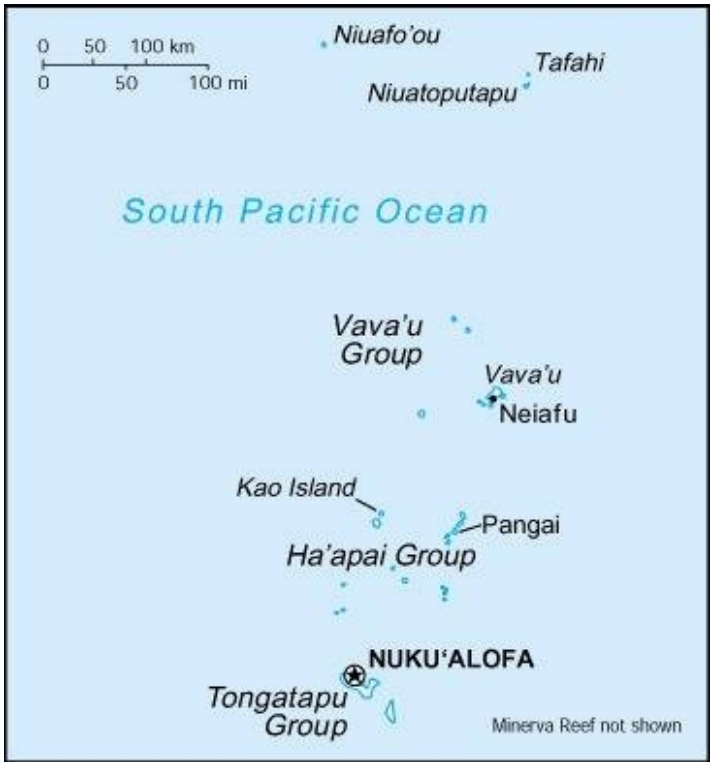
4.1 Overview of the Country and its Major Ports and External Relations

4.1.1 Country Overview

The Kingdom of Tonga (hereafter referred to as "Tonga") is an island nation located in the South Pacific, consisting of 172 islands of varying sizes. Tonga has an exclusive economic zone of 700,000 km², a land area of 720 km², and a population of approximately 100,000. The country is composed of four main island groups: Tongatapu, Ha'apai, Vava'u, and Niuas, from south to north. The Tongatapu group includes Tongatapu Island, where the capital Nuku'alofa is located. Tongatapu Island has an area of 259 km² and a population of approximately 70,000. The Tongatapu group also includes 'Eua Island, which is located about 40 km southeast of Tongatapu Island. 'Eua Island has an area of 87 km² and a population of about 5,000. Over 70% of the country's population resides on these islands.

The average annual temperature is 25°C, and from 2004 to 2013, the average annual rainfall was about 1,800 mm. The period from January to March is the cyclone season, when cyclones that form near the equator develop and move rapidly southward. The most recent major cyclone was Cyclone Ian, which made landfall in January 2014. Cyclone Ian passed northeast of the Ha'apai group and caused extensive damage to homes, infrastructure, and crops across Ha'apai. Cyclone Gita struck in February 2018, recording wind speeds of 60 m/s. The cyclone caused flooding due to a storm surge of about 1 meter and continuous rainfall for 24 hours, with total damages estimated at approximately US$164 million, or about 38% of Tonga's GDP.

Tonga is also close to the Tonga Trench, and as a result, the country experiences frequent earthquakes and volcanic activity. In January 2022, a large eruption occurred at an undersea volcano located about 65 km north of Tongatapu Island. The eruption triggered a tsunami, which caused damage in various parts of Tonga. As such, Tonga faces high risks of natural disasters, including cyclones, earthquakes, and tsunamis, making disaster prevention measures crucial across the entire country.



Source: https://www.cia.gov/the-world-factbook/countries/tonga/map （Accessed: January 2024）

Figure 4.1-1 Tonga location map

4.1.2 Economic and Social Conditions

Tonga's financial situation is dependent on foreign aid, and it also heavily relies on remittances from migrant workers. The government is keen on developing new export crops. Following the success of pumpkins, the government is actively conducting market research and investigating export procedures to other countries. Additionally, the government is focusing on quality control of the products.

4.1.3 Overview of Port Administration

(1) Port Administration Organization

Nuku'alofa port, located on Tongatapu Island where the capital is situated, is managed and operated by the Ports Authority Tonga (PAT), which was established by the Port Authority Act of 1998. All other ports are managed and operated by the Marine and Ports Division of the Ministry of Infrastructure (MOI).

(2) List of Port-related Authorities

- Overall Maritime Supervision: Marine and Ports, Ministry of Infrastructure
- Law Enforcement: Tonga Port Authority

- Human Resource Development: Tonga Maritime Polytechnical Institute (TMPI)
- Ports: Tonga Port Authority
- Marine Pollution Prevention: Ministry of Marine and Ports の Port Administration and Police Department

(3) Overview of Major Ports

Tonga's main ports are located in Nukuʻalofa on Tongatapu Island, Neiafu in the Vavaʻu Islands, and Pangai in the Haʻapai Islands. As mentioned earlier, Nukuʻalofa Port is under the jurisdiction of the Port Authority Tonga (PAT), while the other ports are managed by the Ministry of Infrastructure (MOI). Nukuʻalofa Port is an international port that meets the operational requirements of the International Maritime Organization (IMO). Tonga, consisting of over 170 islands, relies on maritime routes for 98% of its imports, and approximately 90% of Tonga's international trade is conducted through Nukuʻalofa Port.

Table 4.1-1 Overview of Major Ports in Tonga [46]

Island Name	Port Name	Administrator	Characteristics of the Port
Tongatapu Port	Nukuʻalofa Port	PAT	Hub Port, Trade Port, International Tourist Port, Local Port
Vavaʻu Islands	Halaevalu Port	MOI	Hub Port, Trade Port, Local Port
Haʻapai Islands	Taufaʻahau Port	MOI	Hub Port, Trade Port, Local Port
	Prots Port	MOI	Regional Hub Port, Local Port
Niuas Islands	Futu Port	MOI	Regional Hub Port, Local Port
	Pasivulangi Port	MOI	Regional Hub Port, Local Port
ʻEua Island	Nafanua Port	MOI	Regional Hub Port, Local Port

[46] Source：JICA「Preparatory survey report on the project for upgrade of wharf for domestic transport in the Kingdom of Tonga. in Japanese」March 2015

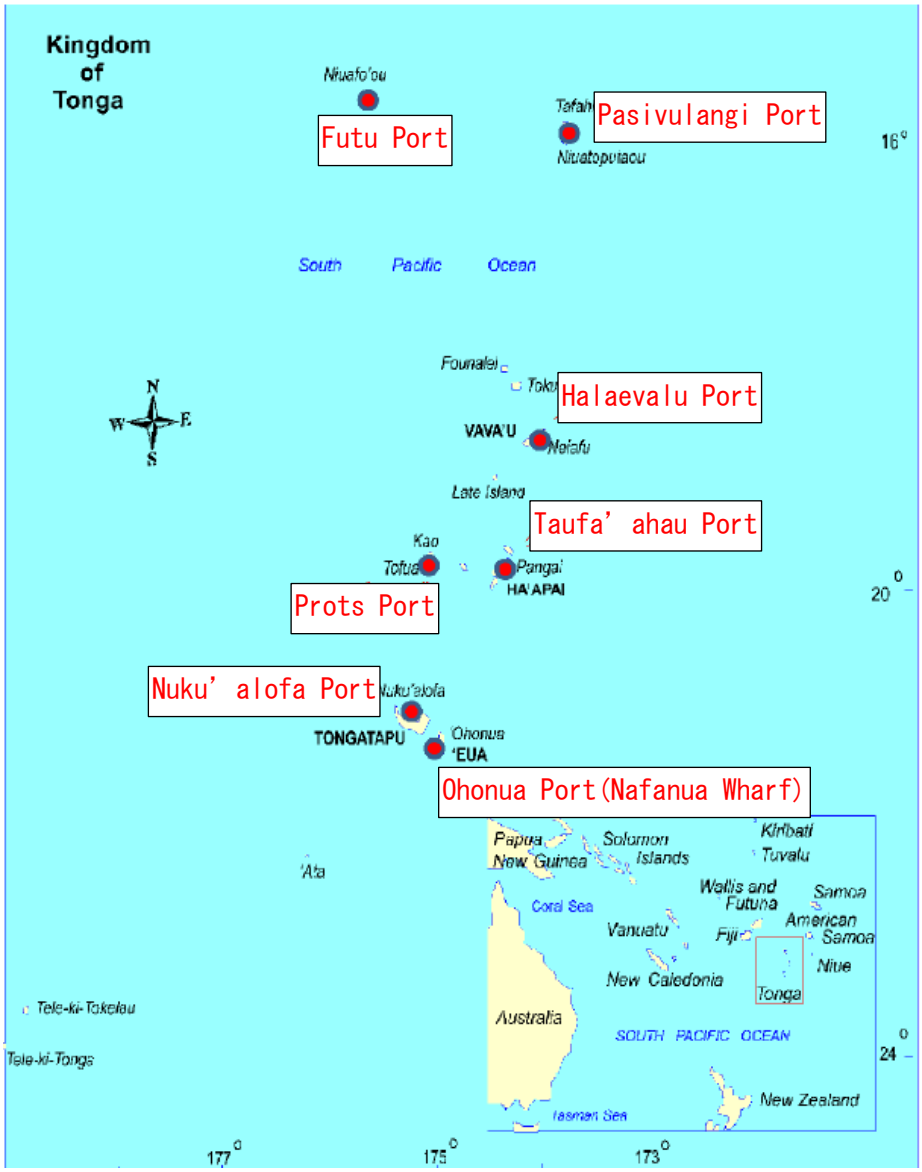


Figure 4.1-2 Location of major ports in Tonga

4.1.4 Cargo Handling Volume

Nuku'alofa port handles approximately 400,000 tons of cargo annually. In addition to 20 dedicated container ships per year, the port also receives general cargo ships and RORO ships. Altogether, approximately 120 cargo ships enter the port annually.

Table 4.1-2 Cargo Volume of Nuku'alofa Port

Fiscal year	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cargo volume (thousand tons)	238	249	290	334	409	383	431	383	412

Source: Port Authority of Tonga HP

Table 4.1-3 Number of Vessel Calls by Vessel Size and Type in Nuku'alofa Port

Ship type	Number of ships	Number of ship call	Total DWT	Total GT	Average DWT	Average GT
Ferry	1	1	37	244	37	244
Fishing (general)	7	68	0	2,537	0	37
Fully cellular containership	9	20	410,892	334,659	20,545	16,733
General cargo	3	24	47,120	38,188	1,963	1,591
General cargo with container capacity	9	62	762,759	630,714	12,303	10,173
Naval Auxiliary Vessel	1	2	0	0	0	0
Passenger ro/ro	1	1	322	420	322	420
Roll On Roll Off	1	1	529	5,864	529	5,864
Roll On Roll Off with container capacity	2	12	217,200	217,200	18,118	18,100
Supply	1	1	4,523	4,523	2,900	4,523
Tug	1	14	2,352	2,352	127	168
Vessel Type (unspecified)	2	53	0	0	0	0
Yacht	2	3	0	0	0	0
Total	40	262	1,443,647	1,236,701	5,510	4,720

Source: Lloyd's List Intelligence Seasearcher data (2021) Analyzed by OCDI

4.2 Neiafu Port in Vava'u Islands

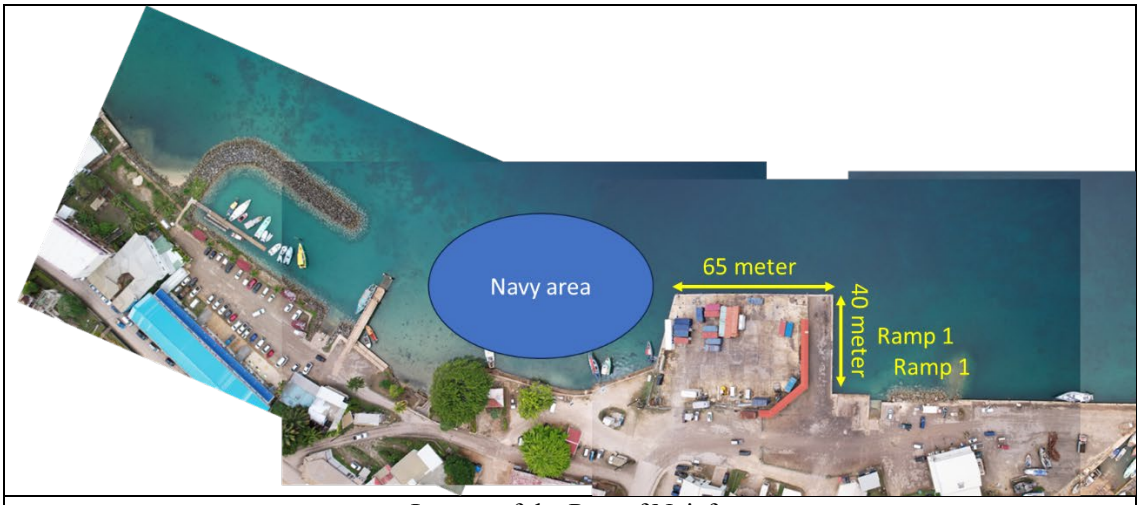
4.2.1 Review issues related to port maintenance and management

(1) Status of port facilities

The Vava'u Islands are located 275 km north of Tongatapu, the main island of Tonga, and consist of the main island of Vava'u and about 40 surrounding islands. Vava'u is a volcanic island, and its rugged coastline forms a good harbor. Neiafu is the second largest city in Tonga after Nuku'alofa, the capital. The beautiful scenery and picturesque harbor attract tourists, and marine sports such as yachting and whale watching are especially popular.

The container service is operated by Matson of NZ. The service was previously operated by Reef, which was acquired by Matson. Only 20ft containers are unloaded at the yard. Reefers are also only 20ft. Most of the cargo is imported. Exports consist of agricultural products such as kava, cassava, and fish but volumes are low. Most of the residents earn their income from farming (harvest) in NZ and Australia. There is no cargo handling equipment. A 40ft forklift and a top lifter should be procured at minimum. While a toplifter and a forklift are currently arranged by the agent, they are old and often break down. The international port (65 m in length) and the domestic port (40 m in length) are shown in Figure 4.2-1, the former being located in front while the latter is on the left side. The military port area can be seen on the right side of the wharf.

(a) Port Plan



Layout of the Port of Neiafu

(b) Port cross-section (survey photos, drone photos)

Design documents for Neiafu port could not be obtained from the Ministry of Infrastructure (MOI). Therefore, photographs taken during the site visit are presented in Figure 4.2-1.

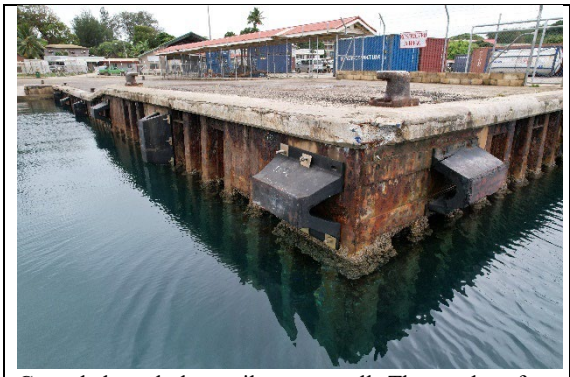


Source: (Photo taken by Survey team in 2024)

Figure 4.2-1 Panoramic View of Neiafu Port

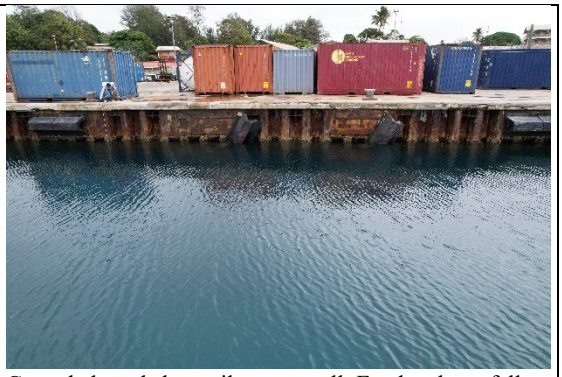
(c) Assessing the current situation through on-site inspections

The wharf at Neiafu port is a steel sheet pile quay wall. According to the site investigation, as shown in Figure 4.2-2, significant corrosion was observed on the sheet piles. In addition, partial damage to the superstructure was identified, possibly due to a vessel collision. Furthermore, as shown in Figure 4.2-3, two fenders had fallen off. MOI officers closely worked together with JICA experts on the site survey. During the site survey, MOI explained the current facility's physical condition and berth allocation on the wharves. JICA experts identified the important check points of the facilities during the survey.



Corroded steel sheet pile quay wall. The yard surface looks normal. (Photo taken by Survey team in 2024)

Figure 4.2-2 Steel Sheet Pile Condition in Neiafu port



Corroded steel sheet pile quay wall. Fenders have fallen off from the jetty. (Photo taken by Survey team in 2024)

Figure 4.2-3 Fender Condition in Neiafu port

(d) Collection and organization of design documents

MOI explained that the design documents on Neiafu port were lost during a cyclone. In addition, JICA does not have any records on the wharf as Neiafu port was constructed by another agency.

(2) Status of Existing Facility and Future Plans

The access channel in front of Neiafu port is often congested due to the narrow width and limited depth. Pilotage is also mandatory for international vessels calling Neiafu port. The maximum navigable vessel in the channel is 100 meters in length with a draft of 5.5 meters. A large cruise vessel must anchor off the entrance channel. Passengers need to get off the cruise ship and onto a ranch boat for landing. Vessel operation is very risky. When the sea level is sufficiently high, a deep draft vessel is allowed to enter provided she can maintain a safe margin of clearance. However, when the sea level is low tide, clearance of at least 30 cm from seabed is required. When a ship with a draft just below the minimum is to enter the port, she must stop the engine and move forward by inertia to the berth. Even though a container vessel is equipped with bow thruster, the operation is very risky. Berthing would be much safer if a tugboat were available.

As the length of the wharf is only 65 meters, only one vessel can berth at a time. In addition, the left side of wharf area is for use by the navy. The right side of the wharf is for fishing port. Extension work on either side is difficult. Thus, MOI has to look for an alternative option to develop the new port outside the bay.

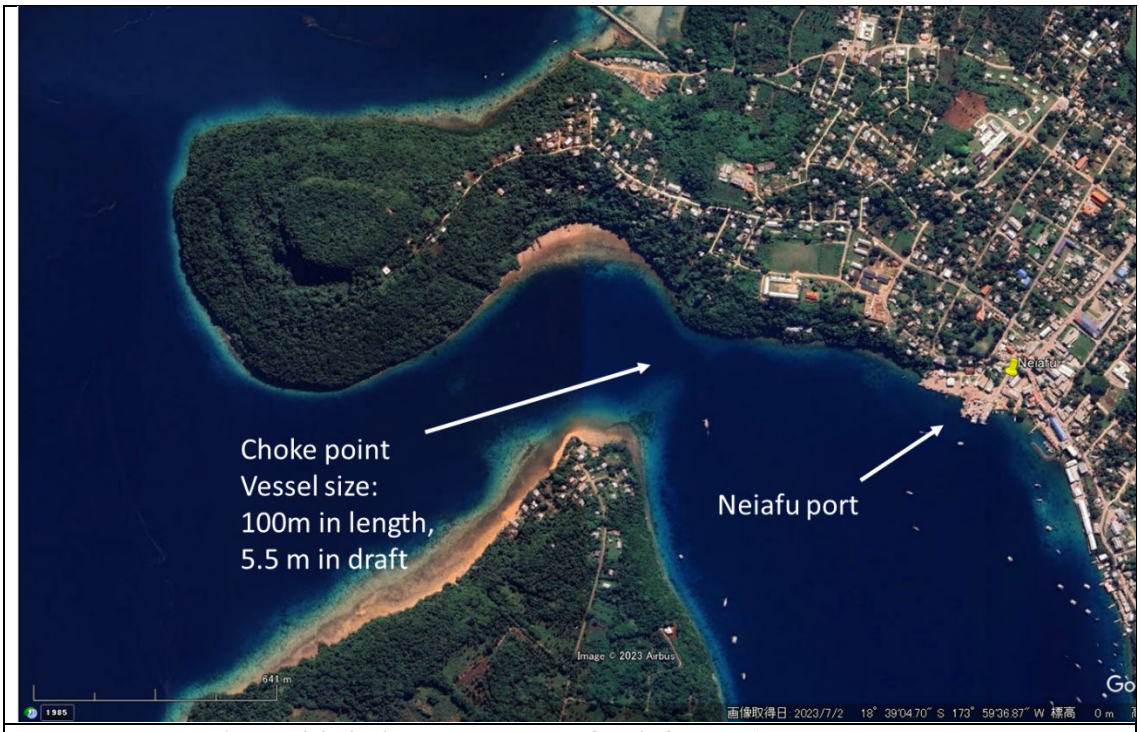


Figure 4.2-4 Figure The Port of Neiafu and Access channel

4.2.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) at Neiafu Port

(1) Collection of data on damage caused by past natural disasters

In this section, we will collect and compile information on natural disasters that affected Neiafu port in the past. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss.

(a) Sea level rise, cyclone and high wave

First, we will review the natural disaster risks across Oceania based on "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[47]". AR6 reports that the occurrence proportion of strong tropical cyclones (categories 3 to 5) among all tropical cyclones globally has increased in the last 40 years, with a moderate level of confidence. AR6 indicates

[47] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

low confidence in the long-term trends of the increasing frequency of tropical cyclones across all categories. In addition, AR6 mentions that the global mean sea level has been rising more rapidly since 1900 than at any other 100-year time in the past 3,000 years, with high confidence.

Next, we will list the major cyclones that have caused critical damage to Tonga in chronological order of their occurrence. Although Neiafu port is a naturally sheltered harbor, it has suffered damage from cyclones in the past. Cyclone *Isaac*, which struck in 1982, was classified as a Category 4 storm and caused severe damage to port facilities due to strong winds and storm surges. Later, in late December 2001, Cyclone *Waka* directly hit the Vava'u Islands and caused extensive damage to Neiafu port. Cyclone *Waka*, also a Category 4 storm, generated strong winds and storm surges that caused moored vessels to drift away. As a result, the pier was damaged, and some mooring posts and fenders were also broken.

(b) Earthquake, Tsunami and volcanic activity

World Bank reported that Oceania was exposed to high risk of tsunamis, earthquakes, and volcanic activity[48]as shown in Figure 4.2-4 to Figure 4.2-6. Tonga consists of islands situated on a small tectonic plate located between the Tonga Ridge to the west and the Tonga Trench to the east. As a result, the earthquake risk is extremely high. As indicated in the seismic hazard map in Figure 4.2-5, ground shaking exceeding 250 cm/s² is expected in a 250-year return period earthquake event. Due to the high likelihood of earthquakes, the tsunami risk is also significant. For Vava‘u Island, where Neiafu port is located, tsunami impacts in the range of 1.5 to 2.0 meters must be considered, as shown by the red box in Figure 4.2-4. In addition, tectonic movement has led to active volcanic activity, and according to Figure 4.2-6, the volcanic hazard level in Vava‘u Island is rated as “Medium.”

The Vava'u Islands, where Neiafu port is located, were formed by relatively old volcanic activity, and no active volcanoes are currently present in the area. However, during the eruption of the Hunga Tonga–Hunga Ha'apai volcano in 2022, volcanic ash fell and a tsunami reached Neiafu, despite the eruption site being approximately 500 km away. At Neiafu port, the tsunami height was observed to be approximately 0.5 to 1.0 meters. While Tonga as a whole is subject to high seismic and volcanic risks, Neiafu port is situated deep within a natural harbor surrounded by complex island formations, and no significant damage has been recorded in the past. Regarding earthquake-related events, a magnitude 8.0 earthquake occurred in 2006 approximately 155 km south of Neiafu port. Although no direct damage to the port was reported, it is believed that a sunken ship from 1949 in Taula, near Neiafu in Vava'u Island, ruptured during the earthquake, causing the copra cargo to surface. In addition, a landslide occurred on Hunga Island, also in the Vava'u Islands, where a steep coastal slope collapsed into the sea.

[48] Pacific Maritime Transport Systems Hazard Exposure Technical Note, World Bank. 2023.

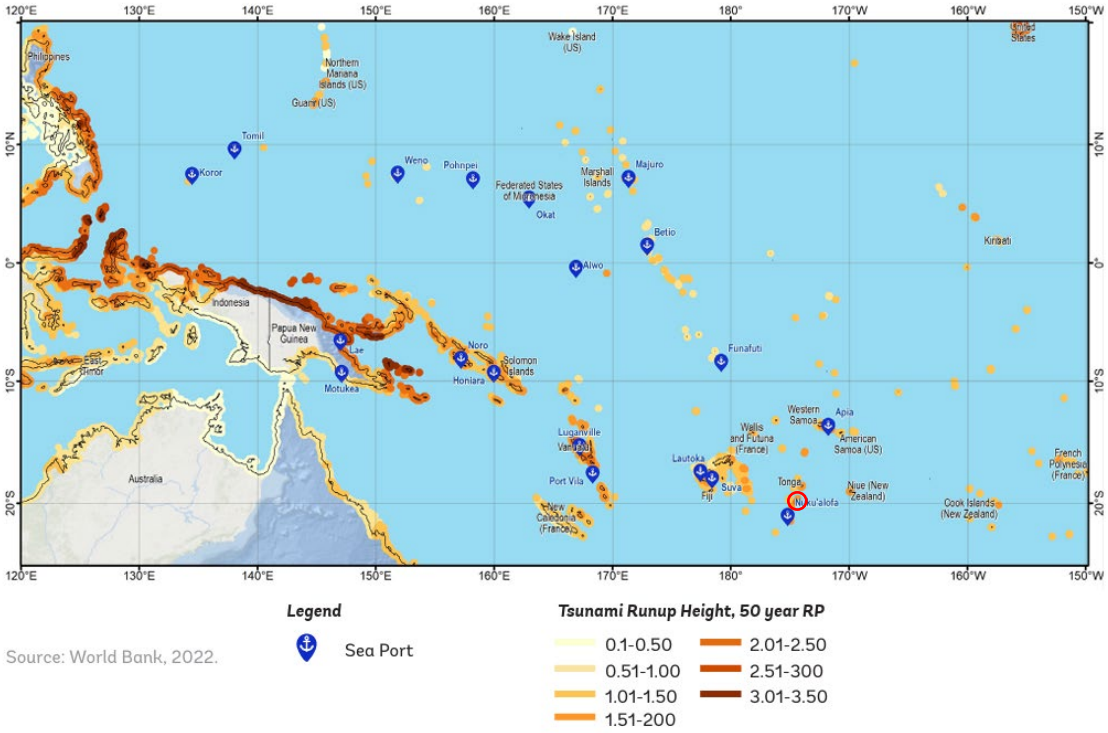


Figure 4.2-5 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

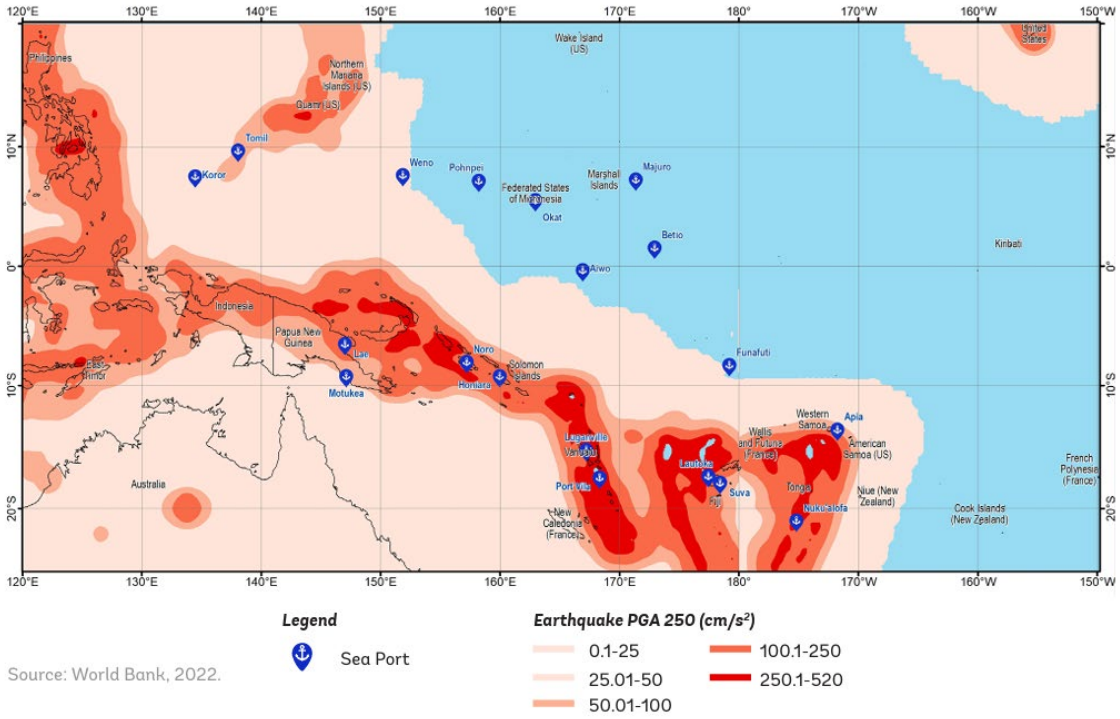


Figure 4.2-6 Earthquake peak ground acceleration (PGA) in cm/s2 for a 250-year return period

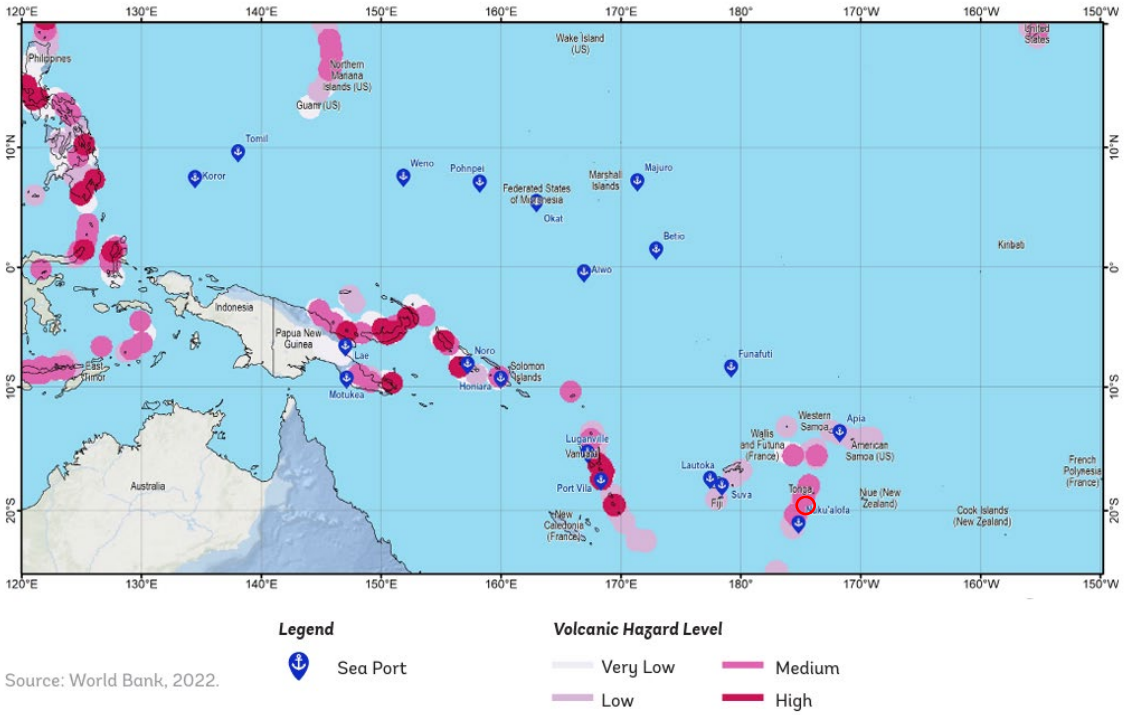


Figure 4.2-7 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

(2) Organization of external force conditions at the design of the existing facilities

In this section, we will collect design documents of the port facilities in Neiafu and examine whether the existing port facilities have sufficient capacity to cope with the forces of expected natural disasters. However, MOI explained that the design documents on Neiafu port were lost during a cyclone. In addition, JICA does not have any documents on the wharf as Neiafu port was constructed by another agency. Therefore, the external force condition in the existing wharf is not clear. Because the steel sheet pile is heavily deteriorated, the JICA expert assumes the wharf has lost most of its original structural integrity.

4.2.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in Neiafu port based on research papers and past records of natural disasters affecting ports.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*[49]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for Neiafu port. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

The multi-hazard heat map selects Nukuʻalofa port as a representative port in Tonga as shown in Table 4.2-1. It is difficult to directly apply the Nukuʻalofa's risk level to Neiafu port's risk level. When evaluating Neiafu port's risk level, we compare the differences and similarities between Neiafu and Nukuʻalofa. Neiafu port is located approximately 275 kilometers north of Nukuʻalofa port. However, since both ports are located on the same tectonic plate, the Tonga Plate, the earthquake PGA in Neiafu may be the same as in Nukuʻalofa: 0.27. This is a comparatively high value in the Pacific. However, a tsunami might have less effect on Neiafu than Nukuʻalofa (1.5-meter maximum inundation height) as Neiafu port is located in a deep inlet area.

Regarding cyclones and storms, both ports lie within the development zone of cyclone attacks. However, Nukuʻalofa Port directly faces the open sea, which results in a long fetch. As a result, wave heights during cyclones can reach up to 9.1 meters, which is very high. On the other hand, Neiafu port is located in a deep inlet, where the fetch is short. Therefore, the impact of high waves caused by cyclones is very limited. A similar pattern is expected for high waves caused by regional strong winds. While high values are predicted around Nukuʻalofa Port, the impact on Neiafu port is expected to be relatively small. Sea level rise itself does not currently pose a direct threat of damage; however, it has the potential to increase the risks associated with storm surges, cyclones, and high waves.

[49] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

Table 4.2-1 Multi-hazard Heat Map Port Exposure (Tonga)

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5. 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High | Medium | Low | Very Low | Not applicable

Table 4.2-2 Methodology for Identifying Natural Disasters and their Scales (Neiafu port)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	The design documents could not be obtained.	Not applicable	Based on historical records, the earthquake magnitude is estimated, and seismic waves are determined by considering the distance from the epicenter and the characteristics of the ground.
Tsunami	The design documents could not be obtained.	Not applicable	Neiafu port is a naturally sheltered harbor located deep within a complex coastal landscape and has a low risk of tsunami impact. However, based on the maximum tsunami recorded in the past, the loads applied to structures are determined by considering tsunami height and flow velocity.
Volcano	The design documents could not be obtained.	Not applicable	The assessment is based on a comprehensive evaluation of the damage caused by past volcanic activity.
Storm Surge	The design documents could not be obtained.	Flood disasters increase due to sea level rise.	According to the hearing with MOI, the tidal range between the normal high water level (H.W.L) and low water level (L.W.L) is approximately 1.3 meters, but it can reach around 2.0 meters during storms. It is necessary to consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	The design documents could not be obtained.	Increase in high waves due to cyclone intensification.	Neiafu port is a naturally sheltered harbor located deep within a complex coastal landscape and has a low risk of wave impact from cyclones However, it is important to objectively consider the increase in waves caused by cyclone intensification. The recent research results, such as future predictions using d4PDF described later, can be used.

(2) Measures against sea level rise and wave power due to climate change

"Japanese port and harbor design standards" explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately determined using the latest research findings and scientific knowledge. Figure 4.2-7 illustrates two conceptual approaches for setting structural strength while considering changes in external forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as "Proactive adaptation." On the other hand, "Adaptive adaptation" refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life, but implementing physical upgrades progressively at appropriate times during the period, depending on material and structural characteristics.

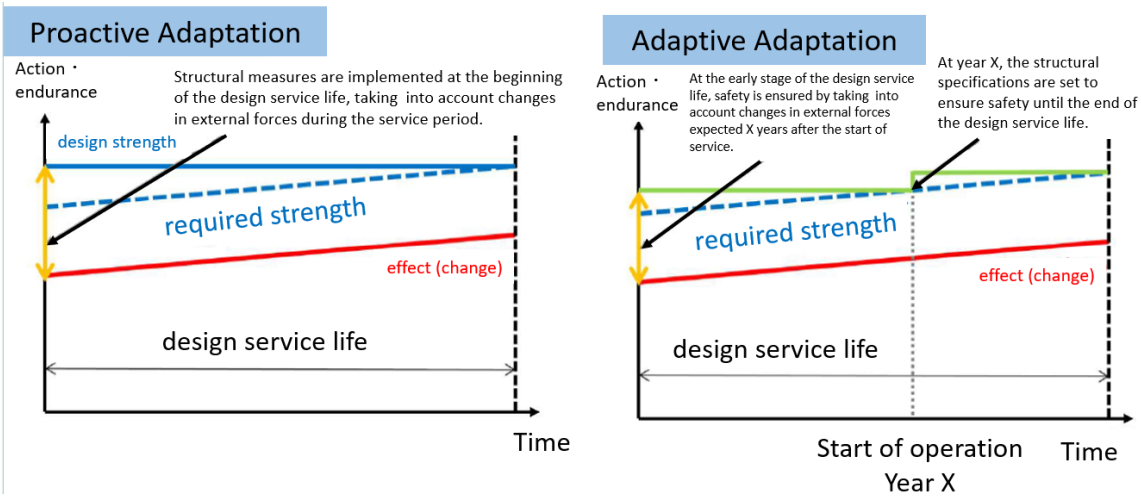


Figure 4.2-8 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

Due to the many uncertainties surrounding climate change, a range of scenarios has been discussed. For example, "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[50]" presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to

[50] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

"holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[51] as a basis when considering the impacts of climate change in port facility design. RCP2.6 corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. Figure 4.2-8 shows the projected median regional sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [52].

The projected sea level rise in Tonga is shown in Figure 4.2-9. By 2050, sea level rise in Tonga is projected to be 0.26 m under the 2°C scenario (SSP1-2.6) and 0.31 m under the 4°C scenario (SSP5-8.5), with a small difference of 0.05 m. On the other hand, by 2100, sea level rise is expected to reach 0.60 m under the 2°C scenario (SSP1-2.6) and 0.97 m under the 4°C scenario (SSP5-8.5), showing a larger difference of 0.37 m. Therefore, depending on the scenario selected, the value of projected sea level rise differs and this must be considered when setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

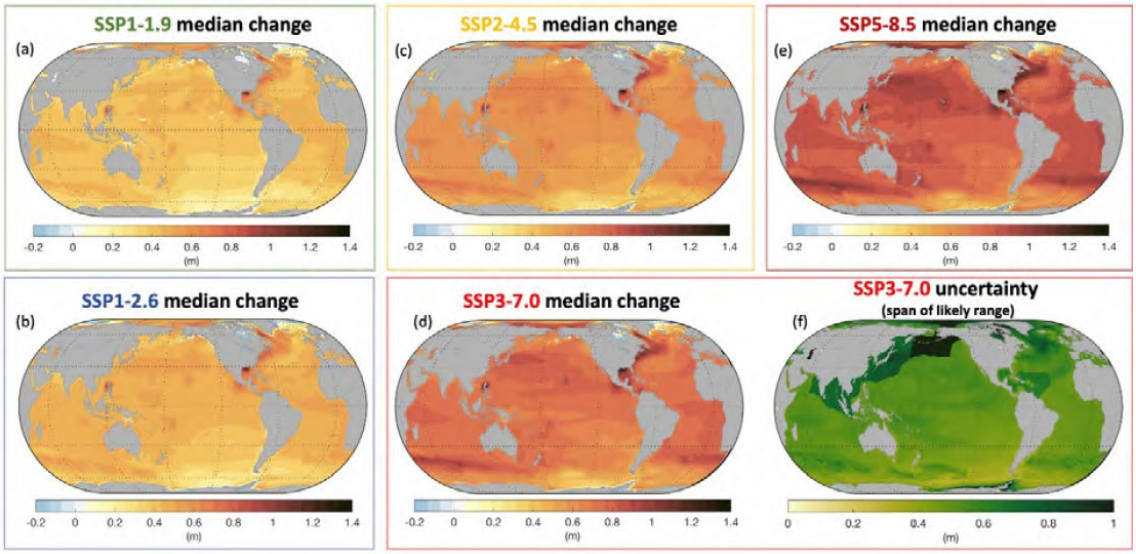


Figure 4.2-9 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

[51] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
[52] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

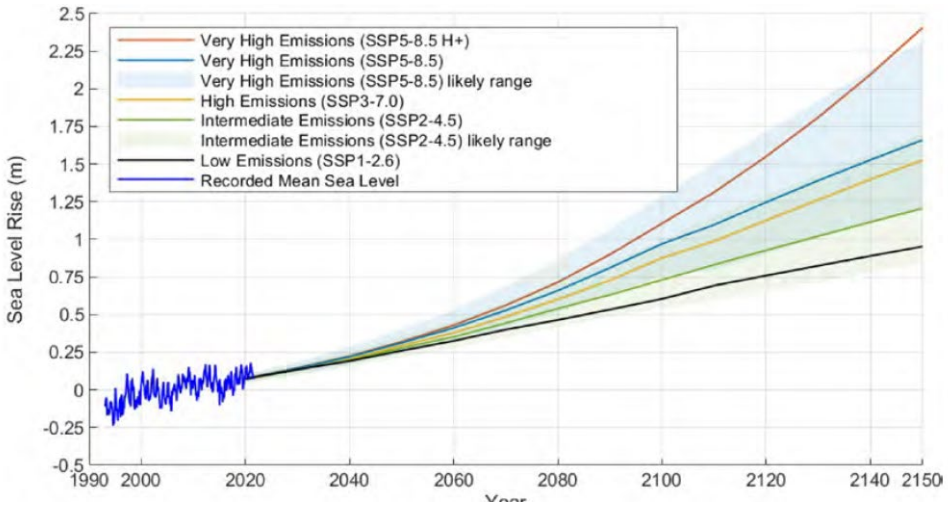


Figure 4.2-10 Sea Level Rise Projections to 2150 for Tonga Relative to 1995–2014 Mean Sea Level

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the “Database for Policy Decision-Making for Future Climate Change” (d4PDF, Mizuta et al. [53]). To predict future changes in extreme weather events such as typhoons due to climate change, a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing Waves and Coasts in the Pacific" (WACOP) project[54]. This project uses four climate models that

[53] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita, M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.
[54] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html(Accessed in July, 2024)

participated in CMIP5. When considering storm surges and high waves, it is essential to incorporate research findings, such as conducting wave simulations using these future climate models.

4.2.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing port facility structures, maintenance conditions and the level of disasters in the previous sections, we will organize MOI's current disaster mitigation plans in terms of time frames and types of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". The natural disaster can be categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 4.2-3.

Table 4.2-3 Classification of adaptations and responses according to natural disasters

Type of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The expert team confirmed the structure of existing facilities and maintenance status of the target port through discussions with the port management agency MOI and available design documents. The existence and implementation status of natural disaster response plans for the respective port facilities were also confirmed. JICA expert team sent questionnaires to each port authority to examine if disaster prevention or mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. The responses from MOI are summarized below.

Results of Questionnaire Survey sent to the Ministry of Infrastructure (MOI)

(2) Maintenance and Management

MOI has not developed a formal maintenance management plan. However, the agency is aware

of the importance of such planning and has prepared an inspection manual. Regular inspections of port facilities are conducted approximately once a year.

(3) Countermeasures against Natural Disasters

Although MOI has developed a tsunami hazard map as part of its disaster response measures, no specific actions have been implemented regarding natural disaster preparedness. However, the following measures are currently being planned as part of future disaster response initiatives.

1) Risk Assessment and Mapping: Hazard Mapping & Vulnerability Assessment
2) Preventive Measures: Structural improvement of the port, land use planning (evacuation routes and safe zones)
3) Preparedness Measures: Early Warning Systems (disaster notification, sirens etc.), evacuation plans, emergency supplies, training and drills
4) Response Measures: Emergency Communication System, Search and Rescue Operations, Medical Assistance
5) Recovery Measures: Damage Assessment, Restoration of Services (repair & rehabilitaion), Financial Assistance etc.
6) Monitoring and Continuous Improvement of the Infrastructure

(4) Emergency Response

Emergency response plans for disasters such as earthquakes, tsunamis, and fires have been fully identified by MOI and communicated to relevant stakeholders. However, a formal port Business Continuity Plan (BCP) has not been developed. The following measures are currently being planned as part of emergency preparedness measures.

1) Initial Assessment and Alerting: assess the Situation, Activate the Emergency Plan, Akert Key Stakeholders
2) Evacuation Procedures: identify evacuation routes, assign evacuation leaders and guides, specify protocols for assisting individuals with disabilities or special needs.
3) Communication Protocols: establish primary and backup communication channels (radios, mobile phones etc.), create a clear chain of command for decision making
4) Containment and Control: assign roles for controlling the emergency (e.g., fire extinguishing shutting off utilities etc.), implementing lockdown
5) First Aid and Medical Response: designated first aid responders and medical support, outline procedures for treating injuries and transporting victims to medical facilities
6) Safety and Security: responders to wear PPE, secure the site to prevent unauthorized access
7) Coordination with Emergency Services: provide detailed information to emergency responders upon arrival, collaborate closely with each stakeholder in supporting each other
8) Documentation and Incident Reporting

9） Recovery and Restoration
10） Review and Evaluation

(5) Climate Change Adaptation

Although MOI is aware of the potential impacts of climate change, such as sea level rise and increased wave heights, no specific actions have been taken to address these issues. However, the following measures are planned as part of future climate change adaptation measures.

1） Risk Assessment and Mapping: Hazard Mapping & Vulnerability Assessment
2） Preventive Measures: Structural improvement of the port, land use planning (evacuation routes and safe zones)
3） Preparedness Measures: Early Warning Systems (disaster notification, sirens etc.), evacuation plans, emergency supplies, training and drills
4） Response Measures: Emergency Communication System, Search and Rescue Operations, Medical Assistance
5） Recovery Measures: Damage Assessment, Restoration of Services (repair & rehabilitation), Financial Assistance etc.
6） Monitoring and Continuous Improvement of the Infrastructure

4.2.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, based on the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*"[55] (hereinafter referred to as "Pacific Ports Vision")shown in Table 4.2-4. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[55] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 4.2-4 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities in Neiafu port are shown below.

(a) Natural disaster adaptation – Resilience indicators: Unengaged

Although the construction year of Neiafu port is unknown, the terminal facilities were expanded in 2013. MOI has developed a tsunami hazard map, but no specific actions have been taken in response to natural disasters. Therefore, the resilience indicator is assessed as Unengaged.

(b) Climate change adaptation – Resilience indicators: Unengaged

Although the construction year of Neiafu port is unknown, the terminal facilities were expanded in 2013. MOI is aware of the potential impacts of climate change, such as sea level rise and increased wave heights, but no specific actions have been taken to address these issues. Therefore, the resilience indicator is assessed as Unengaged.

(c) Emergency response – Resilience indicator: Highly engaged

Although MOI has not formulated a port Business Continuity Plan (BCP), emergency response plans for disasters such as earthquakes, tsunamis, and fires have been fully identified and communicated to relevant stakeholders. These emergency response plans are considered equivalent to a port BCP, and MOI plans to continue reviewing and evaluating them in the future. Therefore, the resilience indicator is assessed as Highly Engaged.

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in Neiafu port in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

Table 4.2-5 Assessment of Impacts of Natural Disasters for Neiafu Port

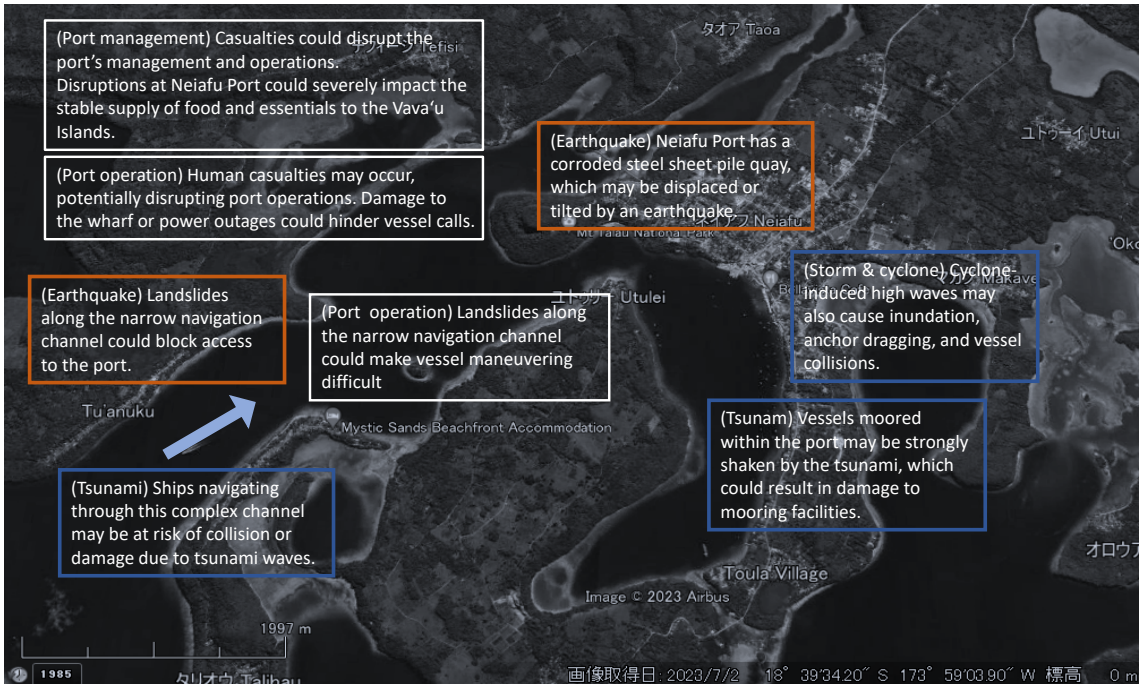
Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	Neiafu port has a steel sheet pile quay structure. The front-facing sheet piles are significantly corroded, and in the event of an earthquake, displacement of the sheet piles and tilting of the quay wall may occur. There is a narrow section along the navigation channel leading to Neiafu port. If an earthquake causes landslides on both sides of the cliffs in this area, access to the port could become impossible.	If injuries occur as a result of an earthquake, the resulting human impact could affect the port's management and operational capacity. Neiafu port serves as the primary entry point for goods into the Vava'u Islands, and any disruption to its operations could have a serious impact on the stable supply of essential goods such as food.	Earthquakes may cause human casualties that could affect operations. Damage to the pier or loss of power supply could also disrupt vessel calls at the port. There is a narrow section along the navigation channel leading to Neiafu port, and if an earthquake causes landslides on both sides of the cliffs, it may become difficult for pilots to maneuver vessels safely.
Tsunami	Neiafu port is in the inland area of a deeply indented island, and incoming tsunamis are likely to be attenuated by surrounding islands before reaching Vava'u. However, since the port lies at the inner end of a narrow waterway, tsunami energy could become concentrated. Ships navigating through this complex channel may be at risk of collision or damage due to tsunami waves. Vessels moored within the port may be strongly shaken by the tsunami, which could result in damage to mooring facilities. If containers are swept away by the tsunami, they may remain trapped	If injuries occur because of a tsunami, the resulting human impact could affect the port's management and operational capacity. Neiafu port serves as the primary entry point for goods into the Vava'u Islands, and any disruption to its operations could have a serious impact on the stable supply of essential goods such as food.	Human casualties caused by tsunamis may affect operations. Damage to the pier or loss of power supply could also disrupt vessel calls at the port.

	within the waterway due to the surrounding complex topography, rather than being carried out to sea.		
Volcano	Active volcanoes have not been identified in the vicinity of the Vava'u Islands, where Neiafu port is located. However, there is a possibility that volcanic ash from distant eruptions may reach the area and accumulate. Nevertheless, the likelihood of the port facilities themselves being directly affected is low.	There are no active volcanoes confirmed in the vicinity of the Vava'u Islands, where Neiafu port is located. However, volcanic ash from distant eruptions may reach the area and accumulate. If volcanic ash accumulates on land, it could disrupt land transportation and affect the port's management and operational capacity.	There are no active volcanoes confirmed in the Vava'u Islands, where Neiafu port is located. However, since other islands in Tonga are vulnerable to volcanic activity, domestic transportation may be delayed, potentially causing disruptions to port operations.
Storm Surge	Neiafu port is surrounded by a group of indented islands that act as a natural breakwater. However, depending on wind direction, wind setup may increase the water level, raising the risk of ship collisions or damage due to storm surge. If containers are swept away by high waves, the complex coastal topography may prevent them from flowing out to the open sea, causing them to remain within the waterway. Currently, the crest elevation of the quay wall at Neiafu port is low, and the risk of inundation is increasing due to the impacts of climate change. When planning future quay wall rehabilitation, raising the crest	If injuries occur as a result of a storm surge, the resulting human impact could affect the port's management and operational capacity. Neiafu port serves as the primary entry point for goods into the Vava'u Islands, and any disruption to its operations could have a serious impact on the stable supply of essential goods such as food.	Human casualties caused by high tides may affect operations. Damage to the pier or loss of power supply could also disrupt vessel calls at the port.

	elevation should also be considered.		
Cyclone	Neiafu port is located deep within an indented island, and the fetch is limited to approximately 3 kilometers at most. However, the port lies along the path of cyclones, and when a cyclone makes landfall on Vava‘u Island, strong winds can generate significant wave development. If large waves reach the wharf, potential damages may include inundation, anchor dragging, and vessel collisions. If containers are swept away by cyclone-induced high waves, the complex topography may prevent them from drifting out to sea, causing them to remain within the waterway.	If injuries occur due to high waves caused by a cyclone, resulting human impact could affect the port’s management and operational capacity. Neiafu port serves as the primary entry point for goods into the Vava‘u Islands, and any disruption to its operations could have a serious impact on the stable supply of essential goods such as food.	Cyclones may cause injuries and other human casualties that could affect operations. Damage to the pier or loss of power supply could also disrupt vessel calls at the port.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in Funafuti port. Figure 4.2-10 illustrates the natural disaster risks and resulting damage in the port. Neiafu Port has a corroded steel sheet pile quay, which may become displaced or tilted during an earthquake. The navigation channel to Neiafu Port is narrow and complex, and landslides could block access to the port. Such a channel may expose vessels to the risk of collision or damage due to tsunami-induced waves. If Neiafu port operations are disrupted, the stable supply of emergency goods, daily goods, energy supplies to Vava’u Islands would be jeopardized.

Therefore, the advisory team proposes to rehabilitate the corroded steel sheet pile wharf to enhance the port’s resilience. This proposal would enable safe and efficient berthing operations. In addition, it accommodates the berthing of large vessels. Since the access channel to Neiafu Port is narrow and shallow, it is advisable to consider widening the channel in combination with this proposal to mitigate the risk of vessel collision caused by landslides or tsunamis during an earthquake.



(Source: Google Earth with annotations by the JICA advisory team)

Figure 4.2-11 Geographical Assessment of Impacts of Natural Disasters for Neiaf port

4.2.6 Formulation of Port Resilience Strategy

In this sub-section, we will try to identify the reason why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans in Neiafu port.

(1) Confirmation of the reasons for staying with the current resilience indicators

The status of countermeasures against natural disasters, climate change adaptation, and emergency response, each evaluated using resilience indicators in Section 4.2.5, was reviewed and assessed based on the perspectives presented in the *Climate Change Adaptation Planning for Ports and Inland Waterways*[56] (hereinafter referred to as the PIANC Guide). The findings are presented below.

(a) Natural disaster adaptation – Resilience indicators: Unengaged

Reason: Actions are not taken at Neiafu port to respond to natural disasters at existing facilities.

- The goal(s), planning horizon, and objectives for natural disaster adaptation have not been established and agreed upon at Neiafu port.

[56] Climate Change Adaptation Planning for Ports and Inland Waterways, PIANC, EnviCom WG Report No. 178-2020

- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has not been completed, and the potential impacts of natural disasters on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the natural disaster adaptation process for Neiafu port.

(b) Climate change adaptation – Resilience indicators: Unengaged

Reason: Actions are not taken at Neiafu port to address climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed upon at Neiafu port.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has not been completed, and the potential impacts of climate changes on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate change is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in Neiafu port.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended to raise the resilience indicators of the existing facilities at Neiafu port for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

(a) Natural disaster adaptation

- Establish goal(s), planning horizons and objectives for natural disaster adaptation at existing facilities in Neiafu port.
- Identify the impact of natural disasters on port assets, operations, and systems in Neiafu port.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.

- Collect information related to natural disaster intensity predictions and determine the extent of the natural disaster.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(b) Climate change adaptation

- Establish goal(s), planning horizon and objectives for climate change adaptation at existing facilities in Neiafu port.
- Identify the impact of climate changes on port assets, operations, and systems in Neiafu port.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information on natural disaster intensity forecasts including the effects of climate change and identify the extent of natural disasters with climate change impacts.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(c) Disasters and Emergency Response

- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans for Neiafu port.
- Maintain emergency response plans for natural disasters at existing facilities in Neiafu port and verify them through annual audits.

(3) Examples of countermeasures

The existing wharf has already deteriorated significantly. Given the limited financial resources, proper maintenance must be carried out by developing a preventive maintenance plan that considers the condition of deterioration, usage status, and priority of each facility. By implementing improvement works in a planned and efficient manner based on such a maintenance plan, it will be possible to reduce maintenance costs and extend the service life of the facilities as shown in Figure 4.2-11.

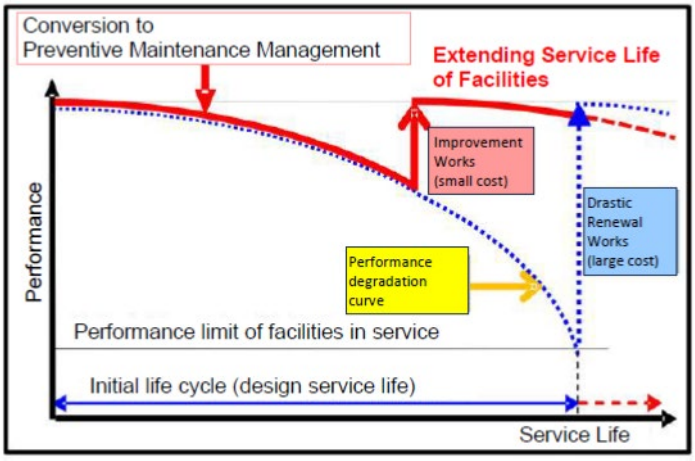


Figure 4.2-12 Preventive maintenance [57]

[57] https://www.cdit.or.jp/english/news/20230525.html

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for Neiafu port are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in Neiafu port is evaluated as "Unengaged."
In order to achieve a higher level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for existing facilities at Neiafu port in terms of their natural disaster adaptation.
It is recommended to identify the impact of natural disasters on port assets, operations, and systems at existing facilities Neiafu port, collecting information necessary to understand the baseline situation, and specifying information necessary for natural disaster risk assessment in order to prepare for the formulation of a natural disaster adaptation plan.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in Neiafu port is evaluated as "Unengaged."
In order to achieve the next level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for climate change adaptation.
It is recommended to collect information on natural disaster intensity forecasts that include the impact of climate change in order to identify the impact of climate change on the port assets, operations, and systems of Neiafu port and to understand the baseline situation.

(c) Disasters and Emergency Response

The resilience indicator outlined in the "*Pacific Port Vision*" for emergency response in Neiafu port is evaluated as "Highly Engaged." To achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and verify that these plans are maintained through annual audits.

(d) Introduction of the Draft Plan for Port Resilience

Neiafu port functions as a container and ferry terminal and is also well known as a tourist destination, However, the current berth can only accept one ship, and its size is not sufficient to accommodate large vessels. The steel sheet piles have corroded significantly, and its structural capacity is almost lost. To facilitate safe and efficient berthing, a new wharf should be developed at Neiafu port. There are two options to develop the new wharf: one is to develop a new wharf outside of the inlet, and the other is to rebuild the existing wharf. However, a natural preservation

area has been designated near the inlet area. Moreover, the site is far from downtown which means that an ccess road would also have to be developed. Therefore, the JICA expert team proposes that a new wharf be constructed at the current site.

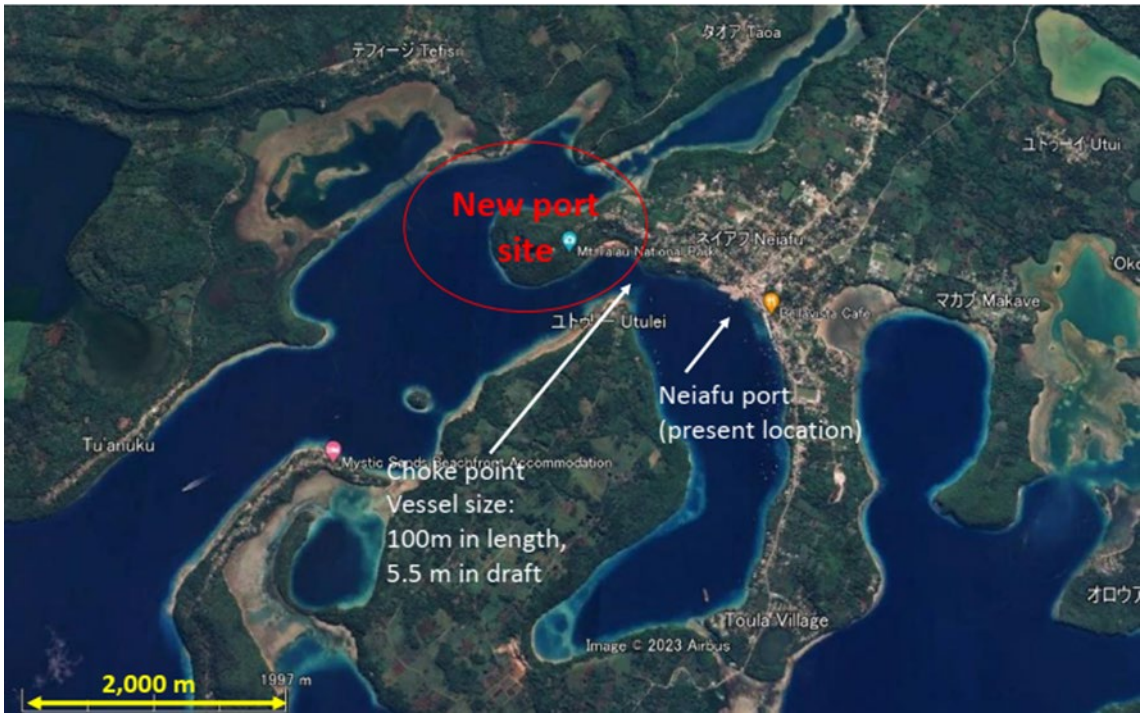


Figure 4.2-13 Site selection condition around Neiafu port

The expert's proposal is to extend the current wharf to the west, opposite the naval basin area. This plan includes a berth with a length of 255 meters which is sufficient for accommodating two vessels (an 8,000 DWT container and a RORO/passenger vessel) simultaneously. A dolphin should be installed in the west water area to moor the stern side of the large cruise vessel. Engineers also should apply global warming and seismic conditions into wharf design. In addition, the access channel should be widened and deepened to enable both cargo vessels and cruise vessels to pass. According to the MOI, the dredging site is composed of hard rocks, not coral rock. Accordingly, a seabed ground condition survey would be essential to estimate the dredging cost.



Figure 4.2-14 Proposed wharf expansion layout

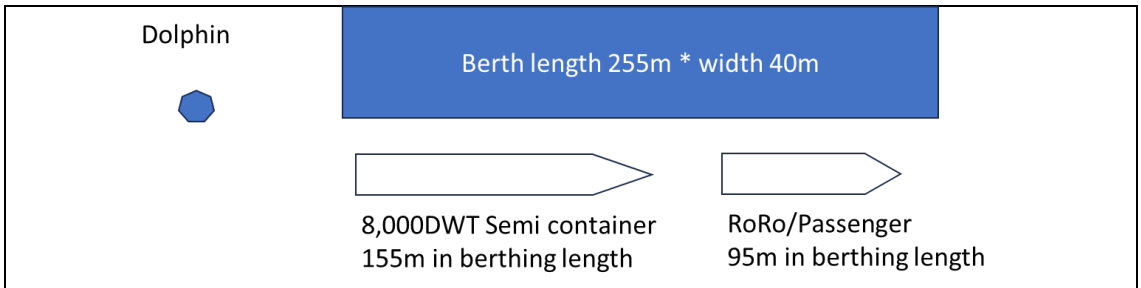


Figure 4.2-15 Extended berth layout to accommodate a container ship and a RoRo/passenger ship simultaneously

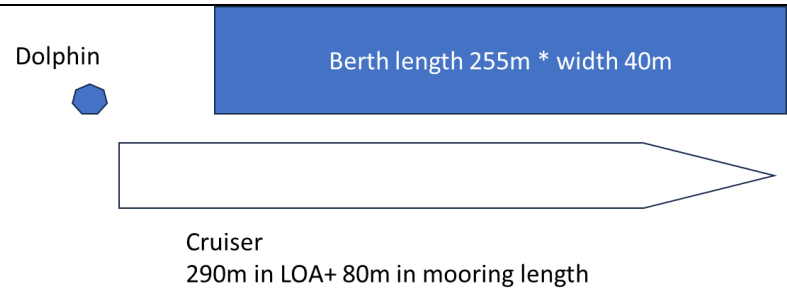


Figure 4.2-16 Cruise ship's berthing layout and mooring dolphin

4.3 Nuku'alofa Port in Tongatapu Island

4.3.1 Review issues related to port maintenance and management

(1) Status of Port facilities

Nuku'alofa port is located on the northern coast of Tongatapu Island. The port consists of several wharves, starting with the Vuna Wharf on the western side, which is used by international passenger ships. Faua Wharf is used by small domestic vessels and large ships for inter-island transport while Queen Salote Wharf is used by international container ships.

(a) Port plan

1． Current Status of Queen Salote Wharf (International Container Terminal)

Queen Salote Wharf, Tonga's principal container terminal, handled 23,882 TEUs in 2021 (compared to 26,046 TEUs in 2019). The terminal consists of two berths: one 93 meters long with a maximum water depth of 12 meters, and another 110 meters long with a maximum water depth of 11 meters. The yard area covers 15,772 m². Cargo handling equipment includes three reach stackers with a 45-ton capacity and 18 forklifts ranging from 3 to 26 tons. No gantry cranes are installed; instead, loading and unloading operations are conducted using deck cranes installed on the vessels.

With the support of the Asian Development Bank (ADB), a rehabilitation and capacity enhancement project (total budget: approximately USD 45 million or JPY 4.8 billion based on an exchange rate of USD 1 = JPY 106), has been underway since 2021. The project includes the extension of the quay at Wharf 2 and reinforcement of the deck and installation of dolphins at Wharf 1, with the aim of bringing the upgraded facilities into service by 2026[58].

Additionally, on November 2, 2023, an extra USD 30 million (equivalent to JPY 4.5 billion at an exchange rate of USD 1 = JPY 150) was provided as supplemental funding for the project. Of this amount, USD 10 million was contributed by ADB and USD 20 million by the Australian Government. The reasons cited for the USD 30 million cost increase include global inflation, rising supply chain costs due to the COVID-19 pandemic, and fuel price hikes resulting from geopolitical factors[59].

[58] ADB Approves $45 Million Grant to Upgrade Tonga's International Port | Asian Development Bank, accessed November 19, 2023

[59] Nuku'alofa Port Upgrade Receives $30 Million in Additional Support | Asian Development Bank, accessed November 19, 2023



Current Status of Queen Salote Wharf



The project to upgrade Queen Sālote Wharf, supported by the Asian Development Bank (ADB), is currently under construction by McConnell Dowell of New Zealand.
The project includes a 50-meter extension of the quay wall at Berth No.2, installation of mooring bollards, rehabilitation of Berth No.1, and improvement of the yard pavement.
Queen Sālote International Wharf Upgrade - Mcconnell Dowell

2. Faua Wharf

The Fau‘a Wharf, a domestic terminal, was completed in June 2018 with grant aid from JICA (total project cost: JPY 3.32 billion). After its completion, the wharf was honored with the name “King Taufa‘ahau Tupou IV Port.” The wharf has been in high demand, with vessel operators procuring new ships. In response, the Ports Authority Tonga (PAT) is planning to begin construction of an additional domestic berth in the area behind the existing domestic terminal, using its own financial resources. The proposed structure will involve driving steel pipe piles along the waterfront and reclaiming the area behind them.

Currently, three vessels operate to and from the Eui Islands:
MV ONEMATO(L/C, 3 times per week)(LOA 21meters)
MV MALAU75(L/C) 3 times per week) (LOA 60 meters)
MV Vaomapa (Fuel, once a week)(LOA45.6meters)

However, the navigable area is narrow and there is not a sufficient turning radius for ferry operations. In addition, the existing breakwater is structurally weak; its crest elevation is low, and the slope behind it was scoured by the tsunami in 2022. As a result, it is difficult to maintain calm water conditions during high wave events.

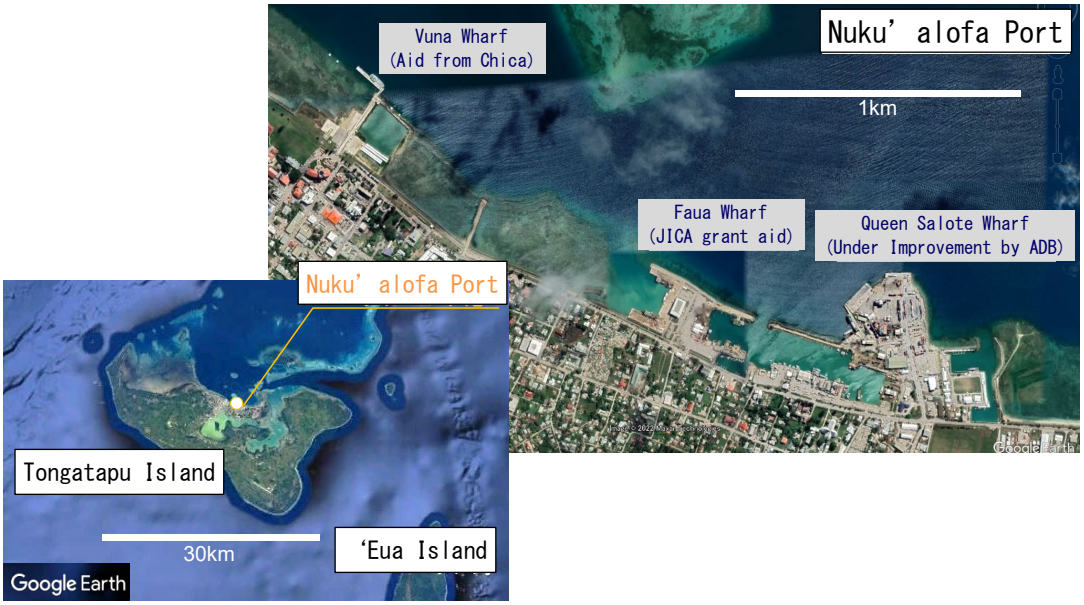


Figure 4.3-1 Location Map and Layout of Nuku’alofa Port

(b) Port cross-section (survey photos, drone photos)

A site investigation was conducted on November 16, 2023. Photographs taken at the locations shown in Figure 4.3-2 are presented in Figure 4.3-3 and Figure 4.3-4.

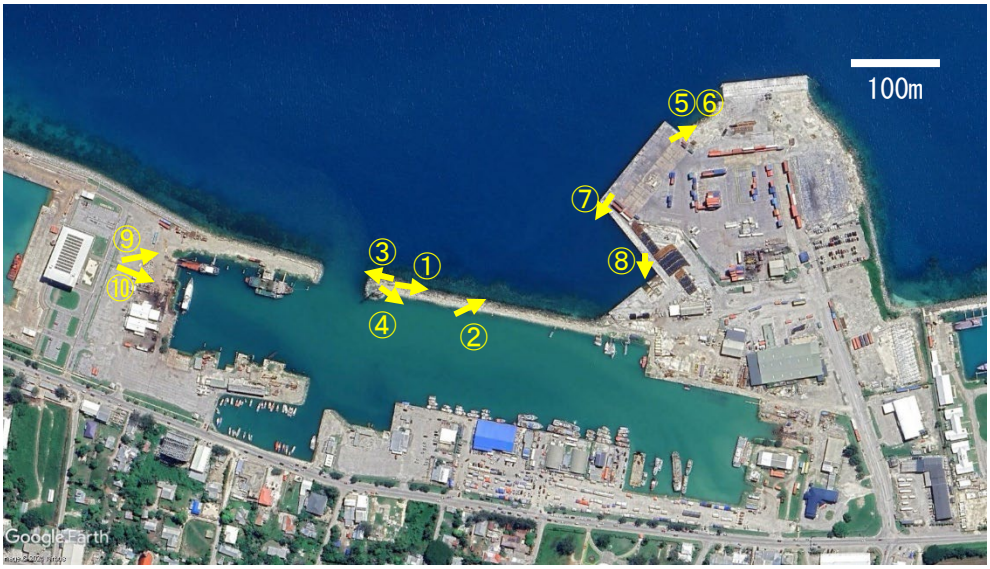


Figure 4.3-2 Location Map of Survey Area



Figure 4.3-3 Survey of breakwater



Figure 4.3-4 Survey photo of Queen Salote Wharf

(c) Assessing the current situation through on-site inspections

In Figure 4.3-6, taken during the site survey, a defect in the seawall at Queen Salote Wharf was observed. This defect could allow wave intrusion, posing a risk of scouring. Therefore, countermeasures are necessary. During the site visit, the survey team explained the survey approach to PAT and discussed facility resilience and maintenance methods. The photographs taken during the survey are shown in Figure 4.3-5.



Figure 4.3-5 Photograph taken during the field survey



Figure 4.3-6 Condition of Seawall Deterioration at Queen Salote Wharf

(d) Collection and organization of design documents from the viewpoint of maintenance and management

The design documents could not be obtained from the Tonga Ports Authority (PAT). However, since the revetment, quay wall, and breakwater facilities at the Fau‘a Wharf in Nuku‘alofa Port were constructed and rehabilitated through Japan’s cooperation, the relevant JICA reports could be obtained.

(e) Overview of the Container Terminal

Terminal Area: Container Yard: 15,772 m²

Number of Berths :2 Berths

Length and Depth Two quay walls: 93 meters (maximum depth of 12 meters) and 110 meters (maximum depth of 11 meters).
The terminal is equipped with three reach stackers with a capacity of 45 tons and 18 forklifts with capacities ranging from 3 to 26 tons.
There are no container cranes; cargo handling is performed using ship-mounted deck cranes.

Table 4.3-1 Specifications of Each Wharf at Nuku'alofa Port

Wharf Name	Berth Name	Length (m)	Depth (m)	Summary
Queen Salote Wharf	No.1 (North)	93	11.6	Containers, General Cargo
	No.2 (Northwest)	110	12	Containers, Tankers, Ro-Ro, General Cargo
	No.3 (West)	100	8	Ro-Ro for Domestic Islands
	No.4 (West)	60	8	Cargo and Passengers for Domestic Islands
Vuna Wharf	No.1	120	12	International Cruise Ships, Naval Vessels
Faua Wharf		3		Small Vessels, Fishing Boats, Pleasure Boats

Source: PORTS AUTHORITY TONGA Homepage, Marine Operations

(f) Overview of Other Terminals

i) Location Map and Plan of Faua Wharf (Domestic Wharf)



Figure 4.3-7 Location Map of Faua Wharf

ii) Specifications of Faua Wharf

Through Japan's grant aid from 2015 to 2018, a passenger terminal, quay, and berthing area were newly constructed at Faua Wharf, which is used by small domestic transport vessels. A wharf for large domestic transport vessels was also developed. In 2021, dredging was carried out to accommodate large ferries.

Table 4.3-2 Specifications of Faua Wharf

Number of Berths	2 berths for large vessels
Length	90 m / berth
Depth	-4.00m
Total Investment Amount	Total project cost: 3.336 billion yen Estimated Contribution - Japan: 3.320 billion yen, Tonga: 0.16 billion yen

4.3.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at Nuku'alofa Port

(1) Collection of data on damage caused by past natural disasters

In this section, we will collect and compile information on natural disasters that affected Nuku'alofa Port in the past. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss.

The advisory team focused on the categories of natural disasters that the target ports had experienced, the scale of the disasters, and the human and material damage, and collected data and records related to previous natural disasters over time. The advisory team requested PAT to provide meteorological and oceanographic data, which are indicators of the scale of natural disasters. However, the data could not be obtained.

According to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), the proportion of intense tropical cyclones (Category 3–5) among all tropical cyclones globally has likely increased over the past 40 years, with medium confidence. In contrast, there is low confidence in long-term trends in the frequency of all categories of tropical cyclones. Similarly, AR6 states that the global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3,000 years, with high confidence. These findings suggest that the potential risks of inundation caused by cyclones, storm surges, and high waves are increasing.

According to a report by the World Bank, as shown in Figure 4.3-8 to Figure 4.3-10, the Pacific region faces high risks from tsunamis, earthquakes, and volcanic activity. Tonga consists of islands situated on a small tectonic plate located between the Tonga Ridge to the west and the Tonga Trench to the east. As a result, the risk of earthquakes is extremely high. As indicated in the seismic hazard map in Figure 4.3-9, ground shaking exceeding 250 cm/s² is expected in a 250-year return period earthquake event. Due to the high likelihood of earthquakes, the tsunami risk is also significant. For Nuku'alofa port, tsunami impacts in the range of 1.5 to 2.0 meters must be considered, as shown by the red box in Figure 4.3-8. In addition, tectonic movement has led to volcanic influence in the region, and according to Figure 4.3-10, the volcanic hazard level in Nuku'alofa port is rated as "Low."

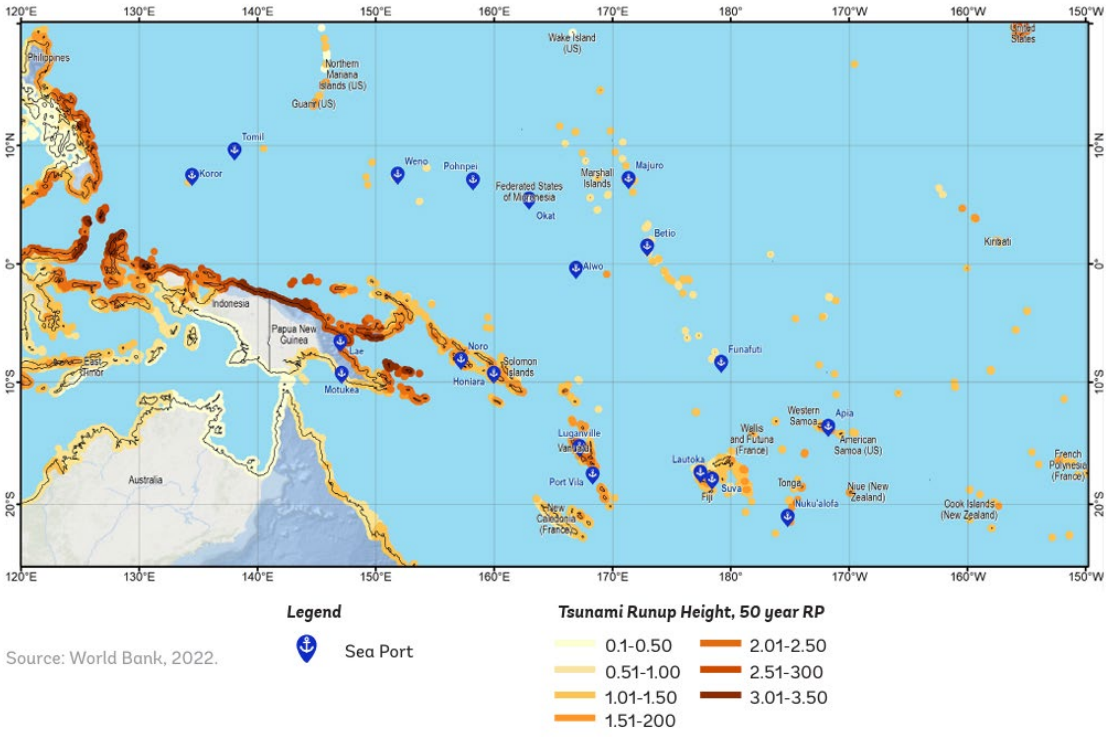


Figure 4.3-8 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

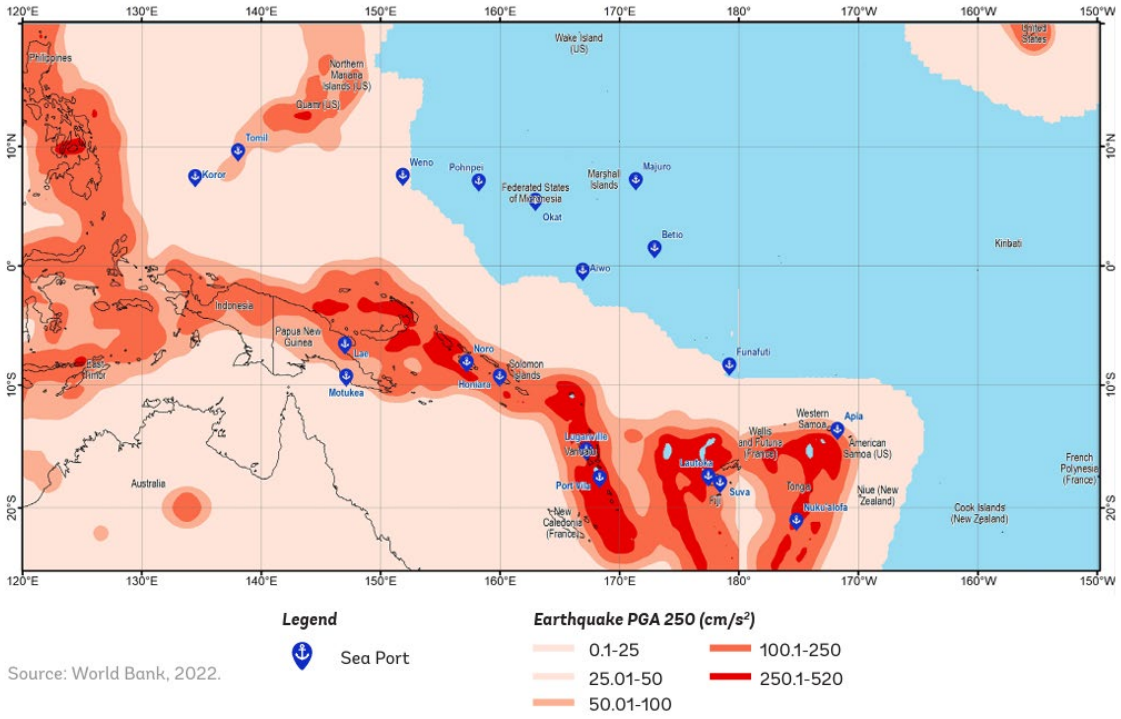


Figure 4.3-9 Earthquake peak ground acceleration (PGA) in cm/s2 for a 250-year return period

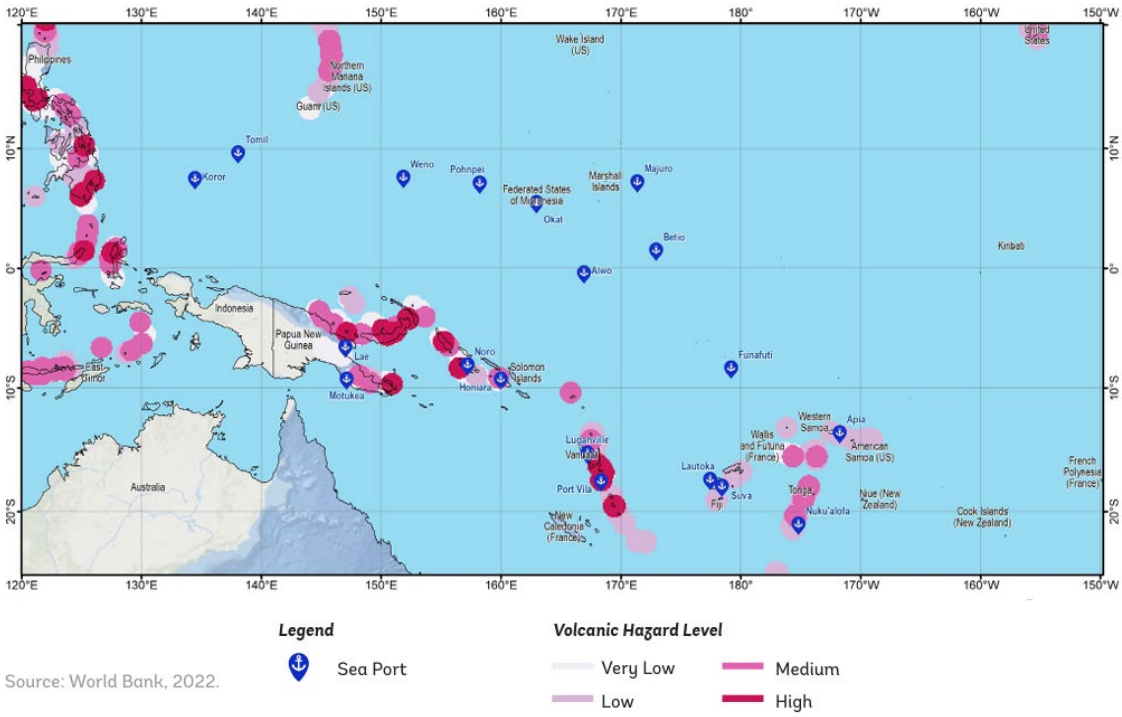


Figure 4.3-10 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

The presence of the Tonga Plate near the eastern coast of Tonga causes frequent earthquakes, creating a high risk of tsunamis. The tsunami following the September 2009 Samoa Islands earthquake resulted in 9 people being reported dead or missing. On January 15, 2022, the eruption of the Tonga Hunga-Tonga-Hunga-Ha'apai submarine volcano and the resulting tsunami, about 65 km north of Nuku'alofa, caused significant damage. According to estimates by the World Bank, the damage amounted to approximately 90.4 million US dollars, equivalent to about 18% of Tonga's GDP. The impact of the damage varied across different ports and wharves in Tonga. On 'Eua Island, significant damage occurred along the coastline and surrounding areas of the main township, Ohonua, requiring repair work on breakwaters, seawalls, and other port facilities.

In Tongatapu, where the capital is located, the western coast facing the open sea was particularly hard hit, with houses being washed away. In contrast, at Nuku'alofa Port, images from the New Zealand Defense Force (NZDF) and local reports indicated surface flooding, loss of container contents, minor damage. However, there was no catastrophic damage, and the impact was considered limited to moderate. Although the port infrastructure in Tongatapu suffered minor damage, it was still possible to load and unload humanitarian supplies after the disaster, and operations were quickly restored.

Additionally, there was a disruption in communication networks due to damage to submarine cables, and ashfall prevented aircraft carrying relief supplies from landing at the airport. In response, neighboring countries like Australia and New Zealand began transporting relief supplies by ship a few days after the eruption. Notably, Tongatapu Island, home to the capital and about 75,000 people, and Ha'apai Island, which is popular with tourists and has about 6,000 residents, have flat terrain. It is essential to provide timely warning and safety information for rapid evacuation in the event of a tsunami.

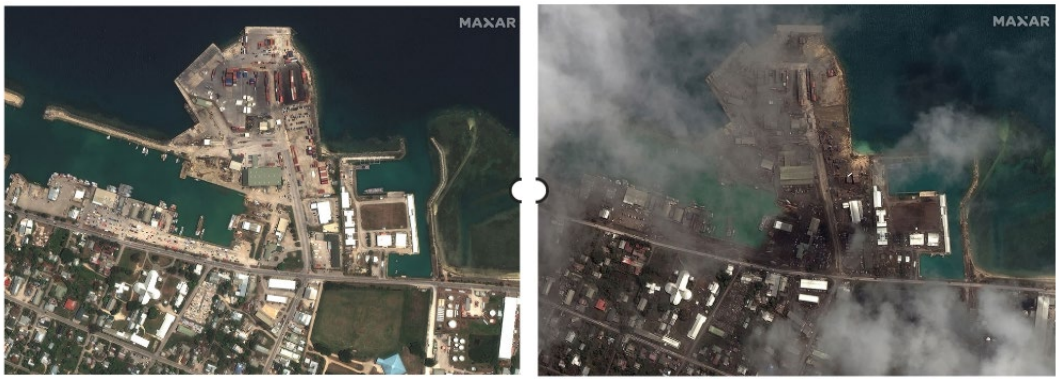


Figure 4.3-11 Aerial Photos of Nuku'alofa Port before and after the Disaster (12/29/2021, 1/18/2022)[60]

[60] Source：BBC News, https://www.bbc.com/news/world-australia-60027360 (Access: January 2024)

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in Nuku'alofa, and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters. The design external forces for the construction of facilities at the Faua Wharf in Nuku'alofa port were collected. According to the JICA Report on the *Preparatory Survey Report on the Project for Upgrade of Wharf for Domestic Transport in the Kingdom of Tonga* (2015), the wharf was designed with cooperation from Japan. The design conditions confirmed by this report are as follows.

Deck Level: DL+3.00 m
Tide Level:
High water level (H.W.L) D.L. +1.5 m
Water depth: DL-4.0m
Design vessels:
Length overall = 53.00mm
Draft = 3.0 m
Gross Tonnage 1,534 tons
Live load conditions
Superimposed Load: 2.0 t/m^2
Wave conditions
Equivalent Deepwater Wave Height: 1.24 m (N)
Wave Period: 14.2 sec
Geotechnical Conditions: Silty sand to gravel layer
Seismic condition: Design Seismic Coefficient (Kh): 0.15

4.3.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in Nuku'alofa port based on research papers and record of natural disasters that hit the ports,

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*[61]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for Nuku'alofa port. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

[61] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

Table 4.3-3 Multi-hazard Heat Map Port Exposure (Tonga)

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5. 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High Medium Low Very Low Not applicable

According to **Table 4.3-3**, the area surrounding Nuku'alofa port is an open sea area, resulting in a long fetch and a very high wave height of 9.1 meters during cyclones. Similarly, high waves generated by regional storms also show significant wave heights at Nuku'alofa port. Although sea level rise itself does not pose a direct risk of damage, it may increase the risks associated with storm surges, cyclones, and high waves. Additionally, since Nuku'alofa port is located on the Tonga Plate, the risks of maximum tsunami inundation height, earthquakes, and volcanic activity are classified as medium.

Table 4.3-4 Methodology for Identifying Natural Disasters and their Scales (Nuku'alofa Port)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Considered Design seismic intensity: kh=0.15	Not applicable	Based on historical records, the earthquake magnitude is estimated, and seismic waves are determined by considering the distance from the epicenter and the characteristics of the ground.
Tsunami	Not considered.	Not applicable	Based on the maximum tsunami recorded in the past, the loads applied to structures are determined by considering tsunami height and flow velocity.
Volcano	Not considered	Not applicable	The assessment is based on a comprehensive evaluation of the damage caused by past volcanic activity.
Storm Surge	Not considered	Flood disasters increase due to sea level rise.	Future sea level rise should be considered objectively. The results of PRIF, which will be described later, can be used as one of the methods.
Cyclone	Equivalent Deepwater Wave Height: 1.24m Wave Period: 14.2sec	Increase in high waves due to cyclone intensification.	The increase in waves caused by cyclone intensification should be considered objectively. Recent research results, such as future predictions using d4PDF described later, can be used.

(2) Measures against sea level rise and wave power due to climate change

"Japanese port and harbor design standards" explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately determined using the latest research findings and scientific knowledge. Figure 4.3-12 illustrates

two conceptual approaches for setting structural strength while considering changes in external forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as "Proactive adaptation." On the other hand, "Adaptive adaptation" refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life, but implementing physical upgrades progressively at appropriate times, depending on material and structural characteristics.

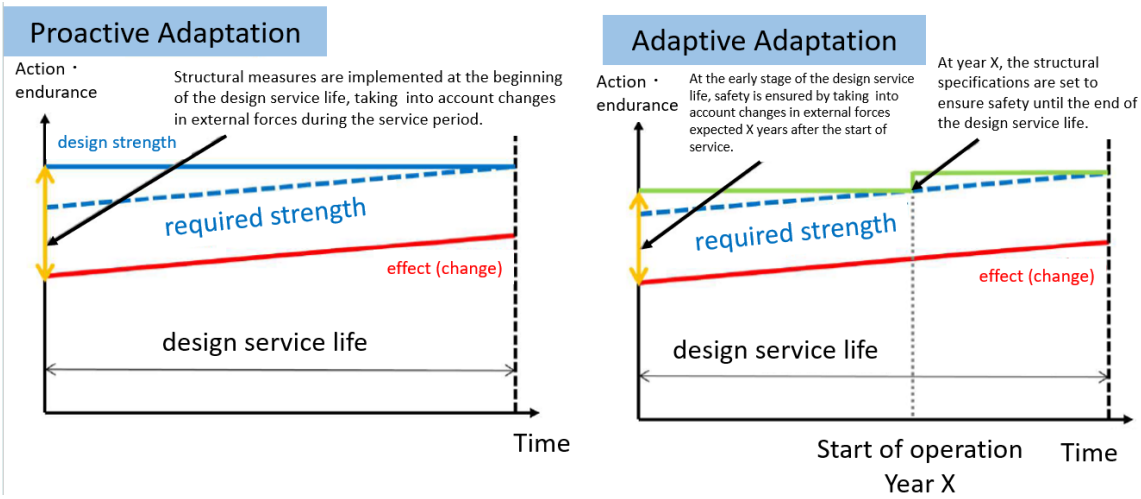


Figure 4.3-12 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power by climate change

Due to the many uncertainties surrounding climate change, a range of scenarios has been discussed. For example, "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[62]" presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[63] as a basis when considering the impacts of climate change in port facility design. RCP2.6

[62] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[63] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. Figure 4.3-13 shows the projected median regional sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [64].

The projected sea level rise in Tonga is shown in Figure 4.3-14. By 2050, sea level rise in Tonga is projected to be 0.26 m under the 2°C scenario (SSP1-2.6) and 0.31 m under the 4°C scenario (SSP5-8.5), with a small difference of 0.05 m. On the other hand, by 2100, sea level rise is expected to reach 0.60 m under the 2°C scenario (SSP1-2.6) and 0.97 m under the 4°C scenario (SSP5-8.5), showing a larger difference of 0.37 m. Therefore, depending on the scenario selected, the value of projected sea level rise differs and this must be considered when setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

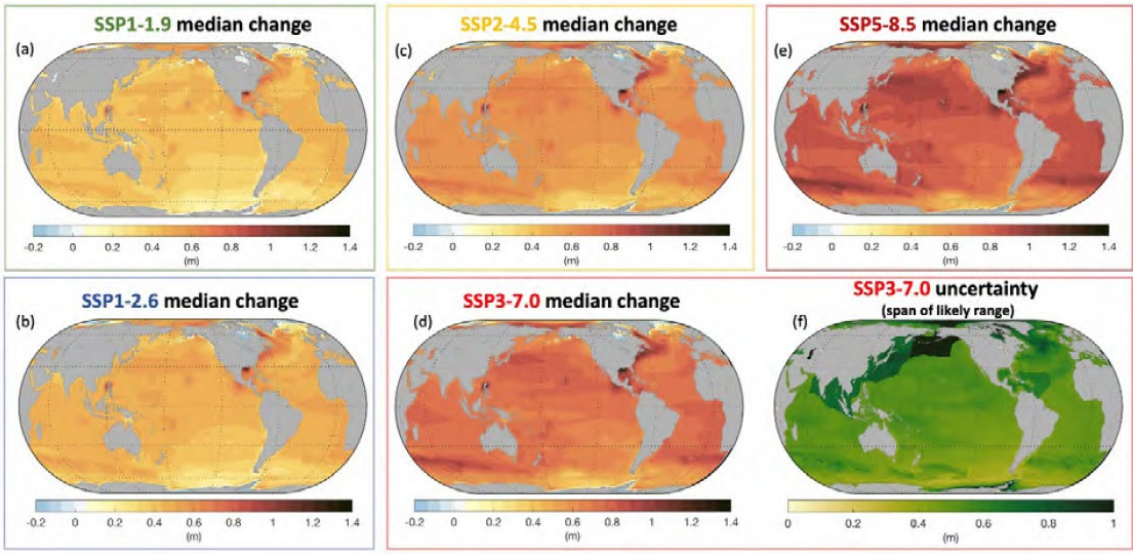


Figure 4.3-13 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

[64] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

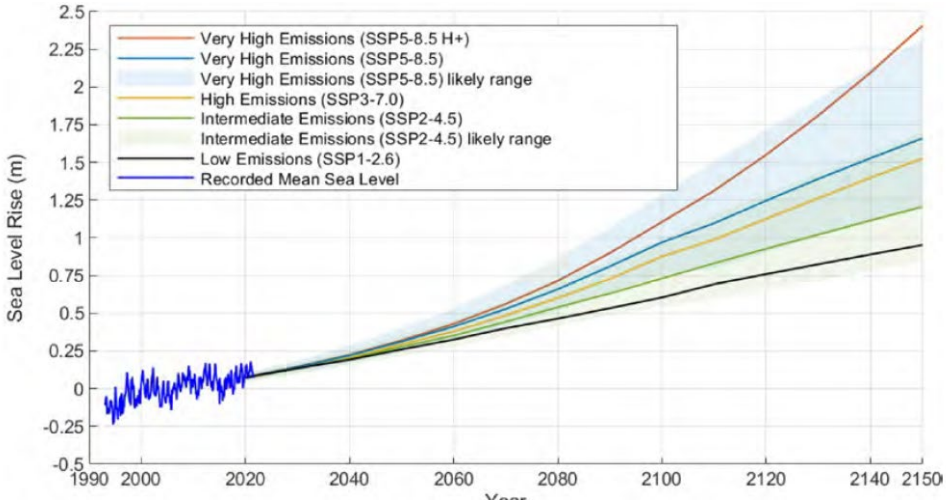


Figure 4.3-14 Sea Level Rise Projections to 2150 for Tonga Relative to 1995–2014 Mean Sea Level

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the “Database for Policy Decision-Making for Future Climate Change” (d4PDF, Mizuta et al. [65]). To predict future changes in extreme weather events such as typhoons due to climate change, a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing Waves and Coasts in the Pacific" (WACOP) project[66]. This project uses four climate models that participated in CMIP5. When considering storm surges and high waves, it is essential to

[65] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita, M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.
[66] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html(Accessed in July, 2024)

incorporate research findings using these future climate models.

4.3.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing port facility structures, maintenance conditions and the level of disasters in the previous sections, we will organize PAT's current disaster mitigation plans in terms of time frame and types of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". Natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 4.3-5.

Table 4.3-5 Classification of adaptations and responses according to natural disaster

Type of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The survey team confirmed the structure of existing facilities and maintenance status of the target port through interviews with PAT and available design documents. The survey team also confirmed the existence and implementation status of natural disaster response plans for the respective port facilities.

JICA experts sent questionnaires to each port authority to examine if disaster prevention or mitigation plans are prepared and being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change. The answers from PAT are summarized below.

(2) Maintenance and Management

PAT has developed a maintenance management plan as part of its maintenance measures. In addition, an inspection manual has been prepared, and inspections of port facilities are conducted at the frequencies indicated below.

1） Almost every day

2） About once a month
3） About once every 6 months
4） About once a year
5） During or after cyclones, earthquakes, etc.

(3) Countermeasures against Natural Disasters

PAT has developed hazard maps for tsunamis, earthquakes, and cyclones as part of its disaster preparedness measures. In addition, it has identified and documented assets, operations, and systems that may be affected by natural disasters. The impacts of such disasters have been analyzed and assessed, and corresponding response plans have been developed to manage identified risks. Both structural (hard) and non-structural (soft) measures have already been implemented. Furthermore, additional measures are currently being planned as part of future preparedness efforts.

1） Cyclones : PAT provides directions for preparation before, during, and after a cyclone
2） Tsunamis : PAT provides tsunami warning and directions for evacuation routes to safe areas.

(4) Emergency Response

PAT has fully established a port BCP for disasters such as earthquakes, tsunamis, and fires, and has clearly communicated it to relevant stakeholders. In addition, the following emergency response actions are currently being planned.

1) In the event of a cyclone, alternative berths will be identified.
2) In the event of an earthquake, barges will be used to load/unload cargoes.
3) Designing evacuation routes for the tsunami evacuation plan

(5) Climate Change Adaptation

PAT has conducted a risk assessment related to climate change adaptation and has developed plans to address natural disaster risks. Currently, the international wharf is undergoing rehabilitation, including raising the deck level by several meters. The following initiatives are planned as part of future efforts.

1） Cyclones : PAT provides directions for preparation before, during, and after a cyclone
2） Tsunamis : PAT provedes tsunami warning and directions for evacuation routes to safe areas.

4.3.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by following the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*"[67] (hereinafter referred to as *Pacific Ports Vision*) shown in Table 4.3-6. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[67] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 4.3-6 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities in Nuku'alofa Port are shown below.

(a) Natural disaster adaptation – Resilience indicators: Highly engaged

Queen Sālote Wharf at Nuku'alofa port was constructed in 1986 and rehabilitated in 1999. A new rehabilitation project is currently underway with support from ADB. Faua Wharf is a relatively new facility, completed in 2018 through cooperation with Japan. PAT has developed a tsunami hazard map, but no specific actions have been taken regarding natural disaster response. Based

on these observations, the resilience indicator is assessed as Highly engaged.

(b) Climate change adaptation – Resilience indicators: Highly engaged

Queen Sālote Wharf at Nuku'alofa port was constructed in 1986 and rehabilitated in 1999. A new rehabilitation project is currently underway with support from ADB. Faua Wharf is a relatively new facility, completed in 2018 through cooperation with Japan. PAT has developed a tsunami hazard map, but no specific actions have been taken regarding natural disaster response. Based on these observations, the resilience indicator is assessed as Highly engaged.

(c) Emergency response – Resilience indicator: Highly engaged

PAT has not yet developed a port BCP (Business Continuity Plan). However, emergency response plans for disasters such as earthquakes, tsunamis, and fires have been fully established and communicated to relevant stakeholders. These emergency plans are considered equivalent to a port BCP. PAT plans to continue reviewing and evaluating them in the future. Based on these observations, the resilience indicator is assessed as Highly engaged.

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in Nuku'alofa Port in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

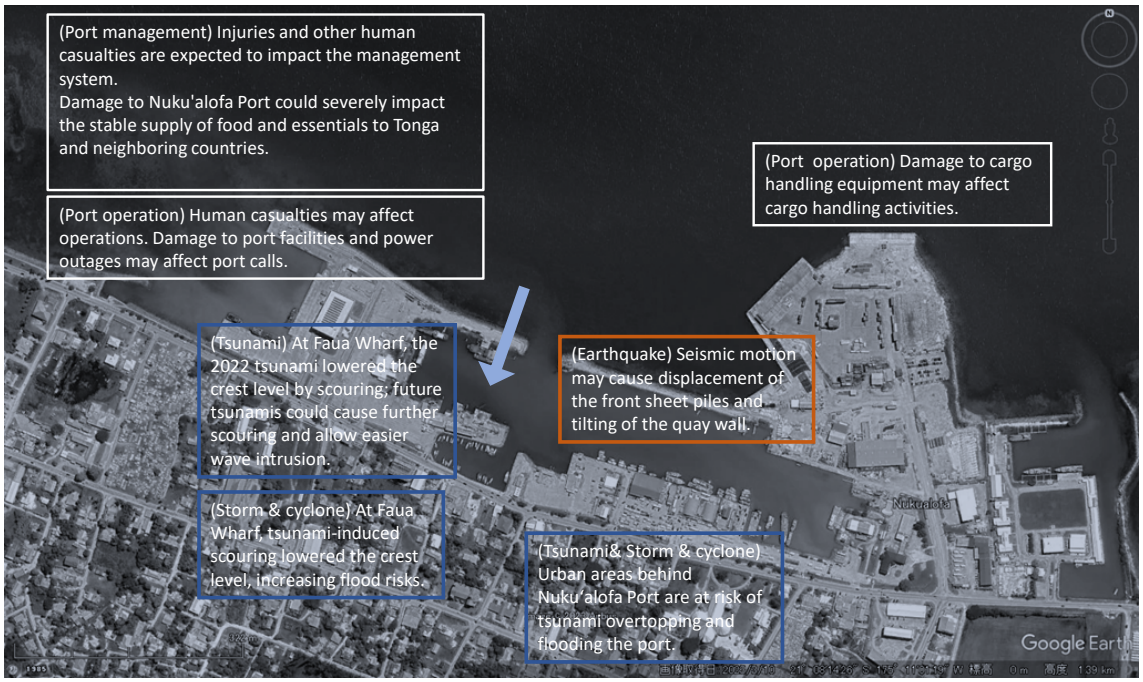
Table 4.3-7 Assessment of Impacts of Natural Disasters for Nuku'alofa Port

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	Both Queen Sālote Wharf and Fau'a Wharf at Nuku'alofa port are primarily anchored sheet pile wall structures. As a result, seismic motion could cause displacement of the front sheet piles and tilting of the quay wall. Damage may also occur to the anchor system, along with ground subsidence in the backland due to liquefaction and cracking of the apron pavement. Additional impacts could include the overturning of cargo-handling equipment and loss of electrical power.	The collapse of ferry terminals and injuries due to an earthquake could affect management systems. Damage to port facilities such as piers is expected to have a significant impact on port operations. Damage to Nuku'alofa is expected to have a significant impact on the stable supply of food and other daily necessities to Tonga and neighboring countries.	Earthquakes may cause human casualties that could affect operations. Damage to port facilities and loss of power may affect port calls. Damage to cargo handling equipment may also affect cargo handling activities.
Tsunami	Nuku'alofa port is located on Tongatapu Island, which faces the open ocean. The island lies on the Tonga Plate, making it susceptible to tsunami impacts. Tsunamis may cause moored vessels to move violently, resulting in damage to the vessels and mooring facilities. Urban areas are located behind Nuku'alofa port, and there is a risk that tsunami waves traveling over the port could impact these areas.	The tsunami is expected to cause injuries and other human casualties, which could affect management systems. Damage to port facilities and the loss of cargo due to the tsunami could have a significant impact on the stable supply of food and other essential goods to Tonga and neighboring countries.	Human casualties caused by tsunamis may affect operations. Damage to port facilities and loss of power may affect the port calls. Collisions and sinking of ships caused by tsunamis may prevent ships from arriving.

	At Faua Wharf, the seaward revetment was scoured by the 2022 tsunami, lowering the crest level. If another tsunami occurs, further scouring may take place, making it easier for waves to enter the port area.		
Volcano	No active volcanoes have been identified near Tongatapu Island, where Nuku'alofa port is located. However, volcanic ash from distant eruptions may reach the area and accumulate. The port facilities are unlikely to be directly affected by the ash.	No active volcanoes have been identified near Tongatapu Island, where Nuku'alofa port is located. Volcanic ash from distant eruptions, however, may reach and accumulate in the area. Such ash deposits could halt land transportation and affect port management operations.	There are no active volcanoes identified on Tongatapu Island, where Nuku'alofa port is located. However, other islands in Tonga are vulnerable to volcanic hazards. As a result, domestic transportation may be delayed, and port operations could be disrupted.
Storm Surge	Nuku'alofa port is located on Tongatapu Island, which faces the open sea. As a result, the effect of wind setup is considered small. However, storm surges may occur due to the suction effect caused by cyclones or low-pressure systems. Such storm surges may cause moored vessels to move violently, leading to damage to both the vessels and the mooring facilities. Urban areas are located	High tides may cause injuries and other human casualties, which could affect management systems. Damage to port facilities and the loss of cargo due to high tides could have a significant impact on the stable supply of food and other goods to Tonga and neighboring countries.	Human casualties caused by high tides may affect operations. Damage to port facilities and loss of power may affect port calls.

	behind Nukuʻalofa port, and there is a risk that storm surge waves traveling over the port could flood and impact these areas.		
Cyclone	Tongatapu Island, where Nukuʻalofa port is located, is a coral island. However, the approach channel to the port is deep, allowing large waves to enter easily. The port also faces the open sea, and the long fetch contributes to the development of high waves. High waves generated by cyclones may cause moored vessels to move violently, leading to damage to both the vessels and mooring facilities. Additional risks include inundation of port facilities, dragging or collision of vessels, loss of container cargo or imported vehicles, and power outages. At Fauʻa Wharf, the seaward revetment was scoured by the 2022 tsunami, resulting in a lowered crest level. During cyclone-induced high waves, it is difficult to maintain calm conditions within the port, and the risk of flooding is very high.	Cyclones may result in casualties and other human damage, which could affect management systems. Strong winds could damage land facilities and close roads, halting land transportation, while high waves could damage port facilities and cause cargo to spill, severely affecting the stable supply of food and other goods to Tonga and neighboring countries.	Cyclones may cause injuries and other human casualties that could affect operations. Strong winds may halt land transportation, which could affect operations. High waves may damage port facilities and cause cargo to spill, which could also affect operations.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in Funafuti port. Figure 4.3-15 illustrates the natural disaster risks and resulting damage in the port. At Faua Wharf, the 2022 tsunami caused scouring that lowered the crest level. Future tsunamis could cause further scouring, making wave intrusion easier. As a result, the urban areas behind the port are exposed to the risk of inundation from tsunamis and storm surges. Nuku'alofa port is the largest international port in Tonga. If port operations are disrupted, the stable supply of emergency goods, daily goods, energy supplies to Tonga would be jeopardized.



(Source: Google Earth with annotations by the JICA advisory team)

Figure 4.3-15 Geographical Assessment of Impacts of Natural Disasters for Nuku'alofa port

4.3.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans.

(1) Confirmation of the reasons for staying with the current resilience indicator

In Section 4.3.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for Nuku'alofa Port. The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in the PIANC guideline. The results are presented below.

(a) Natural disaster adaptation – Resilience indicators: Highly engaged

Reason: Actions are being actively taken at Nuku'alofa port to respond to the natural disasters at existing facilities.

- The potential impacts on critical assets, operations, and systems affected by natural disasters at Nuku'alofa port have been reconfirmed.
- Baseline conditions of port assets, operations, and systems have been identified, and the necessary information has been reconfirmed as being available.
- Information collected on the forecasted intensity of disasters has been reviewed, and the severity of the identified disasters has been confirmed.
- Normal operating conditions (e.g., daily cargo volume, passenger numbers) have been assessed, and the expected impacts during disasters have been confirmed.

(b) Climate change adaptation – Resilience indicators: Highly engaged

Reason: Actions are being actively taken at Nuku'alofa port to address climate change at existing facilities.

- The climate parameters and processes relevant to the critical port assets, operations, and systems have been confirmed.
- Existing baseline data, including information on extreme events, have been collated for each relevant climate parameter or process, and monitoring has been instigated to enhance local knowledge or fill gaps.
- Depending on the planning horizon for the adaptation strategy, climate change scenarios have been agreed, and climate change projections have been collated for relevant parameters and processes.
- Data has been analysed to confirm baseline conditions, identify existing patterns and trends, and determine what is expected to change under each scenario. Both slow onset changes and

expected changes in the frequency or severity of extreme meteorological, oceanographic, or hydrological events have been considered. Data limitations are acknowledged.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in Nuku'alofa port.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at Nuku'alofa Port for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

(a) Natural disaster adaptation

- Agree on the approach to the vulnerability assessment for natural disaster response and confirm changes in susceptibility.
- Identify risk indicators and clarify vulnerable assets, operations, and systems related to natural disaster response.
- Determine the need for and approach to a further risk analysis. If appropriate, assess the likelihood and consequences of risks to complete the risk analysis and identify assets, operations, and systems at risk.

(b) Climate change adaptation

- Agree on the approach to the vulnerability assessment and confirm changes in susceptibility.
- Identify risk indicators and clarify vulnerable assets, operations, and systems for each climate change scenario.
- Determine the need for and approach to a further risk analysis. If appropriate, assess the likelihood and consequences of risks to complete the risk analysis and identify assets, operations, and system at risk.

(c) Disasters and Emergency Response

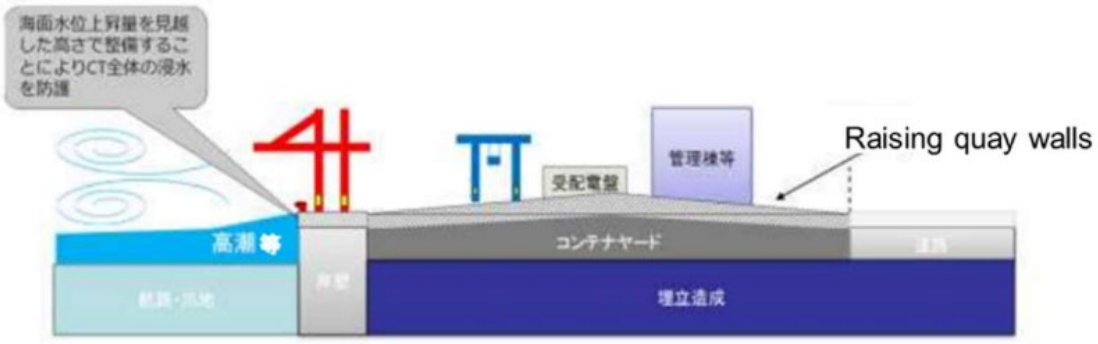
- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans for Nuku'alofa Port.
- Maintain emergency response plans for natural disasters at existing facilities in Nuku'alofa port and verify them through annual audits.

(3) Examples of countermeasures

The following examples present possible countermeasures against storm surges and high waves for existing facilities at Nuku'alofa port. At Queen Sālote Wharf, improvement works have already been carried out with support from ADB. Therefore, the examples below focus on Fau'a Wharf.

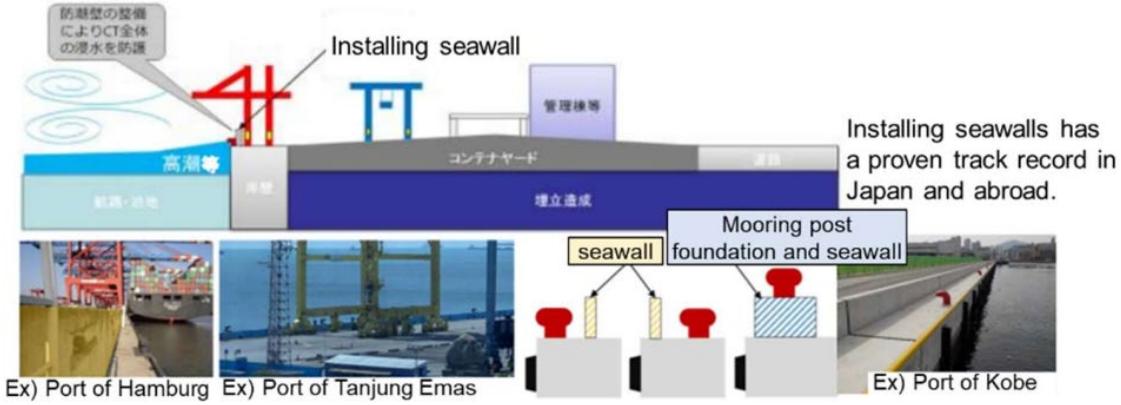
Raising quay walls

The purpose is to raise the height of new or existing wharves to a level that takes into account the effects of storm surges and sea level rise, and to plan or renovate the structure so that it can withstand the resulting increase in load. Faua Wharf at Nuku'alofa port was constructed in 2018 through cooperation with Japan. The deck height of the wharf was determined based on the types of vessels calling at the port and relevant operational considerations.



Installing seawalls

Additional flood walls are installed on existing wharves to prepare for the effects of high tides and sea level rise. Flood walls are sometimes installed in front of or behind mooring posts (bollards) on wharves for mooring and cargo handling operations. In cases where mooring posts can be relocated or newly constructed, a design integrating the flood walls with the foundations of the mooring posts is also considered.



(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for Nuku'alofa Port are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Ports Vision*" for natural disaster adaptation in Neiafu port is evaluated as "Highly engaged."
In order to achieve a higher level of resilience indicator, it is necessary identify risk indicators and align vulnerable assets, operations, and systems in terms of natural disaster response. It is also necessary to determine the need for further risk analysis and the appropriate approach. If needed, risk analysis should be completed to assess the likelihood and consequences of risks in order to identify the assets, operations, and systems that are "at risk."

(b) Climate Change Adaptation

The resilience indicator (KEY RESILIENCE INDICATOR) outlined in the "*Pacific Ports Vision*" for climate change adaptation in Nuku'alofa port is evaluated as "Highly engaged."
In order to achieve the next level of resilience indicator, it is necessary to agree on the approach for vulnerability assessment and to confirm any changes in sensitivity. Risk indicators should be identified, and vulnerable assets, operations, and systems should be aligned for each climate change scenario. It is also necessary to determine the need for further risk analysis and the appropriate approach. If needed, risk analysis should be completed to assess the likelihood and consequences of risks in order to identify the assets, operations, and systems that are "at risk."

(c) Disasters and Emergency Response

The resilience indicator (KEY RESILIENCE INDICATOR) outlined in the "*Pacific Ports Vision*" for emergency response in Nuku'alofa Port is evaluated as "Highly Engaged."
In order to achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and verify that these plans are maintained through annual audits.

(d) Introduction of the Draft Plan for Port Resilience

The PAT's stance regarding Queen Salote Wharf was that no additional investment was necessary at this time, as the improvements were progressing under the ADB project. At Faua Wharf, a domestic pier was constructed through JICA's Grant Aid program at a total project cost of 3.32 billion yen. It was completed in June 2018. The newly developed wharf was named Taufa'ahau Tupou IV Port.
The development of this wharf led to increased demand, with ship operators procuring new

vessels. As a result, the PAT plans to begin constructing piers for domestic vessels at the rear of the domestic wharf using its own funds. The plan involves driving steel pipe piles at the front and reclaiming the land behind them.
However, the water area is narrow, making it difficult to secure a sufficient turning radius for ferry operations, and the front breakwater is inadequate, with a low crest height. The 2022 tsunami caused scouring on the slope behind the breakwater, making it difficult to maintain calm water conditions during high waves.

On the other hand, King Taufa'ahau Tupou IV Port was constructed with a high crest elevation and provides strong wave protection through its revetment structures. In the future, if the domestic terminal development promoted by PAT cannot accommodate the expected increase in port calls, the expansion of King Taufa'ahau Tupou IV Port could be considered as one possible option. The expansion project includes extending the quay to meet demand, widening the approach channel, and relocating the anchorage area. The expansion plan is shown in Figure 4.3-16.

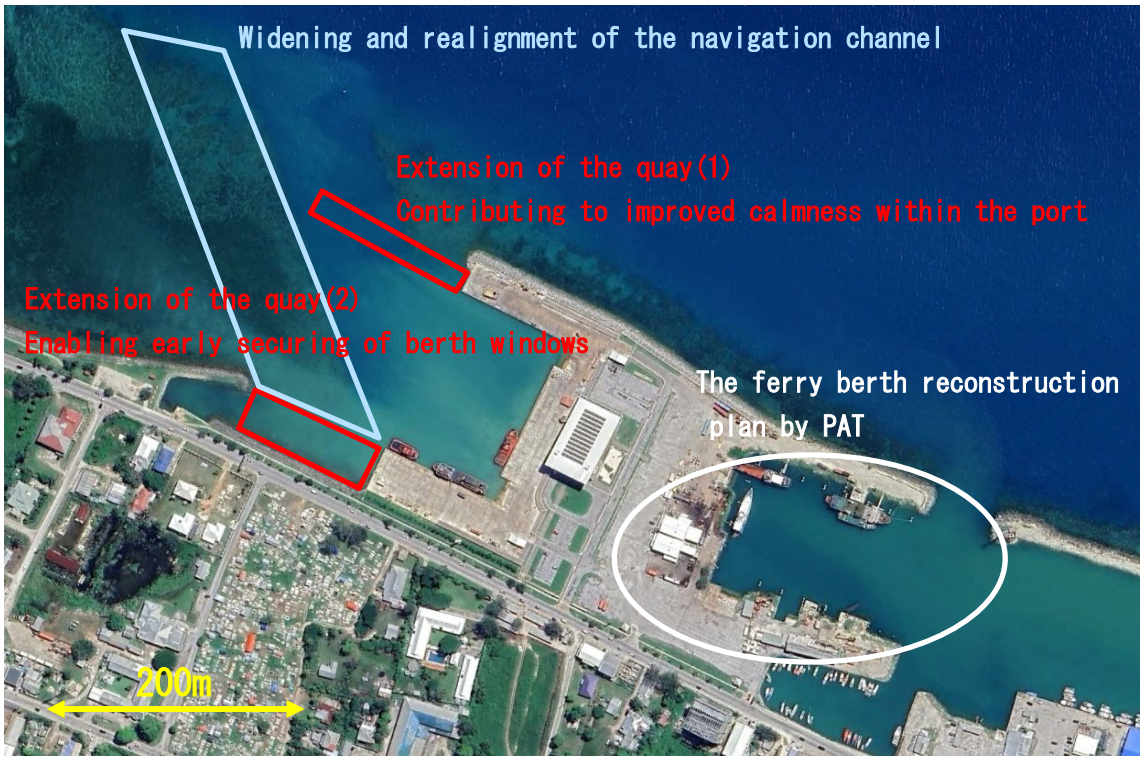


Figure 4.3-16 Expansion Plan for Taufa'ahau Tupou IV Port (Domestic Terminal)

4.4 Ohonua Port (Nafanua Wharf) in ‘Eua Island

4.4.1 Review issues related to port maintenance and management

(1) Status of Port facilities

Ohonua port (Nafanua Wharf) is located on the west coast of ‘Eua Island, facing Tongatapu Island, and operates a ferry service to Nuku‘alofa 5 to 6 times a week. The sailing distance between Nuku‘alofa port and Ohonua port on ‘Eua Island is approximately 40 km, with a travel time of 2.5 to 3 hours on the MV ONEMATO and about 1.5 hours on the MV MALAU, which began service in August 2023. As shown in Figure 4.4-3, Ohonua port (Nafanua Wharf) is an artificially excavated port. Two breakwaters are installed at the port entrance, with the northern breakwater measuring approximately 90 meters and the southern breakwater measuring about 40 meters. At the current ferry berthing location, these breakwaters provided a certain level of wave protection. However, because the distance between the port entrance and the quay wall was short, wave intrusion through the entrance and wave diffraction around the breakwaters caused disruptions to cargo handling operations.



Figure 4.4-1 Ferry to ‘Eua Island (Nuku‘alofa port)
（Photo by Survey team November 17,2023）



Figure 4.4-2 View of the port entrance from the ferry during berthing (‘Eua Island)
（Photo by Survey team November 17,2023）

Waves were observed transmitting through and overtopping the northern breakwater.





Before the Disaster (Google Earth, January 2017)	After the Disaster and Temporary Restoration (Drone Aerial Photo, November 17, 2023)

Figure 4.4-3 Comparison Between the Pre-Tsunami Condition (January 2017) and the Post-Tsunami Temporary Restoration (November 2023)

On the other hand, the water area within the port is narrow and does not provide sufficient space for the safe turning of the currently operating ferry. Due to the limited water area, multiple wave reflections from coastal structures and shorelines are likely to occur, and the calm water conditions required for safe berthing of the ferry are not adequately ensured. As a result, when boarding and disembarking within the port is not possible, the ferry is anchored offshore, and passengers are transferred using small fishing boats. This is highly dangerous during inclement weather or when the water is not calm.





Figure 4.4-4 Boarding by transfer boat when direct boarding within the port is not possible (Photo taken by the survey team: November 18, 2023)

(a) Port plan



Figure 4.4-5 Location Map of Survey Area

(b) Cross section of port facilities

The design documents for Ohonua port (Nafanua Wharf) could not be obtained from MOI. Therefore, photographs taken during the site investigation are presented below. Figure 4.4-7 and Figure 4.4-8 were taken at the positions shown in Figure 4.4-6.

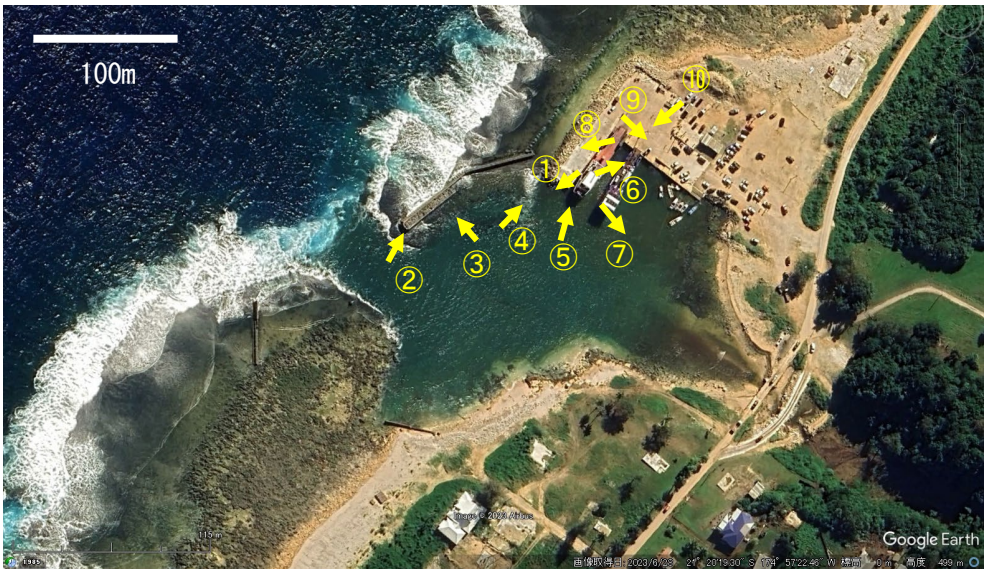


Figure 4.4-6 Location Map of Survey Area



Figure 4.4-7 Survey photo of breakwater



Figure 4.4-8 Survey photo of Nafanua Wharf

(c) Assessing the current situation through on-site inspections

Ohonua port (Nafanua Wharf) is an excavated port with two breakwaters at the entrance. The northern breakwater is approximately 90 meters long, and the southern breakwater is 40 meters long. The northern breakwater allowed waves to pass through and overtop during the tsunami which was caused by a volcanic eruption in January 2022. The rubble that made up the breakwater was scattered, and the outer port rubble was also likely displaced by the tsunami. The rocks appear to be coral stones with many voids. As of November 2023, when the site survey was conducted,

the scattered rubble had been removed. The breakwater had not been restored to its original cross-section, and it is evident that its wave attenuation effectiveness has diminished. During the site visit, the survey team explained the survey approach to MOI and discussed facility resilience and maintenance methods.



Figure 4.4-9 Deterioration of breakwaters

(d) Collection and organization of design documents from the viewpoint of maintenance and management

The design documents could not be obtained from MOI. In addition, since Ohonua port (Nafanua Wharf) was not constructed with support from Japan, JICA was also unable to provide design documents.

4.4.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at Ohonua Port (Nafanua Wharf)

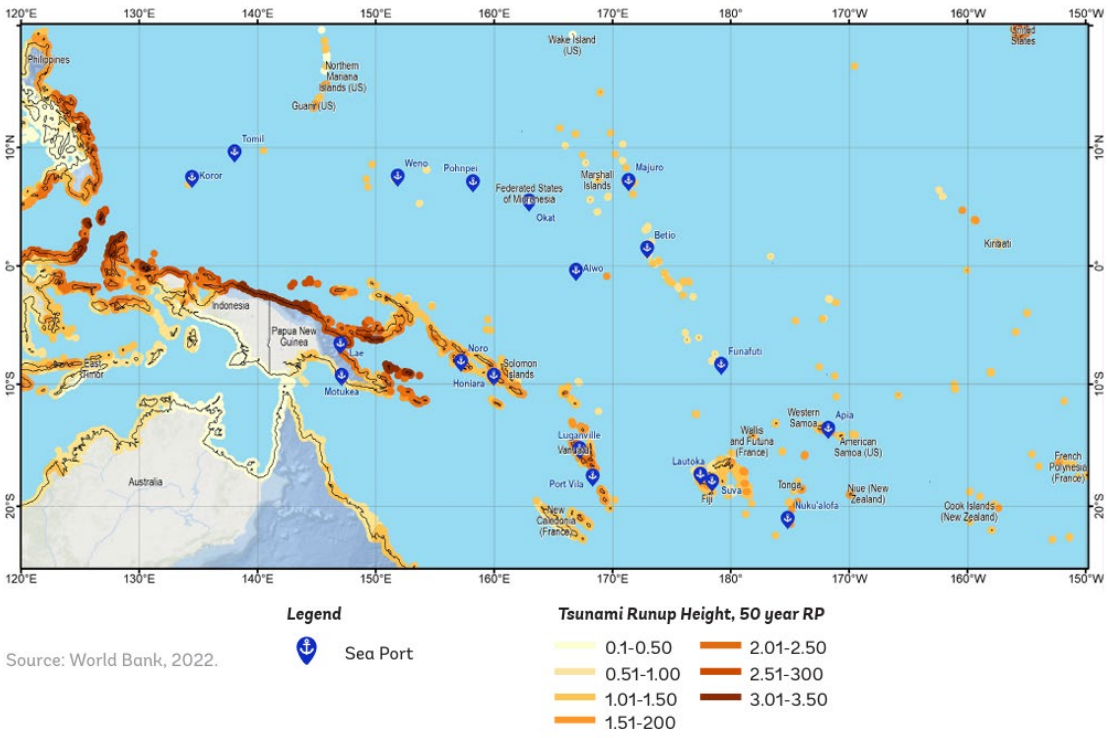
(1) Collection of data on damage caused by past natural disasters

In this section, we will collect reports and compile information on natural disasters that affected Ohonua port (Nafanua Wharf) in the past. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss. The advisory team focused on the categories of natural disasters that the target ports had experienced, the scale of the disasters, and the human and material damage, and collected data and records related to previous natural disasters over time. The advisory team requested MOI to provide meteorological and oceanographic data, which are indicators of the scale of natural disasters. However, the data could not be obtained.

According to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), the proportion of intense tropical cyclones (Category 3–5) among all tropical cyclones globally has likely increased over the past 40 years, with medium confidence. In contrast,

there is low confidence in long-term trends in the frequency of all categories of tropical cyclones. Similarly, AR6 states that the global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3,000 years, with high confidence. These findings suggest that the potential risks of inundation caused by cyclones, storm surges, and high waves are increasing.

According to a report by the World Bank, as shown in Figure 4.4-10 to Figure 4.4-12, the Pacific region faces high risks from tsunamis, earthquakes, and volcanic activity. Tonga consists of islands situated on a small tectonic plate located between the Tonga Ridge to the west and the Tonga Trench to the east. As a result, the earthquake risk is extremely high. ‘Eua Island is located approximately 30 kilometers from Tongatapu Island, where Nuku‘alofa port is situated. As indicated in the seismic hazard map in Figure 4.4-11, ground shaking exceeding 250 cm/s² is expected in a 250-year return period earthquake event. Due to the high likelihood of earthquakes, the tsunami risk is also significant. In the area where Nuku‘alofa port is located, tsunami impacts in the range of 1.5 to 2.0 meters must be considered, as shown by the red box in Figure 4.4-10. Tonga is a region influenced by tectonic activity and subject to volcanic hazards. However, according to Figure 4.4-12, the volcanic hazard level at Nuku‘alofa port is classified as “Low”.



Source: World Bank, 2022.

Figure 4.4-10 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

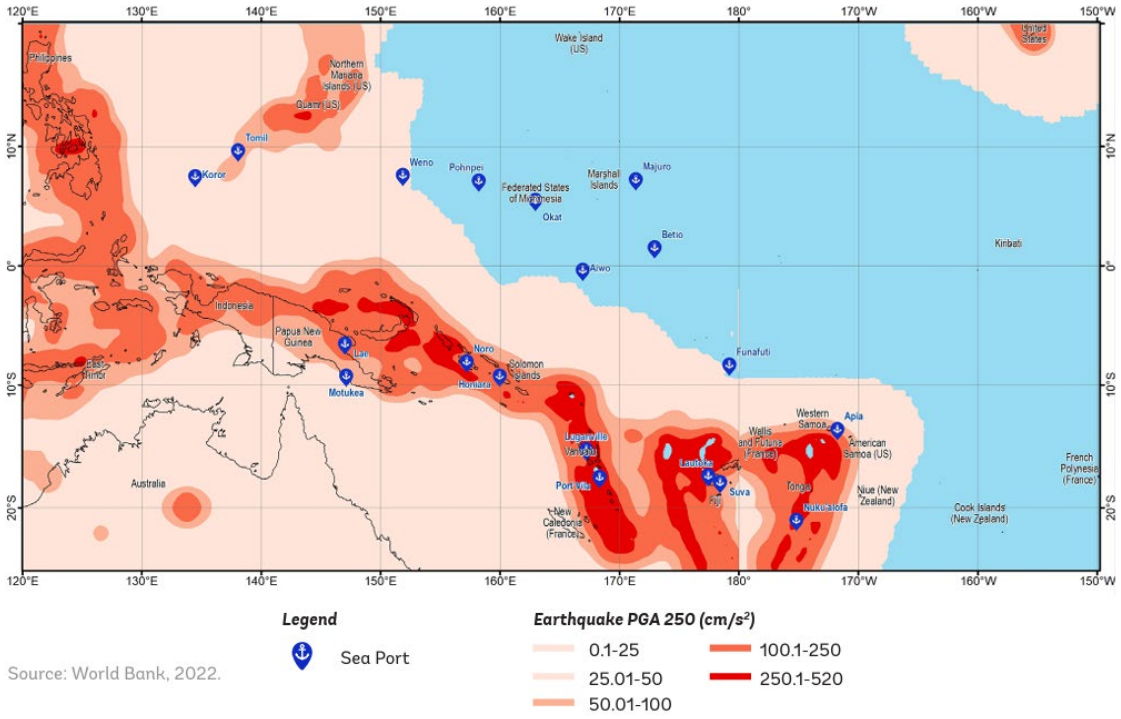


Figure 4.4-11 Earthquake peak ground acceleration (PGA) in cm/s2 for a 250-year return period

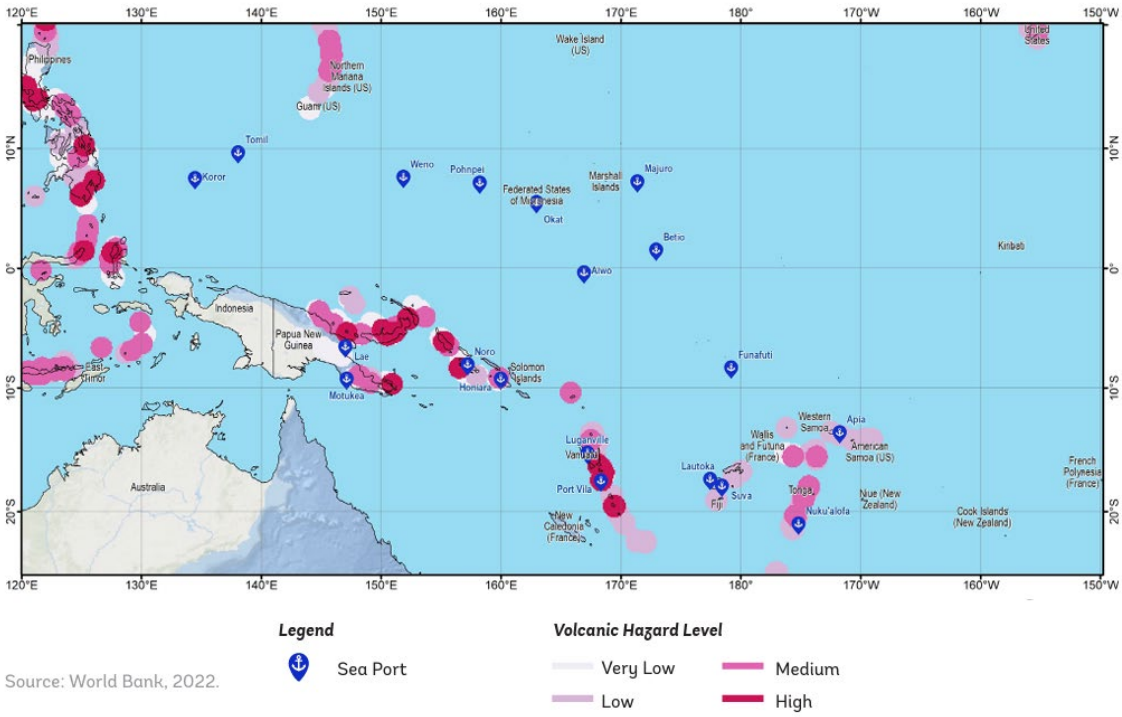


Figure 4.4-12 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

On January 15, 2022, an eruption of the Tonga Hunga-Tonga-Hunga-Ha'apai submarine volcano occurred approximately 65 km north of Nuku'alofa, causing a tsunami that resulted in significant damage. On 'Eua Island, the coastline and surrounding areas of the main township, Ohonua, suffered extensive damage, and the port facilities, including breakwaters and seawalls, required repair work.

In Figure 4.4-13, the northern breakwater, which was intact in June 2016, was damaged by the tsunami in June 2023, with its superstructure scattered.



Figure 4.4-13 Aerial photographs of Ohonuwa Port before and after the disaster (June 2016 and June 2023).

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in Ohonua (Nafanua) and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters. For Ohonua port (Nafanua Port), the design documents could not be obtained from the relevant authorities. Furthermore, since the port was not constructed with Japan's cooperation, JICA could not provide any documentation.

4.4.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in Ohonua port (Nafanua Wharf) based on research papers and records of natural disasters that affected ports.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*[68]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for Ohonua port (Nafanua Wharf). This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

[68] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

Ohonua port (Nafanua Wharf) is located on the western coast of ‘Eua Island, approximately 30 kilometers southeast of Tongatapu Island, where Nuku‘alofa port is situated. Therefore, the types and magnitudes of natural hazards that should be considered for Nafanua Wharf are generally similar to those for Nuku‘alofa port, or the values for Nuku‘alofa can be used as a reference. According to Table 4.4-1, the area surrounding Nuku‘alofa port is an open sea area, resulting in a long fetch and a very high wave height of 9.1 meters during cyclones. Although the western side of Nafanua Wharf is open to the sea, the northwestern direction is partially sheltered by Tongatapu Island, which is expected to reduce wave impact. As a result, the influence of high waves caused by cyclones at Nafanua Wharf is considered to be somewhat lower than at Nuku‘alofa port. The same applies to high waves generated by regional storms, and the impact at Nafanua Wharf is assumed to be smaller than the values observed at Nuku‘alofa. While sea level rise itself does not pose a direct threat, it may increase the risks associated with storm surges, cyclones, and high waves. Since Nafanua Wharf is located on the Tonga Plate, the risks related to tsunami inundation height, earthquakes, and volcanic activity are classified as medium.

Table 4.4-1 Multi-hazard Heat Map Port Exposure (Tonga)

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5, 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High | Medium | Low | Very Low | Not applicable

Table 4.4-2 Methodology for Identifying Natural Disasters and their Scales (Ohonua port (Nafanua Wharf))

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	The design documents could not be obtained.	Not applicable	Based on historical records, the earthquake magnitude is estimated, and seismic waves are determined by considering the distance from the epicenter and the characteristics of the ground.
Tsunami	The design documents could not be obtained.	Not applicable	Based on the maximum tsunami recorded in the past, the loads applied to structures are determined by considering tsunami height and flow velocity.
Volcano	The design documents could not be obtained.	Not applicable	The assessment is based on a comprehensive evaluation of the damage caused by past volcanic activity.
Storm Surge	The design documents could not be obtained.	Flood disasters increase due to sea level rise.	Future sea level rise should be considered objectively. The results of PRIF, which will be described later, can be used as one of the methods.
Cyclone	The design documents could not be obtained.	Increase in high waves due to cyclone intensification.	Increase in waves caused by cyclone intensification should be considered objectively. The recent research results, such as future predictions using d4PDF described later, can be used.

(2) Measures against sea level rise and wave power due to climate change

“Japanese port and harbor design standards” explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately determined using the latest research findings and scientific knowledge. Figure 4.4-14 illustrates

two conceptual approaches for setting structural strength while considering changes in external forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as "Proactive adaptation." On the other hand, "Adaptive adaptation" refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life, but implementing physical upgrades progressively at appropriate times, depending on material and structural characteristics.

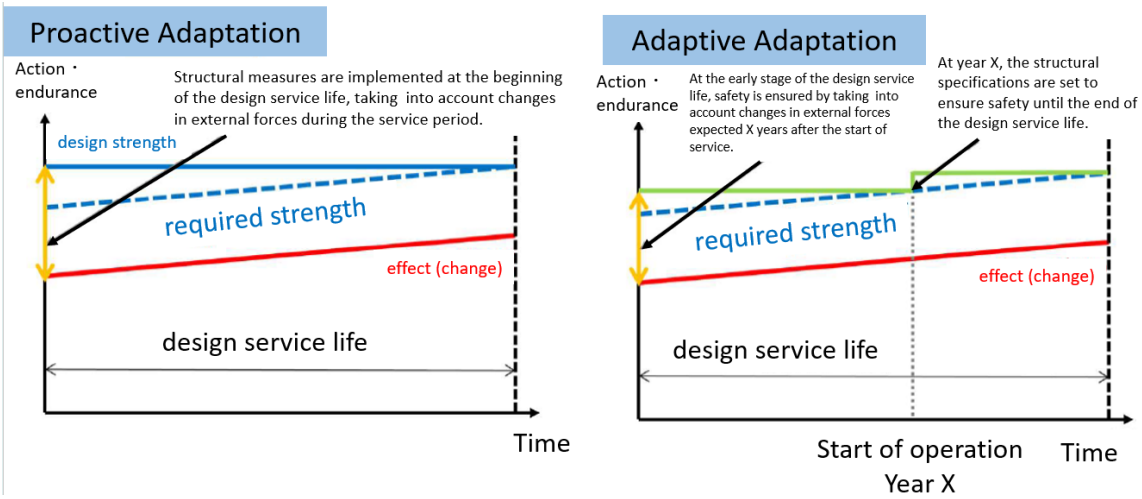


Figure 4.4-14 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power by climate change

Due to the many uncertainties surrounding climate change, a range of scenarios has been discussed. For example, "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[69]" presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[70] as a basis when considering the impacts of climate change in port facility design. RCP2.6

[69] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[70] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. Figure 4.4-15 shows the projected median regional sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [71].

The projected sea level rise in Tonga is shown in Figure 4.4-16. By 2050, sea level rise in Tonga is projected to be 0.26 m under the 2°C scenario (SSP1-2.6) and 0.31 m under the 4°C scenario (SSP5-8.5), with a small difference of 0.05 m. On the other hand, by 2100, sea level rise is expected to reach 0.60 m under the 2°C scenario (SSP1-2.6) and 0.97 m under the 4°C scenario (SSP5-8.5), showing a larger difference of 0.37 m. Therefore, depending on the scenario selected, the value of projected sea level rise differs and this must be considered when setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

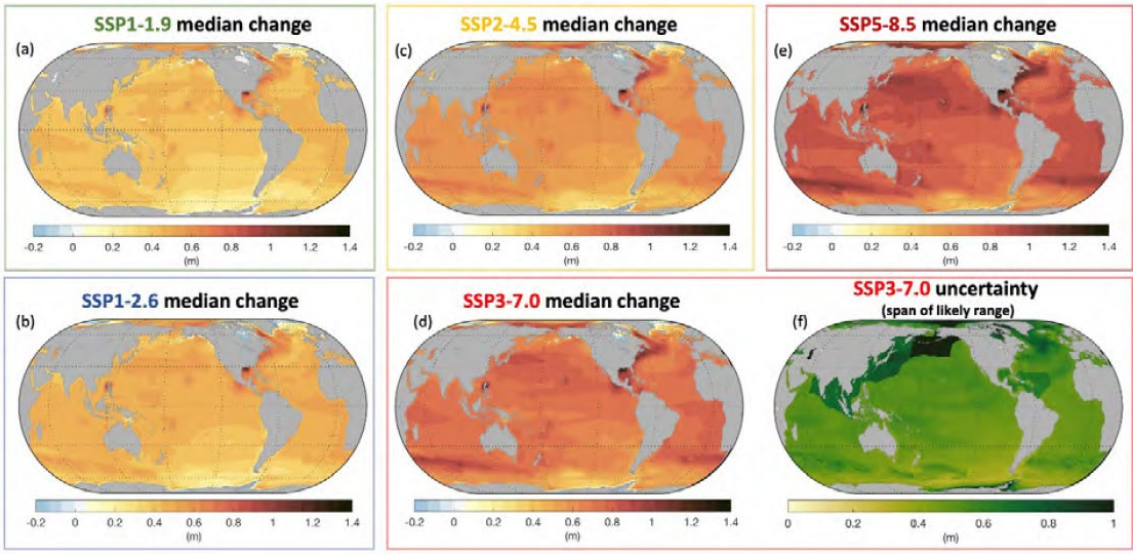


Figure 4.4-15 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

[71] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

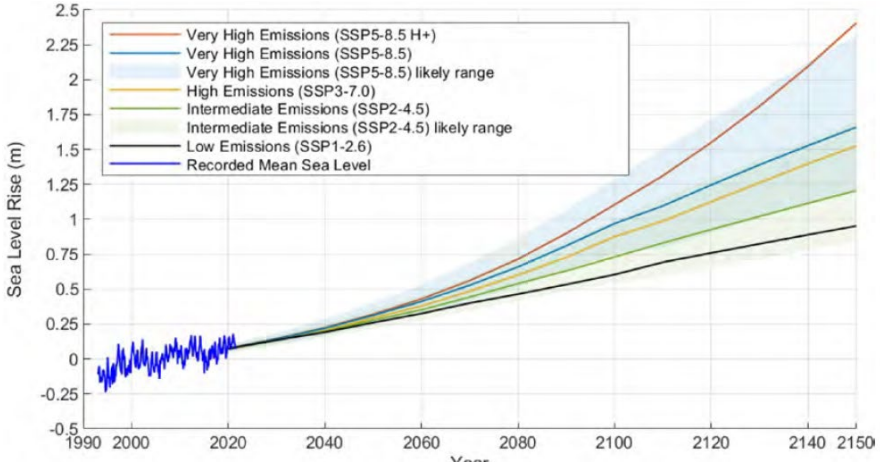


Figure 4.4-16 Sea Level Rise Projections to 2150 for Tonga Relative to 1995–2014 Mean Sea Level

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the “Database for Policy Decision-Making for Future Climate Change” (d4PDF, Mizuta et al. [72]). To predict future changes in extreme weather events such as typhoons due to climate change, a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing Waves and Coasts in the Pacific" (WACOP) project[73]. This project uses four climate models that participated in CMIP5. When considering storm surges and high waves, it is essential to incorporate research findings using these future climate models.

[72] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita, M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.
[73] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html(Accessed in July, 2024)

4.4.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing analysis on port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize MOI's current disaster mitigation plans in terms of time frame and type of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". Natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 4.4-3Table 3.2-4.

Table 4.4-3 Classification of adaptations and responses according to natural disasters

Type of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The survey team (advisory team?) confirmed the structure of existing facilities and maintenance status of the target port through interviews with MOI and available design documents. The survey team also confirmed the existence and implementation status of natural disaster response plans for the respective port facilities. JICA experts sent questionnaires to each port authority to confirm whether disaster prevention or mitigation plans have been prepared and whether they are being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change. The responses from MOI are summarized below.

(2) Maintenance and Management

MOI has not developed a formal maintenance management plan. However, the agency is aware of the importance of such planning and has prepared an inspection manual. Regular inspections of port facilities are conducted approximately once a year.

(3) Countermeasures against Natural Disasters

Although MOI has developed a tsunami hazard map as part of its disaster response measures, no specific actions have been implemented regarding natural disaster preparedness. However, the following measures are currently being planned as part of future disaster response initiatives.

1) Risk Assessment and Mapping: Hazard Mapping & Vulnerability Assessment
2) Preventive Measures: Land use planning (evacuation routes and safe zones)
3) Preparedness Measures: Early Warning Systems (disaster notification, sirens etc.), evacuation plans, emergency supplies, training and drills
4) Response Measures: Emergency Communication System, Search and Rescue Operations, Medical Assistance
5) Recovery Measures: Damage Assessment, Restoration of Services (repair & rehabilitation), Financial Assistance, etc.
6) Monitoring and Continuous Improvement of the Infrastructure

(4) Emergency Response

Emergency response plans for disasters such as earthquakes, tsunamis, and fires have been fully identified by MOI and communicated to relevant stakeholders.
However, a formal port Business Continuity Plan (BCP) has not been developed.
The following measures are currently being planned as part of emergency preparedness measures.

1) Initial Assessment and Alerting: assess the situation, activate the emergency plan, alert key stakeholders
2) Evacuation Procedures: identify evacuation routes, assign evacuation leaders and guides, specify protocols for assisting individuals with disabilities or special needs.
3) Communication Protocols: establish primary and backup communication channels (radios, mobile phones etc.), create clear chain of command for decision making
4) Containment and Control: assign roles for controlling the emergency (eg; fire extinguishing, shutting off utilities etc.), implementing lockdown
5) First Aid and Medical Response: designated first aid responders and medical support, outline procedures for treating injuries and transporting victims to medical facilities
6) Safety and Security: responders to wear PPE, secure the site to prevent unauthorized access
7) Coordination with Emergency Services: provide detailed information to emergency responders upon arrival, collaborate closely with each stakeholder in supporting each other
8) Documentation and Incident Reporting
9) Recovery and Restoration
10) Review and Evaluation

(5) Climate Change Adaptation

Although MOI is aware of the potential impacts of climate change, such as sea level rise and increased wave heights, no specific actions have been taken to address these issues. However, the following measures are planned as part of future climate change adaptation measures.

7） Risk assessment and Mapping: Hazard Mapping & Vulnerability Assessment
8） Preventive Measures: Land Use Planning (evacuation routes and safe zones)
9） Preparedness Measures: Early Warning Systems (disaster notification, sirens etc), evacuation plans, emergency supplies, training and drills
10） Response Measures: Emergency Communication System, Search and Rescue Operations, Medical Assistance
11） Recovery Measures: Damage Assessment, Restoration of Services (repair & rehabilitation), Financial Assistance etc.
12） Monitoring and Continuous Improvement of the Infrastructure

4.4.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by following the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*"[74] (hereinafter referred to as "*Pacific Ports Vision*") to shown in Table 4.4-4. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[74] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 4.4-4 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities in Ohonua port (Nafanua Wharf) are shown below.

(a) Natural disaster adaptation – Resilience indicators: Unengaged

The construction year of Ohonua port (Nafanua Wharf) is unknown. However, the breakwater has been damaged by a past tsunami, and the wharf is showing significant signs of aging and deterioration. MOI has developed a tsunami hazard map, but no specific actions have been taken in response to natural disasters. Based on these observations, the resilience indicator is assessed as Unengaged.

(b) Climate change adaptation – Resilience indicators: Unengaged

The construction year of Ohonua port (Nafanua Wharf) is unknown. However, the breakwater has been damaged by a past tsunami, and the wharf is showing significant signs of aging and deterioration. MOI is aware of the potential impacts of climate change, such as sea level rise and increased wave heights, but no specific actions have been taken to address these issues. Based on these observations, the resilience indicator is assessed as Unengaged.

(c) Emergency response – Resilience indicator: Highly engaged

Although MOI has not formulated a port Business Continuity Plan (BCP), emergency response plans for disasters such as earthquakes, tsunamis, and fires have been fully identified and communicated to relevant stakeholders. These emergency response plans are considered equivalent to a port BCP, and MOI plans to continue reviewing and evaluating them in the future. Based on these observations, the resilience indicator is assessed as Highly Engaged.

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in Ohonua port (Nafanua Wharf) in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

Table 4.4-5 Assessment of Impacts of Natural Disasters for Ohonua port (Nafanua Wharf)

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	Ohonua port (Nafanua Wharf) is located on the eastern coast of 'Eua Island and is close to the Tonga Trench, making it highly vulnerable to earthquakes. Although the structural type of the wharf is unknown, it is highly likely to sustain damage due to seismic motion.	If injuries occur as a result of an earthquake, the resulting human impact could affect the port's management and operational capacity. If the quay wall is damaged, it could have a severe impact on port functions. Ohonua port (Nafanua Wharf) serves as the primary entry point for goods into 'Eua Island, and any disruption to its operations could have a serious impact on the stable supply of essential goods such as food.	Earthquakes may cause human casualties that could affect operations. Damage to the quay wall or loss of power supply could also disrupt vessel calls at the port.
Tsunami	During the tsunami caused by the volcanic eruption in 2022, the breakwater at Ohonua port (Nafanua Wharf) was damaged, despite the port being in the sheltered zone of Tongatapu Island. Even if the breakwater is repaired, without implementing additional tsunami countermeasures, moored vessels may drag anchor or collide with other structures.	If injuries occur as a result of a tsunami, the resulting human impact could affect the port's management and operational capacity. Ohonua port (Nafanua Wharf) serves as the primary entry point for goods into the 'Eua Island, and any disruption to its	Human casualties caused by tsunamis may affect operations. Damage to the quay wall or loss of power supply could also disrupt vessel calls at the port.

		operations could have a serious impact on the stable supply of essential goods such as food.	
Volcano	Active volcanoes have not been identified in the vicinity of 'Eua Island, where Ohonua port (Nafanua Wharf) is located. However, there is a possibility that volcanic ash from distant eruptions may reach the area and accumulate. Nevertheless, the likelihood of the port facilities themselves being directly affected is low.	There are no active volcanoes confirmed in the vicinity of 'Eua Island, where Ohonua port (Nafanua Port) is located. However, volcanic ash from distant eruptions may reach the area and accumulate. If volcanic ash accumulates on land, it could disrupt land transportation and affect the port's management and operational capacity.	There are no active volcanoes confirmed in 'Eua Island, where Ohonua port (Nafanua Wharf) is located. However, since other islands in Tonga are vulnerable to volcanic activity, domestic transportation may be delayed, potentially causing disruptions to port operations.
Storm Surge	Storm surges may cause flooding or damage to the wharf, and may also result in inundation of adjacent port towns. In addition, vessels may drag anchor due to the effects of storm surges.	If injuries occur as a result of a storm surge, the resulting human impact could affect the port's management and operational capacity. Ohonua port (Nafanua Wharf) serves as the primary entry point for goods into 'Eua Island, and any disruption to its operations could have a serious impact on the stable supply of essential goods such as food.	Human casualties caused by high tides may affect operations. Damage to the quay wall or loss of power supply could also disrupt vessel calls at the port.
Cyclone	At Ohonua port (Nafanua Wharf), the breakwater has	If injuries occur due to high waves caused by a	Cyclones may cause injuries and other

	been damaged, resulting in a significant loss of calmness. As a result, high waves caused by cyclones may lead to flooding of the wharf and surrounding areas, as well as vessel dragging and collisions.	cyclone, resulting human impact could affect the port's management and operational capacity. Ohonua port (Nafanua Wharf) serves as the primary entry point for goods into the 'Eua Island, and any disruption to its operations could have a serious impact on the stable supply of essential goods such as food.	human casualties that could affect operations. Damage to the quay wall or loss of power supply could also disrupt vessel calls at the port.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in Funafuti port. Figure 4.4-17 illustrates the natural disaster risks and resulting damage in the port. Although the 2022 tsunami struck a relatively sheltered area, it damaged the breakwater at Ohonua Port (Nafanua Wharf). As a result, the port's calmness has been significantly compromised, increasing the risk of inundation from high waves as well as anchor dragging and collisions of moored vessels. Ohonua Port (Nafanua Wharf) serves as the primary gateway for the supply of goods to 'Eua Island. If port operations are disrupted, the stable supply of emergency goods, daily necessities, and energy would be jeopardized.

Therefore, the advisory team proposes rehabilitating the breakwater to enhance the port's resilience. Even after repairs, however, if additional tsunami countermeasures are not implemented, there remains a risk that moored vessels may drag their anchors or collide with port structures.



(Source: Google Earth with annotations by the JICA advisory team)

Figure 4.4-17 Geographical Assessment of Impacts of Natural Disasters for Ohonua port (Nafanua Wharf)

4.4.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level, and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans.

(1) Confirmation of the reasons for staying with the current resilience indicators

In Section3.2.5 4.4.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for Ohonua port (Nafanua Wharf). The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in the PIANC guideline. The results are presented below.

(a) Natural disaster adaptation – Resilience indicators: Unengaged

Reason: Actions are not taken at Ohonua port (Nafanua Wharf) to respond to natural disasters at existing facilities.

- The goal(s), planning horizon, and objectives for natural disaster adaptatoin have not been established and agreed upon at Ohonua port (Nafanua Wharf).
- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has not been completed, and the potential impacts of natural disasters on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the natural disaster adaptation process for Ohonua port (Nafanua Wharf).

(b) Climate change adaptation – Resilience indicators: Unengaged

Reason: Actions are not taken at Ohonua port (Nafanua Wharf) to address climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed upon at Ohonua port (Nafanua Wharf).
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has not been completed, and the potential impacts of climate changes on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate change is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in Ohonua port (Nafanua Wharf).

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing

facilities at Ohonua port (Nafanua Wharf) for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

Measures to make Ohonua port (Nafanua Wharf) one level higher on the resilience indicators

(a) Natural disaster adaptation

- Establish goal(s), planning horizon and objectives for natural disaster adaptation at existing facilities in Ohonua port (Nafanua Wharf).
- Identify the impact of natural disasters on port assets, operations, and systems in Ohonua port (Nafanua Wharf).
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information related to natural disaster intensity predictions and determine the extent of the natural disaster.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(b) Climate change adaptation

- Establish goal(s), planning horizon and objectives for climate change adaptation at existing facilities in Ohonua port (Nafanua Wharf).
- Identify the impact of climate changes on port assets, operations, and systems in Ohonua port (Nafanua Wharf).
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information on natural disaster intensity forecasts including the effects of climate change and identify the extent of natural disasters with climate change impacts.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(c) Disasters and Emergency Response

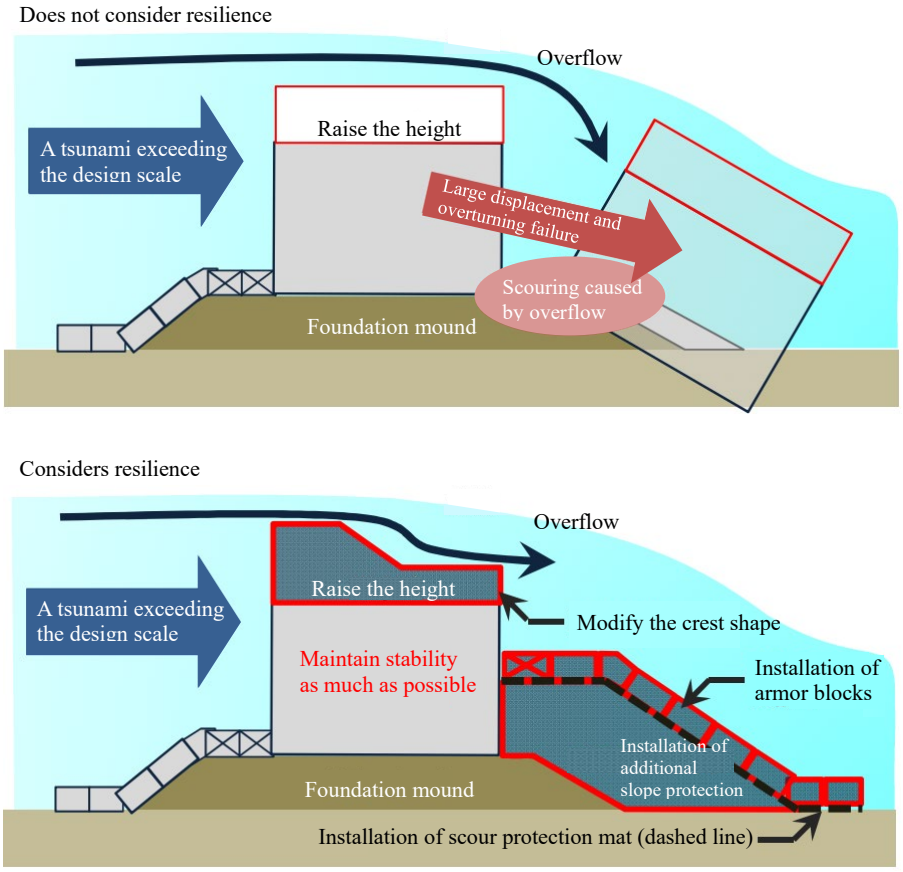
- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans for Ohonua port (Nafanua Wharf).
- Maintain emergency response plans for natural disasters at existing facilities in Ohonua port (Nafanua Wharf) and verify them through annual audits.

(3) Examples of countermeasures

The following example is one of the countermeasures against tsunami for the existing breakwater in Ohonua port (Nafanua Wharf).

・Resilient breakwater

At Ohonua port (Nafanua Wharf), the breakwater's superstructure was displaced by the tsunami caused by the volcanic eruption in 2022. As a result, the structure lost its wave-calming function. In future plans for rehabilitation or reconstruction of the breakwater, it is essential to adopt a resilient structure. This is especially important for facilities with high importance, where damage could lead to serious consequences for human life, property, and socioeconomic activities. Ohonua port (Nafanua Wharf) is the only port on ‘Eua Island and serves as a vital facility for the island’s residents. To ensure the breakwater remains stable even under extreme tsunami forces, the proposed approach includes increasing the crest height, modifying the crest shape, and placing revetment support structures on the landward side. These measures are intended to prevent scouring caused by overflow and to reduce the risk of significant displacement or collapse of the structure.



(This is a proposal to adopt a resilient structure that can maintain its performance even under tsunami forces that exceed those of the design tsunami.)

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for Ohonua port (Nafanua Wharf) are as follows.

(a) Natural Disaster Adaptation

The resilience indicator (KEY RESILIENCE INDICATOR) outlined in the "*Pacific Ports Vision*" for natural disaster adaptation in Ohonua port (Nafanua Wharf) is evaluated as "Unengaged."
In order to achieve a higher level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for existing facilities at Ohonua port (Nafanua Wharf) in terms of their natural disaster adaptation. It is recommended to identify the impact of natural disasters on port assets, operations, and systems at existing facilities in Ohonua port (Nafanua Wharf), collecting information necessary to understand the baseline situation, and specifying information necessary for natural disaster risk assessment in order to prepare for the formulation of a natural disaster adaptation plan.

(b) Climate Change Adaptation

The resilience indicator (KEY RESILIENCE INDICATOR) outlined in the "*Pacific Ports Vision*" for climate change adaptation in Ohonua port (Nafanua Wharf) is evaluated as "Unengaged."
In order to achieve the next level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for climate change adaptation. It is recommended to collect information on natural disaster intensity forecasts that include the impact of climate change in order to identify the impact of climate change on the port assets, operations, and systems of in Ohonua port and to understand the baseline situation.

(c) Disasters and Emergency Response

The resilience indicator (KEY RESILIENCE INDICATOR) outlined in the "*Pacific Ports Vision*" for emergency response in Ohonua port (Nafanua Wharf) is evaluated as "Highly Engaged." In order to achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and verify that these plans are maintained through annual audits.

(d) Introduction of the Draft Plan for Port Resilience

At Ohonua port (Nafanua Wharf), the breakwater was damaged by the tsunami caused by the volcanic eruption in 2022, resulting in a significant loss of calmness within the port. Therefore, based on the two challenges of improving the wave resistance of the existing breakwater and enhancing the calmness within the port, the following resilience measures are proposed.

(i) Improvement of the wave resistance of the existing breakwater

- Use of core material with a high unit weight
- Ensuring a sufficient crest height of the breakwater to prevent overtopping

(ii) Enhancement of calmness within the port

- Extension of the southern breakwater seaward (Recommended length: sufficient to block the view of the open sea from the quay)
- Damping of wave energy within the port through the use of upright wave-absorbing structures on breakwaters and quays.

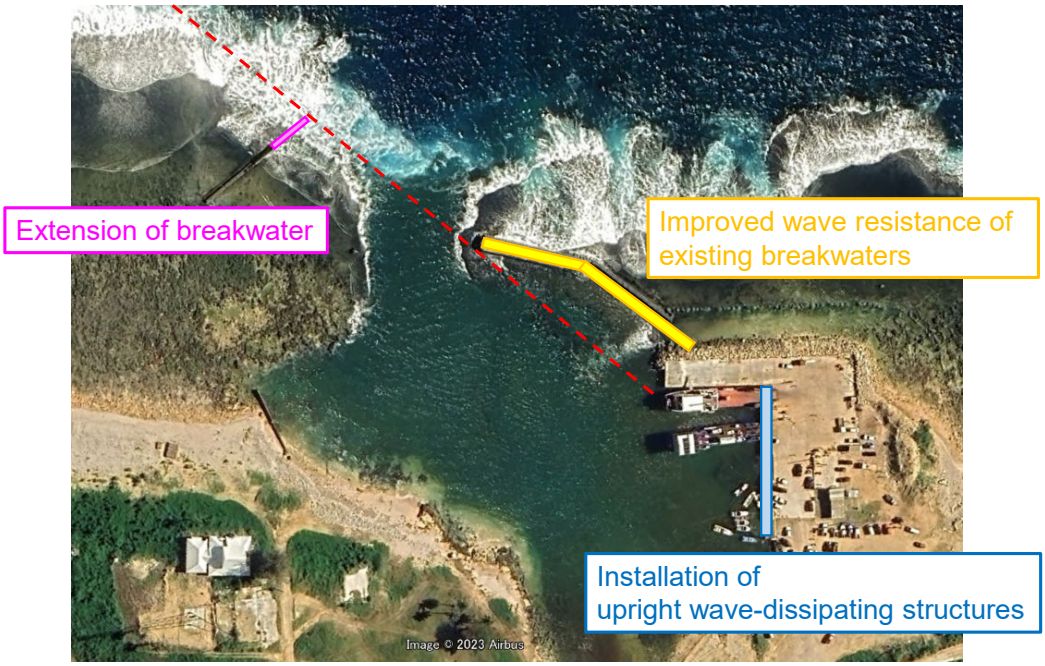


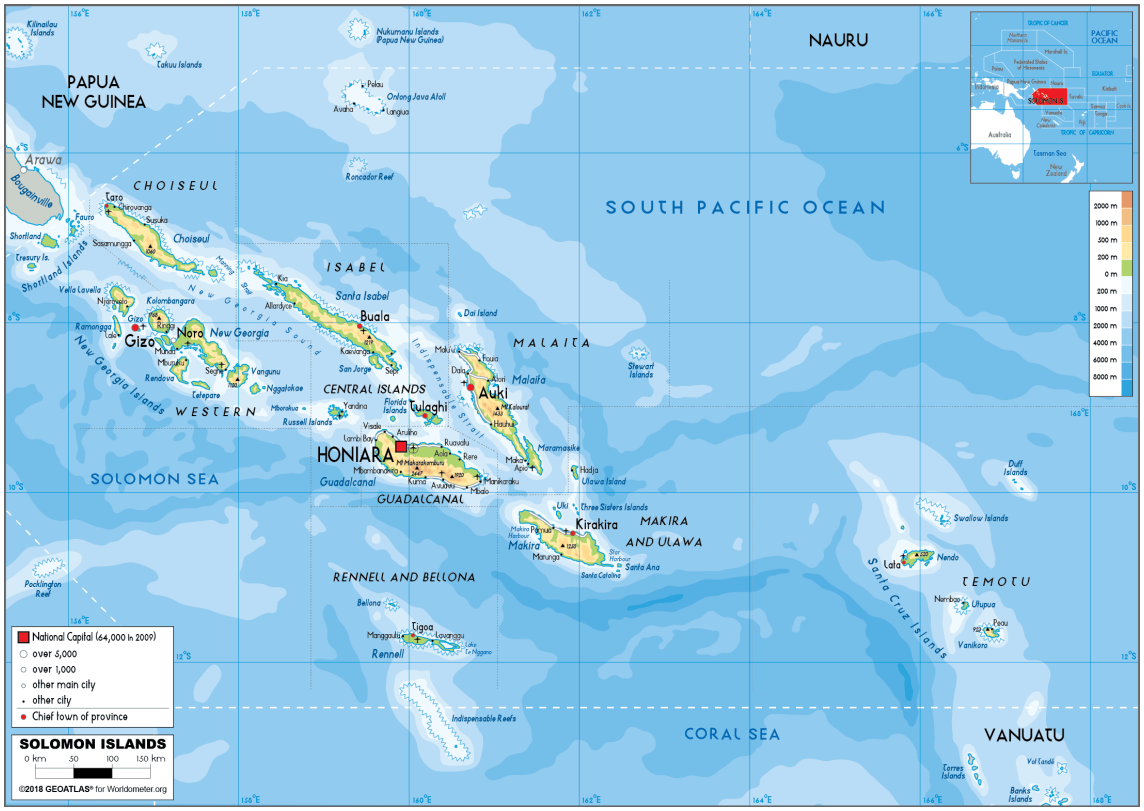
Figure 4.4-18 Proposal for reinforcement of Ohonua port (Nafanua wharf)

5. Solomon Islands

5.1 Overview of the country and its major ports and external relations

5.1.1 Country Overview

The Solomon Islands are a chain of islands in the southwestern Pacific Ocean, approximately 1,800 kilometers northeast of Australia. It is the second largest Pacific Island country and the third-most populous country. The country consists of over 1,000 islands of varying sizes and is administratively divided into nine provinces. The capital is Honiara, located on the northern coast of Guadalcanal Island, with a population of approximately 84,000.



Source: World meters.info; https://www.worldometers.info/img/maps/solomon_physical_map.gif

Figure 5.1-1 Location Map of Solomon Islands

5.1.2 Economic and Social Conditions

Economic development has remained sluggish. However, the Solomon Islands are rich in mineral and marine resources. In addition, they have a relatively large population with a high percentage of young people, making it a potentially attractive market. The Solomon Islands' GNI per capita is US$2,210 (2022 World Bank), and it is listed as a least developed country (LDC) by the United Nations.

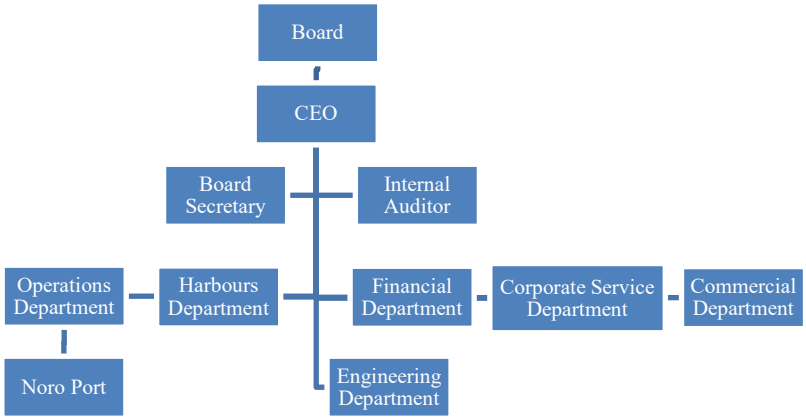
The Solomon Islands' economy is primarily based on agriculture, forestry, and fisheries, which account for approximately 30–40% of GDP. However, most of the population lives in rural areas, where they engage in subsistence farming and sell cash crops such as tubers, vegetables, and seafood to earn cash for education and daily necessities. Although the main export commodities are timber, palm oil, tuna and mackerel, and copra, the country faces a significant trade deficit. Even though the country has significant mineral resources such as gold, nickel and bauxite, land issues have hindered the development of the mining industry. In addition, except for some primary products, the country is heavily dependent on imports commodities. The economy recorded a negative growth from 2019 to 2021 but has turned to positive growth since 2022. The country is heavily dependent on financial support from Australia, New Zealand, and other countries.

5.1.3 Overview of Port Administration

(1) Port Administration Organization

The Solomon Islands Ports Authority (SIPA) was established as a state-owned company by an Act of Parliament on June 4, 1956. The Act was amended in 1996, transforming SIPA into a wholly owned subsidiary of the Solomon Islands Government. It subsequently came under the jurisdiction of the State-Owned Enterprises Act enacted in 2007. SIPA is required to report to the Ministry of Infrastructure Development and is responsible for the operation of two ports: Honiara port and Noro port. Other inland ports (Gizo, Ring Cove, Tulagi, and Yandina) are managed by the respective state governments.

(2) Organization Chart

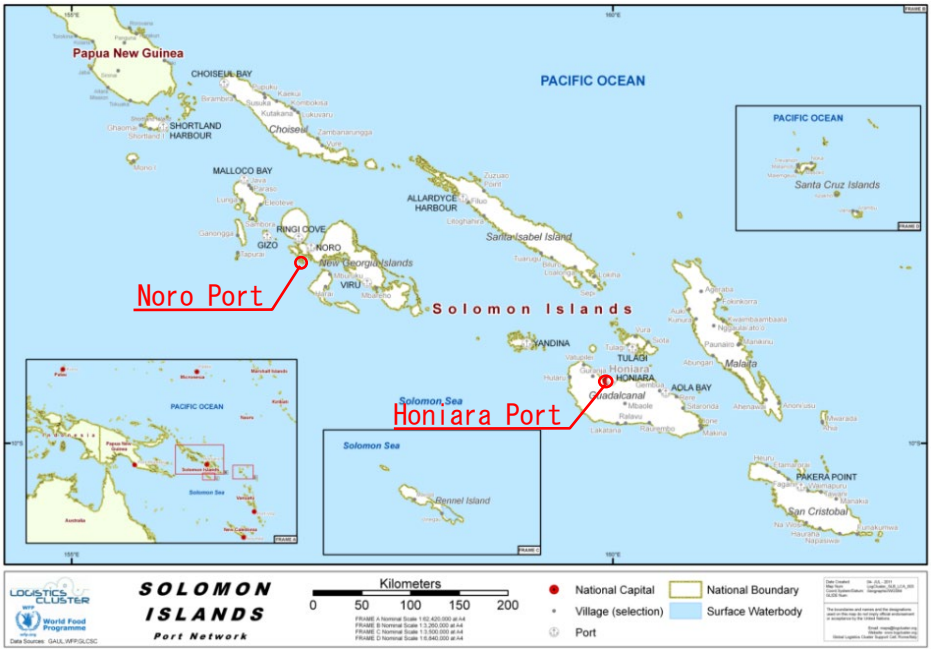


Source: Prepared by Survey team based on the Solomon Ports Annual Report 2018-2019.

Figure 5.1-2 Solomon Islands Ports Authority (SIPA) Organization Chart

(3) Overview of Major Ports

The main ports of the Solomon Islands are Honiara port on Guadalcanal Island and Noro port on New Georgia Island, both of which are international ports (see Figure 5.1-3). Honiara port handles approximately 90% of the international cargo volume. These two ports are in inland waters, resulting in calm sea conditions and deep water, eliminating the need for dredging and making them natural good ports.



Source: World Food Programme

Figure 5.1-3 Location Map of Ports in the Solomon Islands

(a) Honiara Port

Honiara port is in the northern part of Guadalcanal Island, where the capital city of Honiara is situated, and has two international terminals and seven domestic wharves. The No.1 international berth, constructed in the 1980s, has become severely deteriorated. The terminal is being rehabilitated by ADB's support. The No.2 international berth was renovated in 2016 with Japan's grant aid, enabling the simultaneous berthing of two container ships and the berthing of large vessels such as container ships and cruise ships. SIPA is upgrading the domestic wharves by its own finance at Honiara port. Four new domestic wharves are planned, and the first wharf is scheduled to begin operations in February 2024.



Source: prepared by Survey team based on Google Earth

Figure 5.1-4 Layout of Honiara Ports

(b) Noro Port

Noro port consists of an international terminal, a domestic terminal, and the Kitano terminal for fisheries. The international and domestic terminals are managed and operated by SIPA, as is Honiara port. Noro port is equipped with 110 reefer container power units, enabling the export of seafood products such as tuna to Europe and the United States via reefer containers. The ships follow a route operated by Maersk Line, departing from Malaysia, passing through Papua New Guinea, and calling at Noro port. National Fisheries Development (NFD) operates the fishing operations, while SOLTUNA operates the canning factory. The fish caught by NFD are supplied to SOLTUNA as raw materials. SOLTUNA's canned products are also exported to Europe.



Source: Google Earth

Figure 5.1-5 Layout of Noro Port

5.1.4 Cargo handling volume

In the Solomon Islands, tribal conflicts erupted in the late 1990s, causing a significant decline in cargo handling volumes at Honiara port. Following the resolution of the conflict in 2003, cargo handling volumes surged sharply due to economic recovery. Current container cargo handling stands at 30,000–32,000 TEUs annually, with 12–13 container ships and approximately 3 bulk carriers calling per month. Cargo handling is conducted using on-deck cranes; cargo handling operations take 3 days in the case of a 700 TEU container vessel and 1 full day for a 400 TEU container vessel. Table 5.1-1 shows the number of vessel-calls by type and the average size of vessels calling at Honiara Port in 2023. A total of 708 vessels called during the year with fishing vessels, general cargo ships, and container ships accounted for the majority of calls.

Table 5.1-1 Number of Vessel Calls by Type and Size in Honiara Port

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
Bulk carrier	2	4	122,604	76,692	30,651	19,173
Cable ship	1	1	5,970	14,132	5,970	14,132
Chemical tanker	1	2	17,632	10,746	8.816	5,373
Combined chemical and oil tanker	20	22	960,705	572,340	43,668	26,015
Diving support	1	10	0	0	0	0
Fish carrier	1	2	0	2,832	0	1,416
Fishing (general)	66	116	7,217	11,887	62	102
Fully cellular containership	16	83	1,701,755	1,362,997	20,503	16,422
General cargo	3	4	25,818	20,290	6,455	5,073
General cargo with container capacity	6	15	295,639	270,855	19,709	18,057
Landing craft	3	10	5,964	6,244	596	624
Naval Auxiliary Vessel	2	3	26,000	40,000	8,667	13,333
Naval Vessel	1	1	1,022	1,840	1,022	1,840
Passenger (cruise)	5	8	25,579	227,833	3,197	28,479
Passenger Vessel (unspecified)	1	8	0	0	0	0
Patrol ship	4	208	0	4,906	0	24
Product tanker	9	11	536,740	323,258	48,795	29.387
Roll on roll off with container capacity	3	12	211,622	208,087	17,635	17,341
Supply	2	9	40,195	43,346	4,466	4,816
Trawler (All types)	1	2	37,570	45,898	18,785	22,949
Tug	6	143	688	33,271	5	233
Vessel Type (unspecified)	1	1	0	0	0	0
Yacht	16	33	2,246	5,687	68	172
Total	171	708	4,024,966	3,283,141	5,685	4,637

Source: Lloyd's List Intelligence Sea searcher data (2023) analyzed by OCDI

As a result of preliminary discussions with SIPA and SPC, the two ports selected for this project in Solomon Islands are Honiara port and Noro port.

5.2 Honiara Port

5.2.1 Review issues related to port maintenance and management

(1) Status of Port facilities

Honiara port No. 1 International Berth (No. 1 Berth) is a facility that was renovated and upgraded as part of the Honiara Port Development Project implemented by the Asian Development Bank (ADB) from 1982 to 1984 and from 1986 to 1990 and has been in use ever since. Honiara Port No. 2 International Berth (No. 2 Berth) was constructed as part of the "Honiara Port Facility Improvement Project" (total grant amount: 2.68 billion yen) funded by Japan's grant aid, with construction beginning in 2014 and operations commencing in June 2016.

(a) Port Plan



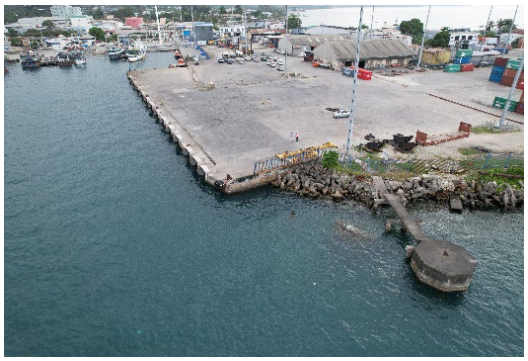
(Photo by Survey team, 11th April 2024)

Figure 5.2-1 Panoramic view of Honiara Port (No. 1 Berth (left) & No. 2 Berth (right))

Table 5.2-1 Specifications of Honiara Port

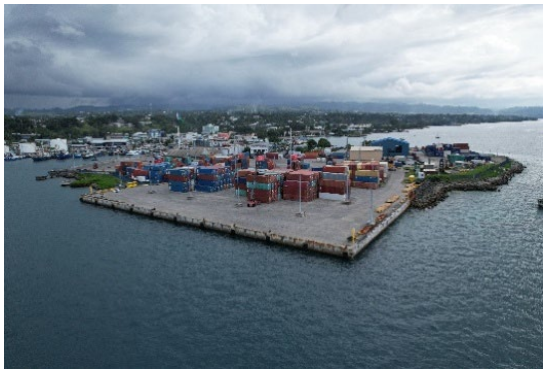
ITEM	WHARF INFORMATION		
Names / lengths / minimum depth	Berths	Length	Depth
	#1 Berth	110	10.5
	#2 Berth	150	11.5
Type of fenders	Harbor Fenders		
Type and surface of wharf	#1 Berth – Tabular with concrete surface #2 Berth – Tabular with concrete surface		
Preferred side of ships alongside	Mostly port side		
ITEM	**ANCHORAGE INFORMATION**		
Minimum depth of anchorage	20 meters		
Type of bottom	A mixture of mud with corals		
Wind current	Variable / Mostly NE winds		
EQUIPMENT	**NUMBER & TYPE**		
Reach stackers	5 (full container), 1 (empty container)		
Top lift:	3 (full container)		
Forklift	3 x 16 MT, 1 x 8 MT		
Tractor Trailer	6		
Reefer facilities	6		

(b) Port cross-section (survey photos, drone photos)



(Photo by Survey team, 2024)

Figure 5.2-2 Panoramic photo of Honiara Port, No.1 Berth



(Photo by Survey team, 2024)

Figure 5.2-3 Panoramic photo of Honiara Port, No.2 Berth

(c) Assessing the current situation through on-site inspections

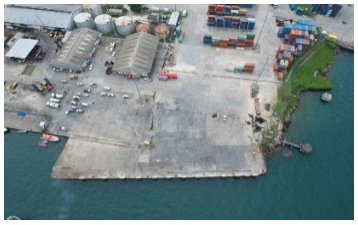
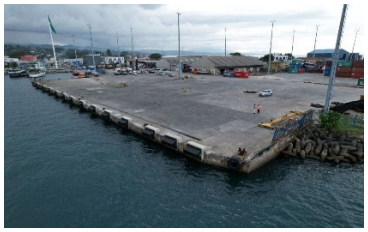
The No. 1 International Berth (No. 1 Berth) is severely deteriorated, with aging issues such as the deterioration of foundation piles and superstructure concrete in the wharf structure. According to SIPA, there have been no significant changes in its operational purpose. Uneven settlement occurred in the apron, but there are no visible traces of collisions, nor any misalignment of the quay line or joints. Cracking due to deterioration is severe in the apron concrete. SIPA has previously carried out temporary repairs, including partial repairs to the concrete pavement in the yard and replacement of fender materials. The No. 2 International Berth (No. 2 Berth) is approximately eight years old at the time of the site survey. The berth facilities are not damaged or deteriorated and remain in good condition. There have been no reports of facility malfunctions from SIPA.

During the site survey, SIPA accompanied the team and exchanged opinions about strengthening port facilities and maintenance methods. The photos taken during the survey are shown in **Figure 5.2-4** and **Figure 5.2-5**.

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Figure 5.2-4 Photo during the field survey

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.1 - Status of No.1 Berth -1	No.2 - Status of No.1 Berth -2	No.3 - Status of No.1 Berth -3

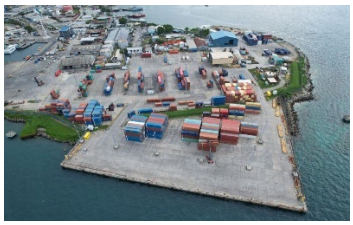
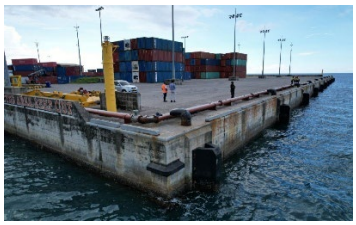
 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.4 - Status of No.2 Berth -1	No.5 - Status of No.2 Berth -2	No.6 - Status of No.2 Berth -3

Figure 5.2-5 Site investigation photos

(d) Collection and organization of design documents from the viewpoint of maintenance and management

The operation and management of two international berths and seven domestic piers in Honiara port is under the control of SIPA. SIPA is responsible for port operation, maintaining and expanding port facilities and attracting investment. SIPA keeps construction documents from the time of construction and drawings of subsequent repairs for facilities at Honiara port.

(2) Implementation Department responsible for Port Management

SIPA is subject to the following obligations under the provisions of the State-Owned Companies Act.

- To provide, maintain, and improve facilities deemed most suitable for the public interest at the designated ports
- To maintain, improve, and regulate the use of the designated ports within the scope deemed most suitable for the public interest
- To provide pilotage services and assistance deemed most suitable for the public interest at the designated ports, their routes, and the territorial waters of the Solomon Islands

(3) Status of Existing Facility and Future Plans

At No.1 International Berth, container cargo handling has been restricted due to the aging of the berth and insufficient structural bearing capacity. SIPA has carried out partial rehabilitation work such as repairing the concrete pavement in the yard and replacing fender materials as a temporary measure. However, SIPA recognized that the full reconstruction of the No.1 International Berth is essential for disaster prevention perspective. Therefore, the Solomon Islands government requested ADB assistance for the port's renovation. The ADB-supported project to demolish and reconstruct the No.1 International Berth was awarded to CCECC, a Chinese state-owned enterprise, in March 2023. On March 5, 2025, the first public hearing on the renovation of the No.1 Berth at Honiara port was held. Local shipping companies and relevant parties were provided with the latest information on the project and the schedule for preparatory work.

The development of the No. 2 International Berth was identified as a key component of the National Transport Plan 2017-2036 (NTP) and the "Honiara Port Facility Improvement Project" was implemented in May 2014 under Japan's grant aid program (total grant amount: 2.681 billion yen). The project was completed and put into operation in June 2016. In this survey, a visual inspection of the terminal facilities was conducted; however, no immediate need for repairs or renovations to the existing facilities was identified.

According to the results of on-site interviews, SIPA is currently considering plans to construct a bulk-dedicated wharf to the north of No. 2 International Berth. The new bulk terminal will be dedicated to the export of copra and palm oil, as well as the import of construction materials such as cement, aggregates, and steel. As the new bulk terminal will not only reduce the waiting time of bulk vessels but also enable No. 2 international terminal to be a dedicated container terminal, efficient and safe vessel and cargo operation in both terminals will be enhanced.

5.2.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at Honiara Port

(1) Collection of data on damage caused by past natural disasters

In this section, we will collect and compile information on natural disasters that have affected the Solomon Islands in the past. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss.

(a) Sea level rise, cyclone and high wave

First, we will review the natural disaster risks across Oceania based on "The 6th Assessment

Report of the Intergovernmental Panel on Climate Change (AR6)[75]". AR6 reports that the occurrence proportion of strong tropical cyclones (categories 3 to 5) among all tropical cyclones globally has increased in the last 40 years, with a moderate level of confidence. AR6 indicates low confidence in the long-term trends of the increasing frequency of tropical cyclones across all categories. In addition, AR6 mentions that the global mean sea level has been rising more rapidly since 1900 than at any other 100-year time in the past 3,000 years, with high confidence.

Next, we will show the major cyclones that have caused critical damage to the Solomon Islands in chronological order of their occurrence. In the Solomon Islands region, the recent major disaster was caused by Cyclone "*Itta"* in April 2014, which triggered flash floods and severe flooding on Guadalcanal Island, resulting in significant damage. In July 2015, Cyclone "*Raquel"* struck, coinciding with a magnitude 5.8 earthquake on Makira Island. This combination of events led to heavy rainfall, flooding, and damage to and collapse of buildings, exacerbating the damage. In April 2020, Cyclone "*Harold"* caused landslides, flooding, damage to and collapse of buildings, and a ferry accident.

(b) Earthquake, tsunami and volcanic activity

World Bank reported that Oceania was exposed to high risk of tsunamis, earthquakes, and volcanic activity[76]. The earthquake peak ground acceleration in Solomon Islands falls in the range of 100.1 to 250 or 250.1 to 520 cm/s², indicating a high seismic hazard (see **Figure 5.2-7).** Tsunami maximum inundation height (MIH) for a 50-year return period in the Slomon Islands falls from 1.51 to 2.0-meter range (see **Figure 5.2-6**). The risk from volcanic activity may be considered medium to high (see **Figure 5.2-8**).

The Solomon Islands are located at the boundary of the Australian Plate and the Pacific Plate and have experienced major earthquakes with magnitude of 7 to 8 in 2007, 2013, and 2022, resulting in human casualties and property damage due to shaking and tsunamis. In the Solomon Islands, port facilities also serve as hubs for receiving disaster relief supplies during emergencies, so it is considered necessary to strengthen the resilience of wharves and implement flood prevention measures against such disasters.

[75] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[76] Pacific Maritime Transport Systems Hazard Exposure Technical Note, World Bank. 2023.

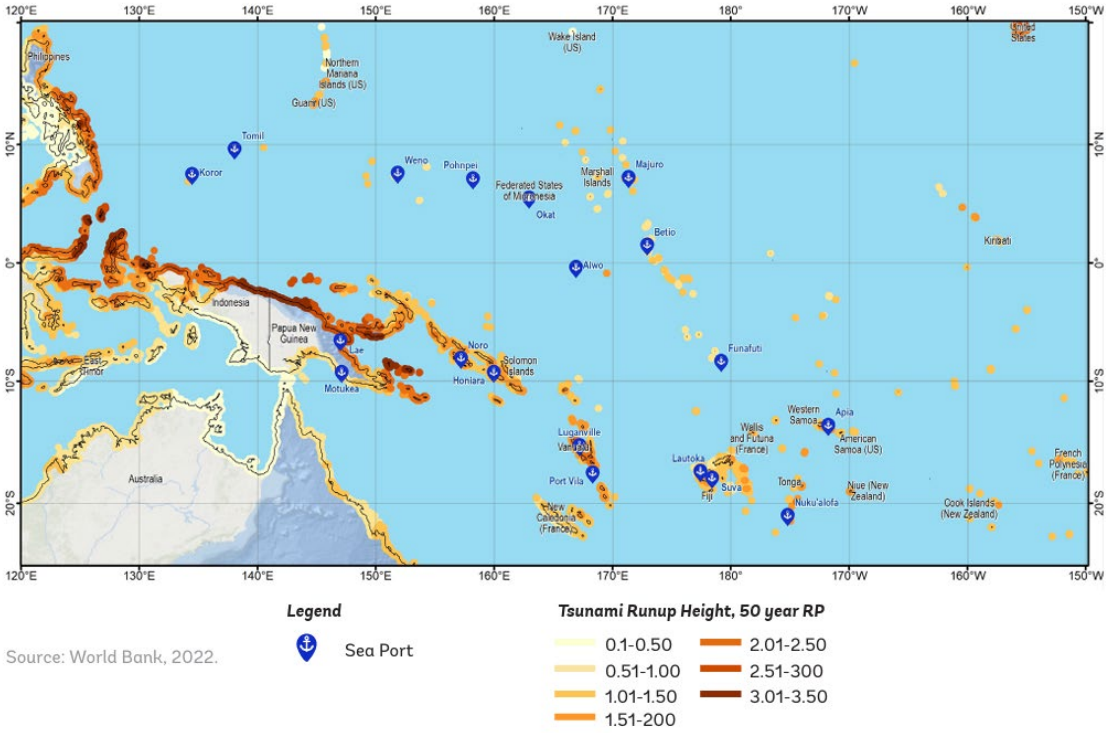


Figure 5.2-6 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

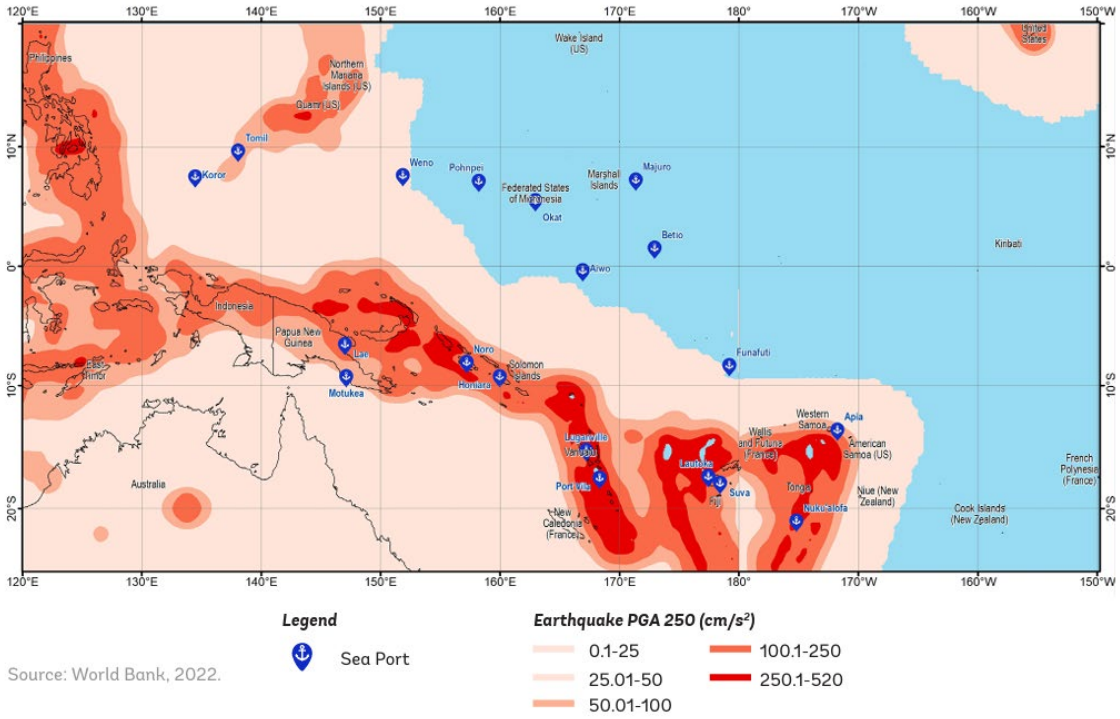


Figure 5.2-7 Earthquake peak ground acceleration (PGA) in cm/s2 for a 250-year return period

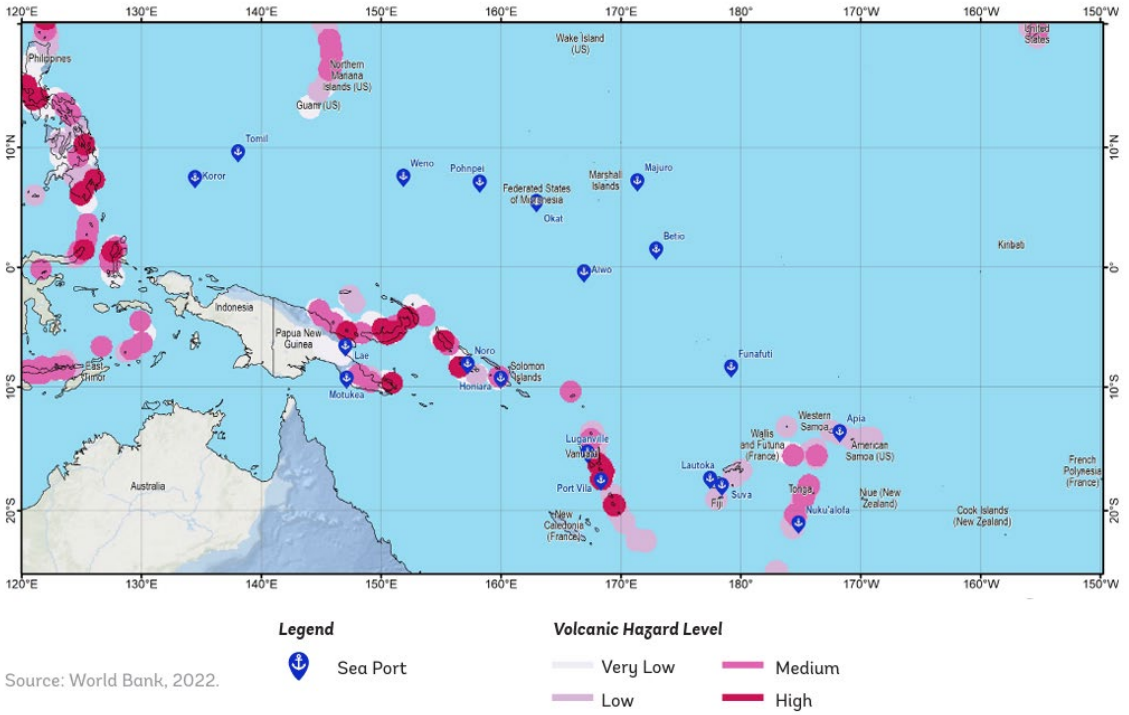


Figure 5.2-8 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in the Honiara Port and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters. The design conditions such as natural conditions, design loads, etc. at the time of construction of the existing facilities of No.2 Berth at Honiara Port have been confirmed referring to the information in the JICA survey report[77].

[77] Solomon Islands Honiara Port Facility Improvement Plan Preparatory Survey (Part 2) Report" JICA, 2013.

Deck level: DL+3.20 m
Tide level:
Mean High Water Spring (MHWS) DL+1.171 m
Mean Low water Spring (MLWS) DL 0.40 m
Water depth: DL-11.0m
Design vessel: (Maximum target vessel)
LOA = 199.50 m
Max. draft: dmax = 10.50 m
DWT = 31,000 DWT
Mooring load: 1,000 kN
Design Berthing velocity: v = 0.10 m/s
Load Condition:
(Cargo loads)
40ft container = 30.48 ton
20ft container = 30.48 ton
(Cargo handling equipment)
Reach Stacker front axle load = 101.9 ton
Top lifter front axle load = 96.9 ton
Wave Condition:
Wave height (offshore wave) Ho = 3.66 m (N~NW)
Wave period (offshore wave) To = 6.7 s
Soil Condition: Sandy Soil
Earthquake: (seismic intensity) Kh = 0.15

According to the JICA survey report, the top elevation of the quay wall at No.1 Berth is DL+2.2 m, and the ground elevation of the container yard behind it is also approximately the same. In contrast, at No.2 Berth, which began operations in 2016, the top elevation was raised by 1.0 m compared to the No.1 Berth to account for the effects of ocean waves and to prevent wave overtopping.

5.2.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in the Honiara Port based on the research papers and past records of natural disasters.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport* [78]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for the Honiara Port. This process will determine if the current port design fails to

[78] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

account for important natural disasters or underestimates the risk of natural hazards.

Referring to Table 5.2-2, the risk of volcanic disasters is high around Honiara Port in the Solomon Islands. Additionally, the risks of high waves during regional storms and the maximum tsunami run-up height are rated as medium. On the other hand, the risks of cyclones, coastal flooding, and earthquakes are rated as low.
The Solomon Islands are located in the "Pacific Ring of Fire," which spans approximately 40,000 km across the Pacific Ocean. Here, the Pacific Plate collides with several surrounding continental plates, causing repeated earthquakes. Most of the world's volcanic eruptions, especially the most severe ones, occur in this region. There are three active volcanoes in Solomon Islands – Kavachi which is one of the most active submarine volcanoes in the south-west Pacific, Savo on Savo Island and Tinakula, a conical stratovolcano in Temotu Province. These volcanoes have the potential to cause significant damage.

The Solomon Islands are frequently hit by earthquakes with magnitudes of 7 to 8. The area around Honiara Port, located north of Guadalcanal Island, has been assessed as having a low risk due to the absence of previous major earthquake epicenters. However, earthquakes exceeding magnitude 8 have been observed to cause significant damage and destruction within a radius of several hundred kilometers. The Peak Ground Acceleration (PGA) of the earthquake to be considered in Honiara is estimated to be 0.19. It is essential in Honiara to take adaptation measures against earthquake disaster.

The Solomon Islands are frequently hit by earthquakes and are also at serious risk of tsunamis. The area around Honiara Port, located north of Guadalcanal Island, is assessed as having a medium risk of tsunamis. The maximum inundation height (MIH) of tsunamis around Honiara is estimated to be 1.7 meters. Appropriate measures are required to respond to tsunami and high wave damage around Honiara Port and the coastal areas.

Cyclones only occur occasionally in the Solomon Islands. They happen about 5 times a year on average. Cyclones rarely make landfall as they tend to turn southward beforehand. The most affected regions are Temotu, Makira and Western Province. The area around Honiara Port is not included in these regions. However, cyclones can cause high waves, with wave heights estimated at 3.2 meters. While cyclone disasters in the Honiara Port area are infrequent, they are a definite possibility, and appropriate measures must be taken to address them.

Table 5.2-2 Multi-hazard Heat Map Port Exposure (Solomon Islands) [79]-Honiara Port

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5. 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicabl	0.27

Colour Legend:

High | Medium | Low | Very Low | Not applicable

[79] *A Blue Transformation for Pacific Maritime Transport*, World Bank. 2023.

Table 5.2-3 Methodology for Identifying Natural Disasters and their Scales (Honiara Port)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Considered Design seismic intensity: kh=0.15	Not applicable	Estimate earthquake waves by considering the scale of past earthquakes and taking into account the distance from the epicenter and ground conditions.
Tsunami	Not considered.	Not applicable	Estimate the loads acting on structures by assuming tsunami heights and flow velocities based on past maximum tsunamis.
Volcano	Not considered	Not applicable	Estimate the impact of volcanic eruptions and ashfall on ports based on records of volcanic eruptions in neighboring countries and past volcanic disasters.
Storm Surge	Considered Deck level: DL +3.2m (DL of existing wharf DL=2.2m ＋1m) Equivalent deep-water wave heigh: H0'=2.78m	Flood disasters increase due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	Considered Offshore wave height Ho = H0=3.66m (N-NW) Offshore wave period T0=6.7 s	Increase in high waves due to cyclone intensification	Consider the increase in waves caused by cyclone intensification objectively. Recent research results, such as future predictions using d4PDF described later can be used.

(2) Measures against sea level rise and wave power by climate change

The effects of sea level rise and waves caused by climate change can be taken into consideration by applying the adaptation measures against climate change described in Japan's "Technical Standards and Commentaries for Port and Harbour Facilities in Japan" (English version, 2025). The concept of adaptation measures against climate change is as shown below.

"Japanese port and harbor design standards" explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately

determined using the latest research findings and scientific knowledge. **Figure 5.2-9** illustrates two conceptual approaches for setting structural strength while considering changes in external forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as "Proactive adaptation." On the other hand, "Adaptive adaptation" refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life but implementing physical upgrades progressively at appropriate times during the period, depending on material and structural characteristics.

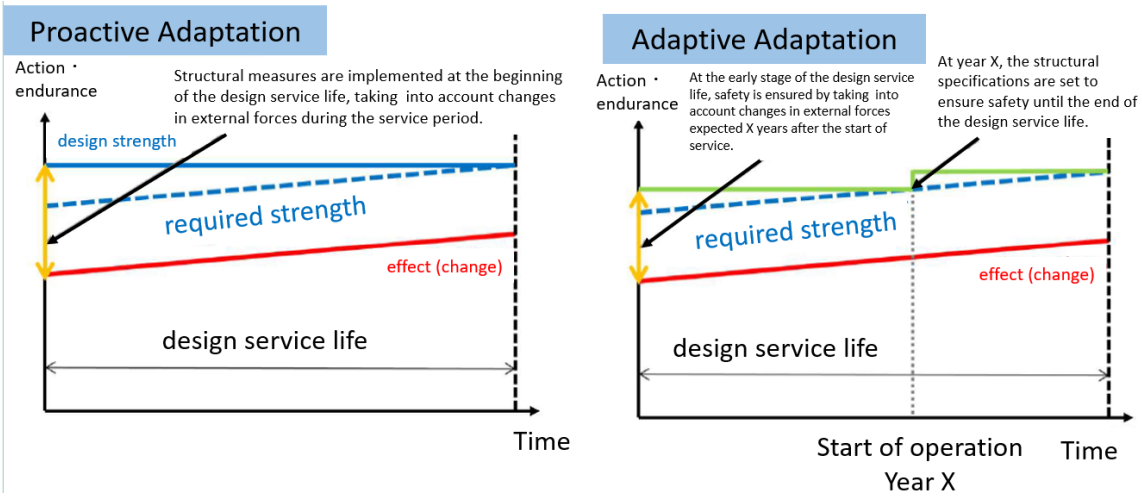


Figure 5.2-9 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

Due to the many uncertainties surrounding climate change, a range of scenarios has been discussed. For example, "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[80]" presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[81]

[80] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[81] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

as a basis when considering the impacts of climate change in port facility design. RCP2.6 corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. **Figure 5.2-10** shows the projected regional median sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [82].

The projected sea level rise in the Solomon Islands is shown in Figure 5.2-11. Sea level rise in the Solomon Islands by 2050 is projected to be 0.22 meters under the 2°C warming scenario (SSP1-2.6). Under the 4°C warming scenario (SSP5-8.5), it is projected to be 0.25 meters, with a small difference between the two scenarios. However, by 2100, the difference becomes significant, with 0.52 meters under the 2°C warming scenario (SSP1-2.6) and 0.85 meters under the 4°C warming scenario (SSP5-8.5). Therefore, depending on the scenario selected, the value of projected sea level rise differs, and this must be considered when setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

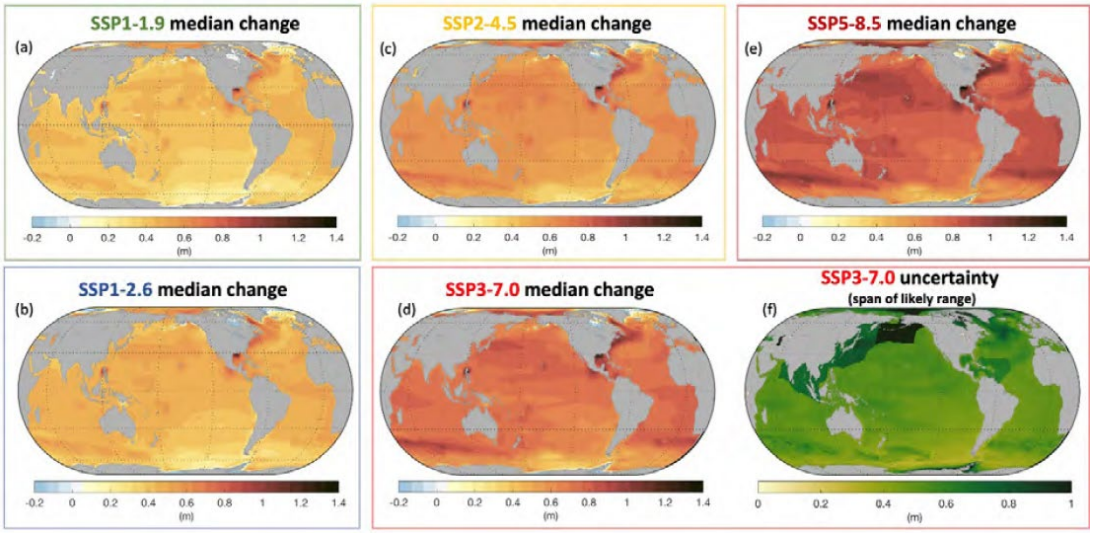


Figure 5.2-10 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

[82] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

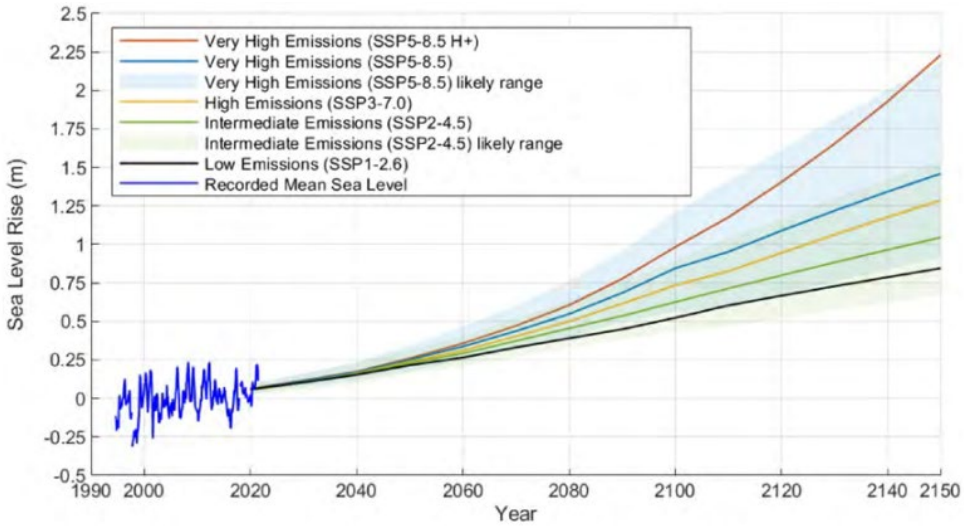


Figure 5.2-11 Sea Level Rise Projections to 2150 for Solomon Islands Relative to 1995-2014 Mean Sea Level

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the "Database for Policy Decision-Making for Future Climate Change" (d4PDF, Mizuta et al. [83]). To predict future changes in extreme weather events such as typhoons due to climate change, a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing

[83] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita, M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.

Waves and Coasts in the Pacific" (WACOP) project[84]. This project uses four climate models that participated in CMIP5. When considering storm surges and high waves, it is essential to incorporate research findings or wave simulations using these future climate models.

5.2.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize SIPA's current disaster mitigation plans in terms of time frames and types of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". Natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in **Table 5.2-4**.

Table 5.2-4 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The expert team confirmed the structure of existing facilities and maintenance status of the target port through discussions with SIPA and available design documents. The existence and implementation status of natural disaster response plans for the respective port facilities were also confirmed. The expert team sent questionnaires to each port authority to examine if the disaster mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change. The responses from SIPA are summarized below.

[84] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html (Accessed in July, 2024)

(2) Results of Questionary Survey

(a) Maintenance and Management

SIPA has created a maintenance plan as part of its maintenance adaptation and has prepared a matrix for inspections. Regular inspections of port facilities are conducted about every six months, with detailed inspections carried out once a year.

(b) Countermeasures against Natural Disasters

SIPA has created hazard maps for storm surges and cyclones as natural disasters, and has identified and documented assets, operations, and systems that are susceptible to the effects of natural disasters. It is in the process of identifying the information necessary to establish baseline conditions. SIPA is also installing wave-dissipating works to counter storm surges and high waves and raising the elevation of new infrastructure facilities as part of its natural disaster adaptation efforts.

(c) Emergency Response

SIPA has developed emergency evacuation plans for disasters such as earthquakes, tsunamis, and fires. A port BCP (business continuity plan) has not been developed to date, but SIPA is currently working with stakeholders and relevant authorities to develop an emergency response plan.

(d) Climate Change Adaptation

SIPA has identified and documented assets, operations, and systems that may be affected by climate change. It has also identified the information necessary to establish baseline conditions. SIPA is developing a climate change adaptation plan by creating risk profiles and risk matrices to understand the impact assessment and response levels of climate change risk measures.

SIPA has formulated and implemented a comprehensive plan covering all port facilities under its jurisdiction for natural disaster response, climate change response, and emergency response. In this survey, the status of each response for the port facilities at the target ports of Honiara Port and Noro Port are confirmed.

5.2.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by examining the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*" [85] (hereinafter referred to as '*Pacific Ports Vision*') shown in **Table 5.2-5**. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[85] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 5.2-5 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities for No.2 Berth in Honiara port are shown below.

(a) Natural disaster adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at Honiara port to address natural disasters at existing facilities. The No.2 International Berth was designed in 2013, construction began in 2014, and it began operations in 2016. The facility design includes raising the elevation of the berth structure to address high waves and tsunamis.

(b) Climate change adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at Honiara Port to address climate change in existing facilities. The No.2 International Berth was designed in 2013, construction began in 2014, and it began operations in 2016. The facility plan includes consideration of wave conditions for high waves and storm surge, and estimates of design waves during abnormal conditions, taking into account cyclones.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: Honiara Port has a comprehensive emergency response plan for natural disasters that has been communicated to stakeholders. The relevant plans and documents are as shown below.

- NATIONAL DISASTER MANAGEMENT PLAN 2018[86]
- Solomon Islands disaster management reference handbook 2023[87]

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in the Honiara Port in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

[86] National Disaster Management Plan, 2018; National-Disaster-Management-Plan-2018.pdf

[87] Solomon Islands disaster management reference handbook 2023; https://www.cfe-dmha.org/LinkClick.aspx?fileticket=QLamPuf0W6Y%3d&portalid=0

Table 5.2-6 Assessment of Impacts of Natural Disasters for Honiara Port

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	The No.2 international Berth at Honiara Port is a steel pipe sheet pile quay wall with anchor structure, and it is susceptible to displacement and tilting of the front sheet pile wall due to seismic motion. Damage to the anchor structure, ground subsidence behind the quay due to liquefaction, and damage to the apron pavement are also possible. Damage such as the overturning of cargo handling equipment and loss of power supply is also possible.	SIPA has a management office in Honiara Port. The collapse of the office and injuries due to an earthquake are likely to affect the management system. The damage to Honiara Port will have a significant impact on the stable supply of food and other daily necessities within the Solomon Islands.	Earthquakes may cause human casualties that could affect operations. Damage to port facilities and loss of power may affect port calls. Damage to cargo handling equipment may also affect cargo handling activities.
Tsunami	Honiara Port's No.2 International Berth is located at the tip of Point Cruz Peninsula, where there is a risk of ship collisions and damage due to tsunamis, as well as the loss of container cargo. There are palm oil storage facilities behind the Berth area, which could result in oil spills and marine pollution if the storage tanks are damaged. Other potential damage includes the overturning of cargo handling equipment and loss of power.	SIPA has a management office in Honiara Port. Tsunami may affect the management system due to human casualties. Damage to port facilities and the loss of cargo due to the tsunami will have a significant impact on the stable supply of food and other necessities within the Solomon Islands.	Human casualties caused by tsunamis may affect operations. Damage to port facilities and loss of power may affect the arrival of ships. Collisions and sinking of ships caused by tsunamis may prevent ships from arriving.
Volcano	The Solomon Islands are at high risk of volcanic disasters. There are concerns about significant damage to port facilities and cargo handling equipment caused by volcanic eruptions and ashfall, as well as the closure of shipping lanes.	Human casualties caused by volcanic eruptions may affect management systems. Damage to port facilities and disruption of land transportation caused by volcanic eruptions could have a significant impact on the stable supply of food and other essential goods within the Solomon Islands.	Human casualties such as injuries caused by volcanic eruptions may affect operations. Volcanic ejecta and ashfall may render port facilities and container yards unusable.
Storm Surge	Honiara Port's No.2 International Berth is located at the tip of Point Cruz Peninsula, where storm surge may cause ships to drift and container cargo to spill. There are palm oil storage facilities behind the berth, which could result in oil spills and marine pollution if the storage tanks are damaged.	Storm surge may cause injuries and other human casualties, which could affect management systems. Damage to port facilities and the loss of cargo due to storm surge could have a significant impact on the stable supply of food and other goods within the Solomon Islands.	Human casualties caused by storm surge may affect operations. Damage to port facilities and loss of power may affect ship arrivals.

Cyclone	Honiara Port's No.2 International Berth is located at the tip of Point Cruz Peninsula, and damage to buildings such as offices and warehouses due to strong cyclone winds, as well as the collapse of stacked containers and lighting equipment, and the overturning of cargo handling machinery, are expected. High waves caused by the cyclone may also result in flooding of port facilities, ships running aground or colliding, the loss of container cargo, and power outages.	Cyclones may cause casualties and other human damage, which could affect management systems. Strong winds could damage land facilities and close roads, halting land transportation, while high waves could damage port facilities and cause cargo to spill, severely affecting the stable supply of food and other goods within the Solomon Islands.	Cyclones may cause injuries and other human casualties that could affect operations. Strong winds may halt land transportation, which could affect operations. High waves may damage port facilities and cause cargo to spill, which could also affect operations.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in Noro Port. Figure 5.2-12 illustrates the natural disaster risks and resulting damage to the port.

No. 2 Berth is steel pipe sheet pile quay wall with anchor structure. An earthquake may affect displacement and tilting of front wall. Ground subsidence due to liquefaction and damage to apron pavement are also concern. Piles of containers could be fallen. The building and warehouse will be damaged. Containers in the yard may be washed away into the sea. This could disrupt vessel entering.

There are palm oil storage facilities behind the berth area, which could result in oil spills and marine pollution. Seawater from the ocean side may flood into the port area due to sea level rise. Damage to Honiara Port could have a significant impact on the stable supply of food and other daily necessities within the Solomon Islands.

The No.2 International Berth was designed in 2013, construction began in 2014, and it began operations in 2016. The facility design includes raising the elevation of the berth structure to address high waves and tsunamis.

Therefore, the advisory team proposes a draft plan for the strengthening of the port functions by constructing a new bulk terminal adjacent to No. 2 Berth to improve efficiency.

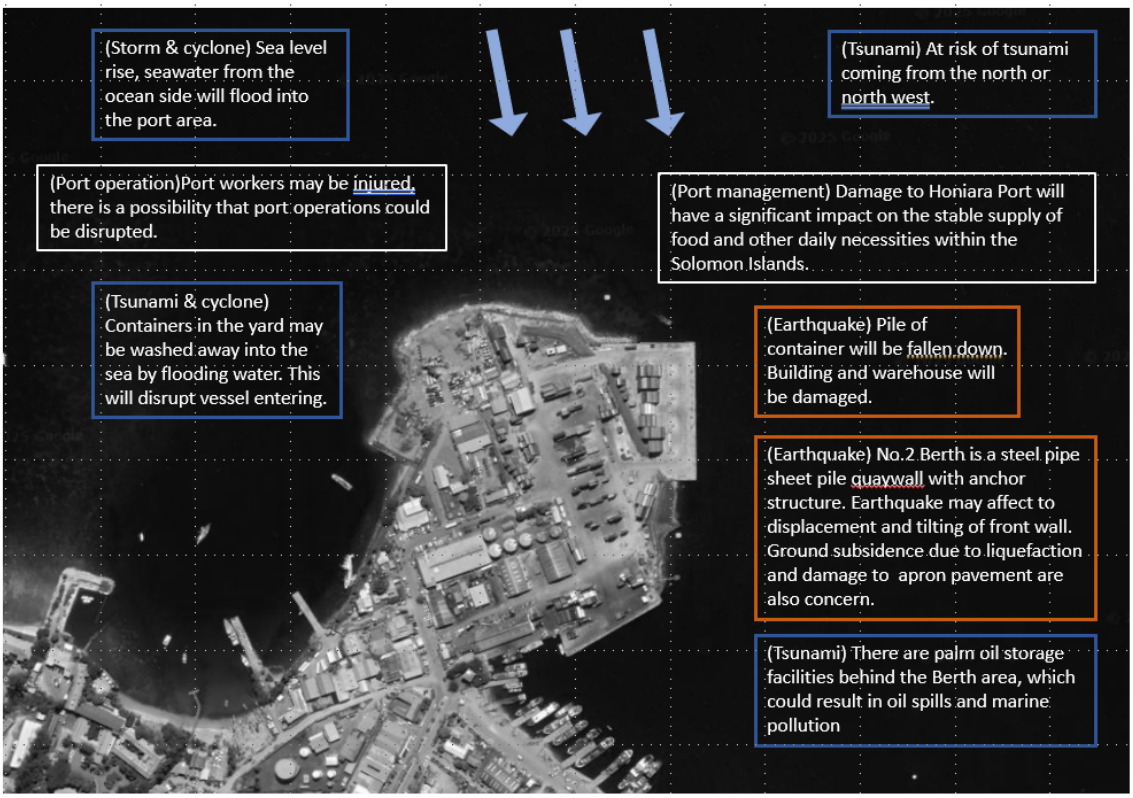


Figure 5.2-12 Geographical characteristics of natural disasters

5.2.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans. The results of existing port facilities for No.2 Berth in Honiara port are as shown below.

(1) Confirmation of the reasons for staying with the current resilience indicators

In Section 5.2.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for Honiara Port. The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in "*CLIMATE CHANGE ADAPTATION PLANNING FOR PORTS AND INLAND WATERWAYS*[88]" (hereinafter referred to as the PIANC guide). The results are presented below.

[88] Climate Change Adaptation Planning for Ports and Inland Waterways, PIANC, EnviCom WG Report No. 178-2020

(a) Natural disaster adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at Honiara port to respond to the natural disasters at existing facilities.

- The goal(s), planning horizon and objectives of the natural disaster adaptation initiative have been established and agreed at Honiara port.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has been completed, and the potential impacts of natural disasters on each have been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the natural disaster adaptation process.

(b) Climate change adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at Honiara port to address climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed at Honiara port.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has been complete, and the potential impacts of climate changes on each have been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate change is in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in Honiara port.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at Honiara port for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

(a) Natural disaster adaptation

- Reconfirm the goal(s), planning horizon and objectives of the natural disaster adaptation initiative established and agreed at Honiara Port.
- Reconfirm the potential impacts of critical assets, operations and systems including interdependencies that could be affected by natural disasters identified.
- Grasp the status of the baseline for port assets, operations, and systems, and reconfirm that necessary information is being provided appropriately.
- Check the information collected on natural disaster intensity forecasts and confirm the severity of the identified disasters.
- Grasp normal operating conditions (daily cargo volume, passenger numbers, etc.) and confirm the predicted impact of disasters.
- Conduct a natural disaster risk assessment and formulate a natural disaster adaptation plan for Honiara Port.

(b) Climate change adaptation

- Confirm the climate parameters and processes relevant to the critical assets, operations and systems identified.
- Collect the existing baseline data including information on extreme events for each relevant climate parameter or process and instigate monitoring to enhance local knowledge or fill gaps.
- Depending on the planning horizon for the adaptation strategy, agree on the climate change scenarios, and collate the climate change projections for relevant parameters and processes.
- Analize Data to confirm baseline conditions, to identify existing patterns and trends, and to determine what changes are expected under each scenario. Consider both slow onset changes and expected changes in the frequency or severity of extreme meteorological, oceanographic or hydrological events. Acknowledge the limitations of the data.
- Conduct a climate change risk assessment and develop a climate adaptation plan for Honiara Port.

(c) Disasters and Emergency Response

- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans for Honiara port.
- Maintain emergency response plans for natural disasters at existing facilities in Honiara port and verify them through annual audits.

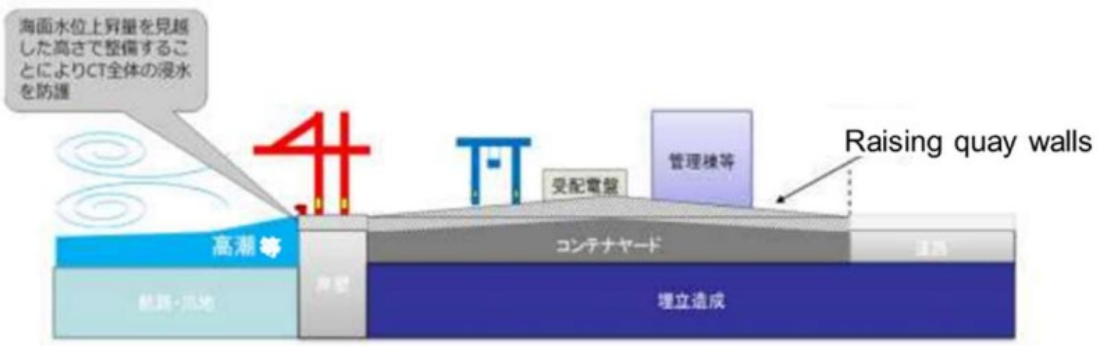
(3) Examples of countermeasures

The following example is one of the measures, which was also adopted for No. 2 Berth, to counter

storm surges and high waves.

The No.2 International Berth began operations in 2016. The facility design includes raising the elevation of the berth structure to address storm surges and high waves. According to a JICA report, the design raises the top elevation by 1.0 meters higher than the existing wharf of No.1 Berth, taking into consideration the effects of waves from the open sea and wave overtopping. This example is also effective as one of the countermeasures against storm surges and cyclones at existing facilities such as other domestic ports or yards behind the wharf.

- **Raising quay walls**



(The concept is to raise the height of new or existing wharves to a level that takes into account the effects of storm surges and sea level rise, and to plan or renovate the structure so that it can withstand the resulting increase in load.)

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for Honiara port are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in Honiara port is evaluated as "Engaged." To achieve the next level of resilience indicator, it is necessary to reconfirm the goal(s), planning horizon, and objectives of natural disaster adaptation, formulate natural disaster adaptation plans for existing facilities in Honiara port, and obtain agreement among stakeholders. It is recommended to reconfirm the impact of natural disasters on port assets, operations, and systems, identify the baseline situation, conduct risk assessments, and formulate plans for Honiara port.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in Honiara port is evaluated as "Engaged." To achieve the next level of resilience indicator, it is

necessary to reconfirm the goal(s), planning horizon, and objectives of climate change adaptation, formulate climate change adaptation plans for existing facilities in Port of Suva, and obtain agreement among stakeholders.

It is recommended to implement the following actions and develop a plan for Honiara port:

- Collect baseline data that includes information on extreme weather events.
- Begin monitoring relevant climate parameters.
- Select climate change scenarios in accordance with the planning horizon for climate change response and collect information on climate change projections.

(c) Disasters and Emergency Response

The resilience indicator outlined in the "*Pacific Port Vision*" for emergency response in Honiara port is evaluated as "Highly Engaged." To achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and verify that these plans are maintained through annual audits.

(d) Introduction of the Draft Plan for Port Resilience

(i) Proposal for Improving Port Function at Honiara Port (Draft Concept)

Honiara port is now capable of handling two container vessels simultaneously and accommodating large vessels (container vessels, cruise ships) after the construction of No. 2 International Berth. A draft plan is prepared to strengthen the port functions by constructing a new bulk terminal to further improve efficiency in anticipation of future increases in cargo handling volumes.

This proposal involves constructing a dedicated bulk terminal at the north side of the No. 2 International Berth (No. 2 Berth) to serve exclusively for the export of copra and palm oil, as well as the import of construction materials (concrete, aggregates, steel, etc.), thereby enabling the No. 2 International Berth to be utilized as a dedicated container terminal. The new bulk terminal will reduce the waiting time of bulk cargo ships at anchor and improve the efficiency of bulk cargo handling operations. The conversion of the No.2 International Berth into a dedicated container terminal will further enhance the efficiency of container cargo handling operations. A tentative plan for the new bulk terminal will be discussed below. The construction cost is estimated referring to cost estimates of the No. 2 International Berth.

(ii) Assumed specifications of vessels

In the Solomon Islands, tribal conflicts began in the late 1990s, causing a significant drop in cargo handling volumes at Honiara port. However, following the resolution of the conflict in 2003, economic recovery led to a sharp increase in cargo handling volumes. Currently, container cargo handling stands at 30,000–32,000 TEU annually, with approximately 12–13 container ships and

3 bulk ships per month.
Container ships call at the port 12 to 13 times per month, while bulk carriers call approximately 3 times per month. Cargo handling is conducted using on-deck cranes, with handling duration of 3 days for 700 TEU containers type and 1 full day for 400 TEU containers type.

Table 5.2-7 shows the number of vessel calls by type and the size at Honiara port in 2021. A total of 541 vessels called during the year with fishing boats, general cargo ships and container vessels accounting for the majority of calls. Container ships entering Honiara port are of two types: fully cellular containerships (average DWT 20,817) and general cargo ships with containers carrying capacity (average DWT 19,919), both of which are outlined in blue. The average size of container ships is 20,000 DWT class. There are three types of tankers: chemical tankers (average DWT 46,729), combined chemical and oil tankers (average DWT 47,129), and product tankers (average DWT 49,832), all of which are outlined in green. The average size of tankers is 50,000 DWT class. According to port technical standards, the LOA of a 20,000 DWT container ship is 175 m, the beam B is 27.0 m, and the full loaded draft D is 10.2 m. On the other hand, the LOA of a 50,000 DWT tanker is 203 m, the beam B is 32.9 m, and the full loaded draft D is 12.3 m.

Based on the above, the bulk terminal will be designed to accommodate the above-mentioned container ships and tankers.

Table 5.2-7 Number of Vessel Calls by Type and Size at Honiara Port (2021)

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
Chemical tanker	1	1	46,792	30,020	46,792	30,020
Combined chemical and oil tanker	12	13	612,679	365,525	47,192	28,117
Diving support	1	2	0	0	0	0
Ferry	1	27	9,612	13,473	356	499
Fish carrier	1	2	0	2,832	0	1,416
Fishing (general)	24	111	2,150	3,870	19	35
Fully cellular containership	15	72	1,498,825	1,225,501	20,817	17,021
General cargo	5	91	37,523	28,413	412	312
General cargo with container capacity	8	33	657,330	570,613	19,919	17,291
Landing craft	3	3	0	2,580	0	860
Patrol ship	4	25	357	2,650	14	106
Product tanker	14	23	1,146,128	680,188	49,832	29.573
Roll on roll off with container capacity	3	11	189,826	189,081	17,257	17,189
Tug	4	122	0	28,910	0	237
Vessel Type (unspecified)	1	1	0	0	0	0
Yacht	3	4	0	0	0	0
Total	100	541	4,201,222	3,143,656	7,766	5,811

Source: Lloyd's List Intelligence Sea searcher data (2021) analyzed by OCDI

Note:

Blue frame: Indicates two types of container vessels entering Honiara port: fully cellular container ships (average DWT 20,817) and general cargo ships with container capacity (average DWT 19,919).

Green frame: Indicates three types of tankers entering Honiara port: chemical tankers (Average DWT 46,729), combined chemical and oil tankers (Average DWT 47,129), and product tankers (Average DWT 49,832).

Typical size and dimensions of design ships (Container ships and Tanker, excerpted from port technical standards):

2. Container Ships

Deadweight tonnage DWT (ton)	Length overall L_{oa} (m)	Length between perpendiculars L_{pp} (m)	Molded breadth B (m)	Full load draft d (m)	Reference: Container carrying capacity (TEU)[Note]
10,000	138	130	22.2	7.9	900 (50–1,345)
20,000	175	165	27.0	10.2	1,700 (648–1,808)
23,000	184	173	28.1	10.8	1,700 (1,400–2,259)
27,000	194	183	29.4	11.9	1,800 (1,356–2,268)
30,000	201	190	30.3	11.9	2,500 (1,728–3,535)
40,000	228	215	31.8	11.9	2,800 (1,700–4,370)
50,000	269	255	32.3	12.8	4,300 (2,496–5,752)
60,000	285	272	35.5	13.5	4,700 (2,815–7,030)
100,000	338	322	45.3	14.6	8,500 (5,541–10,622)
140,000	367	353	48.5	15.8	13,100 (6,600–15,000)
165,000	378	360	52.0	16.2	14,000 (11,000–15,550)
185,000	400	382	59.4	16.2	17,700 (15,908–19,200)
200,000	400	382	59.4	16.2	19,200 (17,608–21,413)

Note: The reference values for the container carrying capacity of each DWT class are median (approximate), minimum, and maximum values.

3. Tankers

Deadweight tonnage DWT (ton)	Length overall L_{oa} (m)	Length between perpendiculars L_{pp} (m)	Molded breadth B (m)	Full load draft d (m)
1,000	61	57	10.2	4.1
2,000	77	72	12.4	5.0
3,000	89	84	13.9	5.6
5,000	107	100	16.1	6.4
10,000	136	128	19.7	7.8
15,000	157	148	22.1	8.8
20,000	173	164	24.0	9.5
30,000	177	168	26.9	10.6
50,000	203	193	32.9	12.3
70,000	223	213	32.9	13.5
90,000	239	228	43.5	14.5
100,000	246	235	43.5	14.9
150,000	274	263	48.9	16.7
300,000	334	322	60.2	22.1

(iii) Assumed conditions for conceptual design

The structural type of the new bulk terminal is assumed as a quay wall structure similar to the No. 2 international Berth based on the JICA survey report, “Solomon Islands, The Project for Improvement of Honiara port Facilities Preparatory Survey (Part 2) Report” (2013). The new bulk terminal will be located adjacent to the north side of the existing No.2 International Berth.

The basic conditions for the conceptual design are as follows.

- The total length of the quay wall is calculated as LOA + ship width B = 203 m + 32.9 m = 235.9 ≒ 240 m.
- The water depth of the quay wall is set to -11.0 m, same as the existing No. 2 Berth.
- The location of the new terminal is considered on the land north of the existing No. 2 Berth.

(iv) Summary of draft plan

Based on the conceptual design result for the new bulk terminal at Honiara port, the draft layout plan and typical cross-section for the steel pipe sheet pile quay wall are shown below.

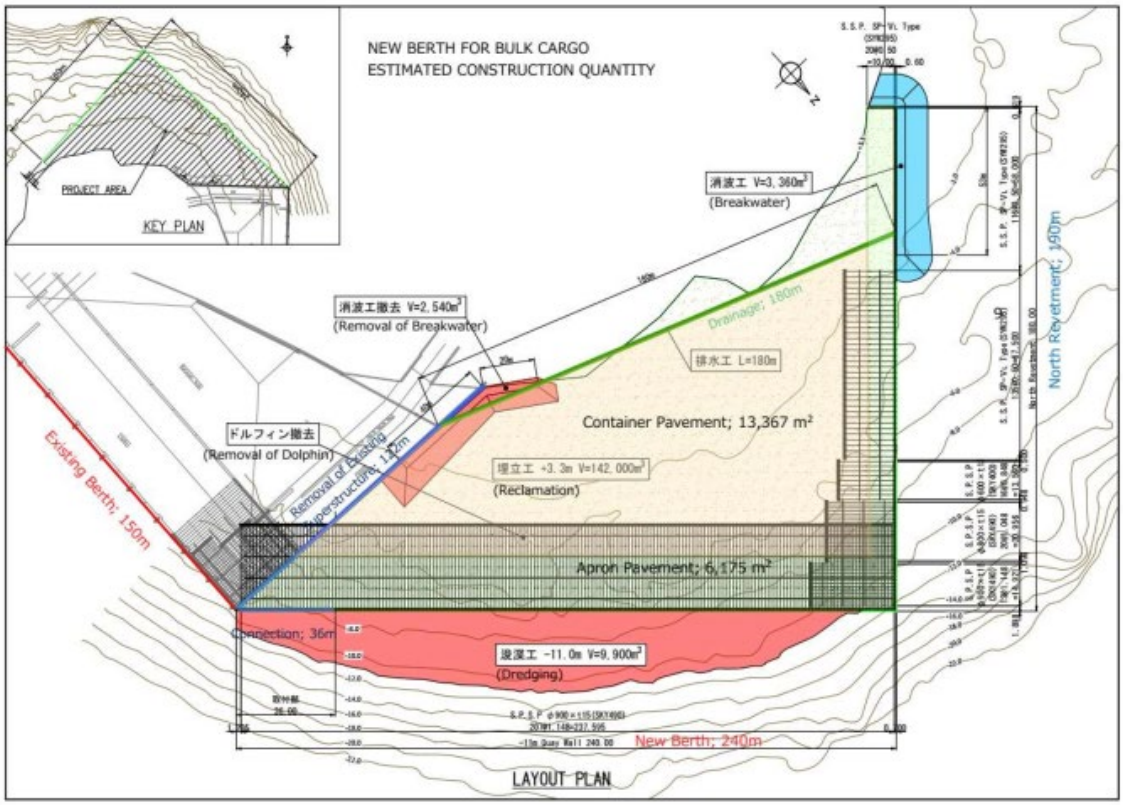


Figure 5.2-13 Layout Plan of the New Bulk Terminal at Honiara Port (draft)

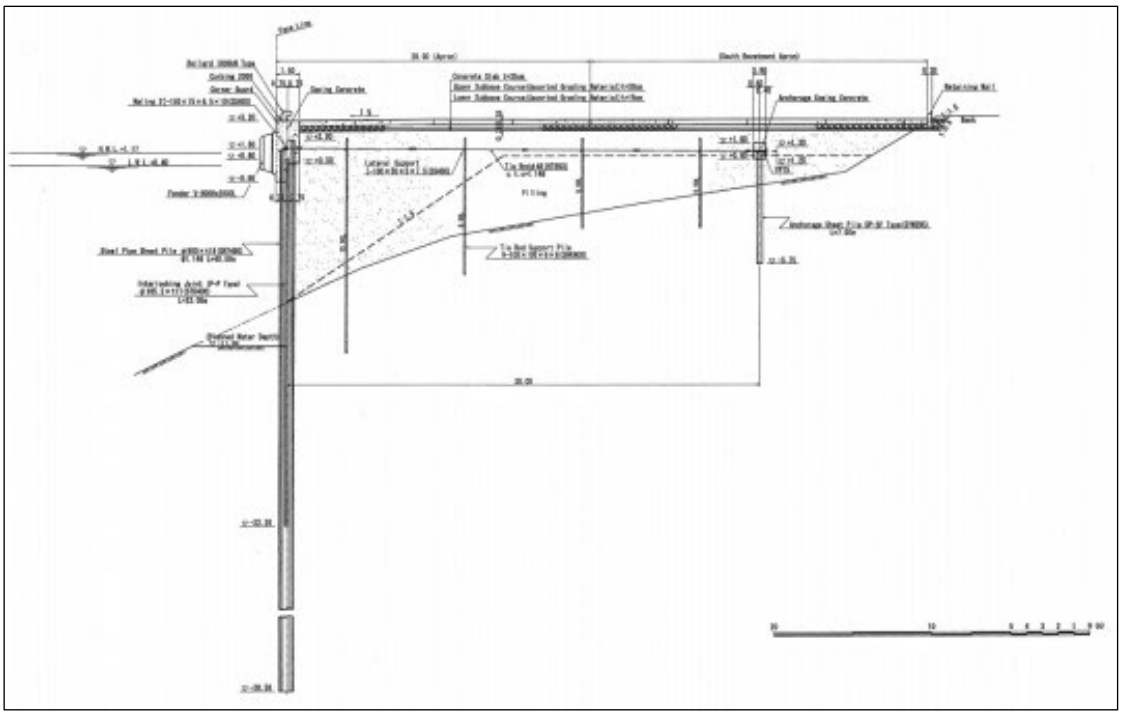


Figure 5.2-14 Typical cross-section of the New Bulk Terminal (draft)

The estimated construction volume for the new bulk terminal was calculated based on the above results, and the preliminary construction cost was estimated as shown below. The preliminary construction cost is estimated by using the construction cost of the No. 2 International Berth as a reference. The effects of exchange rate fluctuations and price increases are reflected in the calculation.

Estimated Construction Cost 1USD = 157.02 JPY (mid of June 2024)

Construction Item	Description	Quantity	uinit	Estimated Cost JPY	Estimated Cost USD (=JPY/157.02)	Remarks
New Berth	Berth Structure	240	m	2,322,480,000	14,790,982	(Existing = 150m)
	Dredging	9,900	m3	49,500,000	315,246	(Existing = 6,680m3)
	Reclamation	142,000	m3	710,000,000	4,521,717	(Existing = 59,000m3)
	Pavement	19,542	m2	898,932,000	5,724,952	(Existing = 10,300m2)
	Drainage	180	m	28,440,000	181,123	(Existing = 97m)
	Others			188,168,000	1,198,370	(Ancillaries, removal, etc.)
North Revetment	Revetment	190	m	475,950,000	3,031,143	(Existing = 122m)
	Breakwater	3,360	m3	178,080,000	1,134,123	(Existing = 2,540m3)
TOTAL		**1**	**LS**	**4,851,550,000**	**30,897,656**	

NOTE:
- The Construction Cost was estimated based on the construction cost of the previous project for Berth No. 2.
- The effect of exchange rates and price increases since the time of construction (in 2014) are taken into account.
(Exchange fluctuations betwenn JPN and SBD = 1.3, Price increase in 10 years = 0.2, are applied to the estimation.)
- The exchange rate was set at 1USD = 157.02JPY as of June 2024. (1SBD = 18.3JPN)

(v) Notes and issues in draft plan

The preliminary study conducted in this survey is based on the following conditions, and further review is necessary before implementation.

1. Demand forecasting and terminal capacity: the preliminary study is based on limited operational information. Detailed and accurate surveys and reviews are necessary for the demand forecasting, operational efficiency, and other aspects related to terminal capacity.
2. Limited review conditions: the layout plan was assumed based on the premise that the structural cross-section of the No. 2 International Berth is feasible, and quantities were calculated accordingly. In the basic design survey, it is necessary to appropriately investigate, review, and evaluate natural conditions and soil conditions to determine the design cross sections appropriately.
3. Cost estimates were calculated based on the construction costs of the No. 2 International Berth, taking into account fluctuations in exchange rates and increases in prices. In the basic design survey, it is necessary to confirm construction material costs, machinery usage fees, labor costs, etc., in the vicinity of Honiara port in the Solomon Islands as actual costs.

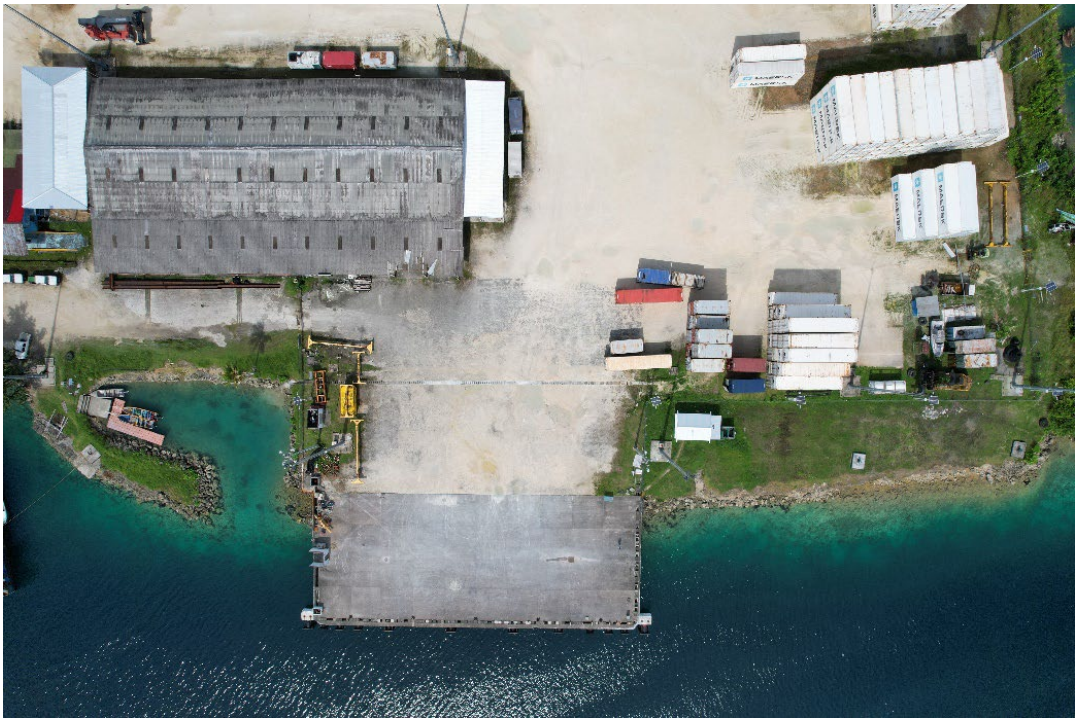
5.3 Noro Port

5.3.1 Review issues related to port maintenance and management

(1) Status of Port facilities

Noro port consists of an international terminal, a domestic terminal, and the Kitano terminal for fisheries. The international and domestic terminals are managed and operated by SIPA, similar to Honiara port. Noro International Terminal is currently undergoing redevelopment to expand its terminal facilities with support from the Australian government.

(a) Port Plan



(Drone Photo by Survey team, April 2024)

Figure 5.3-1 Aerial View of Noro Port

Table 5.3-1 Specifications of Noro Port

ITEM	WHARF INFORMATION		
Names/ lengths / minimum depth	Berth	Length	Depth
	Main Wharf	62.40 Meters	17 – 20 Meters
	Local Wharf	15 Meters	6 – 7 Meters
Type of fenders	Main Wharf – Rubber stripes on hard flat surface. Local Wharf – Truck Tires		
Type of surface of wharf	Noro Main wharf – Concrete Local Wharf - Timber		
Preferred side of ship along side	Starboard Side – For straight forward departure		
ITEM	**ANCHORAGE INFORMATION**		
Minimum depth of anchorage	20 meters		
Type of bottom	Eastern side of Anchorage – Mud, Sand, Gravel Western side of Anchorage – Stone & Gravel		
Wind/ Current	Wind from Northeast & South West Main Current set North & South		
EQUIPMENT	**NUMBER & TYPE**		
Reach stacker	2 x 45 MT		
Forklifts	2 x 45 MT, 1 x 10 MT, 1 x 3 MT.		

(b) Port cross-section

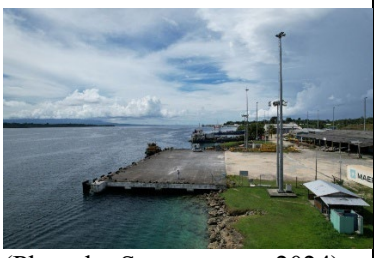


(Dron photo by Survey team, April 2024)

Figure 5.3-2 Front view of Noro Port

(c) Assessing the current situation through on-site inspections

During the on-site survey, corrosion of the mounting brackets for the fender, damage to the front panels, spalling and damage to the concrete, and cracks in the rubber fender itself at the end of the wharf were observed. According to SIPA, there have been no significant changes in the condition of use. The damage to the concrete is thought to be caused by impact from vessels. No misalignment of the quay line or joints was observed. Cracks due to deterioration were observed in the apron concrete. During the site survey, SIPA accompanied the team and exchanged opinions about strengthening port facilities and maintenance methods.

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.1- Status of Noro port -1	No.2- Status of Noro port -2	No.3- Status of Noro port -3

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.4- Damaged concrete -1	No.5- Damaged concrete -2	No.6- Damaged concrete -3

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.7- Status of Fenders -1	No.8- Status of Fenders -2	No.9- Status of Fenders -3

Figure 5.3-3 Site investigation photos

(d) Collection and organization of design documents from the viewpoint of maintenance and management

The international and domestic terminals at Noro port are managed and operated by SIPA, as is Honiara port. SIPA is committed to continuing to improve services at these ports, as well as maintaining, expanding, and investing in the ports. Construction drawings from the time of construction and subsequent repair work for facilities at Noro port were not kept at the Noro port office. They were to be kept at the Honiara office, however, this could not be confirmed.

(2) Implementation Department responsible for Port Management

The Solomon Islands Ports Authority (SIPA) is responsible for the operation of two ports, Honiara port and Noro port. SIPA is subject to the following obligations under the provisions of the State-Owned Companies Act.

- To provide, maintain, and improve facilities deemed most suitable for the public interest at the designated ports
- To maintain, improve, and regulate the use of the designated ports within the scope deemed most suitable for the public interest
- To provide pilotage services and assistance deemed most suitable for the public interest at the designated ports, their routes, and the territorial waters of the Solomon Islands

(3) Status of Existing Facility and Future Plans

Australia's Solomon Islands Infrastructure Program (SIIP) signed a Memorandum of Understanding (MoU) with the Solomon Islands Ports Authority (SIPA) in May 2022 to support the rehabilitation of the country's second-largest port in the western province of Noro. This 8.5 million SBD (1.48 million Australian dollars) project was approved by the Australia-Solomon Islands Joint Management Committee of the SIIP in March 2022. In November 2024, Australia began formal discussions and design work to support the redevelopment of the aging wharf facilities at the Noro International Port.

5.3.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at Noro port

(1) Collection of data on damage caused by past natural disasters

We collected reports on the disasters and compiled information on natural disasters that affected the Solomon Islands over the years in the previous section 7.2.2. Please refer to section 7.2.2 for details.

(a) Sea level rise, cyclone and high wave

In the Solomon Islands region, the recent major disaster was caused by Cyclone "*Itta*" in April 2014, which triggered flash floods and severe flooding on Guadalcanal Island, resulting in significant damage. In July 2015, Cyclone "*Raquel*" struck, coinciding with a magnitude 5.8 earthquake on Makira Island. This combination of events led to heavy rainfall, flooding, and damage to and collapse of buildings, exacerbating the damage. In April 2020, Cyclone "*Harold*" caused landslides, flooding, damage to and collapse of buildings, and a ferry accident.

(b) Earthquake, tsunami and volcanic activity

The Solomon Islands are located at the boundary of the Australian Plate and the Pacific Plate and have experienced major earthquakes with magnitude of 7 to 8 in 2007, 2013, and 2022, resulting in human casualties and property damage due to shaking and tsunamis. In the Solomon Islands, port facilities also serve as hubs for receiving disaster relief supplies during emergencies, so it is considered necessary to strengthen the resilience of wharves and implement flood prevention measures against such disasters.

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in the Noro port and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters.

We requested SIPA to provide data on the design conditions for existing facilities at Noro International Port. However, we were unable to obtain design data from the time of construction. Therefore, we obtained information from the Noro International Port fact sheet.

Deck Level: unknown (not shown in the fact sheet)
Tide Level: 0.5 ~ 1.1m (average tide level)
Water depth: 17 ~ 20 m (minimum depth)

Design vessels: Name of largest ship to call at port:
At Berth: M.V. Shaoshing-LOA199.90m GRT 25,483t
At Anchorage: M.V. Pan Energen-LOA 229m GRT 44,098t

Geotechnical conditions: unknown (not shown in the fact sheet)
Seismic condition: unknown (not shown in the fact sheet)

5.3.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in Noro port based on research papers and past records of natural disasters.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric

number system. We apply the classification into current port design and explore future natural disaster risks for Noro port. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

Referring to Table 5.3-2, the risk of volcanic disasters is high around Noro port in the Solomon Islands. In addition, the risk of high waves during regional storms and the maximum tsunami run-up height is rated as medium. On the other hand, the risk of cyclones, coastal flooding and earthquakes is rated as low.

The Solomon Islands are located in the "Pacific Ring of Fire," which spans approximately 40,000 km across the Pacific Ocean. Here, the Pacific Plate collides with several surrounding continental plates, causing repeated earthquakes. Most of the world's volcanic eruptions, especially the most severe ones, occur in this region. There are three active volcanoes in Solomon Islands – Kavachi which is one of the most active submarine volcanoes in the south-west Pacific, Savo on Savo Island and Tinakula, a conical stratovolcano in Temotu Province. These volcanoes have the potential to cause significant damage.

The Solomon Islands are frequently hit by earthquakes with magnitudes of 7 to 8. The area around Noro Port, located west of New Georgia Island, has been assessed as having a low risk due to the absence of previous major earthquake epicenters. However, earthquakes exceeding magnitude 8 have been observed to cause significant damage and destruction within a radius of several hundred kilometers. The Peak Ground Acceleration (PGA) of the earthquake to be considered in Noro is also estimated to be 0.19 similar to Honiara. It is essential to take adaptation measures against earthquake disaster.

The Solomon Islands are frequently hit by earthquakes and are also at serious risk of tsunamis. The area around Noro Port, located west of New Georgia Island, is assessed as having a medium risk of tsunamis. The maximum inundation height (MIH) of tsunamis around Noro is estimated to be 1.5 meters. Appropriate measures are required to respond to tsunami and high wave damage around Noro Port and the coastal areas.

Cyclones only occur occasionally on the Solomon Islands. They happen about 5 times a year on average. Cyclones often do not make landfall on the Solomon Islands and turn southward beforehand. The most affected regions are Temotu, Makira and Western Province. The area around Noro Port is included in Western Province. Cyclones can cause high waves, with wave heights estimated at 2.8 meters. Even though cyclone disasters in Solomon Islands are infrequent, the area around Noro Port is in the most affected region in the Solomon Islands. Therefore, cyclone disasters are a definite possibility, and appropriate measures must be taken to address them.

Table 5.3-2 Multi-hazard Heat Map Port Exposure (Solomon Islands) -Noro Port

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5, 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High | Medium | Low | Very Low | Not applicable

Source: "A Blue Transformation for Pacific Maritime Transport" (World Bank. 2023. A Blue Transformation for Pacific Maritime Transport. World Bank, Washington, DC. © World Bank.)

Table 5.3-3 Methodology for Identifying Natural Disasters and their Scales (Noro Port)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Could not be confirmed.	Not applicable	Estimate earthquake waves by considering the scale of past earthquakes and taking into account the distance from the epicenter and ground conditions.
Tsunami	Could not be confirmed.	Not applicable	Estimate the loads acting on structures by assuming tsunami heights and flow velocities based on past maximum tsunamis.
Volcano	Could not be confirmed.	Not applicable	Estimate the impact of volcanic eruptions and ashfall on ports based on records of volcanic eruptions in neighboring countries and past volcanic disasters.
Storm Surge	Could not be confirmed.	Flood disasters increase due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	Could not be confirmed.	Increase in high waves due to cyclone intensification	Consider the increase in waves caused by cyclone intensification objectively. Recent research results, such as future predictions using d4PDF described later can be used.

(2) Measures against sea level rise and wave power by climate change

The adaptation measures against sea level rise and wave power by climate change was described in the previous section 5.2.3 (2). Please see section 5.2.3 (2) for details.

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

The projected sea level rise in the Solomon Islands by 2050 is projected to be 0.22 meters under the 2°C warming scenario (SSP1-2.6). Under the 4°C warming scenario (SSP5-8.5), it is projected to be 0.25 meters, with a small difference between the two scenarios. However, by 2100, the difference becomes significant, with 0.52 meters under the 2°C warming scenario (SSP1-2.6) and 0.85 meters under the 4°C warming scenario (SSP5-8.5). Therefore, depending on the scenario selected, the value of projected sea level rise differs, and this must be considered when setting the design service life. Since future projections include uncertainties, it is important to understand the range of future projections.

5.3.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing analysis on port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize SIPA's current disaster mitigation plans in terms of time frames and types of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". Natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 5.3-4.

Table 5.3-4 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The expert team confirmed the structure of existing facilities and maintenance status of the target port through interviews with SIPA and available design documents. The existence and implementation status of natural disaster response plans for the respective port facilities were also confirmed. The expert team sent questionnaires to each port authority to examine if the disaster mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change.
The responses from SIPA are summarized in 5.2.4.

(2) Results of Questionary Survey

Please refer to the responses from FPCL summarized in 5.2.4.

SIPA has formulated and implemented a comprehensive plan covering all port facilities under its jurisdiction for natural disaster response, climate change response, and emergency response. In this survey, the status of each response for the port facilities at the target ports of Honiara port and Noro port are confirmed.

5.3.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by examining the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*" [89] (hereinafter referred to as 'Pacific Ports Vision') shown in Table 5.3-5. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

Table 5.3-5 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

[89] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities in Noro port are shown below.

(a) Natural disaster adaptation – Resilience indicator: Unengaged

Reason: Natural disaster adaptation for existing facilities has not been implemented at Noro port. Noro port was first constructed in 1979, underwent several renovation projects in the 1980s, and was expanded in the 1990s to become the current port facility. It is unclear whether any reassessment of natural conditions was conducted at the time of construction or during the renovation and expansion projects. Information on natural disasters since the 1990s has not been reflected in the current system.

(b) Climate change adaptation - Resilience Indicators: Unengaged

Reason: Climate change adaptation has not been implemented for existing facilities at Noro port. Noro port was first constructed in 1979, underwent several renovation projects in the 1980s, and was expanded in the 1990s to become the current port facility. The impact of sea level rise due to climate change has not been taken into consideration.

(c) Emergency response - Resilience indicator: Engaged

Reason: Noro port has a comprehensive emergency response plan for natural disasters. The relevant plans and documents are as shown below.

- NATIONAL DISASTER MANAGEMENT PLAN 2018[90]
- Solomon Islands disaster management reference handbook 2023[91]

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in the Noro port in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

[90] NATIONAL DISASTER MANAGEMENT PLAN 2018; National-Disaster-Management-Plan-2018.pdf

[91] Solomon Islands disaster management reference handbook 2023; https://www.cfe-dmha.org/LinkClick.aspx?fileticket=QLamPuf0W6Y%3d&portalid=0

Table 5.3-6 Assessment of Impacts of Natural Disasters for Noro Port

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	Noro port is steel pipe sheet pile quay wall with anchor structure, and it is susceptible to displacement and tilting of the front sheet pile wall due to seismic motion. Damage to the anchor structure, ground subsidence behind the quay due to liquefaction, and damage to the apron pavement are also possible. Damage such as the overturning of cargo handling equipment and loss of power supply is also possible.	The collapse of offices at Noro port due to an earthquake and human casualties could affect management systems. The damage to Noro port will have a significant impact on the stable supply of food and other daily necessities on New Georgia Island.	Earthquakes may cause human casualties that could affect operations. Damage to port facilities and loss of power may affect port calls. Damage to cargo handling equipment may also affect cargo handling activities.
Tsunami	Noro port is located at the back of Kula Gulf on the northwestern side of New Georgia Island. It is susceptible to damage from ships colliding or being damaged by tsunamis coming from the north, as well as the loss of container cargo. There are refrigerated container storage facilities in the hinterland, so damage from the loss of refrigerated containers is also a possibility. Damage from the overturning of cargo handling machinery and loss of power is also a possibility.	A tsunami could cause injuries and other human casualties, which may affect the management system. Damage to port facilities and the loss of cargo due to the tsunami will have a significant impact on the stable supply of food and other necessities on New Georgia Island.	Human casualties caused by tsunamis may affect operations. Damage to port facilities and loss of power may affect port calls and cause damage to refrigerated containers.
Volcano	The Solomon Islands are at high risk of volcanic disasters. There are concerns about significant damage to port facilities and cargo handling equipment caused by volcanic eruptions and ashfall, as well as the closure of shipping lanes.	Human casualties caused by volcanic eruptions may affect management systems. Damage to port facilities and disruption of land transportation caused by volcanic eruptions could have a significant impact on the stable supply of food and other essential items within New Georgia Island.	Human casualties such as injuries caused by volcanic eruptions may affect operations. Volcanic ejecta and ashfall may render port facilities and container yards unusable.
Storm Surge	Noro port is located at the back of Kula Gulf on the northwestern side of New Georgia Island and is susceptible to ship groundings due to storm surge and the loss of container cargo. There are refrigerated container storage facilities in the hinterland, so damage from the loss of refrigerated containers is also a concern.	Storm surge may cause injuries and other human casualties, which could affect management systems. Damage to port facilities and the loss of cargo due to storm surge could have a significant impact on the stable supply of food and other necessities on New Georgia Island.	Human casualties caused by storm surge may affect operations. Damage to port facilities and loss of power may affect port calls.
Cyclone	Noro port is located at the back of Kula gulf on the northwestern side of New	Cyclones could cause injuries and other human casualties,	Cyclones may cause injuries and other human

	Georgia Island. Damage to buildings such as offices and warehouses due to strong winds from the cyclone, as well as damage to stacked containers, lighting equipment, and cargo handling machinery, is expected. High waves from the cyclone may also cause flooding of port facilities, ships running aground or colliding, loss of cargo containers, and power outages.	which may affect management systems. Strong winds may damage land facilities and close roads, halting land transportation. High waves may damage port facilities and cause cargo to spill, severely affecting the stable supply of food and other necessities on New Georgia Island.	casualties that could affect operations. Strong winds may halt land transportation, which could affect operations. High waves may damage port facilities and cause cargo to spill, which could also affect operations.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in Noro Port. Figure 5.3-4 illustrates the natural disaster risks and resulting damage to the port.

Noro Port is a steel pipe sheet pile quay wall with anchor structure. An earthquake may affect displacement and tilting of front wall. Ground subsidence due to liquefaction and damage to apron pavement are also concern. Piles of containers could be fallen. The building and warehouse will be damaged. The reefer containers in the yard may be washed away into the sea due to tsunami or cyclone. This could disrupt the vessel entering. Seawater from the north may flood into the port area due to sea level rise.

Damage to Noro port could have a significant impact on the stable supply of food and other daily necessities on New Georgia Island.

A redevelopment project worth 8.5 million SBD (1.48 million Australian dollars) funded by the Solomon Islands Infrastructure Program (SIIP) is currently being conducted at Noro port with the assistance of the Australian government. For this reason, no draft plans for port resilience in Noro Port are made in this project.

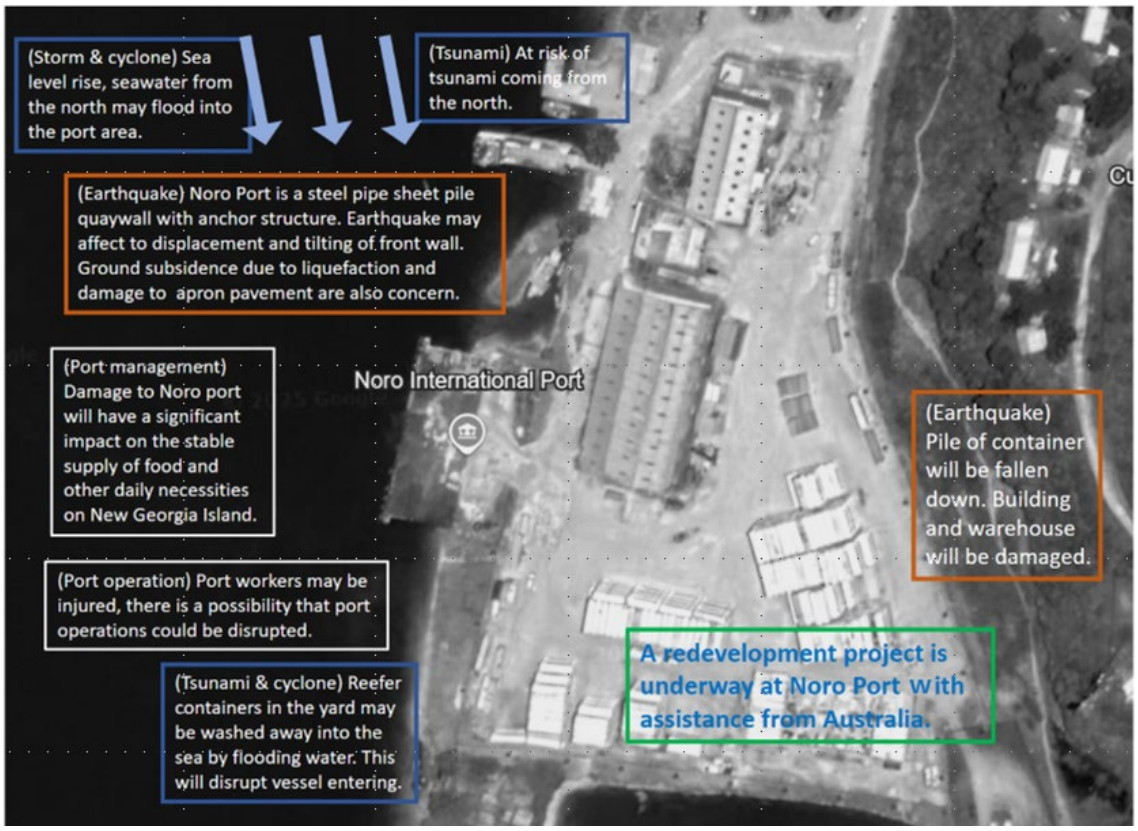


Figure 5.3-4 Geographical characteristics of natural disasters

5.3.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans.

(1) Confirmation of the reasons for staying with the current resilience indicators

In Section 5.3.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for Noro port. The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in PIANC guide. The results are presented below.

(a) Natural disaster adaptation – Resilience indicator: Unengaged

Reason: Actions are not taken at Noro port to respond to the natural disasters at existing facilities.

- The goal(s), planning horizon, and objectives for natural disaster adaptation have not been established and agreed at Noro port.

- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has not been complete, and the potential impacts of natural disasters on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the natural disaster adaptation process for Noro port.

(b) Climate change adaptation - Resilience Indicators: Unengaged

Reason: Actions are not taken at Noro port to address the climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed at Noro port.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has not been complete, and the potential impacts of climate changes on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate changes is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response - Resilience indicator: Engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in Noro port.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at Noro port for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

Measures to make Noro Port one level higher on the resilience indicators

(a) Natural disaster adaptation

- Establish goal(s), planning horizon and objectives for natural disaster adaptation at existing facilities in Noro port.

- Identify the impact of natural disasters on port assets, operations, and systems in Noro port.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information related to natural disaster intensity predictions and determine the extent of the natural disaster.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(b) Climate change adaptation

- Establish goal(s), planning horizon and objectives for climate change adaptation at existing facilities in Noro port.
- Identify the impact of climate changes on port assets, operations, and systems in Noro port.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information on natural disaster intensity forecasts including the effects of climate change and identify the extent of natural disasters with climate change impacts.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(c) Disasters and Emergency Response

- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans.
- Fully develop emergency response plans for natural disasters at existing facilities in Noro port and communicate them to stakeholders.

(3) Examples of countermeasures

The following examples are one of the countermeasures against storm surges and high waves caused by cyclones at the facilities in Noro port.
Redevelopment project of aging wharf facilities at Noro port is currently underway with support from Australia. This project is expected to result in the planning and implementation of fundamental renovation plans that take into account natural disaster and climate change adaptation, such as raising the height of quays, etc.

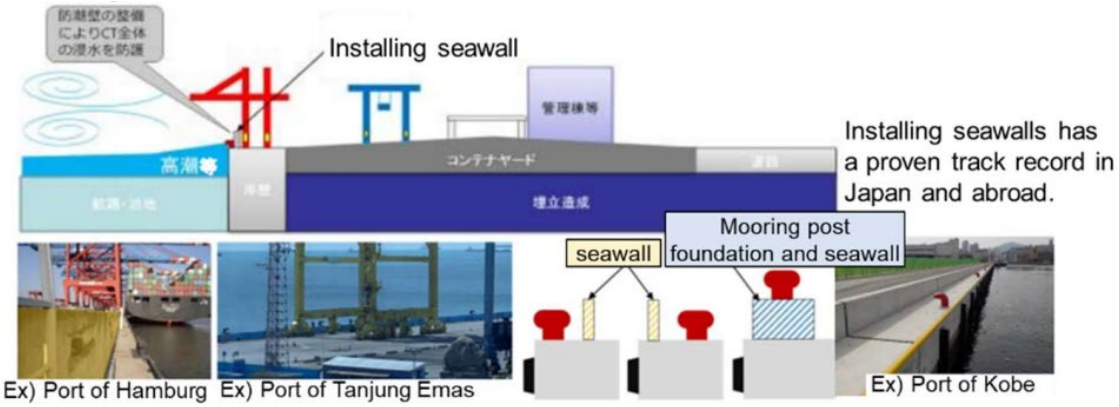
- **Raising quay walls**



(The concept is to raise the height of new or existing wharves to a level that takes into account the effects of storm surges and sea level rise, and to plan or renovate the structure so that it can withstand the resulting increase in load.)

The following example is also effective as one of the countermeasures against storm surges and cyclones at existing facilities surrounding the Noro port.

➢ **Installing seawall**



(The concept is to install additional flood walls on existing wharves to prepare for the effects of high tides and sea level rise. Flood walls are sometimes installed in front of or behind mooring posts (bollards) on wharves for mooring and cargo handling operations. In cases where mooring posts can be relocated or newly constructed, a design integrating the flood walls with the foundations of mooring posts is also considered.)

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for Noro port are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in Noro port is evaluated as "Unengaged."

In order to achieve a higher level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for existing facilities at Noro port in terms of their natural disaster adaptation.

It is recommended to identify the impact of natural disasters on port assets, operations, and systems at existing facilities in Noro port, collecting necessary information to understand the baseline situation, and specifying information necessary for natural disaster risk assessment in order to prepare for the formulation of a natural disaster adaptation plan.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in Noro port is evaluated as "Unengaged."

In order to achieve the next level of resilience indicator, it is necessary to establish goal(s),

planning horizon, and objectives for climate change adaptation.
It is recommended to collect information on natural disaster intensity forecasts that include the impact of climate change in order to identify the impact of climate change on the port assets, operations, and systems of Noro port and to understand the baseline situation.

(c) Disasters and Emergency Response

The resilience indicator outlined in the "*Pacific Port Vision*" for emergency response in Noro port is evaluated as "Engaged."
In order to achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and that emergency response plans for natural disasters at existing facilities in Noro port be fully developed and communicated to stakeholders.

(d) Introduction of the Draft Plan for Port Resilience

A redevelopment project worth 8.5 million SBD (1.48 million Australian dollars) funded by the Solomon Islands Infrastructure Program (SIIP) is currently being conducted at Noro port with the assistance of the Australian government. For this reason, no draft plans for port resilience are made in this project.

6. Independent State of Samoa

6.1 Overview of the country, major ports, and external relations

6.1.1 Country overview

The Independent State of Samoa is a member of the Commonwealth of Nations located in the central South Pacific. The country has a land area of 2,830 km² and consists of seven islands, including Upolu and Savai'i. The capital city of Apia is situated on the northern coast of Upolu Island. Samoa has a hot and humid tropical maritime climate, with an average annual temperature of approximately 27 degrees Celsius. The population is about 222,000, with 90% being Polynesian Samoans. The main industries are agriculture, coastal fisheries, and tourism. Major products include copra, cocoa beans, rubber, and bananas; however, over 80% of the agricultural production is for subsistence use. A location map is shown below.





Source：Samoa Details - The World Factbook
(Accessed: February 2025)

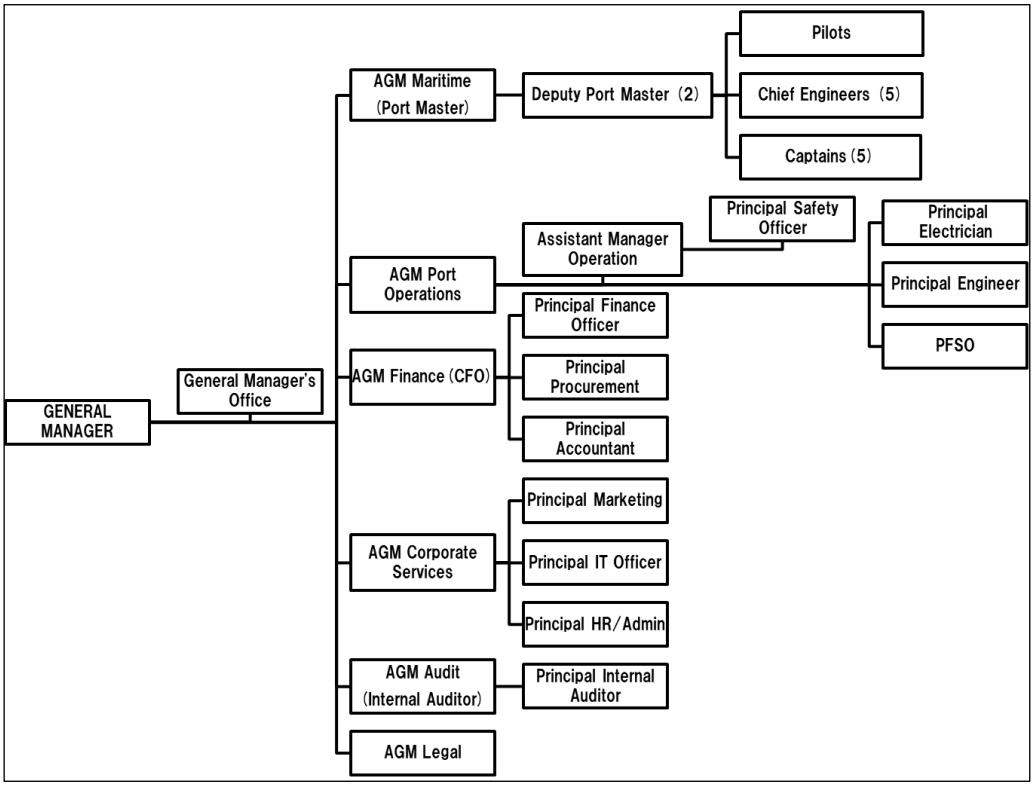
Figure 6.1-1 Location map of Major Ports in Samoa

6.1.2 Overview of major ports

(1) Port administration

Samoa's ports are managed and operated by the Samoa Ports Authority (SPA), a state-owned enterprise established in July 1999 under the Samoa Ports Authority Act of 1998. Previously managed by the Ministry of Transport, SPA took over personnel and major assets from the ports of Apia, Mulifanu'a, Aleipata, Salelologa, and Asau. Under the leadership of the CEO and General

Manager, the organization is structured into six departments: Maritime, Port Management, Finance, Corporate Services, Internal Audit, and Legal Affairs, each headed by an Assistant General Manager.



Source：Based on Governance - https://spasamoa.ws/new/about/our-team/（accessed February 2025）

Figure 6.1-2　Organizational Structure of SPA

6.2 The ports in Samoa

6.2.1 Identification of issues related to port maintenance and management

There are three major ports in Samoa. Apia port is an international trade port in Upolu Island. The other two are domestic ferry terminals: Mulifanu'a port in Upolu Island and Salelologa port in Savai'i Island, which connect the two islands. Research and on-site surveys were conducted to identify the challenges related to port maintenance and management at these locations. JICA experts and SPA representatives visited sites together, observed the current port facility condition, and identified vulnerabilities of the ports in the event of natural disasters. Photos taken during the surveys are shown below.



Picture 6.2-1 Site Visit with JICA experts and SPA representative at Salelologa port

(1) The port of Apia

(a) Status of Port Operation

Samoa is an island nation located in the central South Pacific, heavily dependent on maritime transport for both the life of the people and economic activities. Apia port is the country's sole international port, handling approximately 500,000 tons of cargo annually and serving as the most important port for foreign trade. Major commodities handled at Apia port include exports of food products (such as fruits), and imports of machinery and transport equipment (such as vehicles) and chemicals. Container throughput at Apia port is on a slight upward trend, reaching 45,680 TEUs in 2022.

Table 6.2-1 Cargo handling volume at the port of Apia

	Unit	2018	2019	2020	2021	2022
Container throughput	TEUs	37,091	42,102	41,200	43,933	45,680
Gross tonnage of vessels	t	2,439,148	3,672,558	2,498,536	1,899,338	1,975,034

Source: https://spasamoa.ws/new/newsletters/ Samoa Ports Authority, Annual Report 2022, Apia Port Statistics

The following table shows the number of vessel calls and vessel size by vessel type at Apia port in 2023. Fishing vessels account for the highest number of port calls at 857 followed by passenger ships (137 calls including Ro/Ro type vessels), landing craft (94 calls), container-carrying cargo ships (77 calls), full container ships (56 calls) and cruise ships (15 calls).

Table 6.2-2 Number of Vessel Calls and Size by Type in Apia port

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Avg. DWT	Avg. GT
Cable ship	2	24	195,252	315,792	8,136	13,158
Combined chemical and oil tanker	6	6	302,834	176,966	50,472	29,494
Ferry	1	2	330	1,986	165	993
Fire fighting tug	1	1	480	264	480	264
Fish carrier	1	2	0	9,142	0	4,571
Fishing (general)	81	357	5192	75,339	15	211
Fully cellular containership	10	56	1,149,943	940,995	20,535	16,809
General cargo	1	1	9,106	7,460	9,106	7,460
General cargo with container capacity	11	77	1,008,396	832,634	13,096	10,813
Landing craft	3	94	40,880	47,124	435	501
Naval vessel	1	1	1,022	1,840	1,022	1,840
Oceanographic research	1	2	0	6,190	0	3,095
Passenger (cruise)	13	15	101,436	988,892	6,762	65,926
Passenger Ro/Ro	2	75	13,609	89,364	181	1,192
Passenger vessel (unspecified)	1	62	12,276	30,876	198	498
Patrol ship	1	2	150	1,140	75	570
Product tanker	6	6	250,614	149,371	41,769	24,895
Research	2	3	528	2,276	176	759
Roll on roll off with container capacity	3	12	211,569	208,087	17,631	17,341
Training	1	1	6,974	12,517	6,974	12,517
Tug	1	30	3,660	10,440	122	348
Vessel type (unspecified)	13	44	0	0	0	0
Yacht	53	92	290	1,561	3	17
Total	**215**	**965**	**3,314,541**	**3,910,692**	**3,435**	**4,053**

Source: Analyzed by OCDI based on Lloyd's List Intelligence Seasearcher data (2023).

(b) Status of development of Apia port

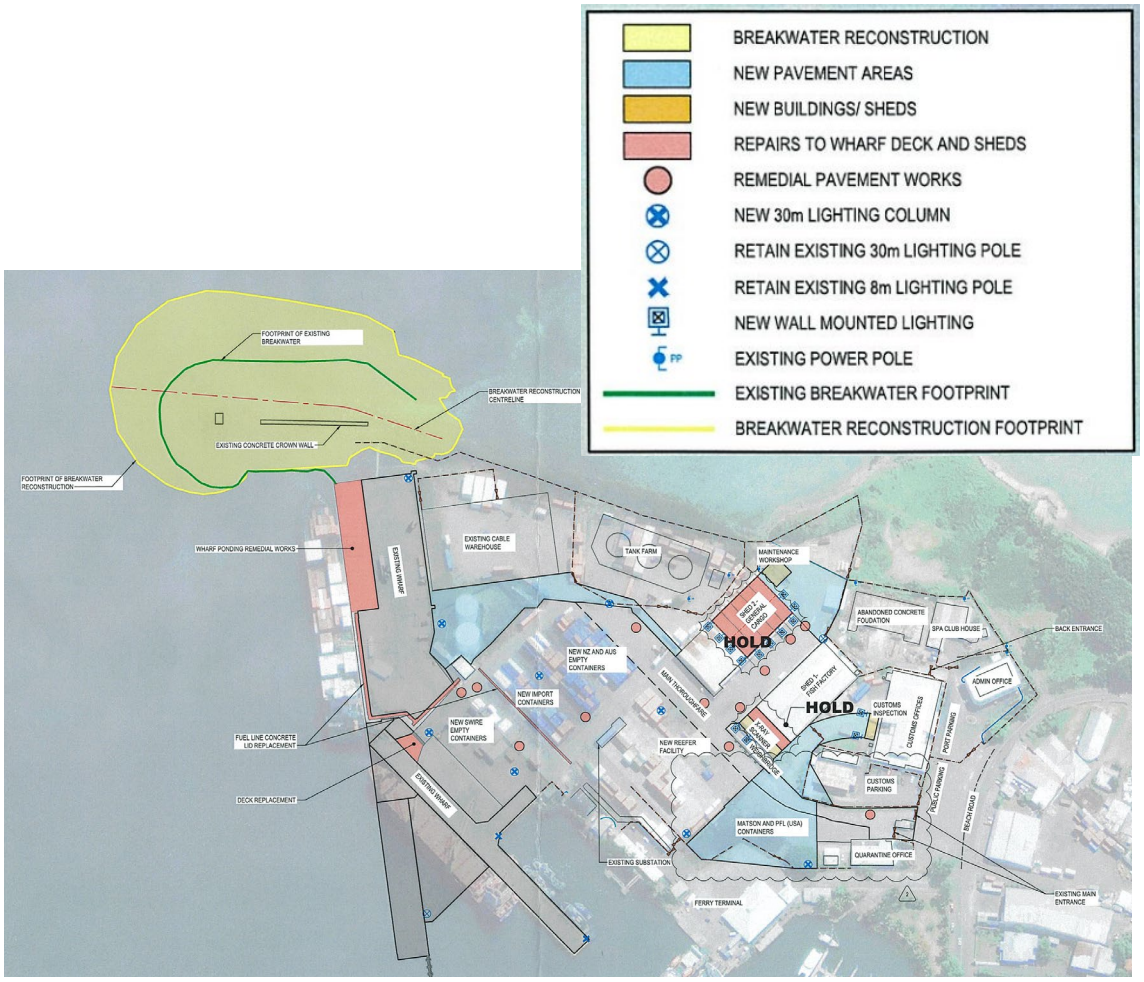
In this paper, we separate Apia port into three wharves for the sake of convenience as shown in the figure below. The first wharf at Apia port was constructed and opened for service in 1966 with the support of New Zealand. Since then, repairs and expansions have been carried out by Japan's grant aid program. In recent years, the size of vessels has become larger. The second wharf was constructed in 2003 to cope with the increasing number of vessels call by Japan's grand aid program. To ensure the safety of ships during entry and departure as well as mooring, a new third wharf was constructed in 2018. As a result, the first and second wharves were integrated into a continuous straight quay, allowing two container ships to dock simultaneously. Furthermore, dolphins were added, enabling the port to accommodate a large cruise ship, which supports the island's tourism industry. This terminal layout plan enables SPA to meet multiple needs while also being cost-effective.



Legend	Year	Description	Remarks
	1966	First Wharf construction	New Zealand's grant aid
	1988～1991	First Wharf Repair	Japan's grant aid(1)
	1988～1991	Container yard expansion	Japan's grant aid(1)
	1988～1991	Pier extension	Japan's grant aid(1)
	1988～1991	Breakwater construction	Japan's grant aid(1)
	2000～2003	Second Wharf construction	Japan's grant aid(2)
	2000～2003	Breakwater renovation	Japan's grant aid(2)
	2016～2018	Repair of Pier extension section	Japan's grant aid(3)
	2016～2018	New Wharf construction	Japan's grant aid(3)

Figure 6.2-1 Development History of Apia port

ADB has been rehabilitating the remaining old facilities since 2019. The project includes breakwater reconstruction, pavement and drainage upgrades on a yard, improved lighting, and the construction of inspection facilities. This project also can contribute to enhance the port's resilience, safety, and operational efficiency.



Source: Obtained from SPA in September 2024.

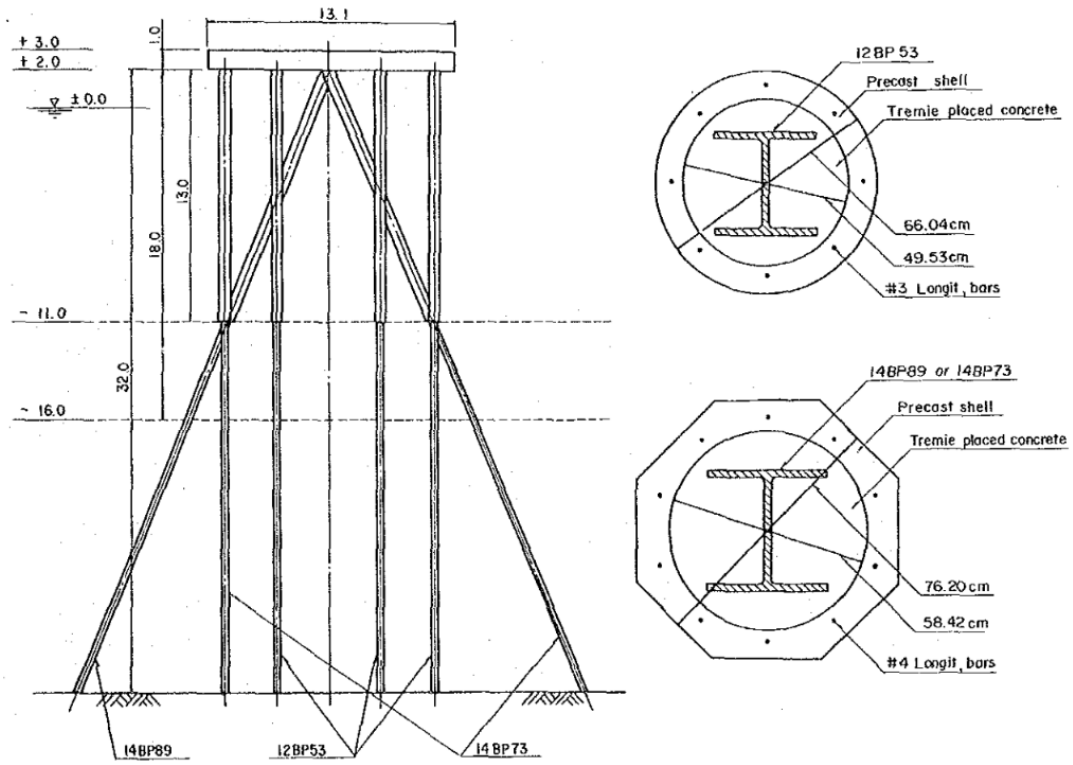
Figure 6.2-2 Enhancing Safety, Security, and Sustainability of Apia Port Civil Works by ADB

(c) Structure of the wharf

The specifications of each wharf in Apia port are as follows.

- The first wharf and Pier Extension: Length 185m, Water Depth 11m, Pier structure (H-piles encased in concrete)
- The second wharf: Length 165m, Water Depth 11m, Quay Wall structure (Steel pipe piles)
- The new wharf: Length 137m, water depth 11m, Pier structure (Steel pipe piles)

The first wharf and pier extension were made of H-shaped steel piles covered with concrete from the seabed to the underside of the deck, as shown in the figure below. The second wharf is a quay wall structure supported by steel pipe piles rather than a pier structure. In addition, the new wharf is a pier structure supported by steel pipe piles. The structural designs of the second wharf and the new wharf are commonly used at modern ports throughout the world.



Source: Basic Design Survey Report on the Apia port Development Plan, Western Samoa, August 1988, Japan International Cooperation Agency

Figure 6.2-3 Pier structure at the First wharf, Apia port

(2) Facility maintenance and management status of Apia port

(a) The First Wharf

The H-shape piles encased in concrete at the first wharf have significantly deteriorated. Cracks and spalling are observed on the surface of the pile heads concrete. The concrete slab is also spalled. Iron bars inside the slab are heavily corroded. As structural capacity has been compromised, SPA has temporarily restricted heavy cargo loading in this area. ADB is providing assistance in repairing the facilities.



Spalling concrete underneath the slab



Spalling concrete underneath the slab

Picture 6.2-2 Deterioration at the First wharf

(b) Pier Extension Area

According to a JICA report[92], the pier extension area was originally designed to handle mainly general cargo with low weight forklifts. However, due to rapid containerization, large cargo handling equipment such as top lifters, that was not anticipated in the original design, came into use. As a result, excessive loads were charged on the pier, leading to rapid damage and deterioration of the slab, beams, and pile heads. Therefore, when the new pier was constructed in 2017, the damaged slab, beams, and pile heads in the pier extension area were all repaired.

	
Spalling concrete and corrosion of the structural reinforcement (Photo from the 2015 report)	Spalling concrete and corrosion of the structural reinforcement (Photo from the 2015 report)

Picture 6.2-3 Deterioration of the Pier Extension Area (before repair)

(c) The Second Wharf

The second wharf was constructed as a steel pipe pile structure in 2003. SPA replaced fenders, but no serious deterioration of the wharf structure has been reported.

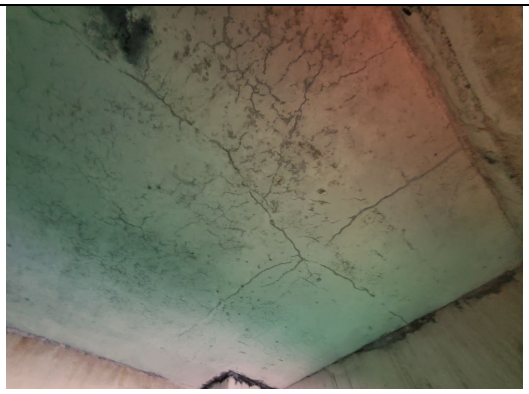
(d) The New Wharf

The new wharf was constructed in 2018 as a pier structure composed of steel pipe piles and a concrete deck. Based on the JICA expert investigation, no significant deterioration has been observed in the piles themselves nor at the pile-to-deck connections. Although hairline cracks were found in some areas beneath the deck, they are considered to be non-critical and can be repaired by methods such as cement filler application or epoxy injection. The structure is in sound condition overall.

[92] Preparatory Survey Report on the Apia Port Improvement Plan for Safety Improvement in Samoa, March 2015, Japan International Cooperation Agency (JICA)



The lower part of the floor slab, steel pipe piles



Hairline cracks

Picture 6.2-4 Deterioration of the New Wharf

(e) Summary of maintenance and management status of Apia port

The pier extension area was repaired and rehabilitated in 2017. The area is currently used as a storage area for empty containers. The second wharf, on the other hand, is not a pier structure but a quay wall structure supported by steel pipe piles. To date, no serious deterioration has been reported. In contrast, the first wharf, which was constructed in 1966, has only recently begun undergoing rehabilitation. The operation of large cargo handling equipment such as top lifters is prohibited in this area. However, fully loaded containers are permitted to be transported by trailer. The key issues at Apia port are summarized below.

i. The first wharf was constructed in 1966 and was originally designed for handling light weight general cargoes. At present, container handling operations are commonly carried out, and containers themselves are considerably heavier than the general cargoes. In addition, container vessels of up to 20,000 DWT are calling at the port. Therefore, both the size of vessels and the weight of cargo have been exceeding the original design specifications. As a result, damage to the concrete piles has been caused by continuous loads equivalent to, or even exceeding, the allowable load on the slab,

ii. Due to the increasing size of container vessels, fenders have been subjected to vessel berthing force impacts beyond the original design over the years which may have accelerated the deterioration of the first wharf and pier extension area, both of which are of pier-type structure. Although no significant displacement of the wall alignment or major level differences at the joints were observed visually, clear signs of structural deterioration were confirmed on the underside of the pier slab, including concrete spalling and corrosion of exposed reinforcing bars,

iii. Spalling and depressions on the surface of the slab of the first wharf are observed. The operation of cargo-handling equipment and the storage of containers are prohibited in some areas. With support from the ADB, removal and repair of the damaged slab are currently underway,

iv. No irregular noise or vibration from the structure was observed during the on-site inspection,

v. No heavy quay cranes such as a gantry cranes or crawler cranes have been operated on the wharves,

vi. Due to the deterioration of the slab on the container yard and the limited bearing capacity, only empty containers can be handled in this area. Since these areas are just behind the container jetty, this restriction has significantly affected container cargo handling efficiency.

(3) The port of Mulifanu'a

(a) Status of Port Operation

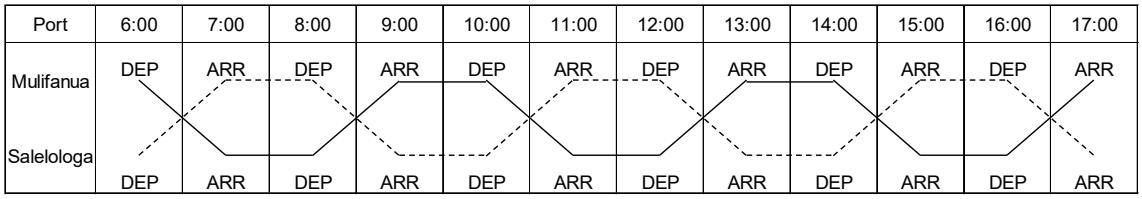
Mulifanu'a port is the ferry terminal in Upolu Island, connecting Upolu Island and Savai'i Island. All international containers are first discharged at Apia port. The cargoes for Upolu are devanned from the containers and loaded onto a truck at Apia port. The truck goes through Upolu and boards a ferry boat from Mulifanu'a port to Salelologa port in Savai'i Island. The ferry boats now transport trucks, vehicles, passengers, and tourists. They play a crucial role in supporting inter-island logistics and the movement of people. Currently, the operational service of this route is managed by the Samoa Shipping Corporation Ltd.

The annual ferry transport volumes from 2020 to 2024 are shown below. In 2023, peak volumes of approximately 750,000 passengers and 110,000 vehicles were recorded. Two ferry boats provide three round trips each per day, or a total of 12 one-way trips per day. On average, 9.15 one-way trips per day were made over the five-year period. The annual operational rate is 76.25%. During peak times, trucks and general vehicles are obliged to wait in line in front of the port gates to embark the ferry boats.

Table 6.2-1 Passenger and cargo transport volume between Mulifanu'a and Salelologa

Item	Unit	2020	2021	2022	2023	2024	Avg.
Passengers	nos	259,342	571,830	591,458	756,498	455,952	527,016
Ferry trips (one-way)	times	2,733	3,616	3,298	4,022	2,798	3,293
Vehicles	nos	47,294	78,038	86,777	117,421	75,146	80,935

Source: SPA data compiled by JICA team

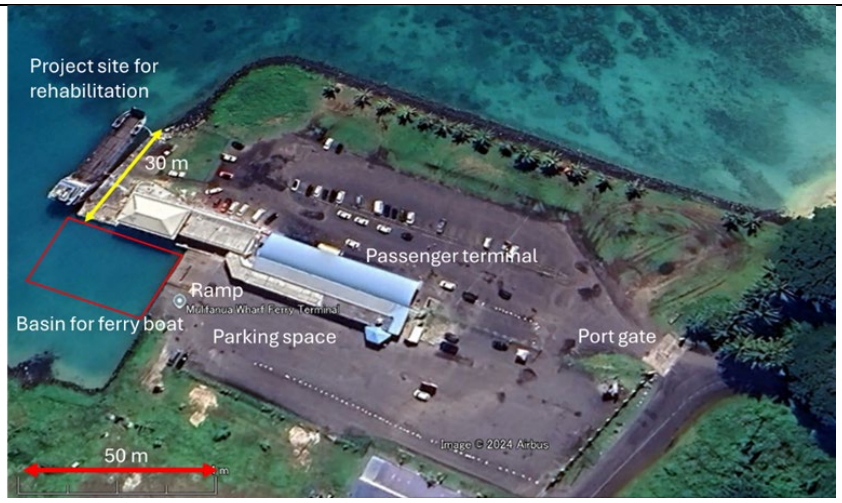


Source: https://www.globtroter.pl/przewodnik/Szukaj,416,samoa,australia,i,oceania.htmlInter-Island Passenger and Cargo Ship Construction Plan for the Independent State of Samoa: Basic Design Survey Report May 2008, JICA

Figure 6.2-4 Ferry timetable

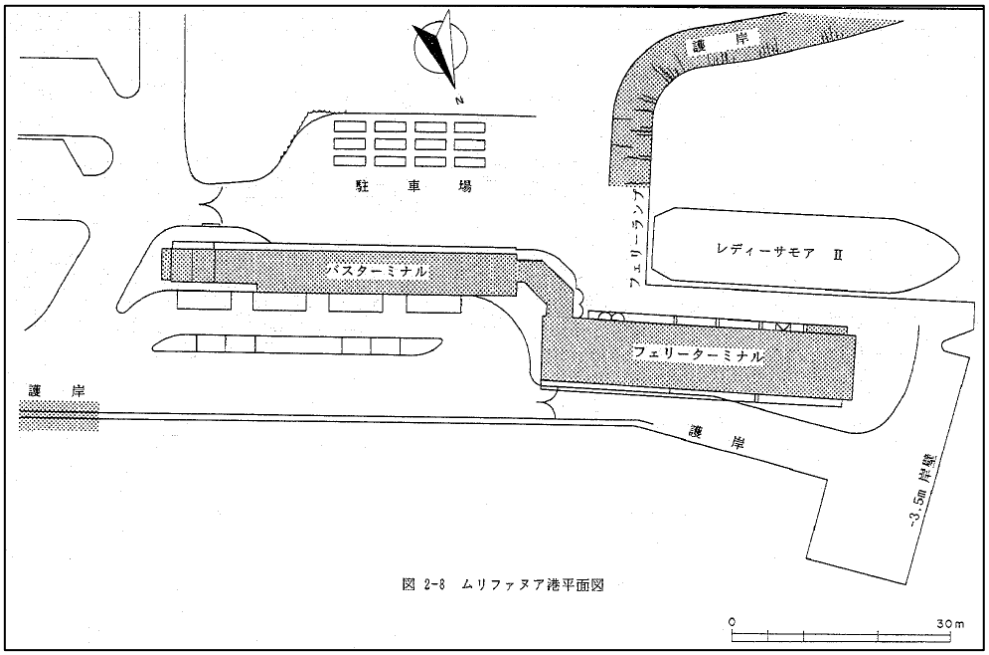
(b) Facility maintenance and management status of Mulifanu'a port

The current ferry terminals at Mulifanu'a port and Salelologa port were constructed with the support of New Zealand in 1972. The original terminal specifications of these ports were the same: terminal length was 45 meters, the width of passenger ramp was 9.5 meters, and the minimum water depth in front of the quay was 3.0 meters. The structure was made of steel sheet piles. Due to the lack of anti-corrosion treatment, the steel sheet piles were corroded heavily, especially in the splash zone and tidal areas. JICA repaired and upgraded the terminals to enhance domestic transport capacity by its grand aid in 1985. In addition, Japan granted ferry boats to cope with the growing demand for passengers and cargoes. Despite being damaged by cyclones "*Ofa*" in 1990, "*Val*" in 1992, and "*Evan*" in 2012, several recovery works were carried out by Japan's grant aid program. The facilities have been well served since then.



Source: Created by JICA team based on Google Maps

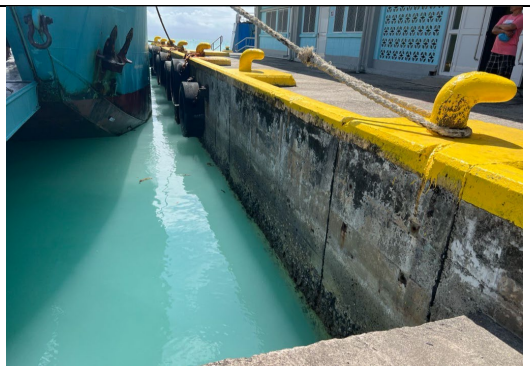
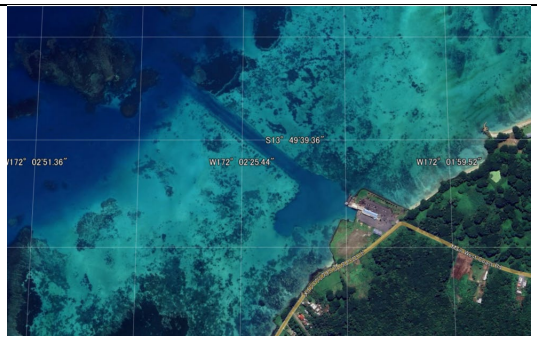
Figure 6.2-5 Existing layout of Mulifanu'a Port



Source: https://www.globtroter.pl/przewodnik/Szukaj,416,samoa,australia,i,oceania.htmlPort and Seawall Disaster Recovery and Reconstruction Plan for Western Samoa Basic Design Survey Report 1992, JICA

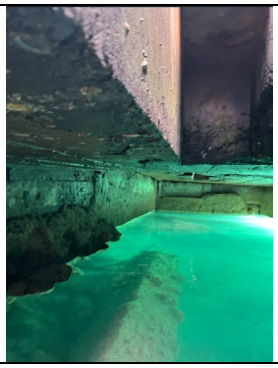
Figure 6.2-6 Layout of Mulifanu'a Port

JICA experts' visual observation could not find any significant deterioration of the ferry terminal. However, all original fenders have dropped off from the jetty. SPA tentatively attached used automobile rubber tires as a substitute for fenders. However, this tentative measure may result in vessel damage during berthing and unberthing operations. Accordingly, normal fenders should be installed. JICA experts also observed wear on the surface of the concrete rampway due to the frequent contact of ship's ramp. However, the wear is not so significant for landing vehicles. We recommend overlaying the eroded surface or attaching a steel plate on the surface of the ramp if the wear gets worse.

	
Used automobile rubber tires are attached as fenders	Ferry docked at the port (Left: -3.5 m quay, right: ferry quay)
	
Wear on the surface of concrete rampway	Panoramic view of the Mulifanu'a port and access channel

Picture 6.2-5 Deterioration of the ferry terminal at Mulifanu'a port

Another terminal with a water depth of 3.5m in depth was constructed as a concrete pile pier in 1957. This terminal is no longer in operation although some ferry boats are moored here. Some mooring bollards were missing. Several large holes on the deck have been left unrepaired. JICA experts' visual inspection through the hole revealed that the deck slab, beams, and concrete piles beneath the pier have significantly deteriorated. The structural strength of the terminal is considered to be insufficient.

	
Top of -3.5 m terminal	Under slab of -3.5 m terminal

Picture 6.2-6 Deterioration of the terminal at Mulifanu'a Port

The maintenance status of Murifanu'a port is summarized below.

i. The current ferry boat operation at the terminal is the same as the original design purpose. No irregular impacts on the terminal during cargo handling or heavy truck loading are reported.

ii. Even though there is no visible damage on the hull of ferry boats, the fenders of the terminal are damaged, missing or have been replaced with used tires. Normal fenders should be installed to protect both the vessels and the quay structure.

iii. JICA experts' visual inspection identified no significant misalignments of the quay line or large gaps in the joints of the quay block. However, the wear on the rampway may hinder a vehicle's ability to smoothly get on and off the boat. Proper repair work is recommended. No signs of settlement nor cave-in on the apron were observed. No irregular noises or vibrations on the terminal facility were detected. The 3.5m deep quay has been decommissioned for cargo handling due to aging. It is tentatively used only for mooring vessels. Its structural capacity is no longer sufficient. It is necessary to either demolish it or take remedial measures before any structural impacts affect the adjacent ferry terminal.

(4) The port of Salelologa

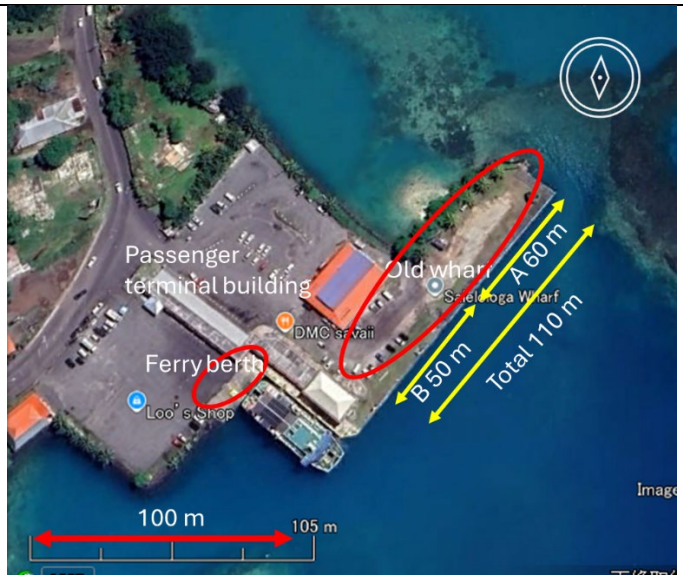
(a) Utilization status

Salelologa port has served as a gateway terminal in the Savai'i island by connecting Upolu and Savai'i. Asau port located on the opposite side of the island and other small ports are primarily used for small boats and fishing vessels.

(b) Facility maintenance and management status of Salelologa port

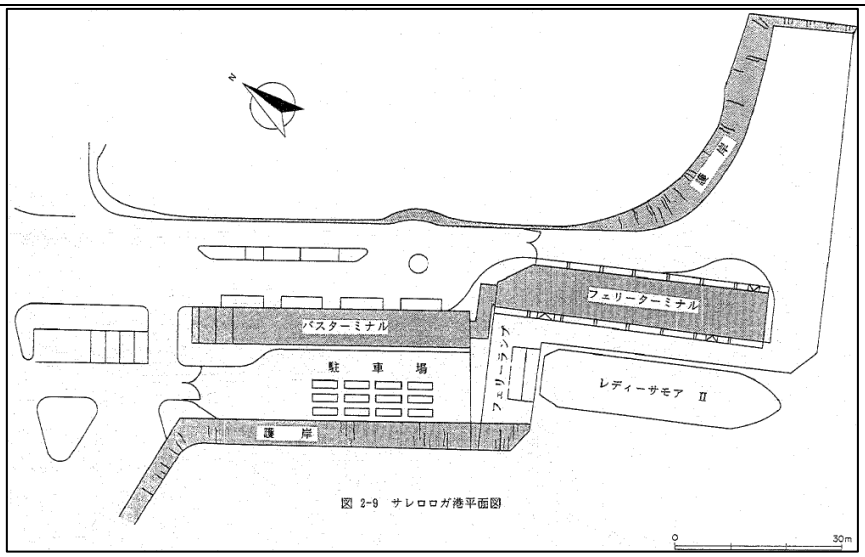
The ferry terminal at Salelologa port, along with the terminal at Mulifanu'a port, was developed in 1985 by Japan's grant aid program to strengthen domestic transport capacity. In response to the growing demand for passenger and cargo transport, Japan also provided newly built ferry boats. The access channel has been widened and deepened as well. Although the damage caused by

cyclone *Ofa* in 1990 was relatively minor, the impact of cyclones *Val* in 1992 and *Evan* in 2012 was significant. Recovery works were carried out with support by Japan.



Source: Created by JICA team based on Google Maps

Figure 6.2-7 Existing Layout of Salelologa Port



Source: Port and Seawall Disaster Recovery and Reconstruction Plan for Western Samoa Basic Design Survey Report 1992, JICA

Figure 6.2-8 Layout of Salelologa Port

JICA experts' visual inspection identified no significant deterioration on the ferry terminal itself. However, all original fenders have dropped off from the ferry terminal. SPA tentatively attached used automobile rubber tires as a substitute for fenders. However, this tentative measure may result in damage to vessels during berthing and unberthing operations. Therefore, normal fenders should be installed. Slight wear on the rampway was observed. The wear has been caused by frequent contact with the vessel's ramp, but it may not cause any issues under current operation.

	
Ferry arriving at Salelologa port (Fenders have fallen off the yellow ferry berth and been replaced with old tires. The old berth is on the right side.)	Slight wear is observed on the surface of the rampway but trucks are able to board and deboard without issue.

Picture 6.2-7 Deterioration of the ferry terminal at Salelologa port

The old berth, adjacent to the ferry terminal, is no longer used. JICA experts' visual inspection identified that section A (see at Picture 6.2-8), on the right side of the old berth with approximately 60 meters in length, was constructed as a concrete pier structure. Several holes of around one meter in diameter are observed. The holes were likely caused by scouring. Even though fishing boats are tentatively moored there, it is not a safe condition for use.

Section B, on the left side of the old berth with approximately 50 meters in length, was constructed as a steel sheet pile structure. Numerous depressions by scouring are observed. It is critically unsafe for vessel docking and mooring. Scouring stretched to the yard area. The structure is assumed to be constructed as either: 1) connected by sheet piling and tie rods, or 2) supported by a concrete retaining wall and concrete beams against the underlying ground. The gravel rock inside the jetty looks like volcanic stones with a certain level of specific gravity, not like light weight coral stones. The design drawings of the old berth were not obtained.

	
Front view of the old berth (Photo taken by JICA team using a drone)	Scour conditions

Picture 6.2-8 Deterioration of the old terminal at Salelologa port

The maintenance status of Salelologa port is summarized below.

i. The current ferry boat operation at the terminal is the same as the original design purpose. No irregular impacts on the terminal during cargo handling or heavy truck loading are reported.
ii. Even though no visible damage to the hull of ferry boats was observed, the fenders on the terminal are missing or have been replaced with used rubber tires. Normal fenders should be installed to protect both the vessels and the quay structure.
iii. JICA experts' visual inspection identified no significant misalignments of the quay line or large gaps in the joints of quay were observed at the ferry terminal. Only light wear on the rampway was observed. No signs of settlement nor cave-in on the apron were observed. No irregular noises or vibrations on the terminal facility were detected.
iv. The old berth is in serious condition. Its structural capacity is no longer sufficient. It is necessary to either remove it or take remedial measures before any structural impacts affect the adjacent ferry terminal.
v. Some navigational aids are missing. As reefs and sediment deposits exist alongside the access channel, proper navigation markers should be promptly installed to ensure safe navigation.

6.2.2 Identification of the scale of natural disasters

(1) Collection of data on damage caused by past natural disasters

In this section, we will collect reports on the disasters, and compile information on natural disasters that affected the ports of Apia, Mulifanu'a and/or Salelologa over the years. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss.

(a) Sea level rise, cyclone and high wave

First, we will review the natural disaster risks across Oceania based on "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)" [93]. AR6 reports that the occurrence proportion of strong tropical cyclones (categories 3 to 5) among all tropical cyclones globally has increased in the last 40 years, with a moderate level of confidence. AR6 indicates low confidence in the long-term trends of the increasing frequency of tropical cyclones across all categories. In addition, AR6 mentions that the global mean sea level has been rising more rapidly since 1900 than at any other 100-year time in the past 3,000 years, with high confidence.

Next, we will list the major cyclones that have caused critical damage to Samoa in chronological order of their occurrence. Cyclone "*Ofa*" damaged breakwaters and wharves, and covered the access channel with sedimentation in 1990 in Apia. Cyclone "*Val*" brought four days of continuous heavy winds of 30 meters per second in 1991. 90% of households were damaged. Cyclone "*Heta*" recorded 5-meter wave height in 2003. Cyclone "*Evan*" also brought strong winds of 30 meters per second for about four days in 2012. The above analysis and cyclone records imply that the risks of damage from cyclones, storm surges, and high waves are potentially increasing.

(b) Earthquake, Tsunami and volcanic activity

World Bank reported that Oceania was exposed to high risk of tsunamis, earthquakes, and volcanic activity[94]as shown in Figure 6.2-9 to Figure 6.2-11. Samoa is in the "Pacific ring of fire" and exposed to earthquakes and tsunamis. The earthquake peak ground acceleration in Samoa falls in the range of 100.1 to 250 cm/s² or more (see Figure 6.2-10). Tsunami maximum inundation height (MIH) for a 50-year return period in Samoa falls in the 1.01 to 1.50 meter range (see Figure 6.2-9). An earthquake with a magnitude of 8.1 occurred in September 2009, and generated a 140 cm runup height in Apia. This tsunami also hit American Samoa with 6-meter runup height. The distance from the nearest trough to Samoa is only about 150 km. The travel time of the seismic ground motion and that of tsunami approach is considerably short. Volcanic hazard levels

[93] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[94] Pacific Maritime Transport Systems Hazard Exposure Technical Note, World Bank. 2023.

covering a 200 km radius from active volcanic events fall under “Low” (see Figure 6.2-11). Even though recent records show no major volcanic eruptions within the territory of Samoa, the Samoan islands were formed by volcanic activity.

JICA experts therefore propose that SPA should adopt measures against earthquakes, tsunamis and volcanic eruptions when designing port facilities and operating their ports. SPA should set tsunami runup height at 2.0 meter or more and adopt earthquake-resistant design for major port facilities. Continued monitoring and collection of data related to seismic activities in the Pacific and tsunami run-up and inundation in Apia are necessary to effectively prepare for disasters.

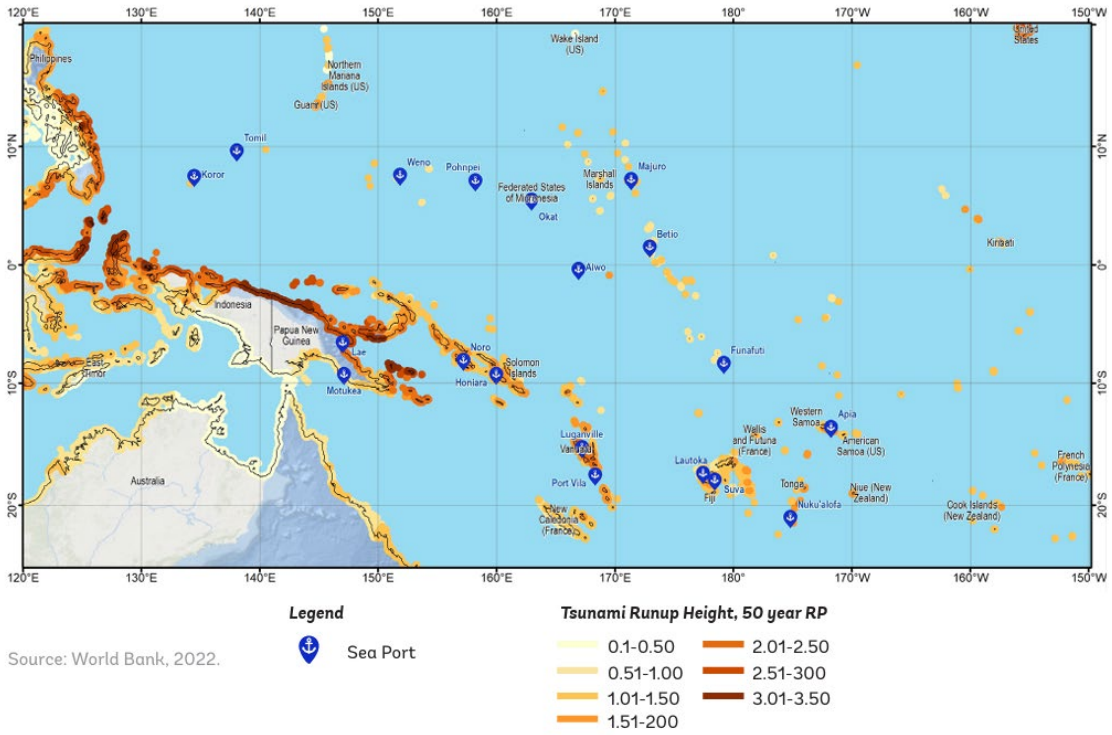


Figure 6.2-9 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

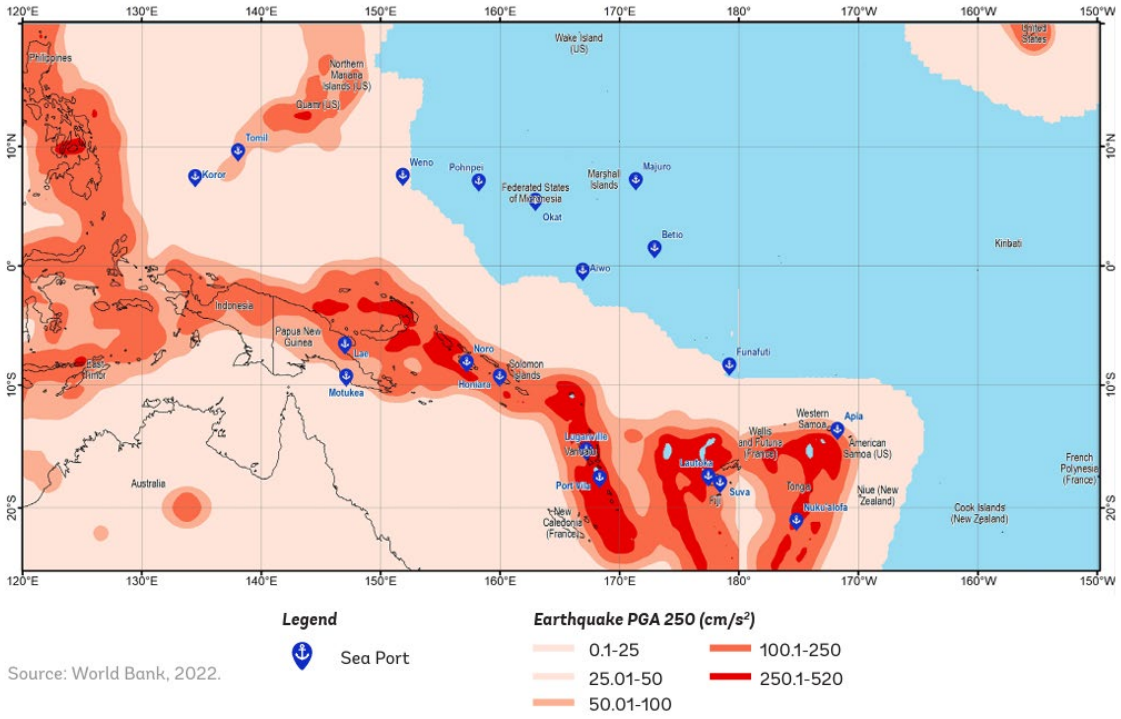


Figure 6.2-10 Earthquake peak ground acceleration in cm/s² for a 250-year return period

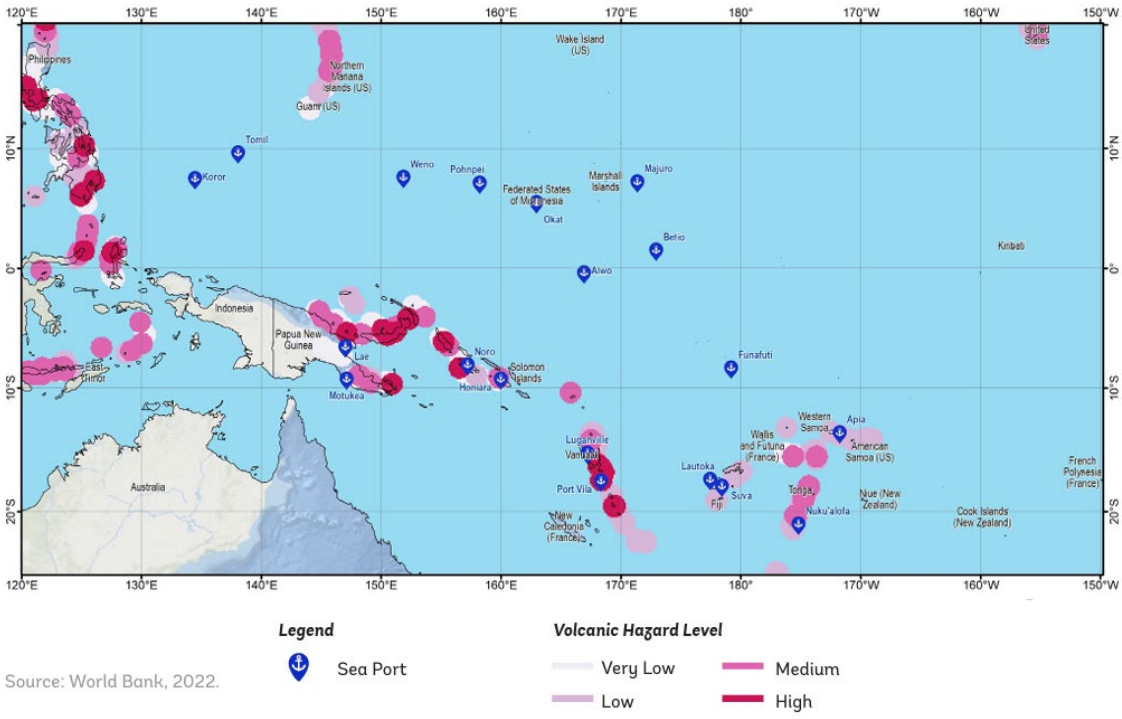


Figure 6.2-11 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

(c) Records of major Cyclones and Tsunamis

We collected data of major cyclones and tsunamis that hit Samoan ports and caused significant damage after 1990.

Name	Specification	Damage
Cyclone "*Ofa*", February 1990[95]	・Maximum average wind speed: Approximately 42 m/s (about 152 km/h) (10-minute average) ・Maximum instantaneous wind speed: Approximately 62 m/s (about 220 km/h) (estimated) ・Central atmospheric pressure: 980 hPa ・Significant wave height: Not recorded. Offshore wave height (H_0) was 8.6 m. ・Wave period: Not recorded. The offshore wave period (T_0) was 12.0 sec.	・Human damage: Unknown ・Property damage: Approximately 25,000 people lost their homes. Road facilities, especially along the coastline, experienced damage with about 50 km of roads washed out on both Upolu and Savaii Islands. Key port facilities, which are vital for maritime transport, also suffered significant damage, including the washing away of breakwaters, collapse of quay walls, obstruction of navigation routes by sediment, and damage or washing away of navigational markers.
Cyclone "*Val*", December 1991	・Maximum average wind speed: Approx. 49 m/s (ten-minute average) ・Maximum instantaneous wind speed: Approx. 64 m/s (one-minute average) ・Central atmospheric pressure: 940 hPa ・Significant wave height: Not recorded. Offshore wave height (H_0) was 10.9 m. ・Wave period: Not recorded. Offshore wave period (T_0) was 12.5 sec.	The total estimated damage from both cyclones was around 300 million USD. As with Cyclone *Ofa*, one of the strongest storms of the century, causing extensive damage due to high winds (winds of about 30 m/s continued for around four days). ・Human damage: 17 people died, including in Samoa and other affected areas. ・Property damage: Approximately 90% of houses were damaged. Infrastructure also suffered severe destruction, with agriculture, power, and communication networks devastated.
Cyclone "Heta" from Dec. 2003 to Jan. 2004	・Maximum Sustained Wind Speed: Approx. 60 m/s (ten-minute average) ・Maximum Instantaneous Wind Speed: Approx. 73 m/s (one minute average) ・Central atmospheric pressure: 915 hPa. ・Significant Wave Height: 13.4 meters wave height were reported in American Samoa ・Wave Period: Not recorded	A large-scale cyclone that struck the region for the first time in over a decade. Coastal areas experienced waves up to 5 meters high. ・Human damage: No fatalities reported in Samoa. 20 people were injured. ・Property damage: Over 600 houses were destroyed and 4,000 damaged in American Samoa. In Savai'i, damage to power lines disrupted communication with urban areas. Samoa suffered several million dollars in damage.
Samoa offshore earthquake and tsunami September 29, 2009	・Moment Magnitude: 8.1 ・Epicenter: Approx. 190 km south of Apia, the capital of Samoa; depth around 18 km ・Tsunami Height: Four tsunami waves between 4.5 m and 6 m struck American Samoa. A tsunami of 140 cm was observed in Apia, Samoa.	Earthquakes commonly occurred along the boundary between the Pacific plate and the Australian plate. Damage from the earthquake itself has been limited because the distance from the epicenter to Samoa is roughly 190 km or more. However, the tsunamis have caused serious damage to Apia. ・Human damage: 192 people died across Samoa, American Samoa, and Tonga. ・Property damage: In southern Samoa, four primary schools and one secondary school were completely destroyed.
Cyclone "*Evan*" December 2012	・Maximum average wind speed: Approx. 49 m/s (ten-minute average) ・Maximum wind gust: Approx. 75 m/s (one minute average) ・Central atmospheric pressure: Approx. 945 hPa	Cyclone "*Evan*" directly hit near Apia, bringing strong winds exceeding 50 m/s, which caused widespread flooding and power outages. One of the most severe natural disasters in Samoa in recent years (wind speed of about 30 m/s continued for approximately 4 days)

[95] Basic design survey report on port disaster recovery plan for Western Samoa, November 1990, JICA

	・Significant wave height: No record ・Wave period: No record	・Human damage: 14 deaths in Samoa ・Property damage: Destruction of homes, schools, and government facilities. About 1,000 houses were damaged, and nearly 700 houses were completely destroyed. Severe damage to infrastructure such as electricity, water supply, and telecommunications. Serious impacts on agriculture and fishing. Economic losses comparable to the 2009 tsunami damage.

(2) External force conditions during the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in Apia, Mulifanu'a and Salelologa, and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters.

(a) Apia port

Apia port has been renovated three time with Japan's aid. The most recent external force conditions can be summarized below based on the new wharf design documents[96] in 2018.

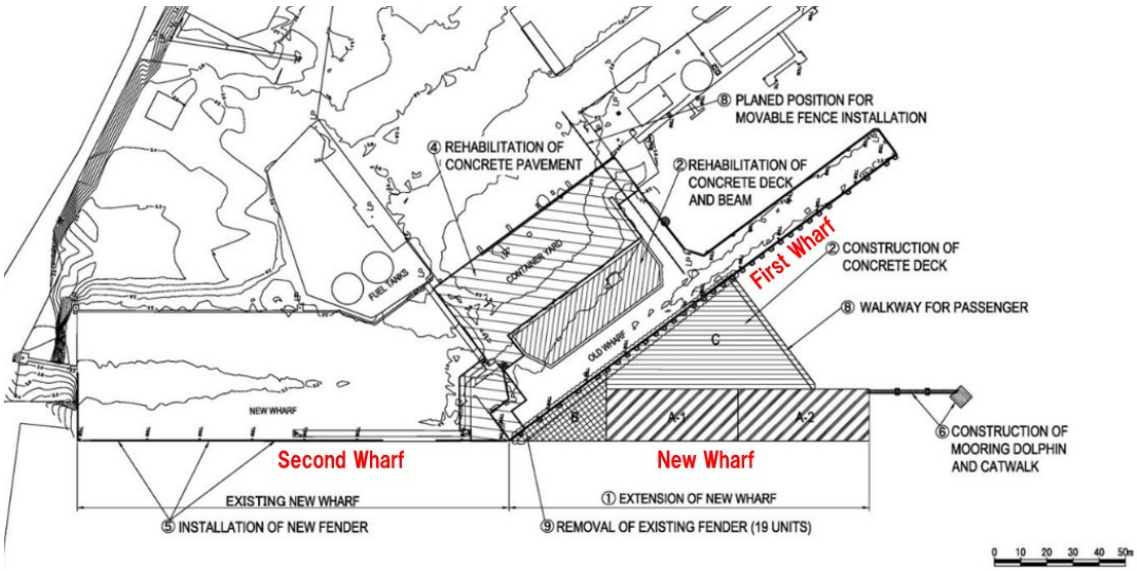


Figure 6.2-12 Construction of new wharf and repair of pier extension section[97]

This project was carried out to construct a new wharf and expand the container yard due to the deterioration of the first wharf and the increasing number of vessel calls. In addition, this design took into account the concept of "sustainable tourism" initiated by the Samoa Development Strategy. The design made it possible to accommodate a large cruise ship (290-meter class in length) and the simultaneous docking of two container ships, each over 100 meters in length. The

[96] Preparatory Survey Report on the Apia Port Improvement Plan for Safety Enhancement, March 2015, JICA
[97] Preparatory Survey Report on the Apia port Improvement Plan for Safety Enhancement, March 2015, JICA

new wharf was extended by 137 meters from 165 meters to 302 meters, and a mooring dolphin was installed. When designing the pier structure, engineers assumed that wave uplift pressure would be negligible on the bearing capacity of the deck. Therefore, they adopted a jetty structure (pile and deck) which was expected to reduce disturbances caused by wave reflection, especially in swelling waves in front of the quay.

The level of the quay deck on the new wharf was kept at +3.0 meters above high water level aligned with that on the second wharf. The engineers gave priority to cost rather than global warming trends in determining the level of the deck. They also assumed that the newly constructed breakwater could mitigate the direct wave intrusion from the open sea.

- Project Period**:** from 2016 to 2018
- Main Scope of Work: Construction of a new wharf (length: 137m)
  Repair of pier extension section
  Construction of new mooring dolphins
- Berth Length: 137m
- Top of the berth Elevation: +3.0m
- Design Water Depth: -11m
- Tidal Levels: H.W.L +1.0m、L.W.L ±0.0m
- Wave Conditions: Offshore significant wave height $(H_0)_{1/3}$ = 8.6m, offshore significant wave period $(T_0)_{1/3}$ = 12.0 sec, wave height in front of existing quay = 2.7m, predominant wave direction = north
- Design Seismic Coefficient: kh=0.16
- Design Vessel: In consideration of the trend that smaller vessels generally have higher berthing speeds, the MV *Southern Cross*—a medium-sized container ship approximately 110m in length, calling at the port 24 times per year—was used as the representative ship for structural analysis (Length: 123.2m, Max Draft: 7.3m, Beam: 20.4m)
- Berthing Speed: 0.10 m/sec
- Soil Conditions: The subsoil at Apia port generally consists of complex interlayers of coral and sand. Bearing strata with an N-value exceeding 50, which can be considered as engineering bedrock, appear at a depth of approximately 30m below the CDL reference level.

(b) Mulifanu'a port and Salelologa port

The ferry terminals at Mulifanu'a port and Salelologa port were renovated using Japan's grant aid program in 1985. The layout and cross section the terminal and design external force conditions are shown in the JICA report[98].

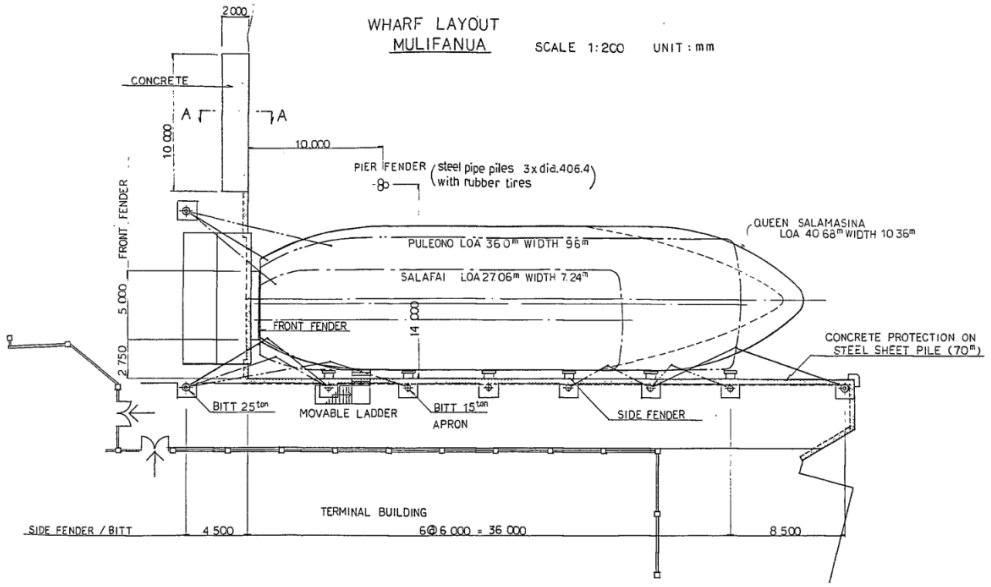


Figure 6.2-13 Mulifanu'a port Plan

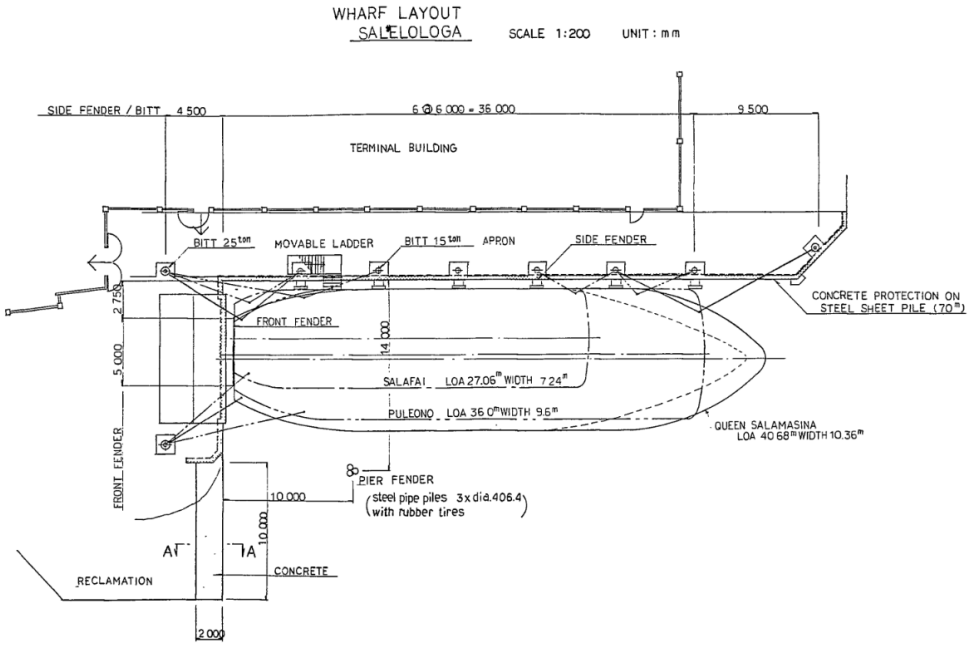


Figure 6.2-14 Salelologa port Plan

[98] Basic Design Survey Report on the Domestic Transport Capacity Enhancement Plan for Western Samoa, December 1984, JICA

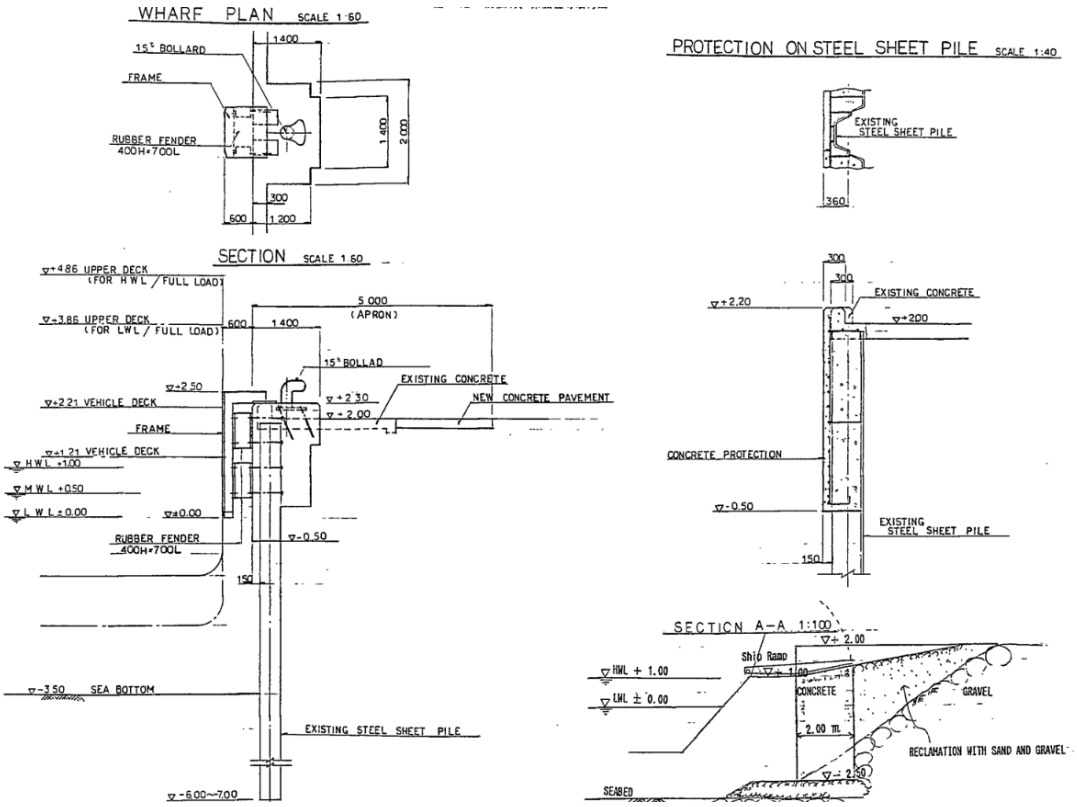


Figure 6.2-15 Section Plan of Mulifanu'a port and Salelologa port

A 15-cm thick concrete coating was applied on the splash and tidal zones in the aged steel sheet pile to prevent further corrosion. Rubber fenders were replaced to accommodate the *Queen Salamasina*. The top of the berth elevation is +2.0 meters above high water sea level. The deck level at the ferry terminals was one meter lower than that at the new wharf in Apia port. JICA experts assumed that the level of the ferry terminals was the optimum height for accommodating ferry boats equipped with ship ramps. However, this deck level leaves terminals vulnerable to cyclones, high waves, and storm surges.

- Project Period: 1984～1985
- Main Scope of Work: Reinforcement of quay walls at Mulifanu'a port and Salelologa port
  Corrosion protection of steel sheet piles
  Installation of fenders
- Berth Length: 45m
- Top of the berth Elevation: +2.0m
- Design Water Depth: -3.5 meters
  (Draft 2.1 m + Trim 0.6 m + Clearance 0.5 m + Incoming wave 0.3 m)
- Tide Levels: H.W.L +1.0m、L.W.L ±0.0m
- Wave Conditions: Wave height = 12.0 m, Period = 5.0 sec
- Design Vessel: *Queen Salamasina* (Length 42.3 m, Draft 2.1 m, Beam 10.4 m)

6.2.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in ports in Samoa based on the research papers and record of natural disasters that hit the ports,

(1) The anticipating natural disasters in Samoa

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*[99]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for Apia port. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

The classification says that the earthquakes are less frequent and of smaller magnitude compared to Tonga and Vanuatu. However, Samoa suffered significant tsunami damage caused by an earthquake with the moment magnitude 8.1 in 2009. The epicenter was 190 km south of Samoa. It is important to prepare for a potential future earthquake and tsunami. The current port facility was designed based on the horizontal acceleration method. To precisely design a facility, engineers should set the earthquake epicenter and magnitude level based on earthquake records in the Pacific. They should carefully examine the ground condition to estimate quake wave speed, direction and power, duration of seismic at the port.

Furthermore, the tsunami runup height was 140 cm in Apia. The current port facilities were designed without considering the tsunami disaster that would cause critical damage to the port and economy. Countermeasures for tsunami in the port facilities should be considered as soon as possible. Tsunami will flow away the cargo from the yard on the sea. The floating cargo makes rescue boats and/or commercial ships difficult to enter the port. Continuous tsunami flow will scour the front and back side of facilities base and make the facility unstable.

As for volcanoes, the classification indicates that the risk is low. The Samoa Islands were composed of mainly basalt from underwater volcanoes that are dormant currently. However, a submarine volcano erupted and caused damage such as ash fall and tsunami in Tonga in 2022. A potential future eruption should be considered in port development and operation.

The classification says that the risk of high waves from cyclones around Apia port is relatively high among the pacific ports. Additionally, the risk of regional storm wave height and coastal flooding is also significant. Recent records also indicate that several strong cyclones attacked

[99] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

Samoa and caused serious damage. It is important to monitor the effect of cyclones and storm surges on port facilities. In addition, available research on the magnitude of sea level rise and wave power due to climate change will be examined and measures to prevent waves from overflowing into the yard will be introduced if deemed necessary.

Table 6.2-2 Multi-hazard Heat Map Port Exposure

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5. 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High | Medium | Low | Very Low | Not applicable

Table 6.2-3 Methodology for Identifying Natural Disasters and their Scales (Apia port)

Types of natural disasters	Design setting in the current facilities	Signs of climate change and global environmental change	Minimizing the risks of future natural disasters
Earthquake	Design Seismic Coefficient kh=0.16	Magnitude 8.1earthquake, 190km off from Apia in 2009.	Prepare the anti-quake facilities. Precisely estimate the earthquake epicenter and magnitude level, quake wave speed, direction and power, duration of seismic activity at the port. Develop the tsunami disaster map
Tsunami	Not considered in the design	1.4-meter runup tsunami in 2009.	Based on the maximum tsunami recorded in the past, the loads applied to structures are determined by considering tsunami height and flow velocity.
Volcanic Eruption	Not considered in the design	A submarine volcano erupted and caused damage in Tonga in 2000. (no damage in Samoa)	Based on past records, while it is not impossible for volcanic ash to reach the area depending on the wind direction, significant damage is not anticipated.
Storm Surge	The top elevation at	Increasing risk of sea	Consider the future sea level rise objectively. One

	H.W.L.+1.0m+2.0m =+3.0m.	level rise and storm surge.	approach is to use the results of PRIF, which will be discussed later.
Cyclone	$H0_{1/3}$=8.6m、$T0_{1/3}$=12.0m ※Based on actual performance during Cyclone *Ofa* in February 1990.	Increasing power of cyclones and thigh waves.	Objectively consider the increase in wave height due to cyclone intensification. Recent research results, such as future projections using d4PDF, which will be discussed later, can be used for this purpose.

(2) A measure against sea level rise and wave power by climate change

"Japanese port and harbor design standards" explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately determined using the latest research findings and scientific knowledge. Figure 6.2-16 illustrates two conceptual approaches for setting structural strength while considering changes in external forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as "Proactive adaptation." On the other hand, "Adaptive adaptation" refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life, but implementing physical upgrades progressively at appropriate times during the period, depending on material and structural characteristics.

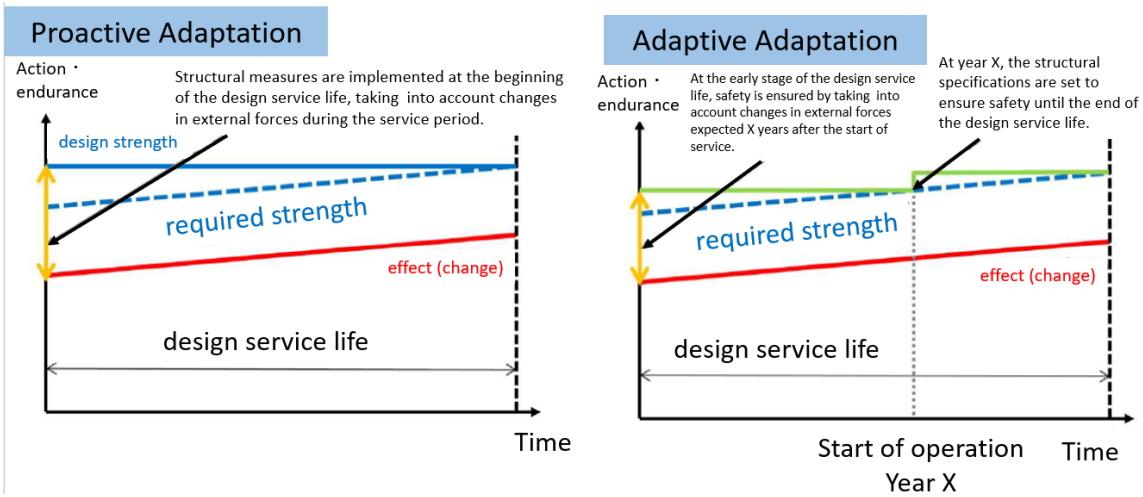


Figure 6.2-16 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power by climate change

Due to the many uncertainties surrounding climate change, a range of scenarios has been discussed. For example, "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[100]" presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[101] as a basis when considering the impacts of climate change in port facility design. RCP2.6 corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. Figure 6.2-17 shows the projected median regional sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [102].

The projected sea level rise in Samoa is shown in Figure 6.2-18. By 2050, sea level rise in Samoa is projected to be 0.30 m under the 2°C scenario (SSP1-2.6) and 0.35 m under the 4°C scenario (SSP5-8.5), with a small difference of 0.05 m. On the other hand, by 2100, sea level rise is expected to reach 0.68 m under the 2°C scenario (SSP1-2.6) and 1.03 m under the 4°C scenario (SSP5-8.5), showing a larger difference of 0.35 m. Therefore, attention must be paid to the correspondence with the design service life. Additionally, since future projections contain uncertainties, it is necessary to understand the range of possible future outcomes.

[100] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[101] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
[102] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

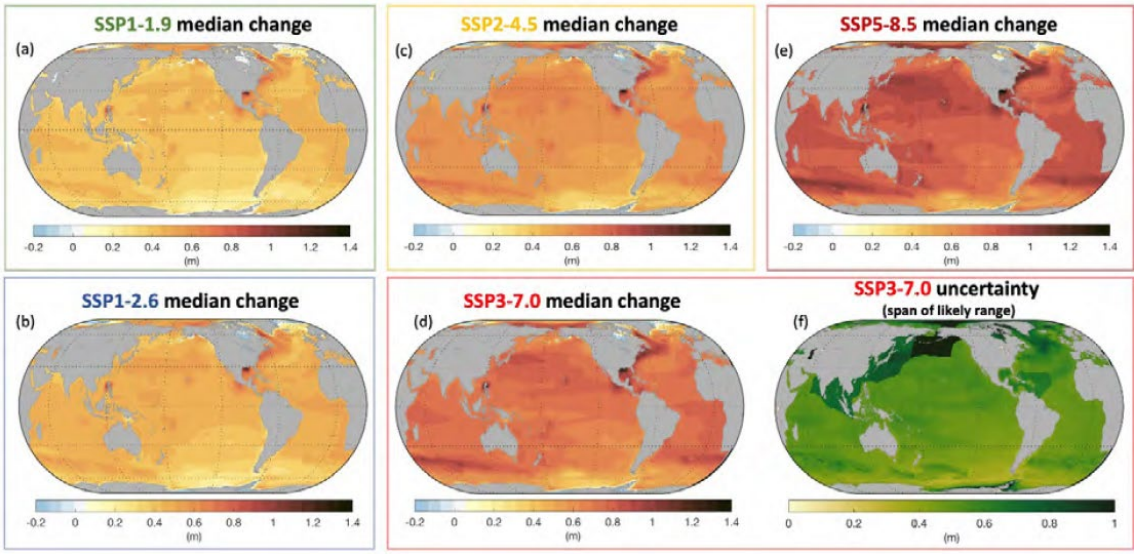


Figure 6.2-17 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

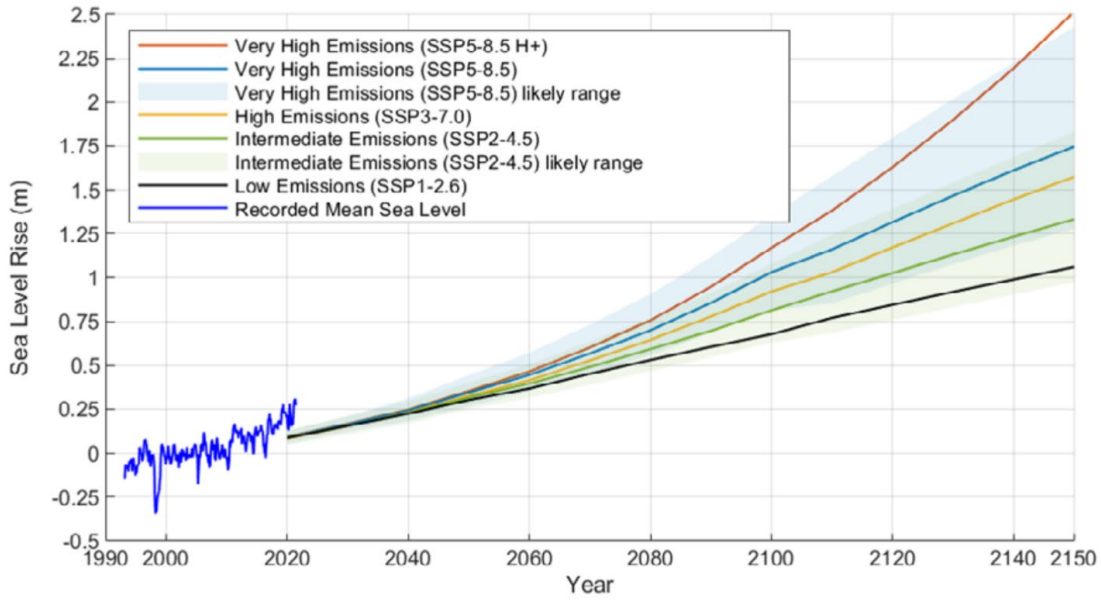


Figure 6.2-18 Sea Level Rise Projections to 2150 for Samoa

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the "Database for Policy Decision-Making for Future Climate Change" (d4PDF, Mizuta et al. [103]). To predict future changes in extreme weather events such as typhoons due to climate change,

[103] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita,

a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing Waves and Coasts in the Pacific" (WACOP) project[104]. This project uses four climate models that participated in CMIP5. When considering storm surges and high waves, it is essential to incorporate research findings, such as conducting wave simulations using these future climate models.

6.2.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing analysis on port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize SPA's current disaster mitigation plans in terms of time frame and type of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". The natural disaster can be categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 6.2-4.

Table 6.2-4 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓

M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.

[104] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html(Accessed in July, 2024)

Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

JICA experts sent questionnaires to each port authority to examine if the disaster prevention or mitigation plans are prepared or not and these plans are properly implemented or not. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change. In Samoa, target ports are all supervised by SPA, the survey results are organized as collective ports, not individual port.

(2) Survey Results for the Samoa Ports Authority

SPA has already developed disaster prevention plans called MHDPP that covers natural disaster adaptation, climate change and emergency response. SPA's answer sheet is also attached below the Table 6.2-5.

(a) Natural disasters adaptation

SPA has already developed "Multi-hazard Disaster Preparedness Plan（MHDPP）" to cope with disasters in ports. The plan is a comprehensive plan that covers not only natural disasters but also climate change and emergency response. The plan includes early-alert system, evacuation route, drill, emergency goods, logistic support system as an emergency response. In addition, the plan prepared several scenarios, also. The plan was evaluated The plan specify vulnerable asset, operation and system

(b) Climate change adaptation

SPA answers that they have been aware of the rise in sea levels and increase in wave height due to climate change and many measures are being implemented at the port to deal with the effects of climate change. MHDPP incorporates climate change resilience measures such as enhanced cyclone preparedness plans, proactive risk assessments to identify vulnerabilities, and environmental monitoring to address rising sea levels and extreme weather events. A risk assessment has been carried out in relation to climate change response.

(c) Emergency response

MHDPP includes detailed emergency actions such as activating early warning systems, coordinating with emergency services, executing pre-established evacuation plans, and mobilizing emergency response resources. Regular training, drills, and ongoing plan evaluations ensure readiness for any emergency. The emergency response plan is maintained and verified through annual audits.

Table 6.2-5 SPA's answer sheet

Natural disasters adaptation: ・SPA has developed a Multi-hazard Disaster Preparedness Plan (MHDPP) to enable prompt and appropriate response in the event of a natural disaster such as a cyclone, storm surge, tsunami, volcanic eruption or earthquake at the port. ・The port has identified and documented assets, operations and systems that could be affected by natural disasters and has identified the information necessary to establish baseline conditions. ・A risk assessment has been conducted regarding natural disaster response, and a plan has been developed to deal with natural disaster risks and disasters. ・The port is implementing a natural disaster response plan which h is verified through annual audits. ・The MHDPP outlines a comprehensive set of measures, including early warning systems, clear evacuation routes, regular training and drills, maintaining inventories of emergency resources, and planning for logistical support during emergencies. The plan also includes hazard-specific procedures for cyclones, marine pollution, and multi-hazard responses, ensuring preparedness across various disaster scenarios. ・SPA does not have any hazard maps for natural disasters in their port. ・According to interviews with SPA personnel, inconsistent terminology was observed in the asset register files for ports, and due to the lack of proper organization, confusion and duplicated entries for assets occurred.
Climate change adaptation: ・SPA has been aware of the rise in sea levels and increase in wave height due to climate change and many measures are being implemented at the port to deal with the effects of climate change. ・The MHDPP incorporates climate change resilience measures such as enhanced cyclone preparedness plans, proactive risk assessments to identify vulnerabilities, and environmental monitoring to address rising sea levels and extreme weather events. Infrastructure upgrades, such as reinforced port facilities, and sustainability-focused policies are also part of the strategy to mitigate the effects of climate change. ・The port has identified assets, operations and systems that may be affected by climate change and has documented these, identifying the information needed to establish baseline conditions. ・A risk assessment has been carried out in relation to climate change response, and a plan has been developed to deal with natural disaster risks and disasters. ・The measures planned under the MHDPP include the development of a disaster risk profile, implementation of emergency response procedures, integration of disaster plans with national frameworks, and coordination with emergency services and port users. Additional actions involve training personnel, ensuring resource availability, and establishing clear communication protocols to minimize risks and facilitate effective disaster management.
Emergency response: ・SPA is familiar with the term "port BCP" ・SPA has a port BCP (business continuity plan). ・Stakeholders and relevant authorities have been identified and are engaged in the development of an emergency response plan. ・The emergency response plan has been fully identified and communicated to stakeholders. ・The emergency response plan is maintained and verified through annual audits. ・The MHDPP includes detailed emergency actions such as activating early warning systems, coordinating with emergency services, executing pre-established evacuation plans, and mobilizing emergency response resources. ・The plan emphasizes clear communication protocols, role definitions, and immediate hazard-specific responses to minimize risks to life, property, and the environment. Regular training, drills, and ongoing plan evaluations ensure readiness for any emergency.

6.2.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by following the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "Pacific Ports Vision 2030-2050 Recognition Framework"[105] shown in Table 6.2-6. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

Table 6.2-6 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

[105] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

(a) Countermeasures against natural disasters －Resilience Indicator level: Highly engaged

Upon reviewing the current situation, it was evaluated that the MHDPP has been developed, with risks identified and measures planned, indicating that efforts are highly engaged.

(b) Climate change adaptation－Resilience Indicator level: Highly engaged

For climate change adaptation, there is a clear recognition of the impacts associated with climate change, and measures are planned within the MHDPP. Evaluation: highly engaged.

(c) Emergency response－Resilience Indicator level: Highly engaged

For emergency response, the importance of a port's Business Continuity Plan (BCP) is clearly understood, and the port BCP has been planned. Additionally, a proper MHDPP is in place, and it undergoes annual reviews and audits. Evaluation: highly engaged.

(2) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in ports of Samoa in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

(a) Apia port

Apia port is geographically situated such that the primary direction of wave and wind patterns throughout the year is from the east, meaning the quay does not face direct wind and waves, keeping the harbor relatively calm. However, from November to April, swell waves from the north can enter, causing disturbance within the port. To address this, the mooring quay has been extended using piles, which helps reduce reflected waves at the pier's front. Additionally, to manage vessel movements during disturbances within the harbor, large cylindrical fenders with high energy absorption capacity are installed to absorb the impact during docking, ensuring the safety of vessel mooring and cargo operations.

Apia port is the only international trade port in Samoa, and with the extension of the pier in 2018, it became capable of accommodating large cruise ships as well as container vessels. Therefore, if the port's operations were to be halted due to a disaster, it would have a significant impact on the national economy, as there are no alternative ports available.

Table 6.2-7 Assessment of the impact of natural disasters in Apia port

Types of natural disasters	Port Facilities	Port management	Port operation
Earthquake	• The northern breakwater and embankment may collapse. • The northern fuel tanks may be damaged, causing fuel spillage and resulting in marine pollution spreading within the bay. • The steel pipe sheet pile quay walls and piers' structures may be damaged. • The warehouse and administration office may collapse. • The four stacked containers on the container yard may collapse. • Damage to power facilities and the collapse of power poles may cause power outages and communication disruptions. • The coastal road pavement may be damaged.	• Power outages stop office operations, including import and export procedures. • Communication disruptions may make it difficult to secure personnel and may delay disaster recovery due to a lack of clear instructions. • Access to up-to-date weather information may be lost. • Restoration of the port may be delayed due to the blockage of coastal roads.	• Export and import activities may be suspended due to damage to quay walls and piers. • The suspension of port operations and road closures on the causeway and surrounding areas may stop the distribution of imported food and other essential goods within Upolu Island and to Savai'i Island.
Tsunami	• A tsunami from the north may destroy the northern breakwater, revetments, and fuel tanks, causing oil to spill into the bay. • Backfill soil behind the quay may be washed away, leading to the collapse of the container yard. • Navigational markers may be swept away by the tsunami. • Containers stacked four high and equipment stored on the container yard may be washed into the harbor by the tsunami, making it difficult for disaster recovery vessels and general cargo ships to enter the port. • Moored vessels may drag anchors due to the tsunami and collide with fenders or quay walls or be washed ashore onto the quay. • Damage to power facilities and the collapse of power poles may cause power outages and communication disruptions. • Coastal roads may collapse due to scouring.	• Power outages stop office operations, including import and export procedures. • Communication disruptions may make it difficult to secure personnel and may delay disaster recovery due to a lack of clear instructions. • Access to up-to-date weather information may be lost. • Restoration of the port may be delayed due to the blockage of coastal roads.	• Export and import activities may be suspended due to damage to quay walls and piers. • The suspension of port operations and road closures on the causeway and surrounding areas may stop the distribution of imported food and other essential goods within Upolu Island and to Savai'i Island. • The loss of navigational markers may interfere with the safe navigation of vessels.

Storm Surge	• The warehouse and administration office may be inundated due to storm surge. • Containers stacked four high and equipment stored on the container yard may be washed into the harbor by the storm surge, making it difficult for disaster recovery vessels and general cargo ships to enter the port. • Moored vessels may drag anchors due to storm surges and collide with fenders or quay walls or be washed ashore onto the quay. • Storm surge may cause power poles and trees to fall, leading to road blockages and power outages. • Storm surge may cause the *Vaisigano River* to flood, leading to the closure of the coastal road to the port.	• Power outages stop office operations, including import and export procedures. • Communication disruptions may make it difficult to secure personnel and may delay disaster recovery due to a lack of clear instructions. • Access to up-to-date weather information may be lost. • Restoration of the port may be delayed due to the blockage of coastal roads.	• Export and import activities may be suspended due to damage to quay walls and piers. • The suspension of port operations and road closures on the causeway and surrounding areas may stop the distribution of imported food and other essential goods within Upolu Island and to Savai'i Island.
Cyclone	• Windstorms may blow off the warehouse roof, scattering materials. • Windstorms may cause containers stacked four high and equipment on the container yard to be blown away. • Windstorms may cause mooring lines to snap, causing the ferry to be pushed onto the quay, resulting in damage to fenders and the quay walls. • Windstorms may cause power poles and trees to fall, leading to road blockages and power outages. • Heavy rainfall may cause the *Vaisigano River* to flood, leading to the closure of the coastal road to the port.	• Power outages stop office operations, including import and export procedures. • Communication disruptions may make it difficult to secure personnel and may delay disaster recovery due to a lack of clear instructions. • Access to up-to-date weather information may be lost. • Restoration of the port may be delayed due to the blockage of coastal roads.	• Export and import activities may be suspended due to damage to quay walls and piers. • The suspension of port operations and road closures on the causeway and surrounding areas may stop the distribution of imported food and other essential goods within Upolu Island and to Savai'i Island.
Volcanic Eruption	Apia port is located approximately 80 kilometers from the crater of *Mt. Matavanu* on Savai'i Island. Therefore, even if *Mt. Matavanu* erupts, there is no possibility that lava will cross the strait and reach Apia port. Additionally, the likelihood of volcanic ash dispersing and reaching Apia port is also low.	There is no damage that would affect the port's management system.	There is no damage that would affect the port's operation system.

(b) Mulifanu'a port and Salelologa port

Mulifanu'a port and Salelologa port are located in a relatively calm sea area, naturally protected by surrounding shallow waters and coral reefs that serve as natural breakwaters. The islands of Upolu and Savai'i are connected by a ferry boat service, and Mulifanu'a port plays a vital role as the ferry terminal situated at the western end of Upolu Island. Cargo imported through Apia port is transported to Savai'i Island via Mulifanu'a port by ferry boat. The terminal facilities' design in both Mulifanu'a and Salelologa are the same. If Mulifanu'a port or Salelologa port were to cease functioning, it would have a serious impact on daily life on Savai'i Island.

Table 6.2-8 Assessment of the impact of natural disasters in Mulifanu'a port and Salelologa port

Types of natural disasters	Port Facilities	Port management	Port operation
Earth quake	• The northern revetment may be washed away. • The steel sheet pile quay wall, gravity-type quay wall, and masonry revetment may be damaged, • The ferry terminal may be damaged. • Damage to power facilities and the collapse of power poles may cause power outages and communication disruptions. • Pavement in parking areas may be damaged. • Coastal roads may collapse due to scouring. • The piles, slab and apron behind the -3.5m pier-type quay wall may be damaged.	• Ferry operations may be suspended due to the collapse of the ferry terminal and power outage. • Power outages and communication disruptions may disrupt the transmission of instructions and orders. • Access to up-to-date weather information may be lost. • Restoration of the port may be delayed due to the blockage of coastal roads.	• Cargo transportation becomes impossible due to damage to the quay walls and piers. • Communication of essential information for the safe navigation of ferries is disrupted due to power outages and communication failures.
Tsunami	• The northern revetment may be washed away. • The steel sheet pile quay wall, gravity-type quay wall, and masonry revetment are damaged, and the backfill soil is washed out. • The windows and walls of the ferry terminal may be damaged by the tsunami. • Moored vessels may drag anchors due to the tsunami and collide with fenders or quay walls or be washed ashore onto the quay. • Damage to power facilities and the collapse of power poles may cause power outages and communication disruptions. • Pavement in parking areas may be damaged. • Coastal roads may collapse due to scouring.	• Ferry operations may be suspended due to the collapse of the ferry terminal and power outage. • Power outages and communication disruptions may disrupt the transmission of instructions and orders. • Access to up-to-date weather information may be lost. • Restoration of the port may be delayed due to the blockage of coastal roads.	Ferry operations may be suspended due to damage to the quay walls and piers.
Storm Surge	• The northern revetment may be washed away. • The steel sheet pile quay wall, gravity-type quay wall, and masonry revetment could be damaged, and the backfill soil could be washed out. • The windows and walls of the ferry terminal may be damaged by the tsunami.	• Ferry operations may be suspended due to the collapse of the ferry terminal and power outage. • Power outages and communication disruptions may disrupt the transmission of instructions and orders. • Access to up-to-date weather information may be lost.	Ferry operations may be suspended due to damage to the quay walls and piers.

	• Moored vessels may drag anchors due to the storm surge and collide with fenders or quay walls or be washed ashore onto the quay. • Damage to power facilities and the collapse of power poles may cause power outages and communication disruptions. • Pavement in parking areas may be damaged. • Coastal roads may collapse due to scouring.	• Restoration of the port may be delayed due to the blockage of coastal roads.	
Cyclone	• Windstorms may cause mooring lines to snap, causing the ferry to be pushed onto the quay, resulting in damage to fenders and the quay walls. • Windstorms may blow off the ferry terminal's roof, scattering materials. • The navigation route may be buried due to the effects of waves. • Windstorms may cause power poles and trees to fall, leading to road blockages and power outages.	• Ferry operations may be suspended due to the collapse of the ferry terminal and power outage. • Power outages and communication disruptions may disrupt the transmission of instructions and orders. • Access to up-to-date weather information may be lost. • Restoration of the port may be delayed due to the blockage of coastal roads.	Ferry operations may be suspended due to damage to the quay walls and piers.
Volcanic Eruption	Mulifanu'a port is located approximately 40 kilometers from the crater of *Mt. Matavanu* on Savai'i Island. Therefore, even in the event of an eruption, there is no possibility that lava would cross the strait and reach Apia port. Additionally, the likelihood of volcanic ash dispersing and reaching Mulifanu'a port is considered low.	There is no damage that would affect the port's management system.	There is no damage that would affect the port's operation system.

6.2.6 Formulation of port resilience strategy

In this sub-section, we will try to identify the reason why the port resilient level remains at the current level, and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans.

(1) Confirmation of the reasons for staying with the current resilience indicators

The status of countermeasures against natural disasters, climate change adaptation, and emergency response, each evaluated using resilience indicators in Section 6.2.5, was reviewed and assessed based on the perspectives presented in the *Climate Change Adaptation Planning for Ports and Inland Waterways*[106] (hereinafter referred to as the PIANC Guide). The findings are presented below.

(a) Countermeasures against natural disasters －Resilience Indicator level: Highly engaged

As previously mentioned, a hazard map has not been developed. However, the MHDPP (adaptation plan) has been established, and various efforts to cope with natural disasters are being made. On the other hand, on-site observations revealed several issues that ideally should have been addressed during normal times but remain unresolved. These include damaged and aging revetments left unrepaired, fenders that have fallen off and been replaced with tires, and piers operating under load restrictions.

Through interviews, it was confirmed that there is a shortage of personnel with the specialized knowledge required for maintenance, and that the organizational structure necessary to implement maintenance activities is not adequately established. These are considered to be the primary reasons why the current indicators remain at their present levels.

(b) Climate change adaptation－Resilience Indicator level: Highly engaged

Regarding climate change adaptation, the MHDPP (adaptation plan) has been developed, and significant efforts are being made in this area. However, specific measures, such as raising the elevation of the quay, have not yet been implemented. Additionally, similar to natural disaster response, there is a shortage of personnel with specialized knowledge. This is likely the reason the current indicator remains at its current level.

[106] Climate Change Adaptation Planning for Ports and Inland Waterways, PIANC, EnviCom WG Report No. 178-2020

(c) Emergency response－Resilience Indicator level: Highly engaged

Similar to natural disaster response and climate change adaptation, emergency response is also progressing, and considerable efforts are being made in this regard. However, as with the aforementioned areas of natural disaster and climate change response, there is an issue of personnel shortages. To accurately assess the situation during a disaster and make quick decisions and directives, personnel with specialized knowledge and a functional organization are required. Once these are established, the effectiveness of the port BCP (Business Continuity Plan) will improve, enabling progress toward the next resilience indicator.

(2) Consideration of measures to advance key resilience indicators one level higher

To enhance the resilience indicators related to countermeasures against natural disasters, climate change adaptation, and emergency response for ports in Samoa, as discussed in section (1), the following measures are recommended to elevate these indicators to the next level.

(a) Countermeasures against natural disasters

To enhance resilience against natural disasters, it is essential to first establish an appropriate maintenance and management system for port infrastructure during normal (non-emergency) times. To this end, the development and retention of personnel with specialized knowledge in maintenance management is an urgent priority. It is also necessary to establish an institutional framework that enables continuous and planned inspection and repair activities, along with securing the financial resources to support such efforts

(b) Climate change adaptation

At the national level, Samoa has been advancing its response to climate change, including the opening of the Pacific Climate Change Centre (PCCC) in September 2019. The PCCC was established as part of the Secretariat of the Pacific Regional Environment Programme (SPREP) and constructed with Japan’s grant aid.

In addition, a project is currently underway with Japanese support to enhance the innovation function of the PCCC, aiming to promote the implementation of innovative climate change measures across the Pacific region. Going forward, the involvement of SPA in such initiatives is expected to contribute to the development of human resources capable of addressing climate change, and to facilitate the phased development of necessary port infrastructure based on prioritized needs. These efforts will help elevate resilience indicators that reflect the country’s adaptive capacity to climate change.

Continued monitoring and accumulation of data related to sea level rise, storm surges, and temperature trends are also essential. As for hard infrastructure measures, it is important to

implement elevation works for critical port facilities based on future projections and prioritization. Strengthening drainage capacity during flooding events is also a key consideration.

(c) Emergency response

In the context of emergency response, in addition to the development of personnel and organizational capacity, securing alternative facilities to ensure business continuity is also critical. For instance, establishing dual transport routes or developing terminal facilities at multiple, dispersed locations can provide operational redundancy, enabling continued functionality even if one site is affected by a disaster. Furthermore, the introduction of floating piers capable of maintaining basic functions under tsunami or storm surge conditions, the development of evacuation routes and towers to facilitate prompt evacuation of port users, the installation of life buoys, and the clear indication of expected tsunami heights are also considered effective countermeasures.

(3) Port resilience measures in Samoa

(a) Establishment of an inland container feeder transport network

Passenger and cargo transport between Upolu Island and Savai'i Island is solely dependent on a sea ferry service connecting Mulifanu'a port and Salelologa port. Containers, including essential goods imported through Apia port, are first devanned in Apia port, then transported by trucks to Mulifanu'a port at the northwestern tip of Upolu Island, and subsequently shipped by a ferry boat to Salelologa port on Savai'i Island. The need for cargo transshipment increases transportation costs and places a logistical burden on the inter-island ferry operation. In addition, both ports lack breakwater facilities, resulting in frequent service suspensions and damage caused by cyclones.

To ensure a stable supply of essential goods to Savai'i Island even during disasters, it is advisable to secure an alternative transport route. By developing such a route, business continuity can be maintained in the event that ferry-based cargo transport becomes difficult due to a disaster. To achieve this, the following two projects are proposed:

a) Expansion of the transshipment container yard at Apia port
b) Rehabilitation of the aging quay at Salelologa port and its redevelopment as a domestic container terminal

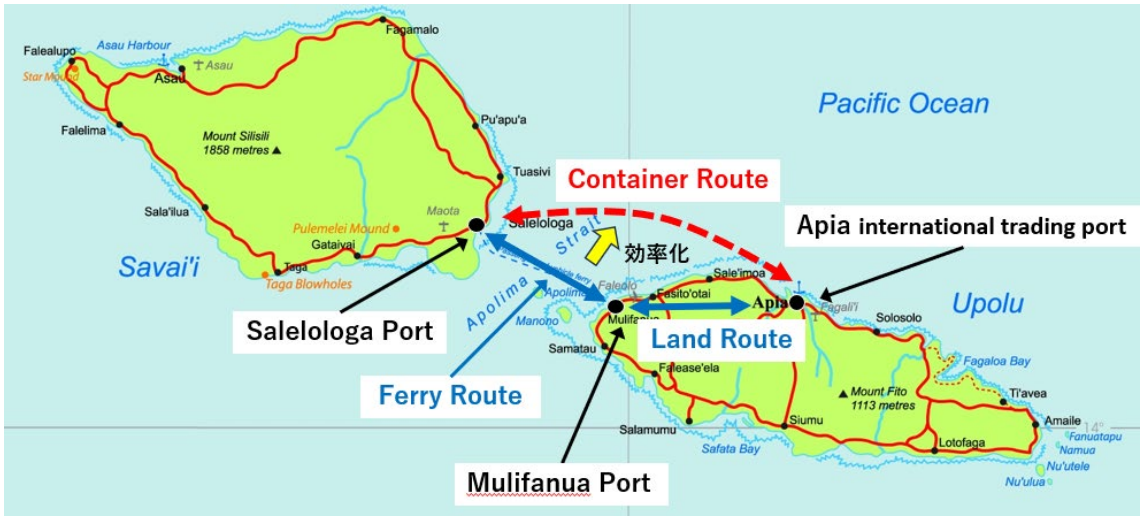


Figure 6.2-19 Container **feeder transport network** between Apia port and Salelologa port

(b) Demand Forecast

In 2023, the container throughput at Apia port was approximately 100,000 TEUs, the majority of which consisted of import cargo. Of this, about one-quarter, roughly 25,000 TEUs annually, 2,100 TEUs monthly, and 520 TEUs weekly, was transported to Salelologa port. With this level of demand, transportation by a small container vessel with a capacity of around 100 TEUs per day (approximately 3,000 to 5,000 gross tons) would be commercially viable. Furthermore, based on data from 2013, the projected container throughput at Salelologa port in 2050 is estimated to reach 46,091 TEUs, indicating continued growth in cargo volume. Therefore, it is necessary to improve transport efficiency and enhance safety by separating cargo and passenger operations.

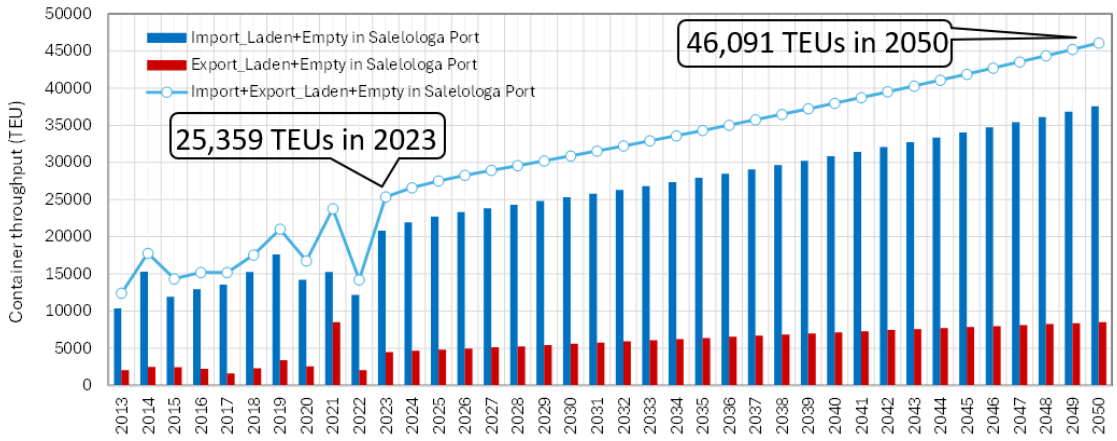


Figure 6.2-20 Container cargo demand forecast for Salelologa port

(c) Vessel specifications for design purposes

The specifications of the vessel size used for design purposes are based on the following vessel, selected from typical 100 TEU class ships commonly used in Japan.

Table 6.2-9 Typical 100TEU class ships commonly used in Japan

Item	Unit	TAKATORI	TACHIBANA	TAKARADUKA	TOKIWA	TAMON	TENMA	KOYO
GRT	ton	499	498	499	499	498	499	499
DWT	ton	1360	1354	1398	1450	1570	1438	1438
Output	PS	2000	2000	2000	2038	2000	2500	2500
Speed	Knot	13.2	13.2	13.2	12.0	12.8	14.0	14.0
Capacity	TEU	142	137	121	118	88	146	146
Reefer capacity	units	32	40	48	40	16	40	40
Length overall	m	78.9	81.0	78.9	77.5	76.4	80.0	80.0
Beam	m	13.0	13.2	13.0	12.5	12.3	13.2	13.2
Draft	m	3.8	3.8	3.8	3.8	4.0	3.7	3.7
Built Year	-	Mar 2021	Jan 2018	Apr 2017	Feb 2017	Mar 2009	Apr 2007	Oct 2006

(d) Expansion of the container yard at Apia port

The No.1 berth at Apia port was constructed in 1966 and has now been in service for 59 years. Due to aging and deterioration, it is no longer suitable for container storage or the operation of cargo-handling equipment, posing significant obstacles to cargo handling activities. Furthermore, the planned operation of a container feeder vessel between Apia port and Salelologa port will require a sufficiently large and continuous area of land in Apia for storing containers unloaded from larger vessels and for transshipment operations. Therefore, the deteriorated No.1 berth facility will be converted to a container yard and integrated with the surrounding land to provide a consolidated area for container operations. The estimated cost of rehabilitation is approximately 10.5 million USD (excluding tax).



Figure 6.2-21 Old wharf renovation area at Apia port

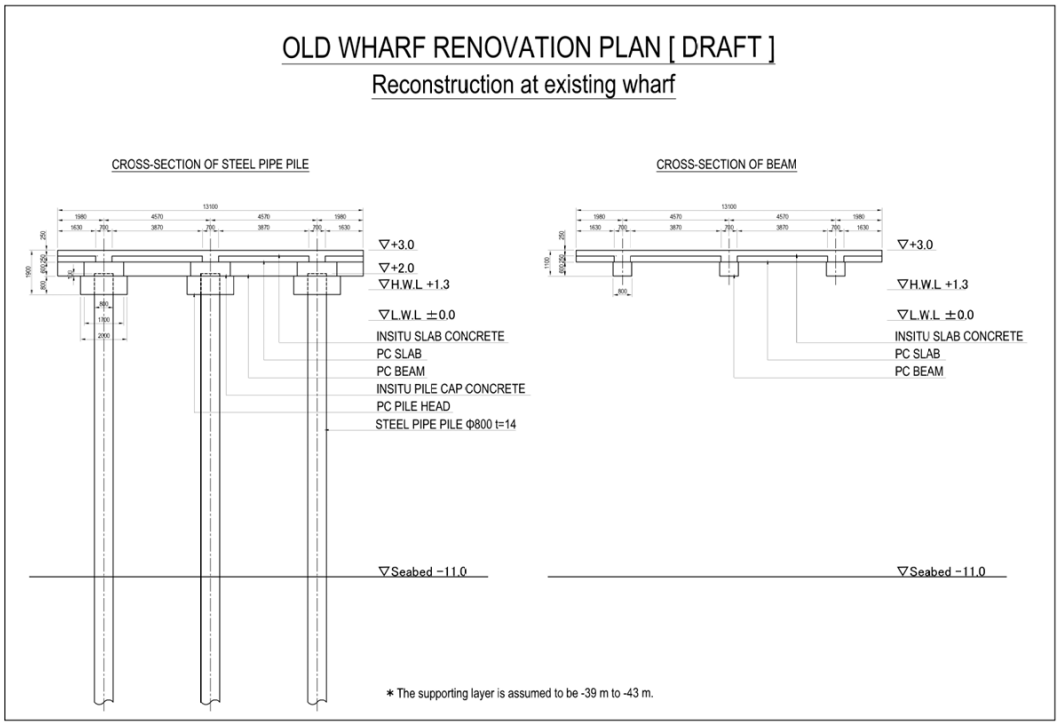


Figure 6.2-22 Old Wharf Renovation Plan - Cross Section

(e) Development of container terminal at Salelologa port

Since the existing berth at Salelologa port is occupied by ferry operations, container handling requires a container yard in the rear area; therefore, a new container berth will be constructed on the site of the former terminal. In the design of the quay wall, a horizontal seismic acceleration equivalent to that of Apia port shall be considered. Regarding wave action, a natural reef (serving as a natural breakwater) extends in front of the port, providing shelter from predominant wind

waves from the west. As for the intensification of cyclones due to global warming, the tranquility within the port is expected to be relatively well maintained unless the swell or wind waves generated by such cyclones directly approach from the limited southeast direction. However, strong winds, heavy rainfall, and other effects accompanying intensified cyclones may pose risks to port buildings and mechanical/electrical facilities. Therefore, it is necessary to take appropriate design and planning measures to minimize potential damage.

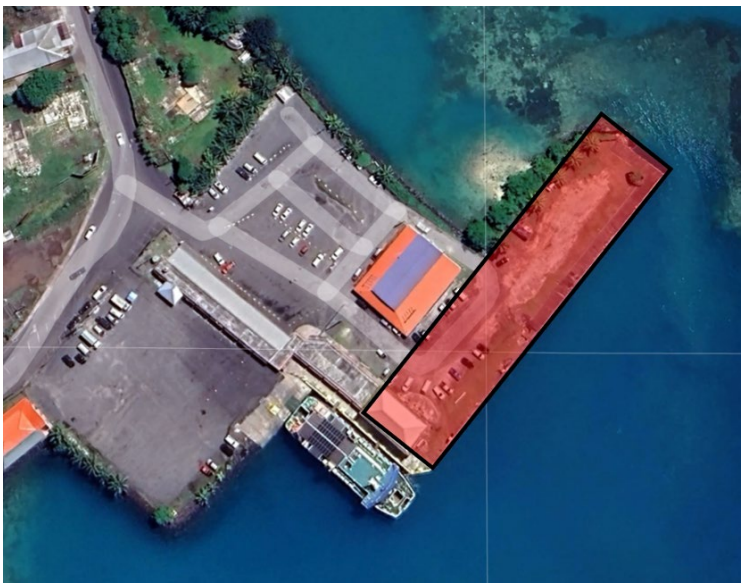


Figure 6.2-23 Site Plan

(f) Design Conditions

・Soil Conditions:

The soil is assumed to be sandy with a standard penetration resistance of N = 10. The existing ground level is taken as -3.5 m.

・Facility Parameters:

Quay top elevation: +2.50 m

Planned water depth: -5.00 m

Design water depth: -5.60 m

・Load Conditions:

Design horizontal seismic coefficient: $kh = 0.15$

(For steel sheet pile structures, this is considered as half of a relatively large base shear coefficient of 0.30)

Surface load:

$q = 20$ kN/m² (under operational conditions)

$q' = 10$ kN/m² (under seismic conditions)

(g) Design Drawing (Draft)

Without removing the existing quay wall, a new steel sheet pile quay wall can be constructed by offsetting the alignment of the new quay wall 3 meters forward.

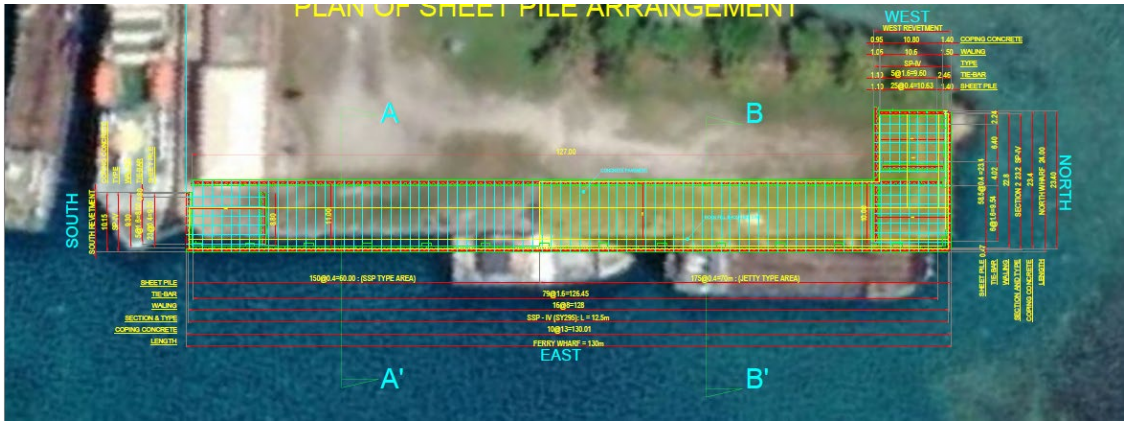


Figure 6.2-24 Sheet Pile Arrangement Plan

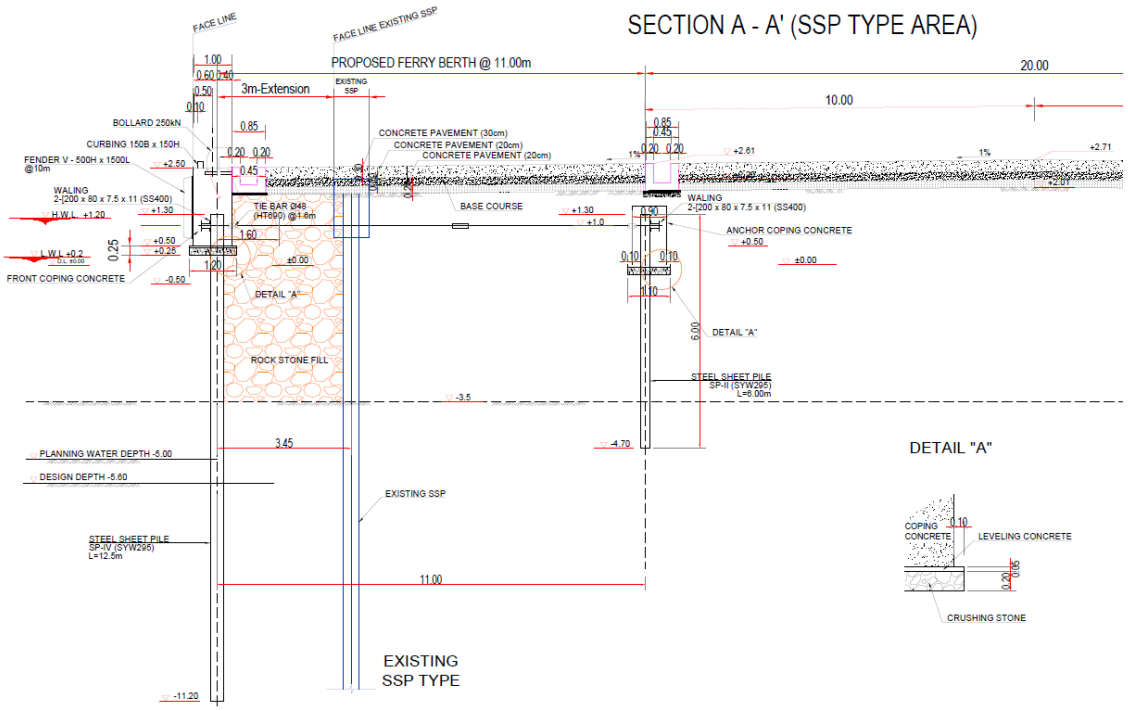


Figure 6.2-25 Typical Cross Section

(h) Estimated costs

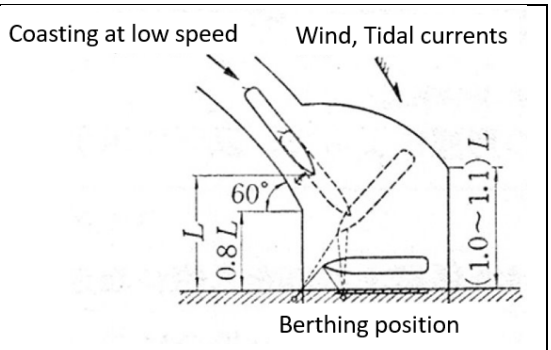
- Renovation for No.1 Berth at Apia port: Approx. 10.5 million USD
- Construction for new container berths at Salelologa port : Approx. 14.0 million USD (excluding tax, as of May1, 2025)

(i) Others

The harbor's anchorage has been secured just within the turning circle of landing craft, and in the future, when developing a container berth, it will also be necessary to deepen the anchorage in front of the quay and to develop a turning basin.



The anchorage in front of the quay



The required berthing

Figure 6.2-26 Area required for berthing

7. Republic of Vanuatu

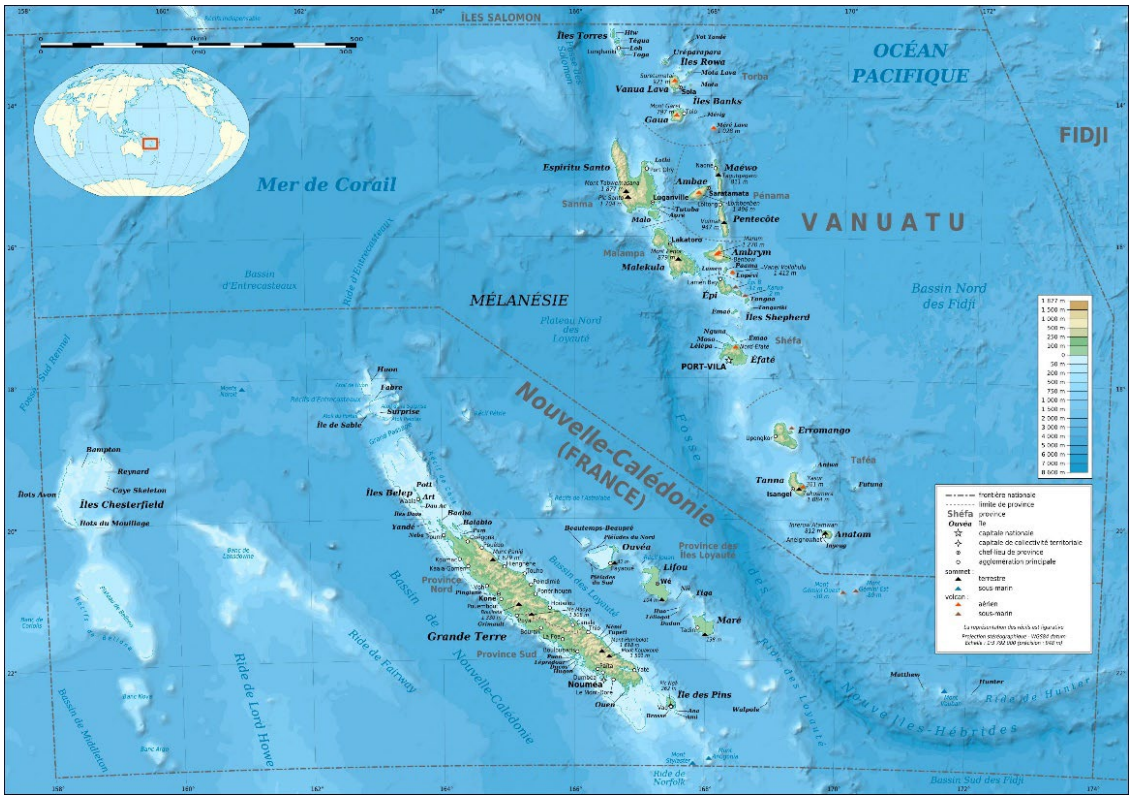
7.1 Overview of the country and its major ports and external relations

7.1.1 Country Overview

The Republic of Vanuatu is located approximately 1,800 km east of Cairns, Australia, and is an archipelago of more than 80 islands stretching approximately 1,200 km from north to south. In July 1980, it gained independence from 74 years of joint British and French rule.

The land area of the Republic of Vanuatu is 12,189 square kilometers, and as of 2021, the total population is 319,137, continuing to increase at a rate of around 2.5% annually. The area of Efate Island, where the capital Port Vila is located, is 900 square kilometers, and 35,901 people, accounting for 11.7% of the total population, are living in Port Vila.

An overview of the country is shown in **Figure 7.1-1**.



Source: https://www.pinterest.com/pin/564568503280729016/
(Access: March 2025)

Figure 7.1-1 Location Map of Republic of Vanuatu

7.1.2 Economic and Social Conditions

The economy of Vanuatu has traditionally been based on subsistence agriculture, mainly taro and yams, and the export of copra. The trade deficits caused by chronic import surpluses has been covered by foreign aid. Since mid-1997, under the cooperation of the Asian Development Bank (ADB) and Australia, a large-scale administrative and economic reform program called the "Comprehensive Reform Program" has been implemented, and in 2003, a medium-term plan called the "Priority Issues and Action Plan" was formulated.

As a result, Vanuatu emerged from the low growth of the early 2000s and achieved remarkable economic growth, becoming a model for economic development in other developing countries. In December 2020, Vanuatu declared its graduation from the list of least developed countries (LDCs), and a celebratory parade was held in Port Vila.

The situation in which 70% of the population engages in subsistence agriculture throughout the country remains basically unchanged. However, in recent years, the diversification of agriculture has led to an increase in exports of cocoa and beef, with beef in particular ranking second only to copra in terms of export volume. In addition, the development of service industries centered on tourism and increased investment in land development and construction are driving the strong economy.

On the other hand, the voluntary liquidation of Air Vanuatu, the state-owned airline, has significantly increased uncertainty regarding future prospects and fiscal outcomes. The suspension of air services threatens short-term service exports, leading to a deterioration in Vanuatu's external debt default risk from "moderate" to "high" in the International Monetary Fund (IMF)'s 2024 Debt Sustainability Analysis (DSA) released in August 2024.

7.1.3 Overview of Port Administration

(1) Port Administration Organization

The Ministry of Infrastructure and Public Utilities (MIPU) of the Government of Vanuatu has three departments, the Civil Aviation Authority of Vanuatu (CAAV), the Department of Ports and Marine, and the Public Works Department.

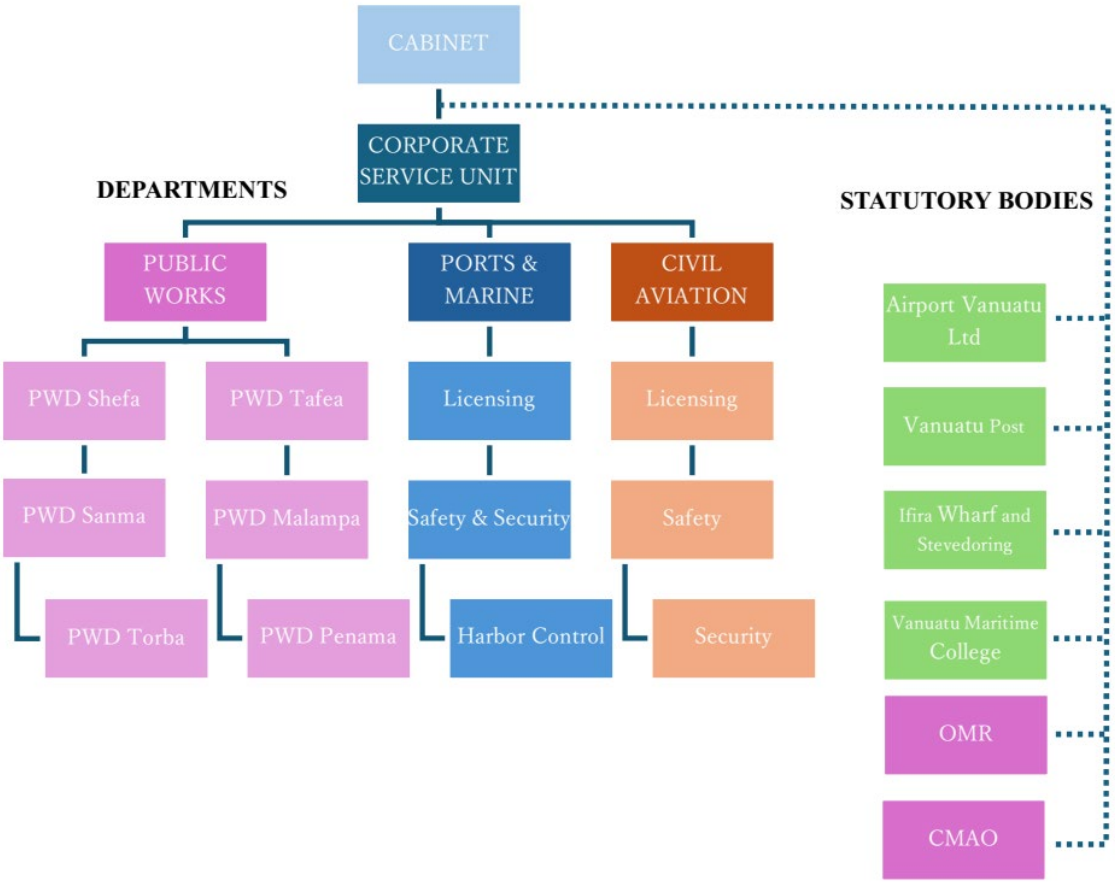
The Civil Aviation Authority of Vanuatu is a statutory body under the Ministry of Infrastructure and Public Utilities which oversees all aspects of the Republic of Vanuatu's civil aviation system including regulating access to the 30+ airports and landing which provide critical aviation infrastructure to the country's 65+ inhabited islands. CAAV's mandated purpose is to ensure the safety of all people who engage in, benefit from or otherwise may be impacted by civil aviation within the nation's sovereign airspace. This being the case, CAAV is also the primary regulator of

autonomous flying drone operations within Vanuatu airspace.

The Ports and Marine Department, which is under the Ministry of Infrastructure & Public Utilities, is responsible for the implementation of the Shipping and Ports Acts which regulates the Republic of Vanuatu's Ports of Entry, interior ports, the role of harbour masters. The harbour masters oversee those ports and additional related aspects of maritime operations within the country.

The Public Works Department is dedicated to contributing to the achievement of the national development goals by providing safe, reliable and affordable infrastructure. Primary task of the department is to manage, maintain and develop the major national transport infrastructure assets – roads, ports and airports.

(2) Organization Chart

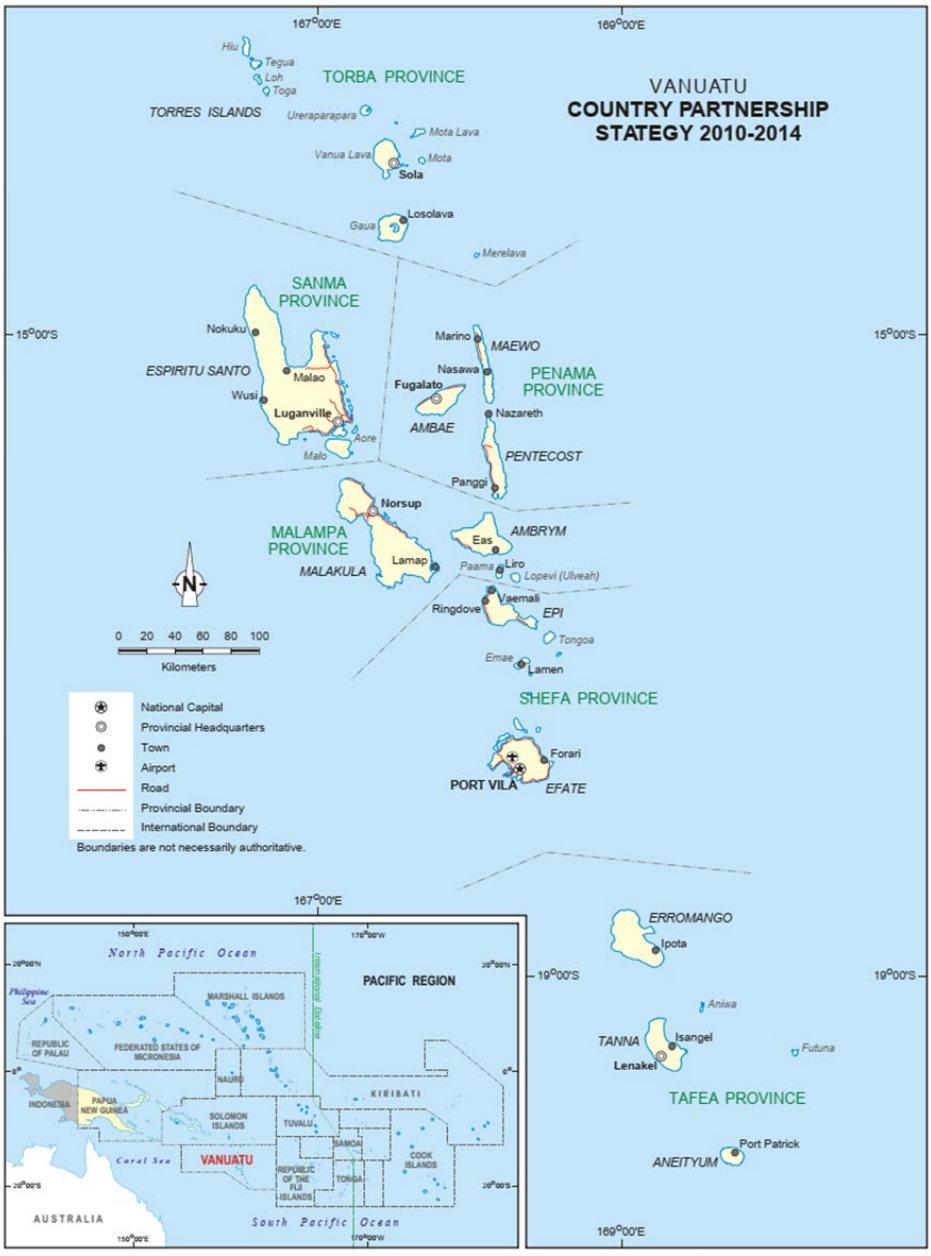


Source: Prepared by Survey team based on information from the Ministry of Infrastructure & Public Utilities, Government of Vanuatu.

Figure 7.1-2 Organizational Chart of the Ministry of Infrastructure and Public Works (MIPU) of the Republic of Vanuatu

(3) Overview of Major Ports

The international trade hubs in Vanuatu are the ports of Port Vila on Efate Island, which serves as a gateway to the country's hinterland and accounts for approximately 90% of its imports. The Port of Luganville on Espritu Santo Island serves as a gateway to the country's northern agricultural regions and is a major export hub.



Source: ADB Country Partnership Strategy, August 2009, Vanuatu 2010-2014

https://www.adb.org/sites/default/files/institutional-document/32408/cps-van-2010-2014_0.pdf

(Access: March 2025)

Figure 7.1-3 Republic of Vanuatu Port Location Map

(a) Ports of Port Vila

The ports of Port Vila on Efate Island in Shefa Province are the major ports of Vanuatu. It consists of the Main International Wharf and the Lapetasi International Multipurpose Wharf. The Main International Wharf handles cruise ships, oil tankers, and gas tankers, while the Lapetasi International Multipurpose Wharf handles international cargo ships. In addition, a new domestic wharf is currently under construction adjacent to the Lapetasi International Multipurpose Wharf.
The Port and Maritime Department oversees two commercial ports in Vanuatu, the ports of Port Vila on Efate Island and the port of Luganville on Espiritu Santo Island. All port cargo handling operations at Lapetashi International Multipurpose Wharf are managed by Ifira Ports Development Services (IPDS).



Source: https://dlca.logcluster.org/vanuatu-211-port-port-vila (Access: March 2025)
(Left: Lapetasi International Multipurpose Wharf, Right: Main International Wharf)

Figure 7.1-4 Layout of Ports of Port Vila

(b) Port of Luganville

The Port of Luganville is located on the southeast coast of Espiritu Santo Island in Sanma Province. The port is used for transshipment of beef, fish, cocoa, and copra (dried coconut), as well as for importing general goods and oils. The port is government-owned and can accommodate cruise ships and tankers. The Port of Luganville is deeper than the Ports of Port Vila.
Adjacent to the Port of Luganville is the Samansen Wharf which handles domestic ships and ferries. The Samansen Wharf can handle only one cargo ship at a time.
The stevedoring company responsible for all stevedoring services at the Port of Luganville is Northern Islands Stevedoring Company Limited (NISCOL). NISCOL handles the loading and unloading of international cargo, storage, and movement of cargo (containers) to delivery sites on Espiritu Santo Island.



Source: https://dlca.logcluster.org/vanuatu-212-port-luganville-santo (Access: January 2024)

(Left: Lugang International Wharf, Right: Samanshen Domestic Wharf)

Figure 7.1-5 Layout of Ports of Luganville

7.1.4 Cargo handling volume

The international cargo handling volume at the Ports of Port Vila was reported to be 13,200 TEU in 2011 [107], but recent cargo handling volumes are not publicly available on the relevant authorities' websites and remain unknown. Similarly, information on the number of vessel calls by vessel type and vessel size at the Ports of Port Vila is also not publicly available.

As a result of preliminary discussions with MIPU and SPC, the two ports selected for this project in Republic of Vanuatu are the Lapetasi International Wharf and the Main International Wharf in Port Vila.

7.2 Lapetasi International Multi-purpose Wharf, Port Vila

7.2.1 Review issues related to port maintenance and management

(1) Status of Port facilities

The Main International Wharf, the first international wharf at Ports of Port Vila, began operations in 1972. The number of ships entering at the port continued to increase following the development of the Main International wharf, including large cruise ships from Australia and New Zealand (NZ). In order to maintain priority for cruise ships using berths, container ships and cargo ships were often forced to suspend cargo handling operations or wait offshore.

[107] https://www2.jica.go.jp/ja/evaluation/pdf/2012_VUT-P1_1_s.pdf

The Vanuatu government has formulated a development plan to convert the Star Wharf, located on the east side of the Main International Port, into an international multipurpose wharf in order to improve the situation at that time.

The development of the Lapetashi International Multipurpose Wharf was proposed by the Vanuatu Government to the Japanese Government after the completion of a feasibility study (F/S) conducted by AusAID, aimed at constructing new facilities for international cargo ships and expanding the yard area.

In response, the Lapetasi International Multipurpose Wharf Development Project, funded by Japanese yen loans, was implemented. The project was completed and put into operation in February 2018.

(a) Port Plan



Source: Prepared by Survey team based on Google Earth

Figure 7.2-1 Panoramic view of Ports of Port Vila (Lapetasi International wharf (right) & Main International Wharf (left))



Source: Photo by Survey team (December 2024)

Figure 7.2-2 Panoramic view of Lapetasi International wharf, Port Vila

Table 7.2-1 Specifications of Lapetasi International Wharf, Port Vila

Lapetasi International Wharf	**Quantity**	**Length (m)**	**Maximum Draft (m)**
Container Berth	1	200	13
Berthing Tugs	1	-	-
Available Equipment	**Number & Type**		
Reach Stackers	2 x 45 tons (full container)		
Reach Stackers	2 x 10 tons (empty container)		
Forklifts	8 nos. (various SWL, 3 tons maximum)		

(b) Port cross-section (survey photos, drone photos)



Source: Photo by Survey team (December 2024)

Figure 7.2-3 Panoramic view of the quay at Lapetasi International Wharf

(c) Assessing the current situation through on-site inspections

According to IPDS, some damage has been observed to the stone revetment in the southwestern part of the terminal due to Cyclones Judy and Kevin, which struck consecutively in 2023. The most severely damaged area is the junction between the concrete structure and the stone revetment. For the 20-meter section of this area, repair plans have already been finalized, and the work has been contracted to Fletcher Company.

At the time of the on-site survey, the wharf facilities and equipment appeared to be in good condition with no damage or malfunctions and were operating without any problems. The Lapetasi International Wharf has contributed to improving the handling capacity of international cargo at Ports of Port Vila, and IPDS expressed its gratitude for this contribution.

During the site survey, IPDS accompanied the team and exchanged opinions about strengthening port facilities and maintenance methods. The photos taken during the survey are shown in **Figure 7.2-4** and **Figure 7.2-5**.



Figure 7.2-4 Photos during the field survey

		
(Photo by Survey team, 2024)	(Photo by Survey team, 2024)	(Photo by Survey team, 2024)
No.1- Stone revetment status -1	No.2- Stone revetment status -2	No.3- Stone revetment status -3

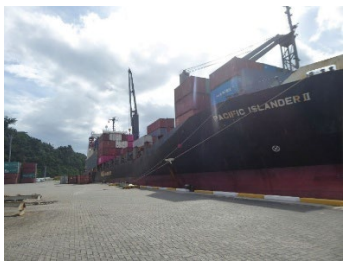
		
(Photo by Survey team, 2024)	(Photo by Survey team, 2024)	(Photo by Survey team, 2024)
No.4 - Lapetashi Wharf Status -1	No.5 - Lapetashi Wharf Status-2	No.6-Lapetashi Wharf Status-3

Figure 7.2-5 Site investigation photos

On December 17, 2024, a magnitude 7.3 earthquake struck the Republic of Vanuatu after the completion of a field survey. JICA conducted an emergency survey in January 2025 for disaster recovery and reconstruction assistance.

It is hoped that the restoration and recovery of the port facilities in Port Vila, which were damaged by the earthquake, will be carried out as soon as possible so that normal operations can resume.

On March 7, 2025, in Port Vila, the capital of the Republic of Vanuatu, the notes regarding a grant of 400 million yen from Japan for the "Economic and Social Development Programme" (equipment for the recovery from earthquake disaster) were signed and exchanged.
This grant aims to support the strengthening of the country's disaster recovery system by providing equipment essential for the disaster recovery from the earthquake (such as power shovels, dump trucks, and water supply vehicles, etc.) for addressing challenges such as debris removal and water supply needs in disaster-affected areas.

(d) Collection and organization of design documents from the viewpoint of maintenance and management

The Ministry of Infrastructure and Public Utilities (MIPU) of the Vanuatu Government oversees three departments, the Civil Aviation Authority of Vanuatu (CAAV), the Department of Ports and Marine, and the Public Works Department. Among these, the Public Works Department is responsible for the management, maintenance, and development of major national transport infrastructure assets such as roads, ports, and airports.
According to IPDS, almost all the data for design documents and drawings related to the construction of the Lapetasi International Wharf were lost due to cyclone disaster. However, some of the documents that were stored in hard copy were spared from damage and are being kept at the office.

(2) Implementation Department responsible for Port Management

The Public Works Department currently manages the entire national road network which consists of nearly 3,000 kilometers of roads in rural and urban areas, while it develops and maintains a number of ports, airports and public buildings.
The Public Works Department is aware of the pivotal role it plays in the sphere of the economic and social development of the country. In whatever we do, we therefore aim to embed the principles of equality, efficiency, resilience and sustainability.
The PWD building unit is also responsible for ensuring all new buildings, refurbishments and modifications comply with the national building code.
PWD has significant commitments in time of disasters by maintaining access and coordinating the Shelter Clusters[108].
PWD currently operates from seven offices located in the six Vanuatu Provinces. The Department employs more than 136 permanent staff.

All port cargo handling operations at Lapetasi International Wharf are managed and operated by Ifira Ports Development Services (IPDS).

[108] Shelter Clusters: Shelter Cluster - Wikipedia

(3) Status of Existing Facility and Future Plans

According to IPDS, the expansion work on the terminal is currently underway. The CFS (Container Freight Station) will be expanded to add 320 square meters of indoor space. In addition, the refrigerated container tower will be expanded to add 28 more spaces and increase the height to five stories.

Some of the stone revetment has been washed away caused by two consecutive cyclones that struck in 2023. The Repair work on the damaged stone revetment has been contracted to Fletcher Company. The company is a subcontractor that previously carried out construction work at the Lapetasi Wharf and is currently constructing a domestic wharf. The Repair work is scheduled to begin early next month, with estimated costs of 11 million VT (approximately 11 million yen).

The Lapetasi International Wharf is operational after the earthquake on December 17, 2024, as of February 2025. However, according to the emergency site investigation conducted in January 2025 for the Vanuatu earthquake, some cracks and subsidence have been observed in the pavement behind the wharf, indicating that rehabilitation works are necessary.
In addition, the roads leading to the Main International Port and Star Wharf remain inaccessible. It is hoped that the functions of the port and surrounding facilities will be restored as soon as possible through the rehabilitation and recovery support provided by international organizations and donor countries.

As part of the Vanuatu Inter-Island Shipping Support Project (VISSP), construction of a new domestic wharf in South Paray began in 2012 but was suspended in 2018. After additional site surveys, the design was revised, and a new tender was issued in 2021. The construction resumed in 2022, and the South Paray Domestic Wharf is scheduled for completion in April 2025.

7.2.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at Lapetasi International Wharf, Port Vila

(1) Collection of data on damage caused by past natural disasters

In this section, we will collect and compile information on natural disasters that have affected the Lapetasi International Warf, Port Vila in the past. Then, we will categorize natural disasters by disaster type, scale, the number of casualties, and the magnitude of economic loss.

(a) Sea level rise, cyclone and high wave

First, we will review the natural disaster risks across Oceania based on “The 6th Assessment

Report of the Intergovernmental Panel on Climate Change (AR6)[109]". AR6 reports that the occurrence proportion of strong tropical cyclones (categories 3 to 5) among all tropical cyclones globally has increased in the last 40 years, with a moderate level of confidence. AR6 indicates low confidence in the long-term trends of the increasing frequency of tropical cyclones across all categories. In addition, AR6 mentions that the global mean sea level has been rising more rapidly since 1900 than at any other 100-year time in the past 3,000 years, with high confidence.

Next, we will show the major cyclones that have caused critical damage to Vanuatu in chronological order of their occurrence. Recently, Cyclone "*Pam*" struck in 2015, Cyclone "*Harold*" in 2020, and Cyclone "*Judy*" (which hit on February 27, 2023) and Cyclone "*Kevin*" (which hit on March 2, 2023) struck consecutively within a few days, causing widespread and severe damage. The ports in Vanuatu have suffered significant damage, including building collapses and flooding of wharf facilities, due to sea-level rise caused by climate change and the intensification of cyclones. The Ministry of Infrastructure and Public Utilities (MIPU) is also deeply concerned about this situation.

(b) Earthquake, tsunami and volcanic activity

World Bank reported that Oceania was exposed to high risk of tsunamis, earthquakes, and volcanic activity[110] as shown in Figure 7.2-6 to Figure 7.2-8. The earthquake peak ground acceleration in Vanuatu falls in the range of 250.1 to 520 cm/s², indicating a high seismic hazard (see Figure 7.2-7**).** Tsunami maximum inundation height (MIH) for a 50-year return period in Vanuatu falls from 2.01 to 2.50-meter range (see Figure 7.2-6). The risk from volcanic activity is considered high (see Figure 7.2-8).

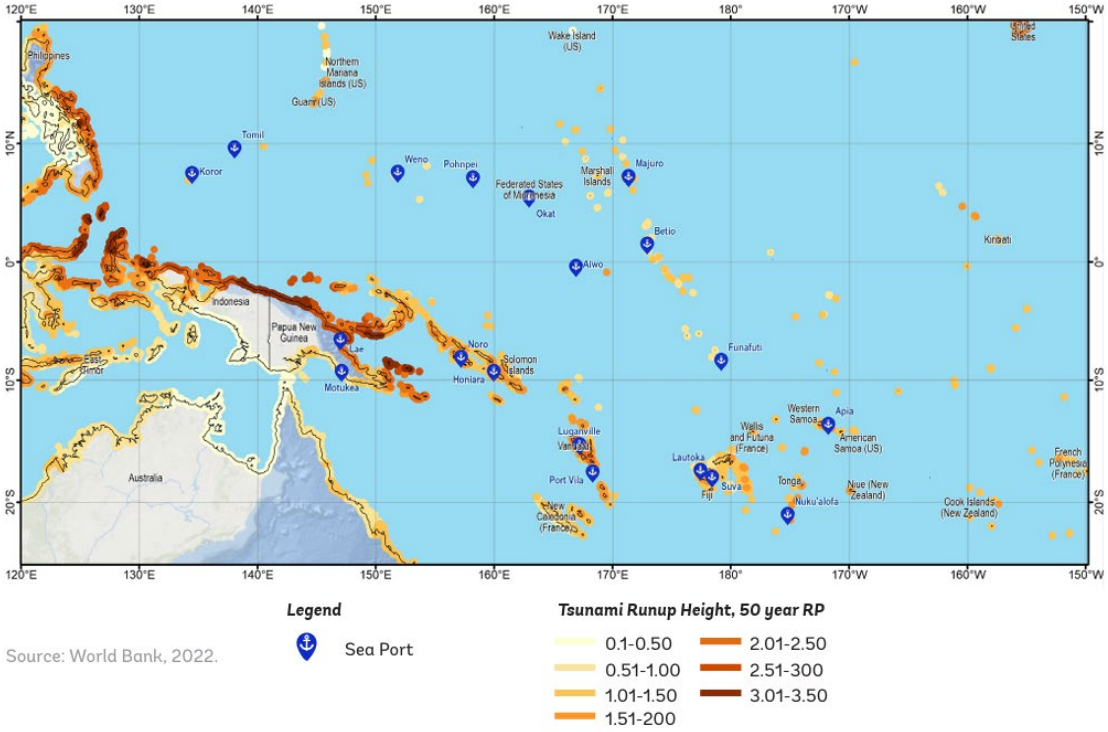
On November 26, 1999, a magnitude 7.5 earthquake struck, causing damage centered around Espiritu Santo Island. On January 3, 2002, a magnitude 7.3 earthquake occurred, resulting in significant damage around Port Vila. On December 17, 2024, a major magnitude 7.3 earthquake struck off the coast of Port Vila City. Multiple buildings collapsed within the city, resulting in casualties and property damage. According to the emergency investigation results, the landslides caused by the earthquake have severed coastal roads and caused damage to the port facilities at the Lapetasi International Multi-Purpose Wharf and the Main International Wharf in Port Vila.

Vanuatu has a total of seven active volcanoes, including one undersea volcano, and is threatened by volcanic eruptions. The 2017-2018 eruption is the largest and most impacting eruption at Ambae in recent history. The thick ash falls have caused significant impacts on Ambae Island in terms of food and water supply, shelter and the health of residents on the island thus producing

[109] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[110] Pacific Maritime Transport Systems Hazard Exposure Technical Note, World Bank. 2023.

significant humanitarian issues. The government of Vanuatu ordered a complete evacuation of the island, home to about 11,000 residents.

The Ports of Port Vila are important ports that also serve as a hub for receiving emergency relief supplies. Therefore, it is considered necessary to implement measures for recovery and rehabilitation from these disasters, as well as to strengthen the wharves and implement flood prevention measures.



Source: World Bank, 2022.

Figure 7.2-6 Tsunami Maximum Inundation Height (MIH) for a 50-year return period

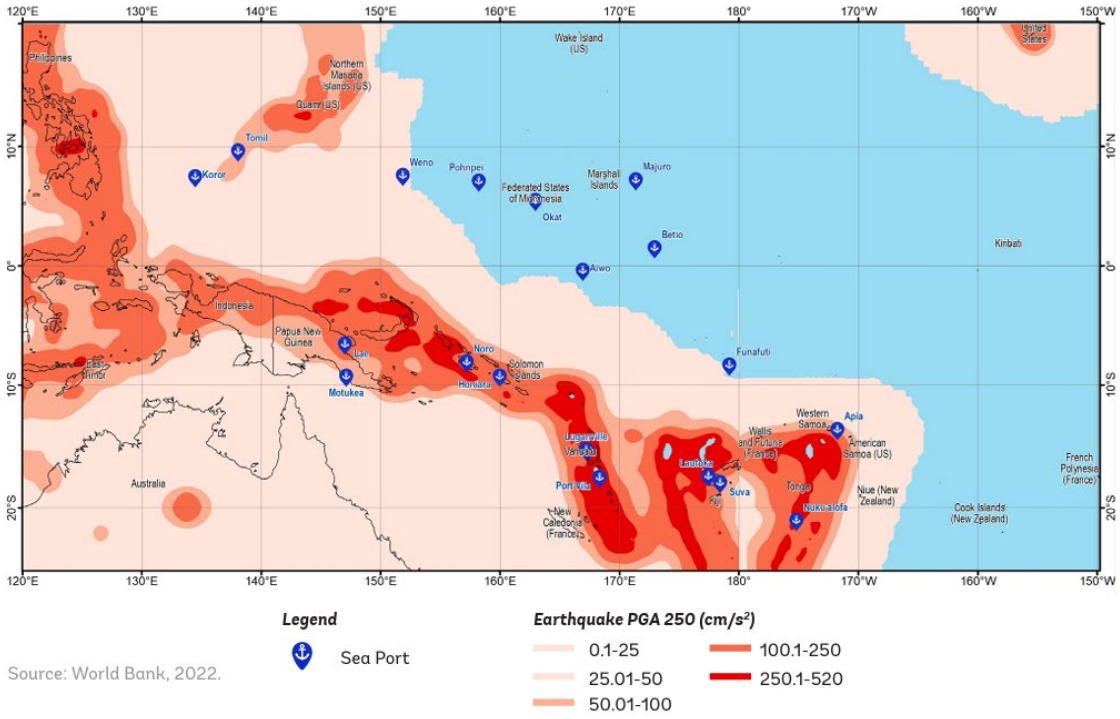


Figure 7.2-7 Earthquake peak ground acceleration (PGA) in cm/s2 for a 250-year return period

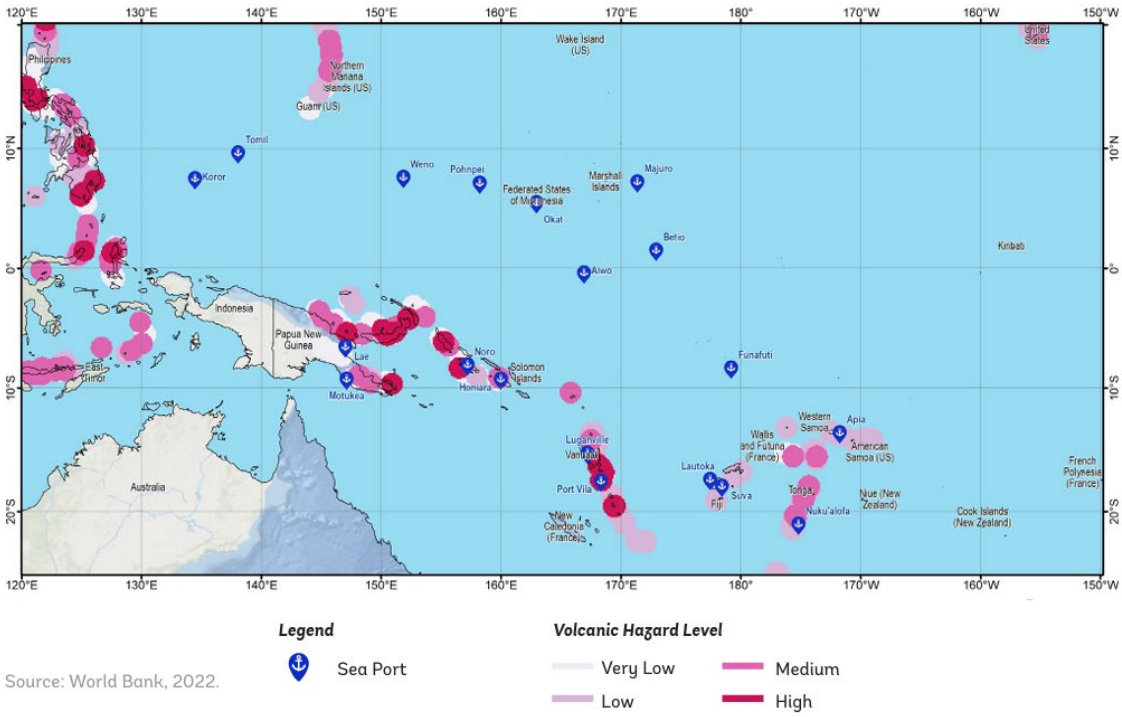


Figure 7.2-8 Volcanic Hazard Levels covering a 200 km radius from active volcanic vents

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in the Lapetasi International Wharf and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters. The design conditions such as natural conditions, design loads, etc. at the time of construction of the existing facilities of the Lapetasi International Multipurpose wharf have been confirmed as follows referring to the information in the JICA documents and drawings.

Deck level: RL+3.90 m
Tide level:
Highest astronomical tide, (HAT): CDL+1.60 m
Mean High Water Spring, (MHWS): CDL+1.30 m
Mean Sea Level, (MSL): CDL+0.90 m
Mean Low Water Spring, (MLWS): CDL+0.40 m
Lowest astronomical tide, (LAT): CDL ±0.0 m
Water depth: CDL -12.30 m

Design vessel: unknown
Geotechnical conditions: unknown
Seismic condition: unknown

(The final design conditions adopted for construction could not be confirmed from JICA documents. Therefore, the information contained in the as-built drawings that could be confirmed has been organized.)

7.2.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in the Lapetasi International Wharf based on the research papers and past record of natural disasters.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport* [111]". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for the Ports of Port Vila. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

[111] A Blue Transformation for Pacific Maritime Transport., World Bank, Washington, 2023. World Bank Document.

Referring to Table 2.2-2, the risk of earthquake disasters is high around Ports of Port Vila in Vanuatu. In addition, the risks of high waves during regional storms and the maximum tsunami run-up height are assessed as medium. On the other hand, the risks of coastal flooding and volcanic disasters are assessed as low.

Vanuatu is located on the "Pacific Ring of Fire," which stretches approximately 40,000 km around the Pacific Ocean. Here, the Pacific Plate collides with several surrounding continental plates, causing repeated earthquakes. Most of the world's volcanic eruptions, especially the most severe ones, occur in this region.

There are seven active volcanoes in Vanuatu. From 5 to 7 April 2023 volcanic activity on Ambae Volcano intensified with very high plumes of steam, gas and ash observed with lava glow at night. As of May 2025, five volcanoes are at Alert Level 2 (Major unrest state) – Yasur on Tanna, Manaro Voui on Ambae, Lopevi on Lopevi, Benbow and Marum on Ambrym and Mount Garet on Gaua [112]. These volcanoes have the potential to cause significant damage.

Vanuatu is located in the South Pacific on the Pacific Ring of Fire, and the region is one of the most seismically active in the world. The island state is therefore frequently and violently affected by earthquakes that reach magnitudes of over 7. The subduction processes at great depth often lead to smaller earthquakes, while the strongest and most consequential quakes tend to occur in shallower regions less than 60 km deep. The frequency of extreme tremors is particularly striking. In hardly any other region of the world do strong earthquakes occur at such a high frequency. The area around Port Vila, located southwest of Efate Island, has been assessed as having a high risk of earthquake disasters. The Peak Ground Acceleration (PGA) of the earthquake to be considered in Port Vila is estimated to be 0.43. It is essential in Port Vila to take adaptation measures against earthquake disaster.

Vanuatu is frequently hit by earthquakes and are also at serious risk of tsunamis. The area around Port Vila is assessed as having a medium risk of tsunamis. The maximum inundation height (MIH) of tsunamis around Port Vila is estimated to be 1.6 meters. Appropriate measures are required to respond to tsunami and high wave damage around Port Vila and the coastal areas.

Cyclones occur frequently in Vanuatu. On average, they happen about 7 times a year. Characteristically, most cyclones not only enter Vanuatu's sphere of influence but also make landfall. Only very few storms turn away beforehand. The most affected regions are Tafea and Shefa. The area around Port Vila belongs to Shefa Province. However, the ports of Port Vila are located inside Vila Bay, behind Ifira Island, so the risk against cyclone is assessed very low. The wave heights due to cyclones are estimated at 0.7 meters. While cyclone disasters in the ports of

[112] Vanuatu Meteorology & Geo-hazards Department; Volcanoes | VMGD

Port Vila area are low, they are a definite possibility, and appropriate measures must be taken to address them.

Table 7.2-2 Multi-hazard Heat Map Port Exposure (Republic of Vanuatu) -Port Vila

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5. 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High Medium Low Very Low Not applicable

Source: “A Blue Transformation for Pacific Maritime Transport” (World Bank. 2023. A Blue Transformation for Pacific Maritime Transport. World Bank, Washington, DC. © World Bank.)

Table 7.2-3 Methodology for Identifying Natural Disasters and their Scales (Lapetasi International Wharf)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Could not be confirmed.	Not applicable	Estimate earthquake waves by considering the scale of past earthquakes and taking into account the distance from the epicenter and ground conditions.
Tsunami	Could not be confirmed.	Not applicable	Estimate the loads acting on structures by assuming tsunami heights and flow velocities based on past maximum tsunamis.
Volcano	Could not be confirmed.	Not applicable	Estimate the impact of volcanic eruptions and ashfall on ports based on records of volcanic eruptions in neighboring countries and past volcanic disasters.
Storm Surge	Could not be confirmed. Deck level: DL +3.9m HAT+1.60 m	Flood disasters increase due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	Could not be confirmed.	Increase in high waves due to cyclone intensification	Consider the increase in waves caused by cyclone intensification objectively. The recent research results, such as future predictions using d4PDF described later can be used.

(2) Measures against sea level rise and wave power by climate change

The effects of sea level rise and waves caused by climate change can be taken into consideration by applying the adaptation measures against climate change described in Japan's, "Technical Standards and Commentaries for Port and Harbour Facilities in Japan" (English version, 2025). The concept of adaptation measures against climate change is as shown below.

"Japanese port and harbor design standards" explicitly state that the impacts of climate change, such as changes in tidal levels and wave conditions, must be considered over the entire design service life of a facility, and required performance must be ensured throughout that period. Accordingly, it is necessary to predict and set external forces based on anticipated changes due to climate change. The standards specify that such changes in external forces should be appropriately determined using the latest research findings and scientific knowledge. **Figure 7.2-9** illustrates

two conceptual approaches for setting structural strength while considering changes in external forces during the design service life.

The approach of designing structural components at the initial stage so that required performance is always ensured during the service life is referred to as "Proactive adaptation." On the other hand, "Adaptive adaptation" refers to the approach of considering the necessary structural specifications at the design stage to meet performance requirements throughout the service life but implementing physical upgrades progressively at appropriate times during the period, depending on material and structural characteristics.

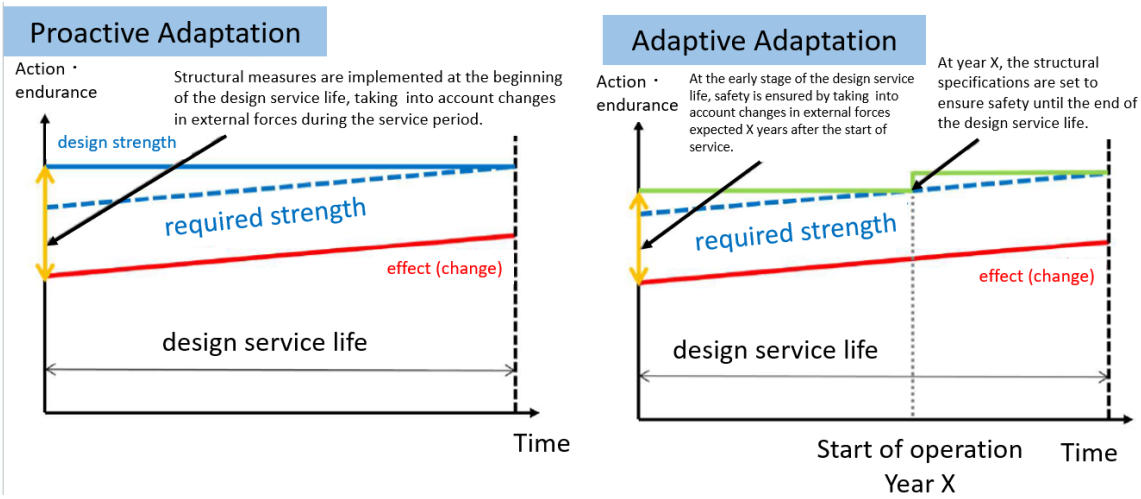


Figure 7.2-9 Setting design strength considering changes in effects during the design service life

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

Due to the many uncertainties surrounding climate change, a range of scenarios have been discussed. For example, "The 6th Assessment Report of the Intergovernmental Panel on Climate Change (AR6)[113]" presents five scenarios based on different levels of greenhouse gas emissions. Under the international framework of the Paris Agreement, the global community committed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." In line with this goal, Japan generally assumes the 2°C warming scenario (RCP2.6) from the Fifth Assessment Report (AR5)[114] as a basis when considering the impacts of climate change in port facility design.

[113] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.
[114] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A.

RCP2.6 corresponds to SSP1-2.6 in AR6. However, it is important to note that the choice of scenario varies by country and requires comprehensive consideration, taking into account uncertainties, economic conditions, and other factors. Figure 7.2-10 shows the projected median regional sea level rise by 2100 under different Shared Socioeconomic Pathways (SSPs), based on the average sea level from 1995 to 2014 in AR6. Regarding sea level rise due to climate change, the Pacific Region Infrastructure Facility (PRIF) presents projected sea level increases based on the estimates from the IPCC AR6 [115].

The projected sea level rise in Vanuatu is shown in Figure 7.2-11.The sea level rise in the Republic of Vanuatu by 2050 is projected to be 0.24 meters under the 2°C warming scenario (SSP1-2.6). Under the 4°C warming scenario (SSP5-8.5), it is projected to be 0.29 meters, with a small difference between the two scenarios. However, by 2100, the difference becomes significant, with 0.56 meters under the 2°C warming scenario (SSP1-2.6) and 0.93 meters under the 4°C warming scenario (SSP5-8.5). Therefore, depending on the scenario selected, the value of projected sea level rise differs, and this must be considered when setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

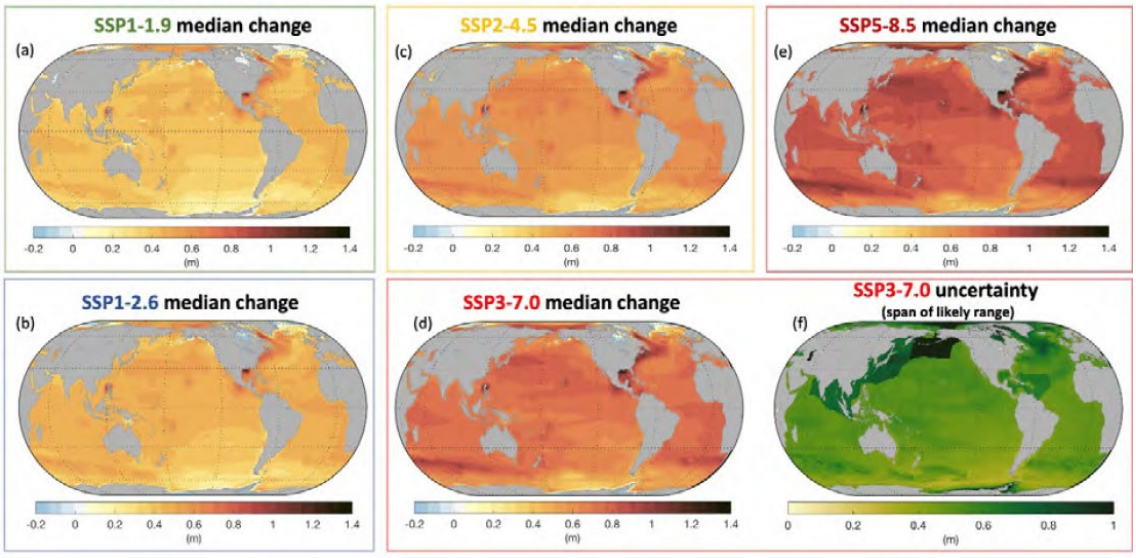


Figure 7.2-10 Regional Median Sea Level Change at 2100 for Different Shared Socioeconomic Pathway Scenarios with respect to the 1995–2014 Mean Sea Level

Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[115] PRIF (2021): Guidance for Managing Sea Level Rise Infrastructure Risk in Pacific Island Countries

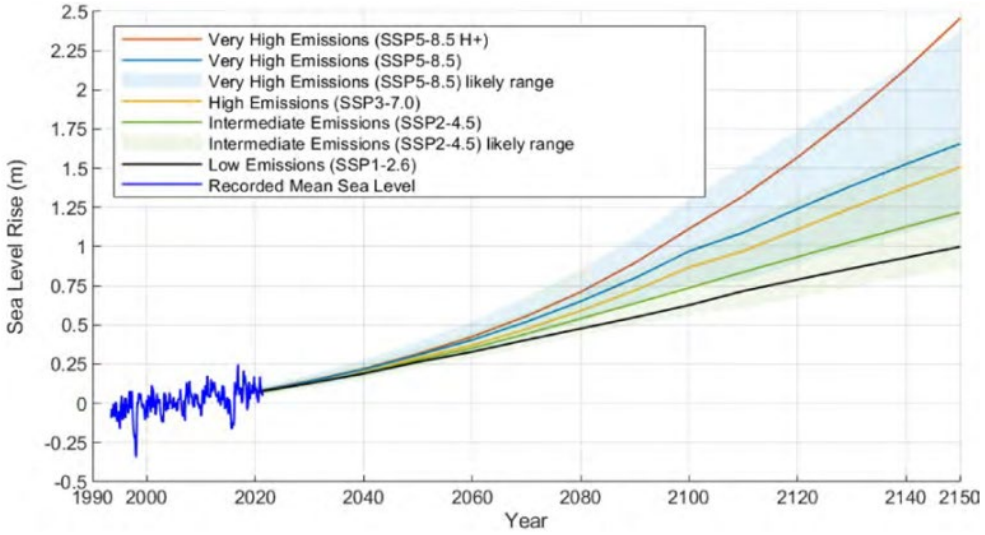


Figure 7.2-11 Sea Level Rise Projections to 2150 for Republic of Vanuatu Relative to 1995-2014 Mean Sea Level

Several studies have been conducted in Japan on future changes in storm surges and high waves caused by climate change. Below is an example of a methodological study in Japan on forecasting storm surges and high waves. Currently, the commonly used forecasting method in Japan is based on the “Database for Policy Decision-Making for Future Climate Change” (d4PDF, Mizuta et al. [116]). To predict future changes in extreme weather events such as typhoons due to climate change, a sufficient number of event samples is required. For this reason, Japan developed the d4PDF dataset, which provides over 5,000 years of simulated climate data. The d4PDF includes historical experiments representing the current climate and future experiments representing projected climates, with two warming scenarios: +2K and +4K. The future experiments include six different spatial patterns of future sea surface temperature changes, based on representative projections from the CMIP5 project, which contributed to the IPCC AR5. Using this database, wave simulations are conducted, and future design wave conditions are estimated through extreme value analysis.

The d4PDF provides high-resolution data with a 20 km grid around Japan. In addition, global data with a 60 km mesh are also available, which, while less precise, can still be used for analysis in the South Pacific. In research focusing on the Pacific region, the Pacific Community (SPC) is currently conducting future projections using climate and wave models under the "Changing Waves and Coasts in the Pacific" (WACOP) project[117]. This project uses four climate models that

[116] Mizuta, R., A. Murata, M. Ishii, H. Shiogama, K. Hibino, N. Mori, O. Arakawa, Y. Imada, K. Yoshida, T. Aoyagi, H. Kawase, M. Mori, Y. Okada, T. Shimura, T. Nagatomo, M. Ikeda, H. Endo, M. Nosaka, M. Arai, C. Takahashi, K. Tanaka, T. Takemi, Y. Tachikawa, K. Temur, Y. Kamae, M. Watanabe, H. Sasaki, A. Kitoh, I. Takayabu, E. Nakakita, M. Kimoto (2017) ：Over 5000 years of ensemble future climate simulations by 60 km global and 20 km regional atmospheric models, The Bulletin of the American Meteorological Society (BAMS), July, pp.1383-1398.
[117] Changing Waves and Coasts in the Pacific:https://wacop.gsd.spc.int/index.html (Accessed in July, 2024)

participated in CMIP5. When considering storm surges and high waves, it is essential to incorporate research findings or wave simulations using these future climate models.

7.2.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize IPDS's current disaster mitigation plans in terms of time frames and types of disasters.

(1) Classification of responses according to phase

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". Natural disasters are categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in **Table 7.2-4**.

Table 7.2-4 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The expert team confirmed the structure of existing facilities and maintenance status of the target port through discussions with IPDS and available design documents. The existence and implementation status of natural disaster response plans for the respective port facilities were also confirmed. The expert team sent questionnaires to each port authority to examine if the disaster mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change.

(2) Results of Questionary Survey

An earthquake struck Vanuatu on December 17, 2024, affecting the area around Ports of Port Vila. IDPS was unable to provide responses to its questionnaire survey.

PWD has formulated and implemented a comprehensive plan covering all port facilities under its jurisdiction for natural disaster response, climate change response, and emergency response. In this survey, the status of each response for the port facilities at the target ports of Lapetasi International Wharf and Main International Wharf are confirmed.

7.2.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by examining the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*" [118] (hereinafter referred to as 'Pacific Ports Vision') shown in Table 7.2-5. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[118] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 7.2-5 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities for Lapetasi International Wharf in the Ports of Port Vila are shown below.

(a) Natural disaster adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at Lapetasi International Wharf to address natural disasters at

existing facilities.
The Lapetasi International Wharf was designed in 2012, underwent construction work from 2015, and it began operations in 2018. The facility design includes raising the elevation of the wharf deck to address high waves and tsunamis.

(b) Climate change adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at Lapetasi International Wharf to address climate change in existing facilities.
The Lapetasi International Wharf was designed in 2012, underwent construction work from 2015, and it began operations in 2018. The facility plan takes into account the effects of climate change on wave conditions for high waves and storm surges when determining the wharf elevation.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: The Lapetasi International Wharf has a comprehensive emergency response plan for natural disasters that have been communicated to stakeholders. The relevant plans and documents are as shown below[119].

- Vanuatu National Policy on Climate Change and Disaster-Induced Displacement 2018
- Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030
- NDMO Strategic Plan 2016-2020
- STANDARD OPERATING PROCEDURES

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in the Lapetasi International Wharf in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

[119] Vanuatu National Disaster Management Office (NDMO) - Downloads - Disaster Risk Management

Table 7.2-6 Assessment of Impacts of Natural Disasters for Lapetasi International Wharf

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	The Lapetasi International Wharf is a steel pipe sheet pile quaywall with anchor structure, and it is susceptible to displacement and tilting of the front sheet pile wall due to seismic motion. Damage to the anchor structure, subsidence behind the quay due to liquefaction, and damage to the apron pavement are also possible. Damage such as the overturning of cargo handling equipment and loss of power supply is also possible.	The collapse of offices and injuries due to an earthquake are likely to affect the management systems. The damage to port facilities is expected to have a significant impact on port operations. The damage to the Lapetasi Wharf will have a significant impact on the stable supply of food and other daily necessities within Vanuatu.	Earthquakes may cause human casualties that could affect operations. Damage to port facilities and loss of power may affect port calls. Damage to cargo handling equipment may also affect cargo handling activities.
Tsunami	The Lapetasi International Wharf is located on the Vila Bay at the eastern side of Mele Bay, on the southwestern side of Efate Island, and is susceptible to damage from ships colliding or being damaged by tsunamis, as well as the spill of container cargo and imported vehicles from the hinterland. Other potential damage includes the overturning of cargo handling equipment and loss of power.	Human casualties due to tsunami may affect the management system. Damage to port facilities and the loss of cargo due to the tsunami may have a significant impact on the stable supply of food and other essential items to Vanuatu.	Human casualties caused by tsunamis may affect operations. Damage to port facilities and loss of power may affect the port calls. Collisions and sinking of ships caused by tsunamis may prevent ships from arriving.
Volcano	The Republic of Vanuatu is at high risk of volcanic disasters. Although Port Vila itself has a relatively low risk of volcanic eruptions, there are concerns about damage to port facilities and cargo handling equipment, as well as the closure of shipping lanes, due to volcanic eruptions and ash fall from surrounding islands.	Human casualties caused by volcanic eruptions may affect management systems. Damage to port facilities and disruption of land transportation caused by volcanic eruptions could have a significant impact on the stable supply of food and other essential goods to Vanuatu.	Human casualties such as injuries caused by volcanic eruptions may affect operations. Volcanic ejecta and ashfall may render port facilities and container yards unusable.
Storm Surge	Flooding of port facilities and container yards behind the wharf due to storm surge is expected. The impacts of ships running aground and the spill of container cargo and imported vehicles are expected.	Human casualties caused by storm surges may affect management systems. Damage to port facilities and spill of cargo due to storm surges may have a significant impact on the stable supply of food and other essential goods to Vanuatu.	Human casualties caused by storm surges may affect operations. Damage to port facilities and loss of power may affect port calls.
Cyclone	The strong winds of the cyclone may cause damage to the	Cyclones may cause casualties and other human damage,	Cyclones may cause injuries and other human casualties

	buildings such as offices and warehouses, as well as the collapse of stacked containers and lighting equipment, and the overturning of cargo handling machinery. The high waves caused by the cyclone may also result in flooding of port facilities, ships running aground or colliding, the spill of container cargo and imported vehicles, and power outages.	which may affect management systems. Strong winds may damage land facilities and close roads, halting land transportation, while high waves may damage port facilities and cause cargo to spill, severely affecting the stable supply of food and other necessities within Vanuatu.	that could affect operations. Strong winds may halt land transportation, which could affect operations. High waves may damage port facilities and cause cargo to spill, which could also affect operations.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in the Lapetasi International wharf in Port Vila.Figure 7.2-12 illustrates the natural disaster risks and resulting damage to the port.
Lapetasi International Wharf is a steel pipe sheet pile quay wall with anchor structure. Earthquake may affect displacement and tilting of the front sheet pile wall due to seismic motion. Piles of containers could be fallen. The building and warehouse will be damaged. Seawater from the ocean side will flood into the port area due to sea level rise. Containers in the yard may be washed away into the sea. This may disrupt vessel entering.
Damage to the Lapetasi International Wharf could have a significant impact on the stable supply of food and other daily necessities within Vanuatu.

The Lapetasi International Wharf is currently undergoing site surveys by international organizations and major donor countries to discuss support measures for the earthquake disaster recovery and rehabilitation. Therefore, this project will not develop a draft resilience plan.

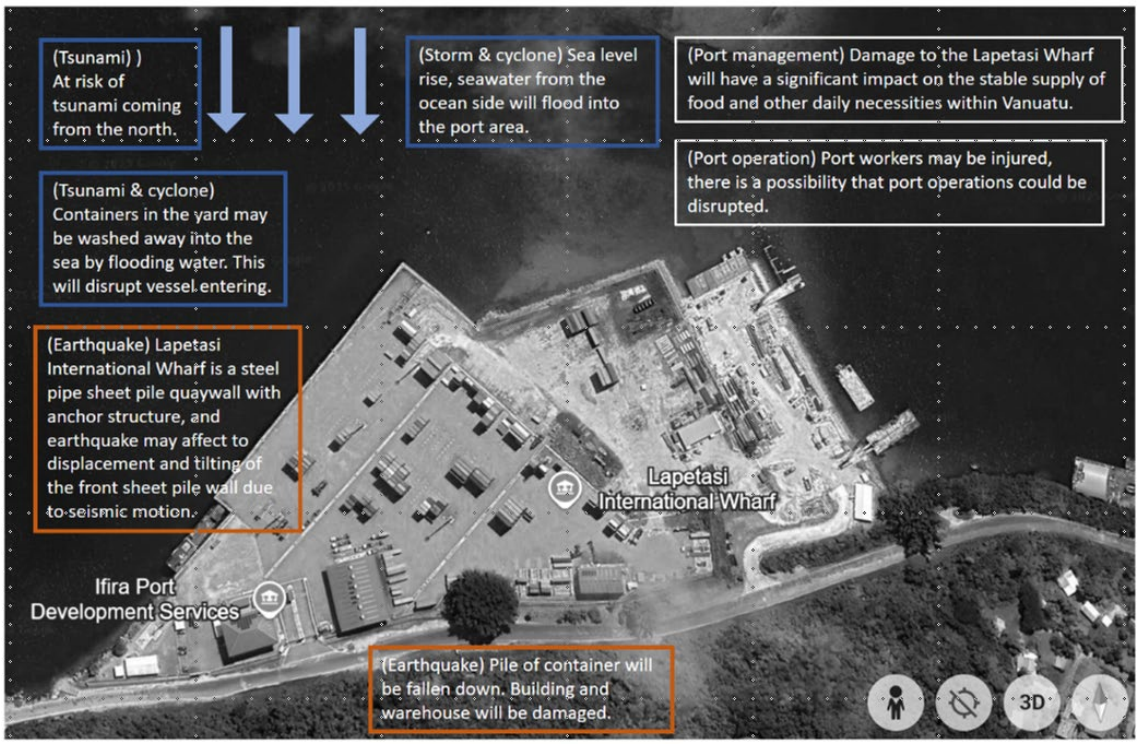


Figure 7.2-12 Geographical characteristics of natural disasters

7.2.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans. The results of existing port facilities for Lapetasi International Wharf in Port Vila are as shown below.

(1) Confirmation of the reasons for staying with the current resilience indicators

In Section 7.2.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for the Lapetasi International wharf. The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in "*CLIMATE CHANGE ADAPTATION PLANNING FOR PORTS AND INLAND WATERWAYS* [120] " (PIANC, EnviCom WG Report No. 178-2020) (hereinafter referred to as the PIANC guide). The results are presented below.

[120]Climate Change Adaptation Planning for Ports and Inland Waterways, PIANC, EnviCom WG Report No. 178-2020

(a) Natural disaster adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at the Lapetasi International Wharf to respond to the natural disasters at existing facilities.

- The goal(s), planning horizon and objectives of the natural disaster adaptation initiative have been established and agreed at the Lapetasi International Wharf.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has been completed, and the potential impacts of natural disasters on each have been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the natural disaster adaptation process.

(b) Climate change adaptation – Resilience indicators: Engaged

Reason: Actions are being taken at the Lapetasi International Wharf to address climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed at the Lapetasi International Wharf.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has been complete, and the potential impacts of climate changes on each have been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate change is in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the climate change adaptation process.

(c) Emergency response – Resilience indicator: Highly engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in the Lapetasi International Wharf.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at Lapetasi International Wharf for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

Measures to make Lapetasi International Wharf one level higher on the resilience indicators

(a) Natural disaster adaptation

- Reconfirm the goal(s), planning horizon and objectives of the natural disaster adaptation initiative established and agreed at the Lapetasi International Wharf.
- Reconfirm the potential impacts of critical assets, operations and systems including interdependencies that could be affected by natural disasters identified.
- Grasp the status of the baseline for port assets, operations, and systems, and reconfirm that necessary information is being provided appropriately.
- Check the information collected on natural disaster intensity forecasts and confirm the severity of the identified disasters.
- Grasp normal operating conditions (daily cargo volume, passenger numbers, etc.) and confirm the predicted impact of disasters.
- Conduct a natural disaster risk assessment and formulate a natural disaster adaptation plan for the Lapetasi International Wharf.

(b) Climate change adaptation

- Confirm the climate parameters and processes relevant to the critical assets, operations and systems identified.
- Collate the existing baseline data including information on extreme events for each relevant climate parameter or process and instigate monitoring to enhance local knowledge or fill gaps.
- Depending on the planning horizon for the adaptation strategy, agree on the climate change scenarios, and collate the climate change projections for relevant parameters and processes.
- Analize Data to confirm baseline conditions, to identify existing patterns and trends, and to determine what changes are expected under each scenario. Consider both slow onset changes and expected changes in the frequency or severity of extreme meteorological, oceanographic or hydrological events. Acknowledge the limitations of the data.
- Conduct a climate change risk assessment and develop a climate change adaptation plan for the Lapetasi International Wharf.

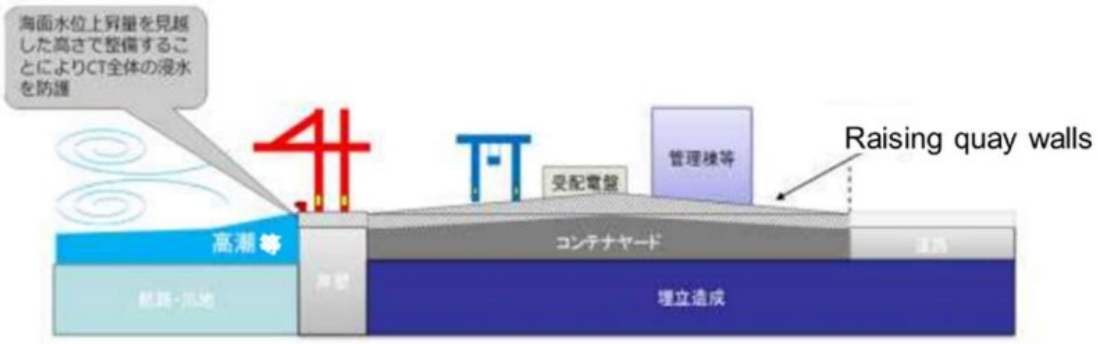
(c) Disasters and Emergency Response

- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans for the Lapetasi International Wharf.
- Maintain emergency response plans for natural disasters at existing facilities in the Lapetasi International Wharf and verify them through annual audits.

(3) Examples of countermeasures

The following example is one of the measures, which was also adopted for the Laetasi International Wharf, to counter storm surges and high waves.
The Lapetasi International Wharf was constructed with Japanese yen loan assistance and began operations in February 2018. The elevation of the wharf deck was determined taking into consideration the existing elevation of the container yard behind it and the effects of sea level rise due to climate change, etc.

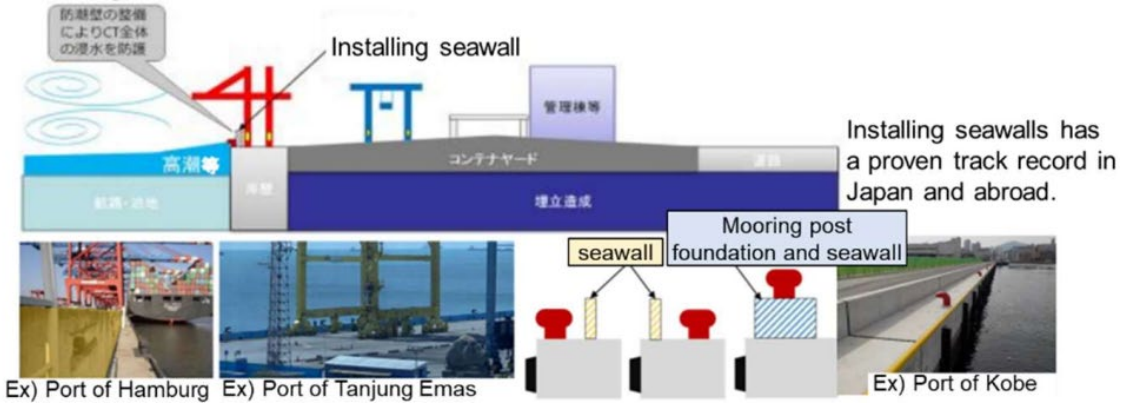
- **Raising quay walls**



(The concept is to raise the height of new or existing wharves to a level that takes into account the effects of storm surges and sea level rise, and to plan or renovate the structure so that it can withstand the resulting increase in load.)

The following example is also effective as one of the countermeasures against storm surges and heigh waves at existing facilities such as other domestic ports in Vanuatu.

- **Installing seawall**



(The concept is to install additional flood walls on existing wharves to prepare for the effects of high tides and sea level rise. Flood walls are sometimes installed in front of or behind mooring posts (bollards) on wharves for mooring and cargo handling operations. In cases where mooring posts can be relocated or newly constructed, a design integrating the flood walls with the foundations of mooring posts is also considered.)

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for Lapetasi International Wharf are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in the Lapetasi International Wharf is evaluated as "Engaged."
In order to achieve the next level of resilience indicator, it is necessary to reconfirm the goal(s), planning horizon, and objectives for natural disaster adaptation, formulate a natural disaster adaptation plan for existing facilities in the Lapetasi International Wharf, and obtain agreement among stakeholders. It is recommended to reconfirm the impact of natural disasters on port assets, operations, and systems, identify the baseline situation, conduct a risk assessment, and formulate a plan for the Lapataci International Wharf.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in the Lapetasi International Wharf is evaluated as "Engaged."
In order to achieve the next level of resilience indicator, it is necessary to reconfirm the goal(s), planning horizon, and objectives of climate change adaptation, formulate a climate change adaptation plan for existing facilities in the Lapetasi International Wharf and obtain agreement among stakeholders.
It is recommended to implement the following actions and develop a plan for the Lapetasi International Wharf.

- Collect baseline data that includes information on extreme weather events.
- Begin monitoring relevant climate parameters.
- Select climate change scenarios in accordance with the planning horizon for climate change adaptation and collect information on climate change projections.

(c) Disasters and Emergency Response

The resilience indicator outlined in the "*Pacific Port Vision*" for emergency response in the Lapetasi international Wharf is evaluated as "Highly Engaged."

In order to achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and verify that these plans are maintained through annual audits.

(d) Introduction of the Draft Plan for Port Resilience

The Lapetasi International Multipurpose Wharf is currently undergoing site surveys by international organizations and major donor countries to discuss support measures for the earthquake disaster recovery and rehabilitation. Therefore, this project will not develop a draft resilience plan.

7.3 Main International Wharf, Port Vila

7.3.1 Review issues related to port maintenance and management

(1) Status of Port facilities

The Main International Wharf began its operation in 1972. At that time, it primarily handled bulk cargo and palletized cargo, which were the main types of port cargo, and cargo handling operations using forklifts, etc. were conducted to directly transport cargo through the connecting bridge to the warehouses behind the wharf.

In response to a request from the Government of the Republic of Vanuatu, the Japanese government conducted a preliminary survey and basic design survey in 2007, followed by the implementation of the "Project for Improvement of Port Vila Port Main Wharf" as a grant aid project in 2008. The project aimed to ensure smooth cargo handling operations at the Main International Wharf and improve the berthing environment for entering vessels, through the renovation of the area behind the wharf and the provision of tugboats and pilot boats.

(a) Port Plan



(Drone Photo by Survey team, December 2024)

Figure 7.3-1 Aerial View of Main International Wharf, Port Vila

Table 7.3-1 Specifications of Main International Wharf

Main International Wharf	Quantity	Length (m)	Maximum Draft (m)
Conventional Berth	1	220	10
Berthing Tugs	1	-	-

(Main international wharf has space for containers, but this is reserved for containers seized by customs.)

(b) Port cross-section (survey photos, drone photos)



(Photo by Survey team, December 2024)

Figure 7.3-2 Panoramic view of pier at Main International Wharf

(c) Assessing the current situation through on-site inspections

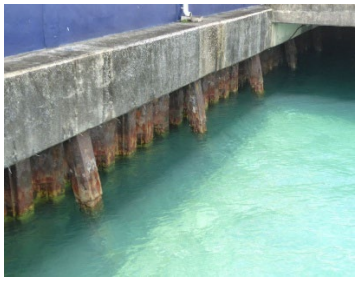
The Main International Wharf is severely deteriorated due to corrosion of steel piles and aging of superstructure concrete. Compared to the time of construction, the size of ships has increased, but measures to address this have been slow. The Ports and Maritime Department (PMD) is conducting minor maintenance such as navigation aids, but repairs for the wharf structures and maintenance of the fender materials are not carried out until now.

During the on-site survey, some damages and deteriorations were observed on the wharf structure,

such as corrosion of steel sheet piles for retaining wall behind the pier, corrosion of steel piles of the connecting bridge, cracks and breaks in rubber fenders of the pier, peeling of concrete in the superstructure, and corrosion of corner metal fittings, etc. During the site survey, the Ports and Marine Department accompanied the team and exchanged opinions about strengthening port facilities and maintenance methods. The photos taken during the survey are shown in **Figure 7.3-3** and **Figure 7.3-4**.



Figure 7.3-3 Photos during the filed survey

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.1- Main Wharf Status -1	No.2- Steel sheet pile wall -1	No.3- Steel sheet pile wall -2

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.4- Steel piles of bridge -1	No.5- Steel piles of bridge -2	No.6- Steel piles of bridge -3

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.7- Front face of pier -1	No.8- Front face of pier -2	No.9- Front face of pier -3

 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)	 (Photo by Survey team, 2024)
No.10- Rubber fender -1	No.11- Rubber fender -2	No.12- Rubber fender -3

Figure 7.3-4 Site investigation photos

(d) Collection and organization of design documents from the viewpoint of maintenance and management

The Ministry of Infrastructure and Public Utilities (MIPU) of the Vanuatu Government oversees three departments: the Civil Aviation Authority of Vanuatu (CAAV), the Department of Ports and Marine, and the Public Works Department. Among these, the Public Works Department is responsible for the management, maintenance, and development of major national transportation infrastructure assets such as roads, ports, and airports.
According to the Department of Ports and Marine, the port authority for Main International Wharf, almost all design documents and drawings from the time of construction and subsequent repair work for Main International Wharf were lost due to the cyclone disaster. Some documents that were stored in hard copy and escaped damage are being kept at the office.

(2) Implementation Department responsible for Port Management

The Public Works Department currently manages the entire national road network which consists of nearly 3,000 kilometers of roads in rural and urban areas, while it develops and maintains a number of ports, airports and public buildings.
The Public Works Department is aware of the pivotal role it plays in the sphere of the economic and social development of the country. In whatever we do, we therefore aim to embed the principles of equality, efficiency, resilience and sustainability.
The PWD building unit is also responsible for ensuring all new buildings, refurbishments and modifications comply with the national building code.
PWD has significant commitments in time of disasters by maintaining access and coordinating the Shelter Clusters[121].
PWD currently operates from seven offices located in the six Vanuatu Provinces. The Department employs more than 136 permanent staff.

The Main International Wharf is under the responsibility of the Ports and Maritime Department. They manage and operate the implementation of the Shipping Act and Port Act that regulates the role of port administrators and other related maritime affairs.

(3) Status of Existing Facility and Future Plans

As of February 2025, damage to the Main International Wharf from the earthquake on 17 December 2024, has not yet been repaired. The road leading to the Main International Wharf and Star Wharf remains inaccessible. As a result, residents of Ifira Point are required to take a boat from Vila Marina to access the area. Domestic vessels are utilizing the Mala Base port and the

[121] Shelter Clusters: Shelter Cluster - Wikipedia

Government Wharf, which is located near the Petroleum Services Company.

It is hoped that the functions of the port and surrounding facilities will be restored as soon as possible through recovery and rehabilitation assistance from international organizations and donor countries.

7.3.2 Identification of the scale of natural disasters (earthquake, tsunami, volcano eruption, storm surge, cyclone) to be assumed at Main International Wharf, Port Vila

(1) Collection of data on damage caused by past natural disasters

We collected reports on the disasters and compiled information on natural disasters that affected Vanuatu over the years in the previous section 7.2.2. Please refer to section 7.2.2 for details.

(a) Sea level rise, cyclone and high wave

The ports of the Republic of Vanuatu have suffered significant damage, including building collapses and flooding of wharf facilities, due to sea-level rise caused by climate change and the intensification of cyclones. The Ministry of Infrastructure and Public Utilities (MIPU) is also deeply concerned about this situation. Recently, Cyclone "*Pam*" struck in 2015, Cyclone "*Harold*" in 2020, and Cyclone "*Judy*" (which hit on February 27, 2023) and Cyclone "*Kevin*" (which hit on March 2, 2023) struck consecutively within a few days, causing widespread and severe damage.

(b) Earthquake, tsunami and volcanic activity

On November 26, 1999, a magnitude 7.5 earthquake struck, causing damage centered around Espiritu Santo Island. On January 3, 2002, a magnitude 7.3 earthquake occurred, resulting in significant damage around Port Vila. On December 17, 2024, a major magnitude 7.3 earthquake struck off the coast of Port Vila City. Multiple buildings collapsed within the city, resulting in casualties and property damage. According to the emergency investigation results, the landslides caused by the earthquake have severed coastal roads and caused damage to the port facilities at the Lapetasi International Multi-Purpose Wharf and the Main International Wharf in Port Vila.
The Ports of Port Vila are important ports that also serve as a hub for receiving emergency relief supplies. Therefore, it is considered necessary to implement measures for recovery and rehabilitation from these disasters, as well as to strengthen the wharves and implement flood prevention measures.

(2) Organization of external force conditions at the design of the existing facilities

In this sub-section, we will collect design documents of the port facilities in the Main International Wharf and examine whether the existing port facilities have sufficient bearing capacity to cope with the forces of expected natural disasters.

The design conditions such as natural conditions, design loads, etc. at the time of construction of the existing facilities of the Main International Wharf have been confirmed as follows referring to the information in the JICA documents and drawings.
(The values in parentheses regarding tide levels are those for the Lapetasi International Wharf. They are nearly equivalent.)

Deck level: RL+3.50 m
Tide level:

Highest astronomical tide, (HAT):	CDL+1.60 m	(CDL+1.60 m)
Mean High Water Spring, (MHWS):	CDL+1.30 m	(CDL+1.30 m)
Mean Sea Level, (MSL):	CDL+0.90 m	(CDL+0.90 m)
Mean Low Water Spring, (MLWS):	CDL+0.50 m	(CDL+0.40 m)
Lowest astronomical tide, (LAT):	CDL+0.20 m	(CDL ±0.0 m)

Water depth: CDL -10.70 m
Design vessel: unknown
Geotechnical conditions: unknown
Seismic condition: unknown

7.3.3 Identification of anticipated natural disasters and estimation of their scale

In this sub-section, we discuss natural disasters and their scale in the Main International wharf based on research papers and past records of natural disasters.

(1) Estimation of the magnitude of future natural disasters

World Bank classified the multi-hazard heat map port exposure in each port in the Pacific in the report "*A Blue Transformation for Pacific Maritime Transport*". This classification covers possible natural hazard items in the Pacific countries and evaluates the level of risk using a metric number system. We apply the classification into current port design and explore future natural disaster risks for the Main International Wharf. This process will determine if the current port design fails to account for important natural disasters or underestimates the risk of natural hazards.

The Main International Wharf is located on the west of the Lapetasi International Wharf in Port Vila. Therefore, the natural disasters and their magnitude that should be considered for the Main

International Wharf are applied the same as those for the Lapetasi International Wharf. Please refer to section 7.2.3 for details.

The summary of the natural disasters and their scales that should be considered at Port Vila in Republic of Vanuatu is shown in Table 7.3-2.
Referring to Table 7.3-2, the Port Vila area of the Republic of Vanuatu is at high risk of earthquake disasters. In addition, the risk of high waves during regional storms and the maximum tsunami run-up height are assessed as medium. On the other hand, the risk of coastal flooding and volcanic disasters is assessed as low.

Table 7.3-2 Multi-hazard Heat Map Port Exposure (Republic of Vanuatu) -Port Vila

Country	Port	Port Category	Wave Fetch Conditions (1)	T/Cyclone Gust Speed (km/h) (2)	T/Cyclone Wave Height (m) (3)	Regional Storm Wave Height (m) (4)	Coastal Flooding (m) (5)	Tsunami Max. Inund. Height (m) (6)	Earthquake PGA (g) (7)	Volcanic Hazard Level (8)	SLR (SSP5-8.5. 2050 (m) (9)
Tonga	Nukualofa	Primary	Open	178	9.1	4.1	1.3	1.5	0.27	Medium	0.27
Vanuatu	Luganville	Primary	Open	141	6.7	3.3	1.5	1.8	0.30	High	0.24
Samoa	Apia	Primary & Hub	Open	159	7.9	3.0	1.5	1.1	0.09	Low	0.31
Fiji	Suva	Primary & Hub	Open	136	6.4	2.7	2.0	1.3	0.28	Low	0.26
Solomon Islands	Honiara	Primary & Hub	Limited by Central Province Islands	116	3.2	2.2	0.8	1.7	0.19	High	0.22
Solomon Islands	Noro	Primary	Semi-enclosed	91	2.8	2.2	0.6	1.5	0.19	High	0.22
Vanuatu	Port Vila	Primary	Sheltered	140	0.7	2.2	1.0	1.6	0.43	Low	0.25
Tuvalu	Funafuti	Primary	Limited by lagoon	87	1.2	3.0	1.4	1.1	0.11	Not applicable	0.27

Colour Legend:

High | Medium | Low | Very Low | Not applicable

Source: “A Blue Transformation for Pacific Maritime Transport” (World Bank. 2023. A Blue Transformation for Pacific Maritime Transport. World Bank, Washington, DC. © World Bank.)

Table 7.3-3 Methodology for Identifying Natural Disasters and their Scales (Main International Wharf)

Types of Natural Disasters	Approach in design of existing facilities	Signs of climate change and global environmental change	Assumptions for future natural disasters
Earthquake	Could not be confirmed.	Not applicable	Estimate earthquake waves by considering the scale of past earthquakes and taking into account the distance from the epicenter and ground conditions.
Tsunami	Could not be confirmed.	Not applicable	Estimate the loads acting on structures by assuming tsunami heights and flow velocities based on past maximum tsunamis.
Volcano	Could not be confirmed.	Not applicable	Estimate the impact of volcanic eruptions and ashfall on ports based on records of volcanic eruptions in neighboring countries and past volcanic disasters.
Storm Surge	Could not be confirmed.護 Deck level DL +3.5m HAT+1.60 m	Flood disasters increases due to sea level rise.	Consider future sea level rise objectively. The results of PRIF, which will be described later can be used as one of the methods.
Cyclone	Could not be confirmed.	Increase in high waves due to cyclone intensification	Consider the increase in waves caused by cyclone intensification objectively. Recent research results, such as future predictions using d4PDF described later can be used.

(2) Measures against sea level rise and wave power by climate change

The adaptation measures against sea level rise and wave power by climate change was described in the previous section 7.2.3 (2). Please see section 7.2.3 (2) for details.

(3) Estimation of the magnitude of sea level rise and wave power due to climate change

The projected sea level rise in the Republic of Vanuatu by 2050 is projected to be 0.24 meters under the 2°C warming scenario (SSP1-2.6). Under the 4°C warming scenario (SSP5-8.5), it is projected to be 0.29 meters, with a small difference between the two scenarios. However, by 2100, the difference becomes significant, with 0.56 meters under the 2°C warming scenario (SSP1-2.6) and 0.93 meters under the 4°C warming scenario (SSP5-8.5). Therefore, depending on the scenario selected, the value of projected sea level rise differs, and this must be considered when

setting the design service life. Since future projections include uncertainties, it is necessary to understand the range of future projections.

7.3.4 Review the current status of natural disaster adaptation, climate change adaptation, and emergency response

In this section, after reviewing analysis on port facility structure, maintenance conditions and the level of disasters in the previous sections, we will organize the Department of Ports and Marine's current disaster mitigation plans in terms of time frames and types of disasters.

In organizing the time frame for responding to disasters and climate change, we divided the time frame into "Medium- to long-term preventive measures" and "emergency response measures". The natural disaster can be categorized into earthquake, tsunami, volcanic eruption, storm surge, and cyclone as shown in Table 7.3-4.

Table 7.3-4 Classification of adaptations and responses according to natural disasters

Types of Natural Disasters	Medium- and long-term preventive measures		Emergency response (Response within 48 hours)
	Natural Disaster Adaptation	Climate Change Adaptation	
Earthquake	✓	—	✓
Tsunami	✓	—	✓
Volcano Eruption	✓	—	✓
Storm Surge	✓	✓	✓
Cyclone	✓	✓	✓

The expert team confirmed the structure of existing facilities and maintenance status of the target port through discussions with the Department of Ports and Marine in Vanuatu and available design documents. The existence and implementation status of natural disaster response plans for the respective port facilities were also confirmed. The expert team sent questionnaires to each port authority to examine if the disaster mitigation plans have been prepared and are being properly implemented. The survey was carried out from December 2024 to January 2025. The survey covers four fields such as maintenance, natural disaster, emergency response and climate change.

An earthquake struck Vanuatu on December 17, 2024, affecting the area around Ports of Port Vila. The Department of Ports and Marine was unable to provide responses to its questionnaire survey.

7.3.5 Assessment of adaptation plans for natural disasters, climate change, and emergency response

(1) Evaluation of the current disaster resilience level by key resilience indicators

In this sub-section, by following the disaster adaptation plans in each port, the JICA experts assess the current disaster prevention level in each port by applying the "key resilience indicator matrix" in "*Pacific Ports Vision 2030-2050 Recognition Framework*" [122] (hereinafter referred to as 'Pacific Ports
Vision') shown in Table 7.3-5. In addition, we will explore the level of damage to port facilities, port management and port operation when the estimated level of disaster occurs in each port.

[122] Pacific Ports Vision 2030-2050 Recognition Framework, Pacific community 2(e): MTCC Pacific Updates Pacific Ports vision 2030-2050 recognition framework - Pacific Ports vision 2030-2050 recognition framework - Pacific Data Hub

Table 7.3-5 Key Resilience Indicators and Requirements

Indicator	Unengaged	Engaged	Highly engaged	Leading
Natural disaster adaptation	No action has been undertaken on natural disaster adaptation.	Port has identified and documented the assets, operations and systems that could be affected by natural disaster, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address natural disaster risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the natural disaster adaptation plan, verified via an annual audit.
Climate change adaptation	No action has been undertaken on climate change adaptation.	Port has identified and documented the assets, operations and systems that could be affected by climate change, and has identified what information is needed to establish baseline conditions, in accordance with steps 1 and 2 of the PIANC guide on climate change adaptation.	A risk assessment has been undertaken and a plan developed to address climate risks and hazards in accordance with steps 3 and 4 of the PIANC guide on climate change adaptation.	The port is progressing implementation of the climate change adaptation plan, verified via an annual audit (coinciding with an audit of the carbon footprint of the port).
Disasters and emergency response	No plans exist for emergency response.	Stakeholders and relevant authorities have been identified and are being engaged with in the development of an emergency response plan.	The emergency response plan is fully developed and has been communicated.	The emergency response plan is being maintained, verified via an annual audit.

(2) Confirmation and evaluation by key resilience indicators

The results of evaluating the level of resilience indicators for natural disaster adaptation, climate change adaptation, and emergency response at existing port facilities in Main International Wharf are shown below.

(a) Natural disaster adaptation – Resilience indicator: Unengaged

Reason: The Main International Wharf began operations in 1972. Subsequently, with grant aid from the Japanese government, the “The Project for Improvement of Port Vila Main Wharf” was implemented in 2008. This project included the renovation of the area behind the wharf and the

provision of tugboats and pilot boats. However, repairs to existing wharves and existing quay were not carried out. Therefore, the current information on natural disasters has not been reflected.

(b) Climate change adaptation - Resilience Indicators: Unengaged

Reason: The Main International Wharf began operations in 1972.Subsequently, with grant aid from the Japanese government, the "The Project for Improvement of Port Vila Main Wharf" was implemented in 2008. This project included the renovation of the area behind the wharf and the provision of tugboats and pilot boats. However, repairs to existing wharves and existing quay were not carried out. Therefore, the effects of climate change, such as sea-level rise, have not been reflected.

(c) Emergency response - Resilience indicator: Engaged

Reason: The Main International wharf has a comprehensive emergency response plan for natural disasters.
Internal and external stakeholders have been identified, and measures have been taken to ensure their involvement in the development of the emergency response plan. The relevant plans and documents are as shown below[123].

- Vanuatu National Policy on Climate Change and Disaster-Induced Displacement 2018
- Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030
- NDMO Strategic Plan 2016-2020
- STANDARD OPERATING PROCEDURES

(3) Impact assessment of possible natural disasters

The potential impacts on port facilities, port management systems, and port operations in the Main International Wharf in the event of natural disasters will be assessed. Damages will be described in detail to the extent possible based on the current condition of port and disaster adaptation measures.

[123] Vanuatu National Disaster Management Office (NDMO) - Downloads - Disaster Risk Management

Table 7.3-6 Assessment of Impacts of Natural Disasters for Main International wharf

Types of Disasters	Port facilities	Port management system	Port operation
Earthquake	The main international wharf at Ports of Port Vila is a pile-supported pier with a steel sheet pile quay wall behind it. The steel piles of the foundation and the concrete slabs of the superstructure are corroded and deteriorated, and severe damage from earthquakes is expected. Damage such as the overturning of cargo handling equipment and loss of power supply is also expected.	The collapse of offices and injuries due to an earthquake may affect management systems. The damage to port facilities is expected to have a significant impact on port operations. Damage to the main international wharf at Port Vila is expected to have a significant impact on the stable supply of energy resources such as oil and natural gas to Vanuatu.	Earthquakes may cause human casualties that could affect operations. Damage to port facilities and loss of power may affect the port calls.
Tsunami	Main International Wharf is located west of Lapetashi International Wharf in the southwestern part of Efate Island, and may be affected by ship collisions and damage caused by tsunamis. Damage such as power outages is also possible.	Tsunami could cause human casualties, which may affect the management system. Damage to port facilities caused by the tsunami will have a significant impact on the stable supply of energy resources such as oil and natural gas to Vanuatu.	Human casualties caused by tsunamis may affect operations. Damage to port facilities and loss of power may affect port calls.
Volcano	The Republic of Vanuatu is at high risk of volcanic disasters. Although Port Vila itself has a relatively low risk of volcanic eruptions, there are concerns about damage to port facilities and cargo handling equipment, as well as the closure of shipping lanes, due to volcanic eruptions and ash fall from surrounding islands.	Human casualties caused by volcanic eruptions may affect management systems. Damage to port facilities and disruption of land transportation caused by volcanic eruptions could have a significant impact on the stable supply of energy resources such as oil and natural gas to Vanuatu.	Human casualties such as injuries caused by volcanic eruptions may affect operations. Volcanic ejecta and ashfall may render port facilities unusable.
Storm Surge	Flooding of port facilities due to storm surges is a concern. The impact of ships running aground and the spill of container cargo is also a concern.	Human casualties caused by storm surges may affect management systems. Storm surges may cause damage to port facilities and have a significant impact on the stable supply of energy resources such as oil and natural gas to Vanuatu.	Human casualties caused by storm surges may affect operations. Damage to port facilities and loss of power may affect port calls.
Cyclone	The strong winds of the cyclone may cause damage to buildings such as offices and warehouses, as well as the collapse of lighting equipment and the overturning of cargo handling machinery. High waves caused by the cyclone may also result in	Cyclones could cause casualties and other human damage, which may affect management systems. Strong winds may damage land facilities and close roads, halting land transportation, while high waves may damage	Cyclones may cause injuries and other human casualties that could affect operations. Strong winds may halt land transportation, which could affect operations, and high waves may damage port facilities, which could also

	flooding of port facilities, ships running aground or colliding, and loss of power.	port facilities and severely disrupt the stable supply of energy resources such as oil and natural gas to Vanuatu.	affect operations.

In addition, the advisory team assessed the risks of natural disasters based on geographic conditions, port layout, and aging conditions of the facilities in Main International Wharf in Port Vila. Figure 7.3-5 illustrates the natural disaster risks and resulting damage to the port.

Main International Wharf is a pile-suspended pier and a steel sheet pile quay wall behind it. Steel pipe piles and concrete superstructure are corroded and deteriorated. An earthquake may cause severe damage to those structures. The building and warehouse could be damaged. Damage to port facilities and loss of power may affect port calls. Damage to oil and gas equipment may also affect energy supply. Seawater from the ocean side will flood into the port area due to sea level rise. Cargo or equipment in the yard may be washed away into the sea. This could disrupt vessel entering.

Damage to Main Wharf at Port Vila may have a significant impact on the stable supply of energy resources such as oil and natural gas to Vanuatu.

On the other hand, the wharf sustained damage in the earthquake of December 17, 2024. The Main International wharf is the energy import base for the Republic of Vanuatu, and measures to strengthen its resilience are considered urgent from the perspective of ensuring a stable energy supply.

Therefore, the advisory team proposes a preliminary plan for the renovation of the existing wharf at the Main International Wharf.

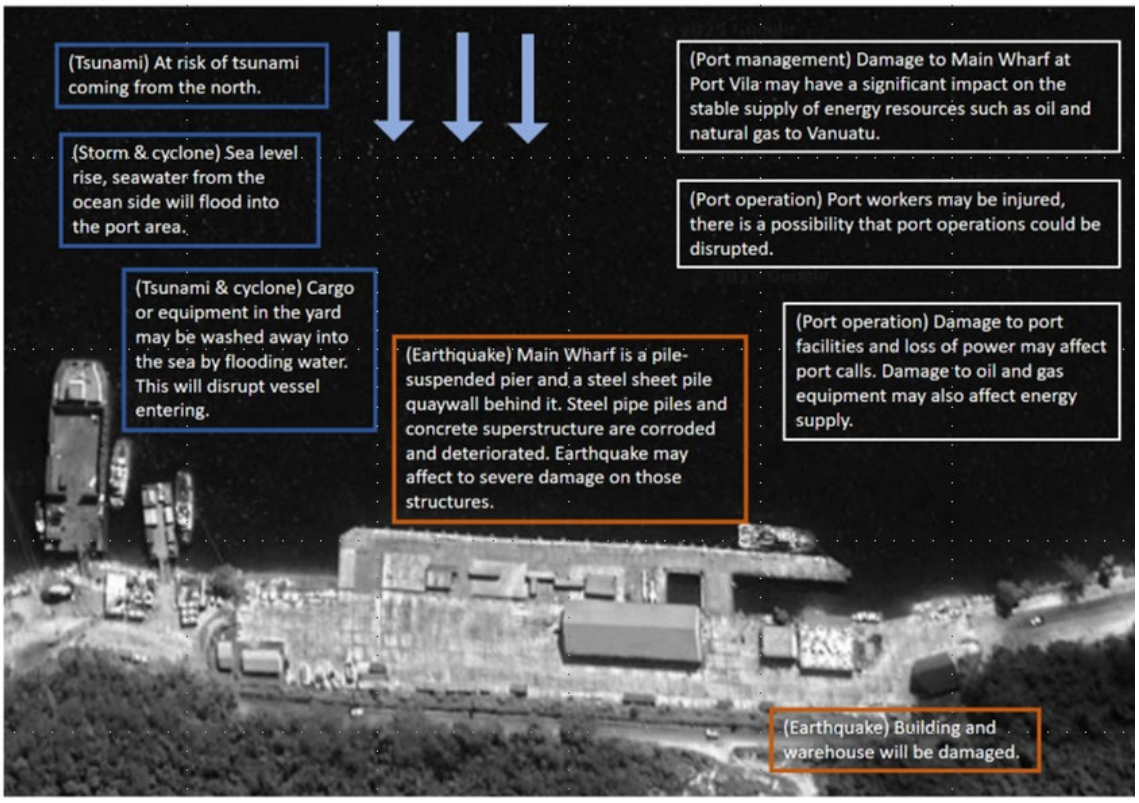


Figure 7.3-5 Geographical characteristics of natural disasters

7.3.6 Formulation of Port Resilience Strategy

In this sub-section, we will examine why the port resilient level remains at the current level and propose measures to upgrade it to the next level. In addition, we will compile a port resilience strategy covering measures for mitigating the risks of natural disasters and port facility maintenance plans.

(1) Confirmation of the reasons for staying with the current resilience indicators

In Section 7.3.5, the current status of natural disaster adaptation, climate change adaptation, and emergency response were evaluated using the resilience indicator for the Main International Wharf. The reasons for the current resilience indicator levels are confirmed based on the perspectives outlined in PIANC guide. The results are presented below.

(a) Natural disaster adaptation – Resilience indicator: Unengaged

Reason: Actions are not taken at the Main International Wharf to respond to the natural disasters at existing facilities.

- The goal(s), planning horizon, and objectives for natural disaster adaptation have not been

established and agreed at the Main International wharf.

- An inventory of critical assets, operations and systems including interdependencies that could be affected by natural disasters has not been complete, and the potential impacts of natural disasters on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of natural disasters is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the natural disaster adaptation process for the Main International wharf.

(b) Climate change adaptation - Resilience Indicators: Unengaged

Reason: Actions are not taken at the Main International Wharf to address climate change in existing facilities.

- The goal(s), planning horizon and objectives of the climate change adaptation initiative have been established and agreed at the Main International Wharf.
- An inventory of critical assets, operations and systems including interdependencies that could be affected by climate changes has not been complete, and the potential impacts of climate changes on each have not been identified.
- Monitoring of physical asset condition, operational performance and the consequences of extreme events due to climate changes is not in place, along with a fit-for-purpose data management system.
- Relevant internal and external stakeholders have been identified, but actions have not been taken to ensure they are engaged in the climate change adaptation process for the Main International wharf.

(c) Emergency response - Resilience indicator: Engaged

Reason: A comprehensive emergency response plan for natural disasters has been developed and communicated to stakeholders in the Main International Wharf.

- Relevant internal and external stakeholders have been identified, and actions have been taken to ensure they are engaged in the development of emergency response plans.

(2) Consideration of measures to advance key resilience indicators one level higher

The following measures are recommended in order to raise the resilience indicators of the existing facilities at Main International Wharf for natural disaster adaptation, climate change adaptation, and emergency response to the next level.

Measures to make Main International Wharf one level higher on the resilience indicators

(a) Natural disaster adaptation

- Establish goal(s), planning horizon and objectives for natural disaster adaptation at existing facilities in the Main International Wharf.
- Identify the impact of natural disasters on port assets, operations, and systems in the Main International Wharf.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information related to natural disaster intensity predictions and determine the extent of the natural disaster.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

(b) Climate change adaptation

- Establish goal(s), planning horizon and objectives for climate change adaptation at existing facilities in Main International Wharf.
- Identify the impact of climate changes on port assets, operations, and systems in the Main International Wharf.
- Grasp the baseline conditions of port assets, operations, and systems, and identify necessary information.
- Collect information on natural disaster intensity forecasts including the effects of climate change and identify the extent of natural disasters with climate change impacts.
- Monitor operational conditions (such as daily cargo volume, passenger numbers, etc.) and predict the impact of disasters under normal circumstances.

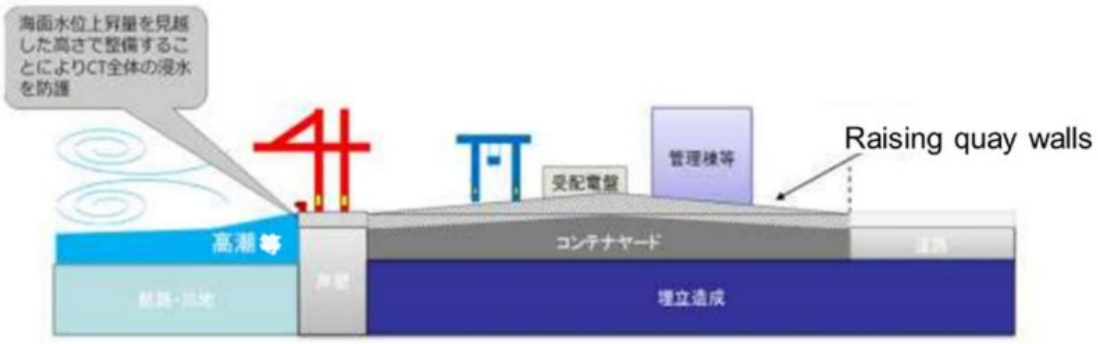
(c) Disasters and Emergency Response

- Reconfirm that stakeholders and relevant authorities are involved in the development of emergency response plans.
- Fully develop emergency response plans for natural disasters at existing facilities in the Main International Wharf and communicate them to stakeholders.

(3) Examples of countermeasures

The Main International Wharf began operations in 1972. Subsequently, with grant aid from the Japanese government, the improvement project was implemented in 2008. This project included the renovation of the area behind the wharf and the provision of tugboats and pilot boats. However, repairs to existing wharves and existing quay were not carried out. The current information on natural disasters is not reflected on the existing structures. When assessments of the impact of natural disasters are being incorporated into future plan, the following example is one of the countermeasures against storm surge and high waves caused by cyclones for the facilities in Main wharf

- **Raising quay walls**



(The concept is to raise the height of new or existing wharves to a level that takes into account the effects of storm surges and sea level rise, and to plan or renovate the structure so that it can withstand the resulting increase in load.)

The Main International Wharf handles cruise ship calls and the reception of dangerous goods such as petroleum and LPG in Port Vila. In addition to the aging of existing facilities, the Main International wharf was damaged by the earthquake in December 2024.
As a result, it is necessary to plan and implement a comprehensive renovation plan promptly.

(4) Summary of Port Resilience Strategy

The key measures to be considered in the port resilience strategy for Main International Wharf are as follows.

(a) Natural Disaster Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for natural disaster adaptation in the Main International Wharf is evaluated as "Unengaged."
In order to achieve a higher level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for existing facilities at the Main International Wharf in terms of their natural disaster adaptation.
It is recommended to identify the impact of natural disasters on port assets, operations, and systems at existing facilities in the Main International Wharf, collecting information necessary to understand the baseline situation, and specifying information necessary for natural disaster risk assessment in order to prepare for the formulation of a natural disaster adaptation plan.

(b) Climate Change Adaptation

The resilience indicator outlined in the "*Pacific Port Vision*" for climate change adaptation in the Main International Wharf is evaluated as "Unengaged."
In order to achieve the next level of resilience indicator, it is necessary to establish goal(s), planning horizon, and objectives for climate change adaptation.
It is recommended to collect information on natural disaster intensity forecasts that include the impact of climate change in order to identify the impact of climate change on the port assets, operations, and systems of the Main International Wharf and to understand the baseline situation.

(c) Disasters and Emergency Response

The resilience indicator outlined in the "*Pacific Port Vision*" for emergency response in the Main International Wharf is evaluated as "Engaged."
In order to achieve the next level of resilience indicator, it is recommended that stakeholders and relevant authorities reconfirm their involvement in the development of emergency response plans and that emergency response plans for natural disasters at existing facilities in the Main International Wharf be fully developed and communicated to stakeholders.

(d) Introduction of the Draft Plan for Port Resilience

The Main International Wharf handles cruise ship calls as well as the berthing of oil tankers and liquefied petroleum gas (LPG) carriers. However, in addition to the aging of existing facilities, the terminal has been slow to respond to the increasing size of cruise ships and the rise in berthing frequencies, which has led to higher occupancy rates. In response, a preliminary plan for the renovation of the existing wharf at the Main International Wharf has been prepared.

(i) Proposal for Main International Wharf Strengthening Plan (Draft Concept)

The existing pier structure at the Main International Wharf is steel pipe pile pier supported by vertical piles. Based on the results of a visual inspection of the wharf, it is observed that corrosion has progressed in the steel piles, and their load-bearing capacity against lateral loads caused by ship berthing and vertical loads on the pier are likely to be significantly reduced. In addition, it is suspected that the wharf sustained damage in the earthquake of December 2024, resulting in a significant reduction in its remaining load-bearing capacity. Further details will be found pending the results of additional on-site investigations into the earthquake.

The Main International wharf is the energy import base for the Republic of Vanuatu, and measures to strengthen its resilience are considered urgent from the perspective of ensuring a stable energy supply. Furthermore, the Main International Wharf, which also accommodates cruise ships, serves as a valuable tourism industry infrastructure for generating foreign exchange. It is essential that cruise ships can continue to arrive and depart safely and smoothly.

Taking the urgency of the situation into consideration, the draft plan is proposed as a two-phase improvement. First, (1) the dolphins will be installed in front of and behind the wharf to ensure the early provision of temporary berthing for energy vessels and cruise ships and to prevent forces from acting on the existing pier. Second, (2) steel pipe sheet pile walls will be newly installed in front of the existing pier with anchor structures and backfill in the area behind.
This plan will facilitate the renovation of the existing wharf, ensuring safe mooring for vessels and cruise ships, cargo handling operations, and safe passenger access routes.

(ii) Berth Occupancy Ratio of Main International Wharf

The Berth Occupancy Ratio (BOR) at the Main International Wharf from 2020 to 2023 is analyzed and the result is as shown below. Looking at the trend in BOR, although it decreased in 2021, it exceeded 50% in 2023.

Berth Occupancy Ratio (BOR) of Main International Wharf

$$BOR = \frac{\text{Port Stay (hrs)}}{\text{Total Working Time per Berth (hrs/berth) x No. of Berth (berth)}} \times 100\ (\%)$$

Berth Occumancy Ratio （BOR) for Port of Main International Wharf

Year	Vessel no. (no.)	Port Stay (hrs)	Ave. (hrs/vessel)	BOR	Passenger Vessel no. (no.)
2020	87	3179.1	36.5	36.4%	57
2021	37	823.7	22.3	9.4%	5
2022	47	2877.4	61.2	32.9%	21
2023	96	4590.4	47.8	52.5%	69

(iii) Assumed Conditions

The conditions for preliminary consideration of the strengthening plan for the Main International Wharf are as follows.

- Target Vessels

  Cruise Ship : Quantum Of The Seas (Royal Caribbean)
  Length : L = 348 m
  Beam : B = 49 m (max.), B = 41,4 m (at the water level)
  Draught : d = 8.8 m
  Gross Tonnage : GT = 168,666 ton
  Occupancy : 4,905 (max.)

  Product Tanker:
  Length : L = 203 m
  Beam : B = 32.90 m (Port Technical Standards)
  Draught : d = 12.3 m (full draught)
  Dead Weight Tonnage : DWT = 50,000 ton

- Typical Dimensions of the wharf

  Existing pier: Structural Type- Steel Pipe Pile Pier
  Length, L = 212 m, Breadth, B = 9.1 m, Depth, D = -11 m,
  Elevation, H = +2.6 m

- Draft Strengthening Plan (1st step)

  Additional Dolphins:
  East side: 4 nos. , Length L = 72 m,
  West side: 4 nos., Length LK = 72 m.

Land Mooring foundations:

East side: 1 nos. , Length L = 71 m,

West side: 1 nos. , Length L = 85 m.

- Draft Strengthening Plan (2nd step)

New Pier: Structural Type- Steel Pipe Sheet Pile wharf with anchor structure

Length, L = 150 m, Breadth, B = 9.1+14.2+0.5 m = 23.8 m, Depth, D = -11 m,

Elevation, H = +2.6 m

Facility Length after expansion

Total Length = 150m + 72m + 72m + 71m + 85m = 450 m

(iv) Summary of Draft Plan

The result for the strengthening plan considering two-stage development is shown below.

1) Installed dolphins in front of and behind the pier to ensure early temporary berthing of energy vessels and cruise ships and to prevent forces from acting on the existing pier.

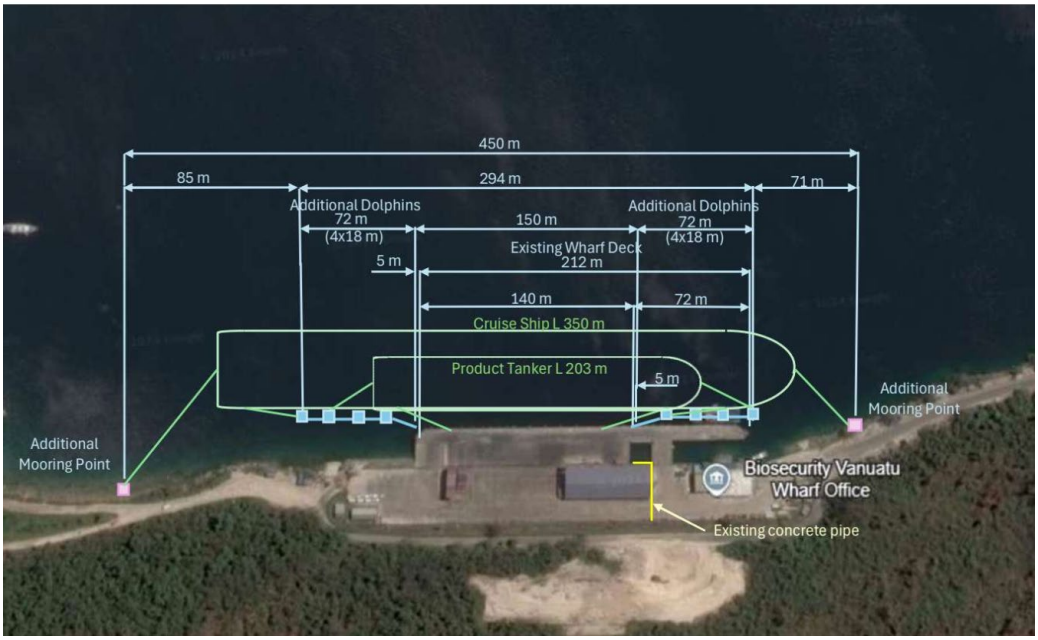


Figure 7.3-6: Overview of the Main International Wharf Strengthening Plan (Phase 1)

2) Installed steel pipe sheet pile walls in front of the existing wharf with anchor structures and backfill in the area behind to facilitate the renovation of the existing wharf, ensuring safe mooring for vessels and cruise ships, cargo handling operations, and safe passenger access routes.

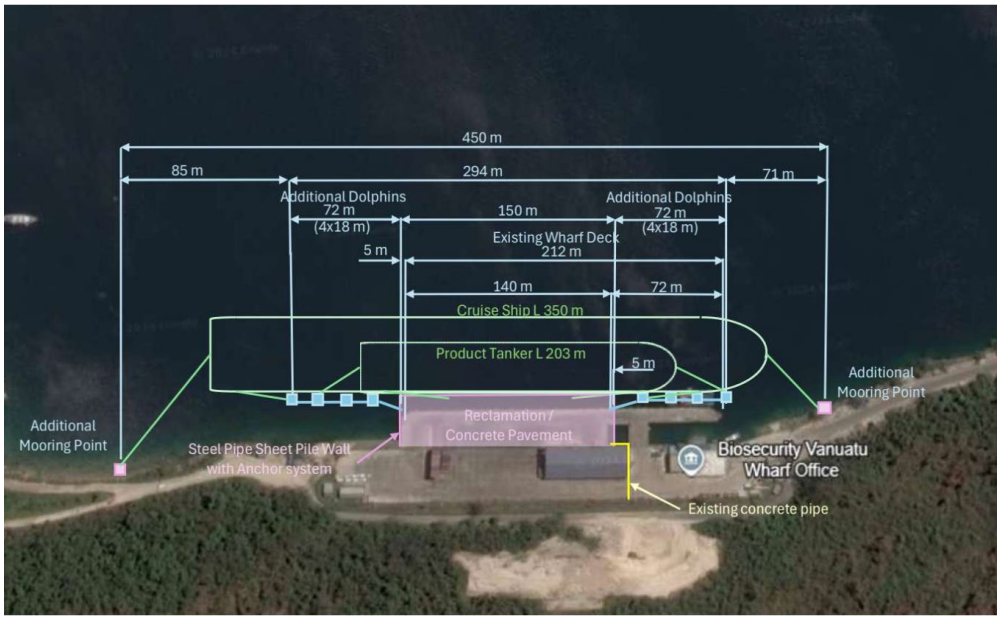
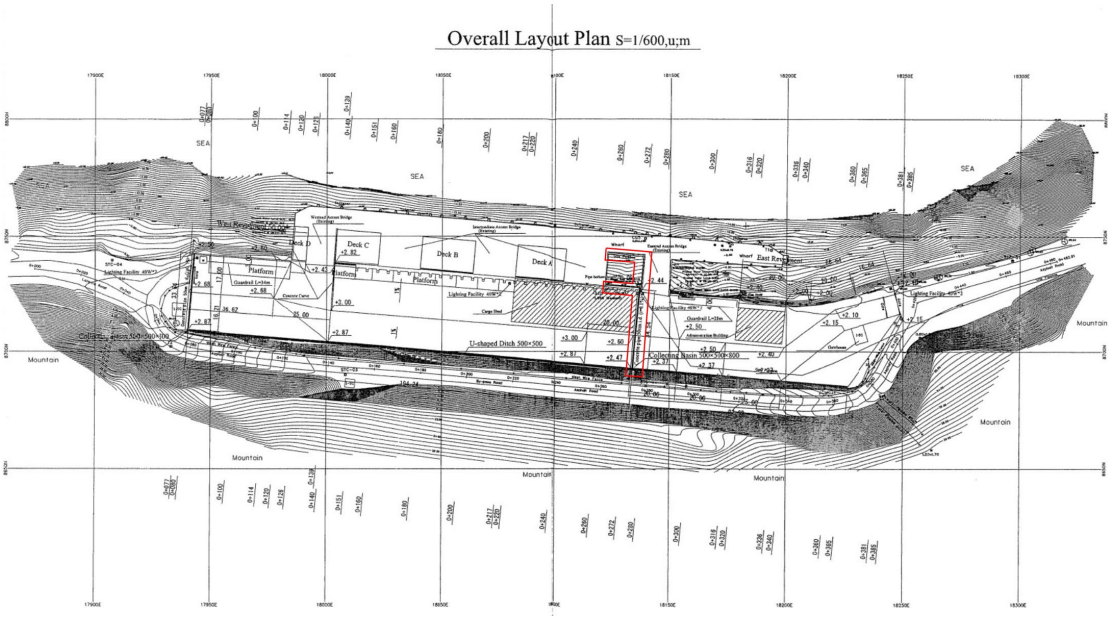


Figure 7.3-7: Overview of the Main International Wharf Strengthening Plan (Phase 2)

Since gas and oil pipes are buried in the existing pier, care must be taken not to interfere with these pipes. (The pipe locations are as follows.)



(v) Notes and issues in draft plan

In conducting the basic design survey for this expansion plan, it is necessary to conduct a site survey of the existing wharf facilities, thoroughly confirm the condition of the pile foundations and concrete of the pier sections, as well as the condition of the retaining sheet pile walls behind the wharf, and reflect information in the demolition plan and landfill plan, etc.

It is recommended to appropriately confirm the presence and layout of buried utilities such as existing piping facilities to create relocation plans as necessary. It is also recommended to conduct soil investigations around the wharf area and re-evaluate meteorological and oceanographic conditions as required for the strengthening plan and implement the basic design appropriately.

(vi) References

[Reference 1]

Number vessel arrival by vessel type at Ports of Port Vila (2023)

2023 Lapetasi Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
fully cellular containership	8	62	937,287	747,999	15,118	12,065
general cargo	1	1	8,188	6,269	8,188	6,269
general cargo with container capacity	5	22	525,281	461,086	23,876	20,958
Naval Vessel	2	3	2,044	3,680	681	1,227
patrol ship	1	1	0	2,453	0	2,453
roll on roll off with container capacity	2	11	199,319	199,100	18,120	18,100
tug	1	1	180	250	180	250
Vessel Type (unspecified)	1	3	0	0	0	0
Total	21	104	1,672,299	1,420,837	16,080	13,662

Vessel types specific to each wharf

2023 Main Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
fishing (general)	4	5	0	314	0	63
Liquified Petroleum Gas Carrier	2	2	9,927	9,005	4,964	4,503
Naval Vessel	1	4	4,088	7,360	1,022	1,840
passenger (cruise)	6	53	259,661	2,745,161	4,899	51,795
Passenger Vessel (unspecified)	1	1	99	1,553	99	1,553
patrol ship	2	3	79	331	26	110
product tanker	3	13	650,383	387,031	50,029	29,772
Roll On Roll Off	1	1	1,499	1,142	1,499	1,142
salvage tug	1	1	288	426	288	426
supply	1	2	9,600	10,408	4,800	5,204
tug	3	4	724	869	181	217
Vessel Type (unspecified)	6	28	0	12,706	0	454
yacht	9	31	1,088	5,906	35	191
Total	40	148	937,436	3,182,212	6,334	21,501

[Reference 2]

Number vessel arrival by vessel type at Ports of Port Vila (before 2023)

2020 Lapetasi Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
fully cellular containership	12	52	888,251	715,291	17,082	13,756
general cargo	1	1	16,953	13,110	16,953	13,110
general cargo with container capacity	4	14	253,789	238,830	18,128	17,059
Naval Auxiliary Vessel	1	1	13,000	20,000	13,000	20,000
passenger (cruise)	3	3	12,724	104,314	4,241	34,771
roll on roll off with container capacity	2	10	181,175	181,000	18,118	18,100
tug	2	43	3,026	4,012	70	93
Total	25	124	1,368,918	1,276,557	11,040	10,295

2020 Main Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
Combined chemical and oil tanker	3	12	599,095	360,729	49,925	30,061
fish carrier	1	1	2,500	2,900	2,500	2,900
fishing (general)	6	15	0	1,413	0	94
fully cellular containership	1	1	13,970	10,352	13,970	10,352
landing craft	1	1	297	228	297	228
Liquified Petroleum Gas Carrier	1	16	60,736	59,648	3,796	3,728
passenger (cruise)	14	26	213,110	2,213,745	8,197	85,144
product tanker	1	1	49,995	29,983	49,995	29,983
tug	2	24	1,424	1,888	59	79
Vessel Type (unspecified)	2	6	0	0	0	0
Total	32	103	941,127	2,680,886	9,137	26,028

2021 Lapetasi Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
fully cellular containership	9	37	642,313	537,704	17,360	14,533
general cargo with container capacity	6	22	356,402	320,493	16,200	14,568
roll on roll off with container capacity	2	11	199,266	199,100	18,115	18,100
tug	2	26	3,738	4,956	144	191
Total	19	96	1,201,719	1,062,253	12,518	11,065

2021 Main Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
Combined chemical and oil tanker	2	5	249,760	149,364	49,952	29,873
Liquified Petroleum Gas Carrier	4	14	58,182	55,571	4,156	3,969
patrol ship	3	8	436	4,821	55	603
product tanker	3	9	450,383	268,099	50,043	29,789
support	1	39	11,739	10,413	301	267
tug	2	25	3,916	5,192	157	208
Vessel Type (unspecified)	1	1	0	0	0	0
Total	16	101	774,416	493,460	7,667	4,886

2022 Lapetasi Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
fully cellular containership	10	34	661,766	553,525	19,464	16,280
general cargo	2	5	42,602	30,507	8,520	6,101
general cargo with container capacity	6	40	692,099	591,546	17,302	14,789
research	1	1	630	1,200	630	1,200
roll on roll off with container capacity	2	12	217,410	217,200	18,118	18,100
tug	2	24	4,280	5,720	178	238
Vessel type (unspecified)	1	2	0	0	0	0
Total	24	118	1,618,787	1,399,698	13,719	11,862

Vessel types specific to each wharf

2022 Main Wharf

Vessel Type	No. of Vessels	No. of Port Calls	Total DWT	Total GT	Average DWT	Average GT
dredger	1	5	5,920	2,065	1,184	413
general cargo	1	1	8,706	6,275	8,706	6,275
Liquefied Petroleum Gas Carrier	1	15	56,940	55,920	3,796	3,728
Naval Vessel	1	2	400	4,684	200	2,342
passenger (cruise)	4	61	57,188	590,137	938	9,674
patrol ship	2	7	593	2,516	85	359
product tanker	3	14	700,382	416,808	50,027	29,772
Roll On Roll Off	2	4	3,726	3,682	932	921
salvage tug	1	1	288	426	288	426
tug	4	20	3,044	3,979	152	199
Vessel Type (unspecified)	5	12	0	0	0	0
yacht	3	15	0	0	0	0
Total	28	157	837,187	1,086,492	5,332	6,920

[Reference 3] Preliminary evaluation results of acceleration data from the December 2024 Vanuatu earthquake



On December 17, 2024, a large earthquake with a magnitude of 7.3 occurred near Efate Island in Vanuatu. The epicenter was located approximately 43 kilometers west of Efate Island.

The Geohazards Division of the Vanuatu Meteorological and Geohazards Department (VMGD) is responsible for managing the Vanuatu Geophysical Network. There are monitoring stations strategically placed across key islands of Vanuatu to track geophysical activity in real time or near real time. The acceleration time history data from one of the observation stations on Efate Island (RTV) was available as seismic data for the recent Vanuatu earthquake. The preliminary results of the analysis conducted by earthquake experts using this data are presented below.

The following can be inferred from the acceleration time history waveform and the Fourier spectrum waveform.

- The duration is approximately 20 sec, with the main motion lasting approximately 5 sec.
- The max. acceleration is approximately 400 Gal (both NS and EW are approximately the same).
- The dominant frequency is around 7 Hz to 10 Hz, with NS and EW generally overlapping.

The waveform of the acceleration time history is pulsed. Thus, it is considered that the impact on structural damage is small. Generally, the range of frequency in which earthquake damage to port structures is likely to occur is around 1 Hz. Even if a maximum acceleration of 400 Gal due to an earthquake acts at a frequency of 7 Hz, it is considered that the occurrence of damage to the port structures will not be significant.

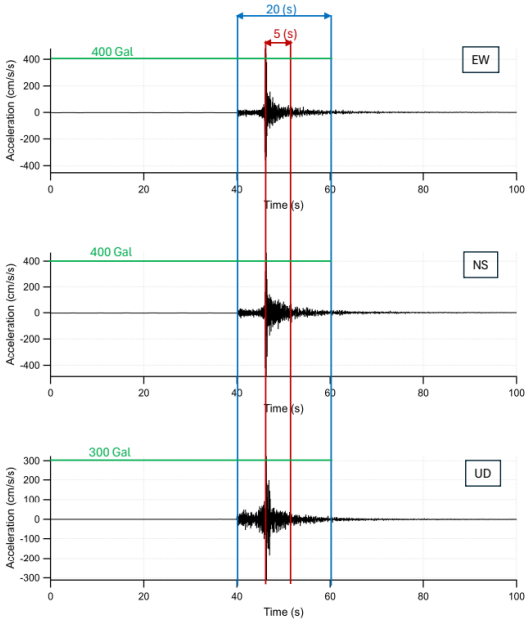


Figure 7.3-8 Seismic acceleration waveform (RTV)

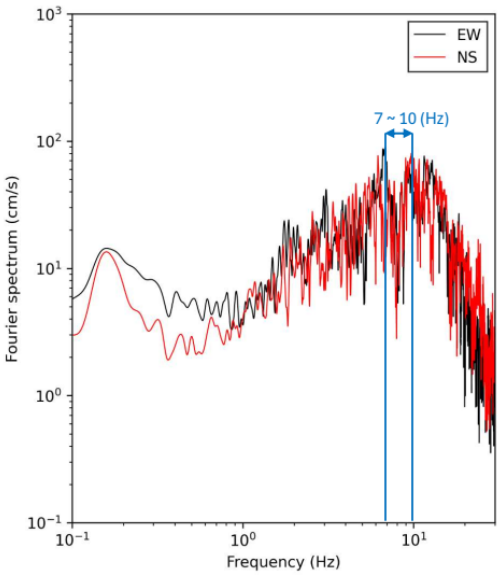


Figure 7.3-9Acceleration Fourier spectrum (RTV)

8. Organization of Seminars

Total Two seminars on port resilience strategies were held for port authorities and stakeholders after completing on-site surveys of target ports in the six target countries.

8.1 The First Seminar

At the first seminar, the advisory team presented the interim results of this project. They also introduced guidelines for maintenance and repair, as well as port design standards for responding to global warming and earthquakes.

Table 8.1-1 Outline of the First Seminar

Date and Time	February 25, 2025, 2:00 p.m. to 5:00 p.m. (Fiji time)
Target Organization	Port administrators of all target ports
Target Participants	Disaster prevention and crisis management personnel of target organizations
Topics	➢ Interim outcomes of the study (Dr. MOTONO Ichio, Executive Directo of OCDI) ➢ Guideline for maintenance and repair of the port facilities (Mr. KIMURA Kazumasa, Senior researcher of OCDI)) ➢ Technical standards for port facilities on global warming, (Dr. YAGYU Tadahiko, Visiting advisor of OCDI) ➢ Port design standards on earthquakes (Dr. SUGANO Takahiro, senior advisor of Port and Airport Research Institute)

8.2 The Second Seminar

At the second seminar, titled “Dissemination seminar on port resilience strategy”, the advisory team first provided an overview of the study results. They also introduced revisions to Japan's port technical standards in response to global warming, as well as measures for enhancing resilience against earthquakes and tsunamis. In addition, they invited Professor Shibasaki from the University of Tokyo as a guest speaker to present an analysis of maritime transport policies based on simulations of international container flows in the Pacific Island countries.

Table 8.2-1 Outline of the Second Seminar

Date and Time	June 10 and 11, 2025, 11:00 a.m. to 3:00 p.m. (Fiji time)
Target Organization	All port administrators, operators, cargo handling and warehousing companies, etc. in all target ports
Target Participants	Disaster prevention and crisis management personnel at target organizations and companies
Topics	➢ Outline of the study results by Dr. MOTONO ➢ Port design for global warming by Mr. FUJII ➢ Earthquake and Tsunami resilience in port structure by Mr. KIMURA ➢ Port resilient strategy in Tuvalu by Mr. OTAKE ➢ Port resilience strategy in Tonga by Mr. OTAKE ➢ Simulating International Maritime Container Flows in the Pacific Islands Countries for Maritime Transport Policy Analysis by Mr. MAGOTA, Dr. SHIBASAKI, The University of Tokyo ➢ Port resilience strategy in Fiji by Mr. FUJII ➢ Port resilience strategy in Samoa by Mr. KIMURA ➢ Port resilience strategy in Vanuatu by Mr. FUJII ➢ Port resilience strategy in Solomon Islands by Mr. FUJII

The details of the second seminar and the list of participants are as shown below.

(1) Agenda for the Second Seminar

Agenda

10th Day First	**10th of June**
10:30	Registration
11:00	**1.** Welcome Remarks Mr. WAKASUGI, Satoshi, Resident Representative, JICA Fiji Office
11:05	**2.** Opening Remarks Mr. Jens Kruger, Deputy Director Ocean and Maritime, SPC
11:10	**3.** Outline of the study results by Dr. MOTONO
11:40	**4.** Port design for global warming by Mr. FUJII
12:00	**5.** Earthquake and Tsunami resilience in port structure by Mr. KIMURA
12:20	**6.** Port resilient strategy in Tuvalu by Mr. OTAKE
12:35	**7.** Port resilience strategy in Tonga by Mr. OTAKE
12:50	Q & A session
13:10 – 15:00	Networking with Lunch
11th Day Second	
10:45	Registration
11:00	**1.** Simulating International Maritime Container Flows in the Pacific Islands Countries for Maritime Transport Policy Analysis by Mr. MAGOTA, Dr. SHIBASAKI, The University of Tokyo
11:30	**2.** Port resilience strategy in Fiji by Mr. FUJII
11:45	**3.** Port resilience strategy in Samoa by Mr. KIMURA
12:00	**4.** Port resilience strategy in Vanuatu by Mr. FUJII
12:15	**5.** Port resilience strategy in Solomon Islands by Mr. FUJII
12:30	Q & A session
12:50	**6.** Closing Remarks
13:00 – 15:00	Networking with Lunch

(2) List of Participants

List of Participants

No.	Names	Organization
Online		
1	Adora Misikea	Niue Maritime
2	Alfred Vaka	JICA – Tonga
3	Chatanantavet Pailin	ECOH
4	Ono Nobuyuki	ECOH
5	Florence Nand	Fiji Ports
6	Geroge Rausi	SIPA
7	Helmer Marmar Lejjena	Ports Authority - Marshall Islands
8	Hiroko Takegami	JICA Vanuatu Office
9	Kelela Tonga	Ministry of Marine and Port Tonga
10	JICA Tonga Office	JICA Tonga
11	PNG Ports Corporation	PNG
12	Thomas Maddison	Marshall Islands
13	Ryuichi Shibasaki	University of Tokyo
14	Lute Tamalii Mundia	Samoa Ports Authority
15	Okazaki Hiroyuki	JICA Solomon Islands
16	Ryosuke Sakai	ECOH
17	Robson Tari	Vanuatu, Department of Ports and Harbor
18	Amelia Bola	SPC
19	Tetsuji Nakasone	JICA Samoa
20	Alo Maileseni	Tonga Ports
21	Upali De Zoysa	Fiji Ports
22	Vajira Piyasena	Fiji Ports
23	Hibito Magota	University of Tokyo
24	Ito Yuji	JICA Fiji
25	Kentaro Suekane	JICA Fiji
26	Satoshi Wakasugi	JICA Fiji
27	Koichi Miyake	OCDI
28	Mavis Joseph	SPC
29	Faranisese Kinivuwai	SPC
30	Pohnpei Port Authority	Federated States of Micronesia
31	Blackview Wave	(TBC)
32	Mori Hirotsugu	OCDI

In- Person		
33	Ichio Motono	OCDI
34	Takeshi Otake	OCDI
35	Nobushige Fujii	OCDI
36	Kazumasa Kimura	OCDI
37	Krishnit Charan	Fiji Ports
38	Satoshi Wakasugi	JICA Fiji
39	Jens Kruger	SPC
40	Yuji Ito	JICA Fiji
41	Tomasi Sauqaqa	Fiji Ports
42	Ryuichi Shibasaki	University of Tokyo
43	Hibito Magota	University of Tokyo
44	D. Upali De Zoysa	Fiji Ports
45	Vajira Piyasena	Fiji Ports
46	Sitalingi Payne	SPC
47	Elenoa Rokodi	SPC

(3) Photos of the Second Seminar

The following are photos taken during the Second Seminar.

<table>
<tr><td colspan="3">  </td></tr>
<tr><td colspan="3">Web participants shooting screen (Participants in web camera)</td></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Presenter 1: Dr. Ichio MOTONO
(Executive Director, OCDI)</td><td>Presenter 2: Mr. Nobushige FUJII
(Senior researcher, OCDI)</td><td>Presenter 3: Mr. Kazumasa KIMURA
(Senior researcher, OCDI)</td></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Presenter 4: Mr. Takeshi OTAKE
(Senior researcher, OCDI)</td><td>Presenter 5: Dr. Ryuichi SHIBASAKI
(Associate Professor,
The University of Tokyo)</td><td>Presenter 6: Mr. Hibito MAGOTA
(Faculty of Engineering,
The University of Tokyo)</td></tr>
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