# The Commonwealth of the Northern Mariana Islands

# Final Post Disaster Watershed Plan

July 2022

US Army Corps of Engineers ®
Honolulu District

*DISCLAIMER: The information presented in this report is to provide a strategic framework of potential options to address problems within the Commonwealth of the Northern Mariana Islands, specifically Saipan, Tinian, and Rota. Options identified will follow normal authorization and budgetary processes of the appropriate agencies. Any costs presented are rough order magnitude estimates used for screening purposes only.*

Cover photo courtesy of the Commonwealth of the Northern Mariana Islands Office of the Governor.

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## Acronyms

| | |
|---|---|
| ALE | Agricultural Land Easements |
| ARC | American Red Cross |
| BECQ-DCRM | Bureau of Environmental and Coastal Quality, Division of Coastal Resources Management |
| BECQ-DEQ | Bureau of Environmental and Coastal Quality, Division of Environmental Quality |
| BOR | Bureau of Reclamation |
| BRIC | Building Resilient Infrastructure and Communities |
| CAP | Continuing Authorities Program |
| CDBG | The Community Development Block Grant |
| CNMI | Commonwealth of the Northern Mariana Islands |
| CPA | Commonwealth Ports Authority |
| COTS | Crown-of-thorns starfish |
| CUC | Commonwealth Utilities Corporation |
| DCRM | Division of Coastal Resources Management |
| DHS | U.S. Department of Homeland Security |
| DLNR | Dept. of Land and Natural Resources, CNMI |
| DOE | Dept. of Energy |
| DOI | Dept. of Interior |
| DOT | Dept. of Transportation |
| DPS | Dept. of Public Safety, CNMI |
| DPW | Dept. of Public Works, CNMI |
| EMPG | Emergency Management Performance Grant |
| ENSO | El Niño Southern Oscillation |
| EPA | Environmental Protection Agency |
| ER | Engineer Regulation |
| EQIP | Environmental Quality Incentive Program-Conservation Incentive Contracts |
| ESA | Endangered Species Act |
| EWN | Engineering with Nature |
| FEMA | Federal Emergency Management Agency |
| FPMS | Floodplain Management Services |
| GHG | Greenhouse Gases |
| GIS | Geographic Information System |
| HCP | Habitat Conservation Plan |
| HMGP | Hazard Mitigation Grant Program |
| HPO | Historic Preservation Office, CNMI |
| HSEM | Homeland Security and Emergency Management, CNMI |
| HUD | U.S. Dept. of Housing and Urban Development |
| IIS | International and Interagency Services |
| IRP | Infrastructure and Recovery Program |
| ITEK | Indigenous Traditional Ecological Knowledge |
| IWMP | Integrated Watershed Management Plans |
| IWR | Institute for Water Resources |
| MINA | Mariana Islands Nature Alliance |
| MPA | Marine Protected Areas |

| | |
|---|---|
| NFWF | National Fish and Wildlife Foundation |
| NMFS | National Marine Fisheries Service |
| NNBF | Natural and Nature-Based Features |
| NOAA | National Oceanic and Atmospheric Administration |
| NPS | National Park Service |
| NRCS | Natural Resources Conservation Service |
| NTHMP | National Tsunami Hazard Mitigation Program |
| NWS | National Weather Service |
| OIA | Office of Insular Affairs |
| OPD | Office of Planning and Development |
| PAR | Population at Risk |
| PAS | Planning Assistance to States |
| PCRP | Pacific Coastal Research and Planning |
| PDT | Project Delivery Team |
| PFOA | Perfluorooctanoic Acid |
| PFOS | Perfluorooctane Sulfonate |
| PIRCA | The Pacific Islands Regional Climate Assessment |
| P.L. | Public Law |
| RCPP | Regional Conservation Partnership Program |
| RSLC | Relative Sea Level Change |
| RSLC | Sea Level Rise |
| TAP | Technical Assistance Program |
| UH | University of Hawai'i |
| U.S. | United States |
| USACE | U.S. Army Corps of Engineers |
| USDA | U.S. Dept. of Agriculture |
| USFWS | U.S. Fish and Wildlife Service |
| USGCRP | U.S. Global Change Research Program |
| USGS | U.S. Geological Survey |
| WA | Watershed Assessment |
| WIIN Act | Water Infrastructure Improvement for the Nation Act |
| WRDA | Water Resources Development Act |
| WRE | Wetland Reserve Easements |

# Executive Summary

## Study Authority

Authority for this Watershed Assessment (WA) is provided by Section 729 of the Water Resources Development Act (WRDA) of 1986 (Public Law 99-662), as amended.

## Study Location

The Commonwealth of the Northern Mariana Islands (CNMI) is a United States (U.S.) commonwealth within the Mariana Archipelago in the western Pacific Ocean (see Figure ES-0-1. Map of CNMI). CNMI is comprised of 14 islands with a total land area just under 184 square miles. The geographic scope for this WA includes the islands of Saipan, Tinian, and Rota, the most populous and largest islands in CNMI and where most of the economic activity occurs. Focusing on these three islands allows the WA to most effectively address CNMI's need for community resilience, which aims to ensure critical systems can resist stressors and rebound quickly from shocks or disturbances. The other islands are mostly uninhabited due to limitations like access to education, commercial ports, infrastructure, power, water, food, and natural hazard threats.

CNMI has a warm and humid tropical climate with minimal temperature variation throughout the year. The dry season occurs between the months of December through June and a wet and humid season occurs between July and November. Most of CNMI's heavy rainfall, high winds, storm surge, and coastal flooding are brought by tropical storms. The typhoon season occurs July through January.

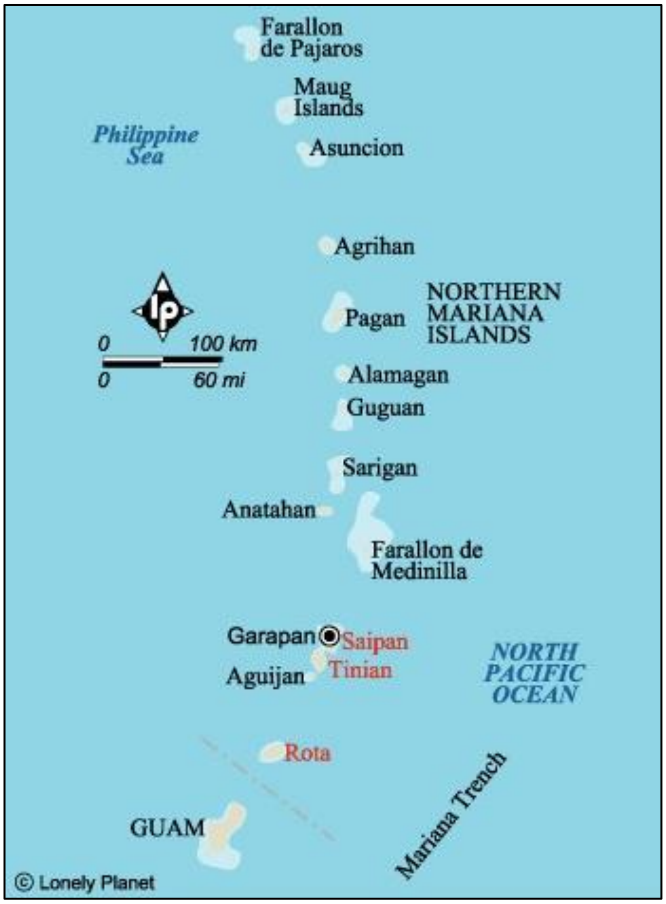



Figure ES-0-1. Map of CNMI

### Study Purpose

Funding for this WA was provided in response to Super Typhoon Yutu, equivalent to a Category 5 hurricane, which struck CNMI in October 2018 and caused widespread damage throughout the islands. The storm resulted in two fatalities and over 100 injuries. There were maximum sustained winds of approximately 180 miles per hour and torrential rain, which led to flooding, power outages, significant damage or destruction to critical infrastructure and buildings, and significant environmental degradation. Super Typhoon Yutu is the strongest recorded typhoon to impact CNMI and the second strongest to strike the U.S. or its territories.

The intent of this WA is to provide recommendations both within and outside of U.S. Army Corps of Engineers (USACE) authorities that will help to rehabilitate and improve the resiliency of damaged infrastructure and natural resources, reducing risks to human life and property from future natural hazards. This WA assessed the drivers of social, life loss, economic, and environmental risks through engagement with the public and other Federal and CNMI agencies, subject matter expert consultation, and research utilizing the most current and applicable reports.

### Problems

A wide range of problems stemming from both anthropogenic and weather-related drivers were identified throughout the study area. The following problem statements and stressors were developed collaboratively with input from study partners, stakeholders, and team subject matter experts:

1. Tropical storms and typhoons cause life safety risks, economic damages, and environmental degradation.
    - *Coastal flooding and inundation of built coastal infrastructure (defined as harbor facilities, roadways, power plants, wastewater treatment plants, and septic systems for this study)* can cause erosion, environmental degradation, and damage to structures, which can result in increased risk to life safety.
    - *Loss of power supply* can occur during and after tropical storm and typhoon activity, impacting thousands of residents island-wide, and sometimes continuing for months after the storm has passed, which can result in increased risk to life safety.
    - *Severe winds* can cause damage to structures and utilities throughout an impacted area, which can result in increased risk to life safety.
    - *Maritime supply chain interruptions* can result from tropical storm and typhoon activity and can increase risk to life safety, cause economic damages, and lead to food security issues.

2. Naturally occurring and anthropogenic stressors, including increased environmental degradation, adversely impact marine ecosystems and infrastructure in coastal areas.
    - *Ocean acidification* can cause degradation of corals, economic damages, and habitat loss.
    - *Increasing water temperatures* can cause degradation of corals, economic damages, and habitat loss.
    - *Coral bleaching* can cause degradation of corals, economic damages, biodiversity and habitat loss.
    - *Relative sea level change (RSLC)* can cause economic damages and result in increased risk to coastal infrastructure and loss of habitat.
    - *Land use practices* can alter vegetative cover, increase fire risk and heat stress, impact drainage patterns and water quality, and result in environmental degradation.
    - *Surface runoff* can cause erosion, convey sediments, and carry pollutants that impact water quality and result in environmental degradation.
    - *Coastal erosion/loss of shoreline* can result in increased risk to coastal infrastructure and habitat loss.
    - *Stormwater management issues* occur when non-conforming or non-existent stormwater management infrastructure causes flooding and transports pollution, sending untreated runoff to near shore waters, degrading water quality and affecting ecosystems.
    - *Loss of living break water* can result in degradation of corals, shoreline vegetation, and near shore vegetation, which serves as natural infrastructure to minimize wave intensity, and results in increased shoreline erosion and economic damages.
    - *Nutrient loading* from land use practices, fires, agriculture, stormwater, and wastewater runoff can lead to algal blooms that can impact coral reef communities and other aquatic habitat.

3. Naturally occurring and anthropogenic stressors, including contamination, adversely impact water quality and supply.
    - *Point and nonpoint source pollution (including stormwater management)* can impact water quality and result in environmental degradation.
    - *Groundwater over pumping* can result in saltwater intrusion and reduction in recharge rates, which impact water quality and reduce water supply.
    - *Unmetered water use* can encourage groundwater over pumping and result in saltwater intrusion and impacts to water quality and water supply.
    - *Saltwater intrusion* can impact water quality and reduce water and food supply.
    - *Water leaks in the distribution system* can encourage groundwater over pumping and result in saltwater intrusion impacts to water quality and reduce water supply.
    - *Drought* can exacerbate saltwater intrusion, impact water quality, and reduce water and food supply.

4. Naturally occurring and anthropogenic stressors increase the risk of inland ecosystem degradation and habitat loss.
    - *Invasive species* can cause habitat loss and impact inland ecosystems.
    - *Wildfires* can lead to deforestation, loss of habitat, spread invasive species, decrease biodiversity, and exacerbate sedimentation.
    - *Land use practices* (including stormwater management) can cause environmental degradation, water quality impacts, and habitat loss.

5. Heavy rainfall events that lead to flooding and erosion can cause life safety risks, economic damages, and environmental degradation.
    - *Flash flooding along low lying and populated areas* can cause safety hazards, property damage, stormwater drainage overflows, inhibit evacuation, and cause ecologically destructive erosion.
    - *Sedimentation* can result in impacts to habitats, waterways, and exacerbate riverine flooding.
    - *Riverine erosion* can result in mudslides, increased risk to life safety, economic damages, and cause environmental degradation.
    - *Riverine flooding* can result in increased risk to life safety and cause environmental degradation and economic damages.

6. Tsunamis cause life safety risks and economic damages throughout CNMI.
    - *Tsunami waves* can cause life safety risks, damage to infrastructure, and flooding of coastal and low-lying areas. Although the probability of tsunamis is low, the consequences are high.

### Opportunities

Opportunities are future desirable conditions that may coincide with the solutions to the identified problems in the study area. The project team identified the following opportunities for this WA:

1. Raise awareness on hazard mitigation through public education and informational campaigns.
2. Promote and support sustainable agricultural and fishing practices.
3. Promote sustainable use of terrestrial and marine ecosystems and support eco-tourism.
4. Halt and reverse habitat degradation and biodiversity loss.

5. Reduce erosive impacts of runoff and associated sedimentation to preserve wetland, aquatic, and cultural resources (medicinal plants, cultural keystone species, and sites).
6. Strengthen power infrastructure and promote energy independence to improve access to potable and palatable water and power reliability.
7. Improve access to inter-island transportation and to affordable commodities through maritime shipping.
8. Improve wastewater systems and reduce nonpoint source pollution.
9. Improve availability and sustainable management of safe and environmentally compliant water supply and sanitation.
10. Promote sustainable consumption and production patterns.
11. Strengthen the means of implementation and support partnerships for sustainable development.
12. Preserve cultural connections to the land and water resources.
13. Improve equity of vulnerable and indigenous populations within communities.

### Study Goal and Objectives

The goal of this WA is to develop a framework to increase CNMI's resilience to weather related hazards and reduce the effects of anthropogenic stressors through a focus on natural and nature-based features, where appropriate. To achieve this goal, the following objectives are identified:

1. Reduce human life loss and injuries resulting from natural hazards.
2. Increase community natural hazard preparedness and effectiveness of hazard mitigation activities.
3. Reduce damages and disruption to public and private property and areas of cultural or community importance, from flooding and coastal erosion throughout CNMI.
4. Restore and protect terrestrial and marine resources throughout CNMI.
5. Increase infrastructure and environmental resiliency to RSLC throughout CNMI.
6. Improve water quality and water supply for residents; increase access to potable and palatable water.
7. Increase access to affordable, reliable, sustainable, and modern energy to residents.
8. Avoid or minimize disruptions to port operations, supply chains, and local businesses.
9. Reduce environmental degradation resulting from disasters in impacted areas.
10. Build and maintain resiliency of natural, built, and human systems through safe, smart growth.

### Stakeholder Engagement

USACE worked in collaboration with the study partner and other stakeholders to develop this WA. The CNMI government, represented by the Office of Planning and Development (OPD) and the Bureau of Environmental and Coastal Quality (BECQ) Division of Coastal Resources Management (DCRM) served as the primary study partner and was instrumental in ensuring collaboration with appropriate agencies and other stakeholders. For the purpose of this WA, a stakeholder is defined as any interested party, to include Federal, territorial, and local agencies. Stakeholders were active participants in the decision-making process.

### Planning Process

The watershed planning process aims to provide a comprehensive and strategic evaluation and analysis that includes diverse geographic, physical, institutional, technical, and stakeholder considerations. A WA may address identified water resources needs from any source, regardless of agency responsibilities, and should inform multiple audiences and decision makers at all levels of government, serving as a strategic roadmap to inform future investment decisions by multiple agencies. The USACE six-step watershed planning process is outlined in red in the following Figure ES-0-2.

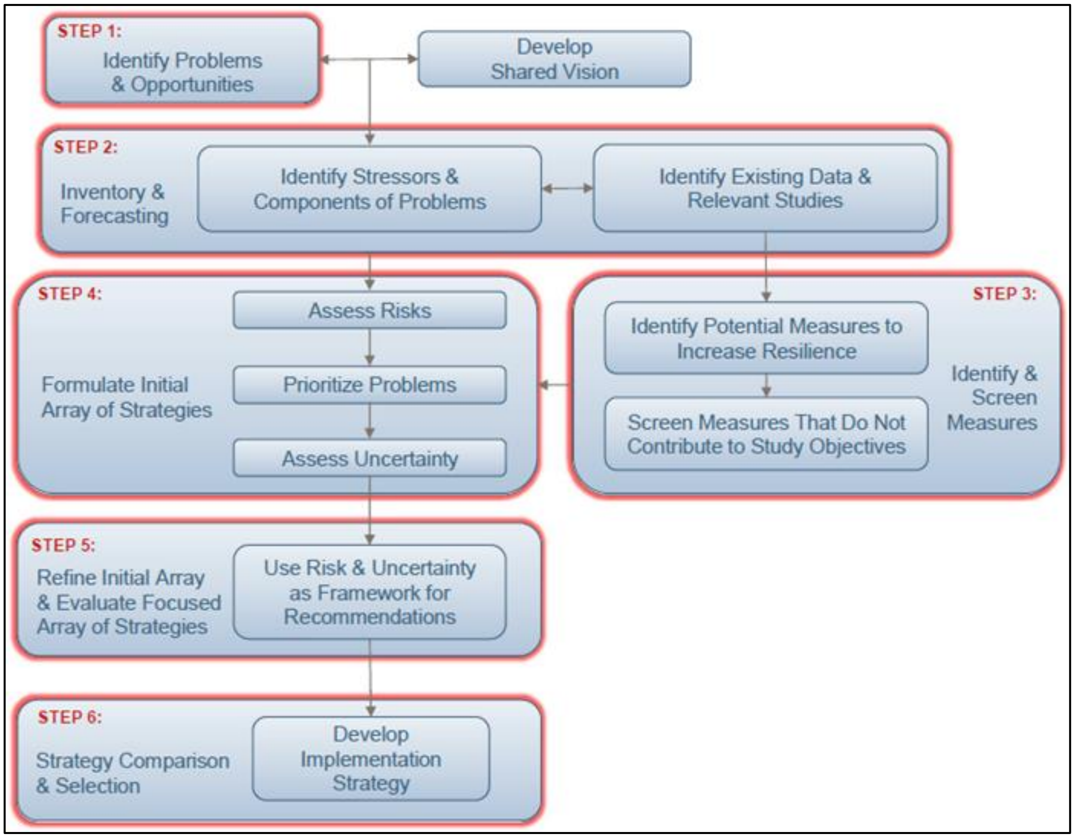
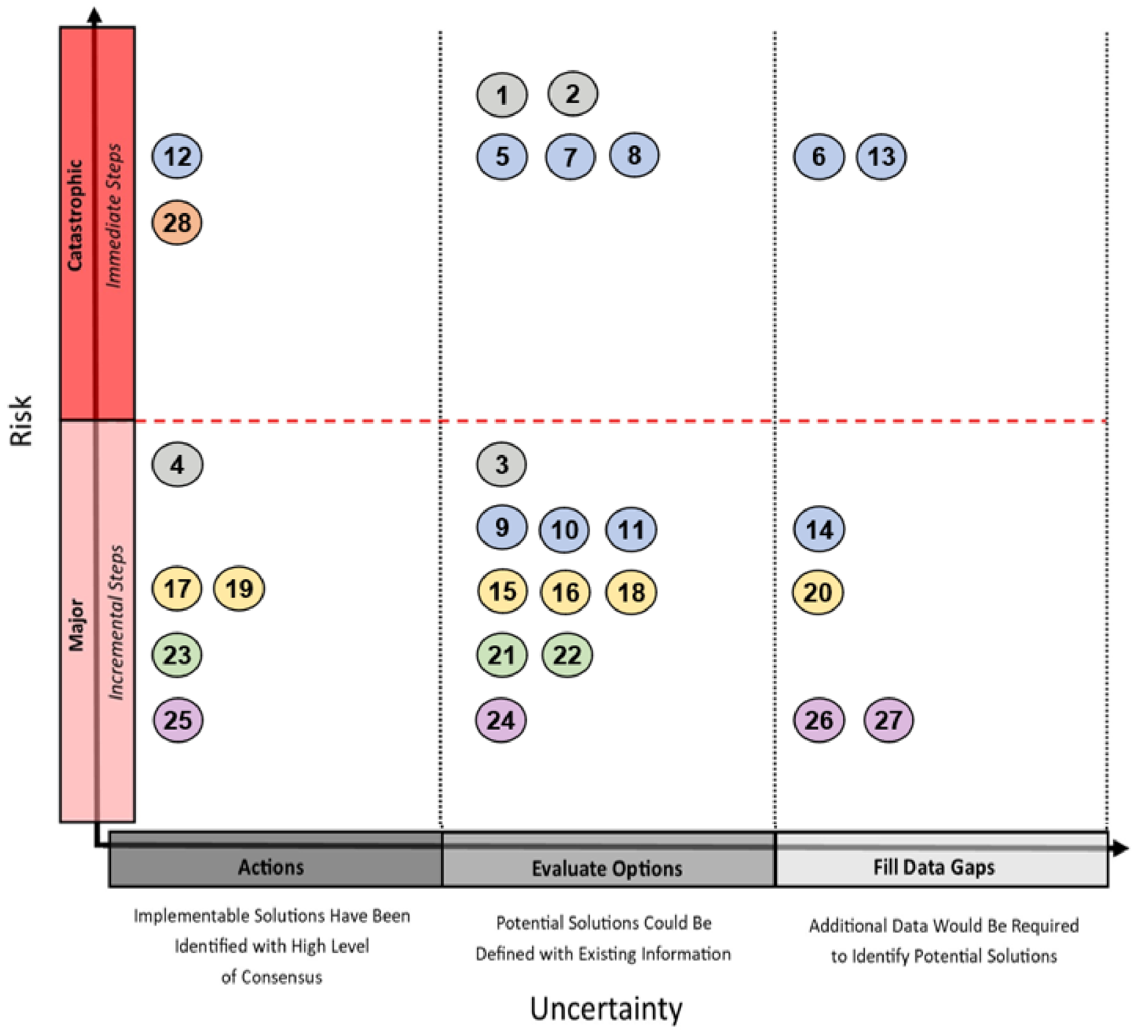



Figure ES-0-2. USACE Six Step Watershed Planning Process

A risk- and uncertainty-based prioritization approach was used to identify potential recommendations to increase resiliency in CNMI within the six-step planning process. After defining the problems and objectives, the USACE team worked closely with stakeholders to identify a set of stressors, or factors that exacerbate vulnerability and hinder resiliency, for each problem category. A risk assessment was then conducted to qualitatively assess each stressor's probability of occurring and the magnitude of its consequence from an economic, social, environmental, and life loss perspective. A qualitative assessment of uncertainty was also performed to identify the level of consensus among stakeholders in implementing potential risk reduction measures for each stressor. The following categories of consensus were developed to frame risk reduction recommendations: actions, evaluate options/further study, and fill data gaps.

Risk and uncertainty results were used to develop a framework for the appropriate recommendations. For social and environmental metrics, the stressors deemed to have catastrophic risks are the ones where permanent impacts have occurred. For economic metrics, these are risks where widespread impacts occur with high frequency. For life loss metrics, highest life loss risks consider the magnitude of potential life loss and the frequency at which the stressor occurs. The range for life loss catastrophic risk spans from frequent events with low magnitude life loss to infrequent events with the potential for high magnitude life loss.

For stressors categorized as catastrophic, near-term steps should be taken to reduce risks through direct actions, evaluating potential options, or filling data gaps, based on the associated solutions' level of uncertainty. All other risks are categorized as "major" or "minor" if they did not possess the highest relative risk, therefore an incremental, or a phased approach, should be taken (or continued) to address those risks. Although some stressors were ranked as minor in individual risk assessments, those stressors were not ranked as minor consistently throughout each risk assessment; therefore, there are no stressors ranked as minor in the overall risk summary plot shown below. For stressors categorized as catastrophic, near-term steps should be taken to reduce risks through direct actions, evaluating potential options, or filling data gaps, based on the associated solutions' level of uncertainty. All other risks are categorized as "major" or "minor" if they did not possess the highest relative risk, therefore an incremental, or a phased approach, should be taken (or continued) to address those risks. Although some stressors were ranked as minor in individual risk assessments, those stressors were not ranked as minor consistently throughout each risk assessment; therefore, there are no stressors ranked as minor in the overall risk summary plot shown below in Figure ES-0-3. For the full risk prioritization process and results, see Chapter 5.




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure ES-0-3. Risk and Uncertainty Assessment

A set of natural or nature-based, non-structural, and structural management measures was developed through synthesizing existing reports and on-going projects in CNMI, gathering stakeholder input, and compiling measures from subject matter experts on the study team. The measures were used to formulate recommendations.

### Recommendations

Recommendations follow the broad outline set forth from the risk and uncertainty assessment results and are made up of a combination of management measures. The team held several coordination meetings with partners and stakeholders, both group and one-on-one sessions, to gain input and concurrence on the recommendations. Valuable insight was provided on the recommendations and on-going efforts/interests this WA could parallel and/or support.

The following recommended strategies are prioritized into near-term strategies (Table ES-0-1) for catastrophic risks and incremental strategies (Table ES-0-2) for major risks. Near-term strategies reduce potentially catastrophic risks while incremental strategies reduce major risks. Each table is further divided into implement, evaluate, and fill data gap options based on the uncertainty assessment results. A suggested timeline of implementation follows each recommendation. Some recommendations have relatively less implementation uncertainty and, therefore, may stray from the standard implementation timeline.

Table ES-0-1. Near-Term Strategies

| Priority | Stressor | Recommendation Focus Area | 0-5 years | 5-10 years | 10+ years |
|---|---|---|---|---|---|
| *Near-Term Actions* | Stormwater Management | Engineering with Nature | Implement | – | – |
| | | Drainage System Improvements | Implement | – | – |
| | Tsunamis | Education and Outreach | Implement | – | – |
| | | Risk Analysis | Implement | – | – |
| | | Emergency Preparedness | Implement | – | – |
| | | Policy/Improved Land Use Planning | Implement | – | – |
| *Near-Term Evaluation of Options* | Coastal Flooding and Inundation of Coastal Infrastructure | Ecosystem Restoration | Evaluate | Implement | – |
| | | Beach Enhancement | Implement | – | – |
| | | Risk Analysis | Evaluate | Implement | – |
| | | Emergency Preparedness | Implement | – | – |
| | | Education and Outreach | Implement | – | – |
| | | Flood Protection Study | Evaluate | Implement | – |
| | | Critical Infrastructure Protection | Evaluate | Implement | – |
| | | Policy | Implement | – | – |
| | | Diversify Energy Sources | Implement | Implement | – |

| Priority | Stressor | Recommendation Focus Area | 0-5 years | 5-10 years | 10+ years |
|---|---|---|---|---|---|
| | RSLC, Coral Bleaching, and Ocean Acidification | Ecosystem Restoration | Evaluate | Implement | – |
| | | Ecosystem Protection | Evaluate | Implement | – |
| | | Beach Enhancement | Implement | – | – |
| | | Emergency Preparedness | Implement | – | – |
| | | Policy / Improved Land Use Planning | Evaluate | Implement | – |
| | | Education and Outreach | Evaluate/ Implement | – | – |
| | | Flood Protection Study | Evaluate | Implement | – |
| | | Structural Enhancements and Processes | Evaluate | Implement | – |
| | | Critical Infrastructure | Evaluate | Implement | – |
| *Data Gaps to be Filled in the Near-Term* | Increasing Water Temperatures, Loss of a Living Break Water | Ecosystem Restoration | Fill Data Gaps/ Evaluate | Evaluate/ Implement | Implement |

Table ES-0-2. Incremental Strategies

| Priority | Stressor | Recommendation Focus Area | 0-10 years | 10-15 years | 15+ years |
|---|---|---|---|---|---|
| *Incremental Actions* | Maritime Supply Chain Interruptions | Emergency Preparedness | Implement | – | – |
| | | Alternative Docking Locations | Implement | – | – |
| | | Weather Forecasting | Implement | – | – |
| | | Critical Infrastructure Protection | Implement | Implement | – |
| | Unmetered Water Use, Water Leaks in the Distribution System | Ecosystem Restoration | Evaluate | Implement | – |
| | | Education and Outreach | Implement | – | – |
| | | Enhanced Water Supply Management | Implement | Implement | – |
| | | Policy | Implement | Implement | – |
| | | Structural Enhancement | Implement | Implement | Implement |
| | | Ecosystem Restoration | Evaluate | Implement | – |

| Priority | Stressor | Recommendation Focus Area | 0-10 years | 10-15 years | 15+ years |
|---|---|---|---|---|---|
| | Land Use Practices (Inland) | Engineering with Nature | Evaluate | Implement | – |
| | | Policy/Improved Land Use Planning | Implement | Implement | – |
| | | Risk Analysis | Evaluate | Implement | – |
| | | Education and Outreach | Implement | – | – |
| | | Community Services | Implement | Implement | – |
| | Riverine Sedimentation | Ecosystem Restoration | Evaluate | Implement | – |
| | | Sheer Stress Analysis | Evaluate | Implement | – |
| | | Training | Implement | Implement | – |
| | | Policy/Improved Land Use Planning | Implement | Implement | – |
| | | Drainage System Improvements | Evaluate | Implement | Implement |
| *Incremental Evaluation of Options* | Severe Winds | Emergency Preparedness | Implement | Implement | – |
| | | Policy | Evaluate | Implement | Implement |
| | Land Use Practices (Coastal), Surface Runoff, Coastal Erosion/Loss of Shoreline | Ecosystem Restoration | Evaluate | Implement | Implement |
| | | Engineering with Nature | Evaluate | Implement | Implement |
| | | Beach Enhancement | Evaluate | Implement | Implement |
| | | Drainage System Improvements | Evaluate | Implement | Implement |
| | | Policy/Improved Land Use Planning | Evaluate/ Implement | Implement | Implement |
| | | Engagement and Outreach | Evaluate/ Implement | Implement | Implement |
| | | Erosion Analysis | Evaluate | Implement | Implement |
| | | Structural Enhancements | Evaluate | Implement | Implement |
| | Point/Nonpoint Source Pollution, Groundwater Over Pumping, Saltwater Intrusion | Training and Education | Evaluate/ Implement | Implement | Implement |
| | | Engineering with Nature | Evaluate | Implement | Implement |
| | | Policy/Improved Land Use Planning | Evaluate/ Implement | Implement | Implement |
| | | Alert System | Evaluate/ Implement | Implement | Implement |
| | | Community Services | Evaluate/ Implement | Implement | Implement |
| | | Septic System Analysis | Evaluate | Implement | Implement |
| | | Structural Enhancements | Evaluate | Implement | Implement |

| Priority | Stressor | Recommendation Focus Area | 0-10 years | 10-15 years | 15+ years |
|---|---|---|---|---|---|
| | Invasive Species, Wildfires | Ecosystem Restoration | Evaluate | Implement | Implement |
| | | Emergency Preparedness | Evaluate/ Implement | Implement | Implement |
| | | Wildfire Prevention | Evaluate | Implement | Implement |
| | | Community Engagement | Evaluate | Implement | Implement |
| | | Policy | Evaluate/ Implement | Implement | Implement |
| | Flash Flooding Along Low Lying and Populated Areas | Ecosystem Restoration | Evaluate | Implement | Implement |
| | | Engineering With Nature | Evaluate | Implement | Implement |
| | | Drainage System Improvements | Evaluate | Implement | Implement |
| | | Education & Outreach | Evaluate/ Implement | Implement | Implement |
| | | Risk Analysis | Evaluate | Implement | Implement |
| | | Flood Protection Study | Evaluate | Implement | Implement |
| | | Policy | Evaluate/ Implement | Implement | Implement |
| | | Real-Time Gaging Networks | Evaluate | Implement | Implement |
| | | Structural Enhancements | Evaluate | Implement | Implement |
| *Data Gaps to be Filled in Incremental Steps* | Nutrient Loading | Policy | Fill Data Gaps | Evaluate | Implement |
| | | Septic System Analysis and Repairs | Fill Data Gaps | Evaluate | Implement |
| | | Stream Monitoring | Fill Data Gaps | Evaluate | Implement |
| | Drought | Drought Planning | Fill Data Gaps | Evaluate | Implement |
| | | Structural Enhancements | Fill Data Gaps | Evaluate | Implement |
| | Riverine Erosion, Riverine Flooding | Hydrology and Hydraulics Analysis | Fill Data Gaps | Evaluate | Implement |
| | | Engineering with Nature | Fill Data Gaps | Evaluate | Implement |
| | | Real-Time Gaging Networks | Fill Data Gaps | Evaluate | Implement |
| | | Flood Protection Study | Fill Data Gaps | Evaluate | Implement |
| | | Critical Infrastructure Protection | Fill Data Gaps | Evaluate | Implement |

# 1 Study Information

## 1.1 Study Authority

Authority for this Watershed Assessment (WA) is provided by Section 729 of the Water Resources Development Act (WRDA) of 1986 (Public Law (P.L) 99-662, title VII, Section 729), as amended, which authorizes the U.S. Army Corps of Engineers (USACE) to:

> *"Assess the water resources needs of river basins and watersheds of the United States including needs related to –*
> *(1) ecosystem protection and restoration;*
> *(2) flood damage reduction;*
> *(3) navigation and ports;*
> *(4) watershed protection;*
> *(5) water supply;*
> *(6) and drought preparedness."*

## 1.2 Federal Interest

There is Federal interest in the WA to investigate strategies to increase community resilience from post-disaster effects in the Commonwealth of the Northern Mariana Islands (CNMI or Commonwealth).

## 1.3 Purpose & Scope

Funding for this WA was provided in response to Super Typhoon Yutu, equivalent to a Category 5 hurricane, which struck CNMI in October 2018 and caused widespread damage throughout the islands. The storm resulted in two fatalities and over 100 injuries. There were maximum sustained winds of approximately 180 miles per hour and torrential rain, which led to flooding, power outages, significant damage or destruction to critical infrastructure and buildings, and significant environmental degradation. Yutu is the strongest recorded typhoon to impact CNMI and the second strongest to strike the U.S. or its territories.

The intent of this WA is to provide recommendations both within and outside of USACE authorities that will help to rehabilitate and improve the resiliency of damaged infrastructure and natural resources, reducing risks to human life and property from future natural hazards in CNMI. It incorporates available information related to recent storm damages from Super Typhoon Yutu, as well as other past storms that had a major impact on CNMI. The WA assessed the drivers of social, life loss, economic, and environmental risks through engagement with the public and other Federal and CNMI agencies, subject matter expert consultation, and research with the most recent reports available.

## 1.4 Shared Vision Planning Process

The shared vision statement, shown below, encompasses the perspectives of study stakeholders and was used as the basis for the development of planning objectives, per Engineer Regulation (ER) 1105-2-102. The shared vision statement was developed in collaboration with local stakeholders and was endorsed by CNMI. A memorandum for record (MFR) was signed by USACE on February 4, 2021, documenting the successful completion of the Shared Vision Milestone meeting on January 26, 2021. The shared vision statement is as follows:

*"To counter vulnerability to weather and water related hazards, increasing resiliency through social, economic, and environmentally sustainable development is imperative and can be accomplished by planning for natural hazards, protecting infrastructure, and conserving resources. This watershed assessment, focusing on the three most populous islands of Saipan, Tinian, and Rota, envisions a future CNMI where residents can safely weather storms and rebound with revitalized infrastructure to provide improved water supply and sanitation, reliable energy supplies and distribution, and sustainable localized agriculture and economic development. It is a future where marine and terrestrial ecosystems are restored and used sustainably, and biodiversity and cultural resources are preserved while action is taken to combat climate change."*

## 1.5 Study Background & Location

The Commonwealth of the Northern Mariana Islands, also known as Sankattan Siha Na Islas Mariånas in Chamorro, is a U.S. Commonwealth within the Mariana Archipelago in the western Pacific Ocean. CNMI is comprised of 14 islands with a total land area just under 184 square miles (Figure 1-1). The majority of CNMI's 47,000 residents reside on the islands of Saipan, Tinian, and Rota at the southern end of the archipelago. The indigenous cultural group on CNMI and Guam are the Chamorro (Chamoru) people who settled on the islands around 4,000 years ago. By the 17$^{th}$ century, CNMI was occupied by the Spanish, which was soon followed by German possession starting in 1899 and Japanese mandates and settlement during World War I and II. After Japan's defeat in World War II, the Northern Marianas emerged as the Commonwealth of the Northern Mariana Islands from the Trust Territory of the Pacific Islands, which the U.S. administered as a trustee. It wasn't until 1975 that CNMI become a U.S. territory through Public Law 94-241 (90 Stat.263) (the Covenant), eventually adopting its own constitution in 1977 and first constitutional government in 1978. The Chamorro, Carolinians, and other Pacific Islander groups make up around 34.9% of CNMI's population and roughly 49.9% falls under the Asian ethnic group, which includes Filipino, Chinese, and Korean residents.

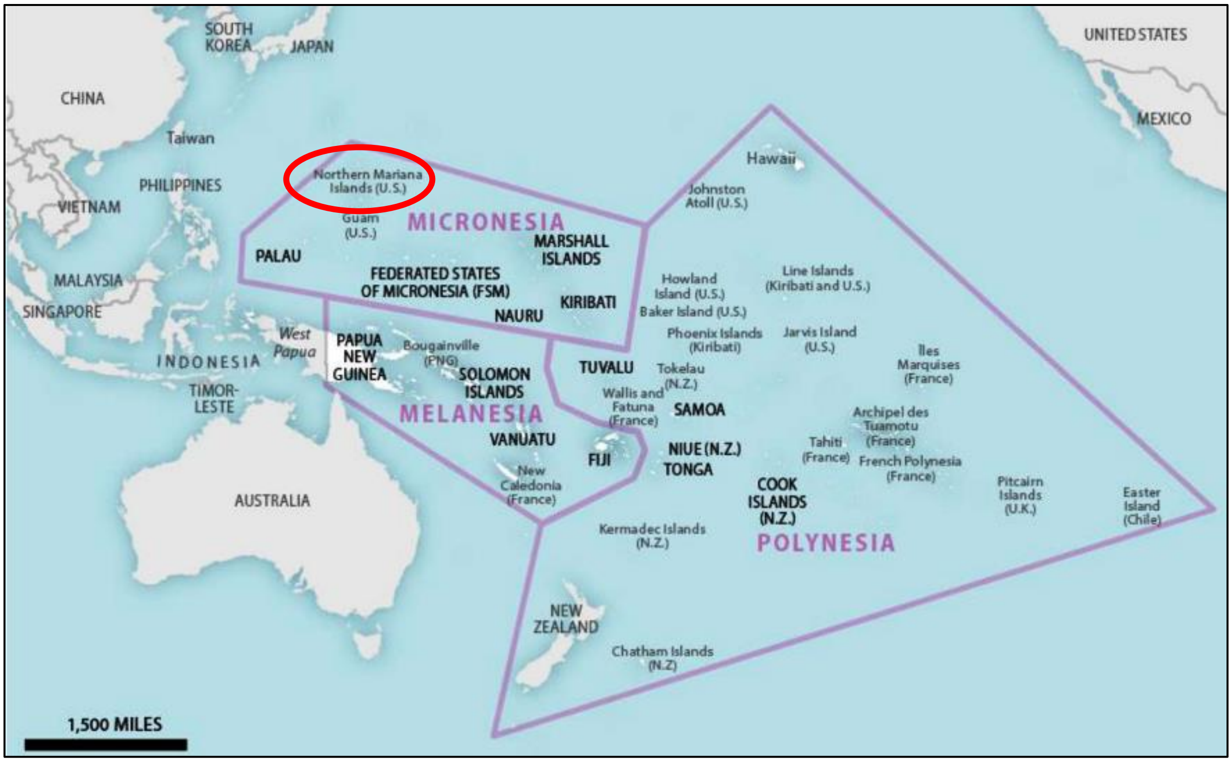



Figure 1-1. Location of CNMI (Source: Congressional Research Office)

According to the 2020 census, Saipan has a population of approximately 43,000 (land area of 46 square miles); Tinian has a population of approximately 2,000 (land area of 39 square miles); Rota has a population of approximately 2,000 (land area of 33 square miles); and the remaining 11 islands have a population of seven (land area of 60 square miles) (U.S. Census Bureau, 2020).

The geographic scope for this WA includes the islands of Saipan, Tinian, and Rota the most populous and largest islands in CNMI (Figure 1-2). Focusing on these three islands allows the WA to most effectively address CNMI's need for community resilience, which aims to ensure that critical systems can resist stressors and rebound quickly from shocks or disturbances. The other islands are mostly uninhabited due to limitations like access to education, commercial ports, infrastructure, power, water, and food, and natural hazard threats.

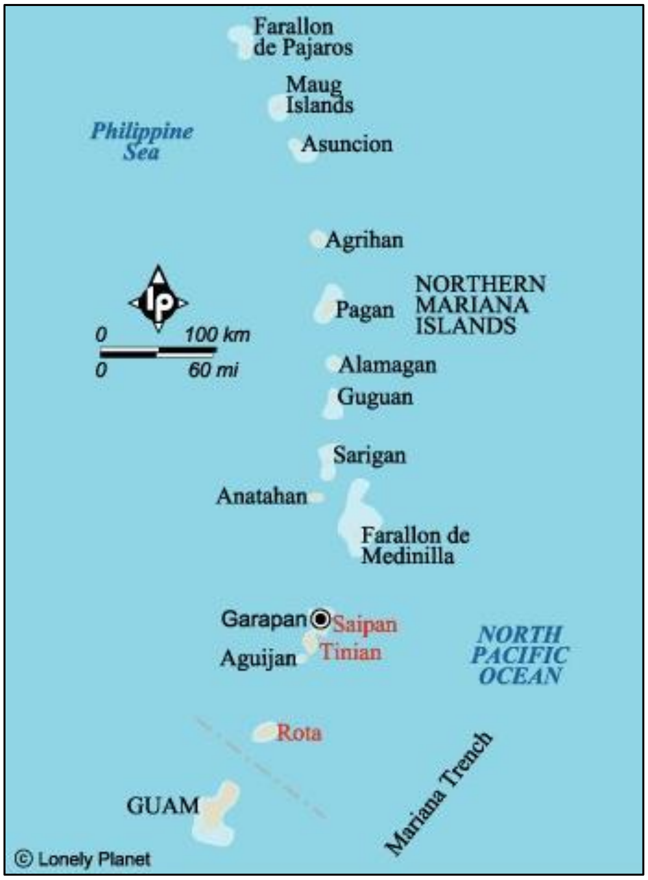


Figure 1-2. Study Area Comprised of Saipan, Tinian, and Rota

CNMI has a warm and humid tropical climate with minimal temperature variation throughout the year, with an average temperature of 84° F. The dry season occurs between the months of December and June and a wet and humid season occurs between July and November. The mean annual precipitation is 69.6 inches. Annual precipitation averages and intensities have remained relatively constant over time, but CNMI is expected to experience greater extremes in rainfall (intensification) as well as droughts in the future (NOAA et al., 2021; V.W. Keener et al., 2013). Most of CNMI's heavy rainfall, high winds, storm surge, and coastal flooding are brought by tropical storms. The typhoon season typically occurs July through January; however, typhoons have occurred in April and May.

CNMI is comprised of four municipalities: Saipan, Tinian, Rota, and the Northern Islands, which includes the remaining 11 islands. Most of CNMI's economic activity occurs on Saipan, Tinian, and Rota due to population distribution. The Chamorro people have cultural and traditional connections and activities related to the land, its resources, and waters across all three islands. Following the closure of several garment factories in the early 2000s, the manufacturing industry began to decline, while the hospitality and tourism industries increased. Today, the CNMI's 'ocean economy' includes tourism, fishing, and recreation sectors, and accounts for almost half of the Commonwealth's total employment. These activities bring in roughly $922 million annually (NOAA, 2020).

# 2 Interagency & Public Alignment

Watershed studies are intended to produce more comprehensive evaluations that include diverse stakeholder considerations. Given the broad and inclusive nature of watershed studies, interagency alignment was critical for effective study execution.

Two months after this study initiated, the COVID-19 pandemic struck the world and redefined how interagency partners engage and collaborate with each other. As a result, the study team relied almost entirely on virtual interactions across four time zones and for some, a 15-hour time difference. Unable to go on a site visit early in the project, the study team communicated often with our partner and stakeholders to better understand the study area. As the study progressed, interagency alignment and concurrence was obtained throughout the study process, from scoping the study to prioritizing actions.

In March 2022, the opportunity for a site visit became possible and the team visited Saipan, Tinian, and Rota. During this time, a series of in-person meetings were held with both local and Federal agencies to share study updates, listen to local concerns and input, and ground truth the work to-date. To better understand the islands' geography and issues, the team visited coastal, cultural, and inland sites.

## 2.1 Stakeholder Engagement

USACE worked in collaboration with the study partner and other stakeholders to develop the WA. The CNMI government, represented by the Office of Planning and Development (OPD) and the Bureau of Environmental and Coastal Quality (BECQ) Division of Coastal Resources Management (DCRM) served as the primary study partner and was instrumental in ensuring collaboration with appropriate agencies and other stakeholders. For the purpose of this WA, a stakeholder is defined as any interested party, to include Federal, territorial, and local agencies. Stakeholders were active participants in the decision-making process (Table 2-1 and Table 2-2) and were provided the opportunity to comment on the draft report when it was released for public and interagency review.

USACE organized and/or participated in the following recurring meetings:

- **Stakeholder Meetings** were organized and led by USACE. The purpose of these ad-hoc meetings was to obtain stakeholder input and concurrence on the watershed study planning process.

- **The Water and Power Interagency Working Group** was organized and led by USACE. Monthly meetings offered a platform for Federal Agencies with a footprint in CNMI to discuss water and power issues and provide updates on ongoing Federal projects.

- **The Watershed Working Group** was organized and led by DCRM. During these monthly meetings, CNMI stakeholders provided updates on ongoing Watershed Management Plans.

- **Yutu Interagency Coordination Meetings** were organized and led by the Federal Emergency Management Agency (FEMA), as part of the Major Disaster Declaration

(4404) Mission. Federal agencies with ongoing recovery projects in CNMI provided updates during these monthly meetings.

More information on the meetings led by USACE, including participants, dates, meeting purpose, meeting summary, and slides can be found in Appendix A: Interagency Alignment.

### 2.1.1 Local Partner and Stakeholders

For this study, local partners included several government agencies in CNMI with subject matter expertise in their mission area shown in Table 2-1. These agencies participated in stakeholder meetings to provide input, refine our planning process, and review progress in the study. The following agencies and local non-profit organizations were active participants in stakeholder meetings and were instrumental in the overall development of the study.

- **BECQ, DCRM's** mission is to protect and enhance the CNMI's coastal resources for residents and visitors through effective and adaptive resource management, interagency collaboration, and stakeholder engagement, in a manner that builds and sustains community resilience and well-being.

- **Office of Planning and Development (OPD)** is located within the Office of the Governor and was established in 2017 to provide short- and long-term guidance on economic, infrastructure, and physical development of CNMI. OPD assists other local agencies to harmonize and improve planning efforts and assists in implementation of comprehensive planning activities at all levels of government.

- **BECQ, Division of Environmental Quality (DEQ)** works under BECQ to serve the public through wise management of CNMI natural resources, and by supporting healthy communities, a sustainable environment, and a vibrant economy.

- **CNMI Historic Preservation Office (HPO)** promotes the preservation of the historic and cultural heritage of the Northern Mariana Islands and prohibits the destruction of historic properties, including the looting of artifacts and cultural material across the commonwealth.

- **Commonwealth Utilities Corporation (CUC)** is a state government corporation that operates the electric power, water and wastewater services on Saipan, Tinian, and Rota.

- **Commonwealth Ports Authority (CPA)** manages and operates all the airports and seaports throughout the Northern Marianas.

- **Pacific Coastal Research & Planning (PCRP)** is a small non-profit group based in CNMI that's devoted to better understanding and improving coastal environments in the Pacific Region. Their work includes environmental planning, geospatial analysis & mapping, fisheries management, marine monitoring and research, and coastal hazard mitigation.

- **Mariana Islands Nature Alliance (MINA)** is a community-based, nonprofit organization that fosters community watch and outreach efforts to achieve CNMI's long-term goals for a sustainable future.

Table 2-1. CNMI Watershed Assessment Local Partner and Stakeholder Expertise

| Organization | Purview | | | |
|---|---|---|---|---|
| | Flooding/ Storm Risk | Water Quality | Environmental | Energy |
| **Local Agencies** | | | | |
| OPD | ✓ | ✓ | ✓ | ✓ |
| BECQ-DCRM | ✓ | ✓ | ✓ | – |
| BECQ-DEQ | ✓ | ✓ | ✓ | – |
| HPO | – | – | ✓ | – |
| CUC | – | ✓ | – | ✓ |
| CPA | ✓ | – | – | – |
| PCRP | ✓ | – | ✓ | – |
| MINA | – | – | ✓ | – |
| Office of the Mayor of Tinian | ✓ | ✓ | ✓ | ✓ |
| Office of the Mayor of Rota | ✓ | ✓ | ✓ | ✓ |
| Office of the Mayor of Saipan | ✓ | ✓ | ✓ | ✓ |

### 2.1.2 Federal Stakeholders

A Federal recovery effort consisting of multiple agencies is unfolding to address longstanding needs in CNMI that were exacerbated by Super Typhoon Yutu in 2018. Following the event, Federal agencies, including FEMA, U.S. Department of Housing and Urban Development (HUD), U.S. Environmental Protection Agency (EPA), and others were allocated hundreds of millions of dollars in funding to support recovery efforts in the near- and long-term, particularly in the areas of water management, power infrastructure, housing, and education. In fact, this study was funded by Congress in response to Super Typhoon Yutu. As such, coordination between Federal stakeholders continues to be crucial to leverage resources, streamline projects, and reduce the overall burden on CNMI caused by the sudden influx of projects to the islands.

As part of the Federal coordination effort, FEMA held monthly Yutu Interagency Coordination meetings where Federal agencies provided updates on ongoing projects. Active participants included FEMA, EPA, HUD, U.S. Department of Energy (DOE) and USACE. These meetings provided the opportunity for Federal agencies to gain a comprehensive understanding of the Federal project portfolio in CNMI, while encouraging discussion to identify gaps and leverage resources. USACE provided monthly briefings on the watershed study and regularly communicated with relevant agencies to advance the study.

One of the gaps identified in the interagency meetings was the need to have more robust discussion on water and power issues in CNMI. As a result, USACE organized and led monthly Water and Power Working Group meetings. These meetings provided a forum for agencies to brainstorm how to address water resources issues and power infrastructure challenges, while leveraging ongoing projects.

FEMA provided a FEMA Project Tracker, which compiled recovery projects supported by Federal agencies. This WA used the FEMA Project Tracker to inform the Implementation Strategy of this study.

Additionally, in accordance with Section 729 of WRDA 1986 (P.L. 99-662), as amended, USACE sent cooperation letters to the EPA, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Natural Resources Conservation Service (NRCS), CNMI Historic Preservation Office (HPO), and National Park Service (NPS). All required Federal agencies provided email responses expressing continued interest and cooperation from all required Federal agencies. Table 2-2 shows a complete list of all the Federal stakeholders engaged in the WA project.

Table 2-2. CNMI Watershed Assessment Federal Expertise

| **Organization** | **Purview** | | | |
|---|---|---|---|---|
| | **Flooding/ Storm Risk** | **Water Quality** | **Environmental** | **Energy** |
| **Federal Agencies** | | | | |
| USACE* | ✓ | ✓ | ✓ | – |
| EPA** | – | ✓ | ✓ | – |
| Dept. of Interior (DOI)**<br>• USFWS<br>• NPS<br>• Office of Insular Affairs (OIA)<br>• U.S. Geological Survey (USGS) | ✓ | ✓ | ✓ | – |
| Dept. of Agriculture (USDA)**<br>• NRCS | – | ✓ | – | – |
| Dept. of Commerce**<br>• NMFS<br>• National Oceanic and Atmospheric Administration (NOAA)<br>• Economic Development Administration | – | – | ✓ | – |
| Federal Emergency Management Agency (FEMA)<br>• Region IX<br>• Pacific Area Office<br>• FEMA Recovery DR-4404 | ✓ | ✓ | – | – |
| U.S. Bureau of Reclamation (BOR) | ✓ | – | – | – |
| DOE | – | – | – | ✓ |
| HUD | ✓ | ✓ | ✓ | – |
| Dept. of Transportation (DOT) | ✓ | – | – | – |

*USACE may investigate each of these three focus areas under various programs (see section 6.3); however, the ability to implement projects will vary depending upon alignment with USACE primary mission areas of flood risk management, coastal storm risk management, ecosystem restoration, and navigation.
**Required by Section 729 of WRDA 1986, as amended.

## 2.2 The Public

During the March 2022 site visit, the team coordinated with local agency public affairs offices on Saipan, Tinian, and Rota to post a public notice announcing the release of the draft report in early March 2022 and a 45-day public review and comment period. Initial plans to organize public meetings and engage directly with local communities during the site visit were advised against due to the ongoing COVID-19 pandemic.

## 2.3 Current and Future Initiatives

CNMI continues to recover from Typhoon Yutu. Both local and Federal entities have invested and continue to invest significant funding and human capital in projects and initiatives to increase natural hazard resiliency. Table 2-3 and Table 2-4 summarize ongoing and planned Federal and local projects.

Table 2-3. Current and Future Federal Projects

| Problem | Project | Description | Agency |
|---|---|---|---|
| **Flood** | CNMI Silver Jackets Team | Local agency-led teams exist in all states and several territories, bringing together multiple state, Federal, and sometimes tribal and local agencies to learn from one another in reducing risk from floods and other natural hazards. | Multiple |
| **Flood** | CNMI Coastal Study (Source: FEMA, 2021) | This study provides new and updated coastal flood risk information for the coastlines of Saipan, Tinian, and Rota. | FEMA |
| **Flood, Water Quality, Water Supply** | Community Development Block Grant-Mitigation (CDBG-MIT) | The Northern Marianas Housing Corporation received a total of $16,000,000 in CDBG-MIT funding from HUD to assist in natural hazard recovery and rebuilding efforts resulting from the 2018 Typhoons. | HUD |
| **Water Quality, Water Supply** | Water/Wastewater Grant Assistance for CUC – Disaster Recovery | In 2020 EPA awarded nearly $566,000 to improve post-typhoon waste management in CNMI. | EPA |
| **Water Supply** | Saipan Drinking Water System | In 2020 EPA awarded $17.5 million for infrastructure to protect surface waters and drinking water in the CNMI. | EPA |
| **Power** | Energizing Insular Communities Program | Program funding the following efforts:<br>• $215,336 for the residential rebate program for Energy Efficient/Energy Star appliances in the CNMI<br>• $260,500 for cool roof and LED lighting upgrades at the Saipan International Airport<br>• $299,996 for a pilot project exploring automated electrical power distribution<br>• $328,236 for the installation of solar-powered light systems on public buildings and pathways | DOI |

| Problem | Project | Description | Agency |
|---|---|---|---|
| | | • $370,680 for planning and coordinating technical assistance<br>• $645,000 for a 2.5MW solar PV and battery storage integrated facility design | |
| **Coastal Hazards** | NOAA Marine Economy Study (NOAA, 2021) | This study consists of a series of workshops that gather data from stakeholders to flesh out the Economics National Ocean Watch database. | NOAA |
| **Flood, Tropical Cyclones, Water Quality and Supply** | Community Development Block Grant Disaster Recovery (CDBG-DR) (HUD, 2020) | CNMI was awarded $243,946,000 through the CDBG-DR after the Typhoons of 2018. The CNMI developed and submitted an Action Plan to HUD for approval of a plan that details the use of funds and how it will address long-term recovery efforts. Part of these funds will go toward:<br>• Rehabilitation and reconstruction<br>• Improvement of water tank utilities<br>• Road improvements<br>• Green building standard codes | HUD |
| **Water Quality** | Hazardous Waste Grant Assistance Program | U.S. EPA is awarding $5,693,217 to the CNMI to support effective hazardous and solid waste management to further address impacts of 2018's Super Typhoon Yutu. This funding is supporting multiple efforts including:<br>• Completing natural hazard debris cleanup<br>• Increasing capacity of the BECQ to conduct regulatory and outreach activities for the solid and zero waste management programs<br>• Developing a Comprehensive Integrated Solid Waste Management Plan that will cover the islands of Saipan, Tinian and Rota, and a Zero Waste Management Plan for the island of Tinian<br>• Conducting emergency repairs to the Marpi Landfill on Saipan | EPA |
| **Power** | Safe Smart Growth (Source: Nimbus, 2018) | This project incorporates FEMA-led data analysis into the CNMI Comprehensive Sustainable Development Plan. It focuses on electrical power and telecommunications. | FEMA |
| **Power** | Technical and Advisory Support | This program is designed to develop/enhance institutional capacity to conduct technical analyses and modeling | DOE, FEMA |

| Problem | Project | Description | Agency |
|---|---|---|---|
| | | to support the recovery and long-term resiliency of the CNMI power grid system. | |
| **Flood, Tropical Cyclones,** | Mitigation Assessment Team (MAT) | The MAT Program allows FEMA to assemble and quickly deploy teams of investigators to evaluate the performance of buildings and related infrastructure in response to the effects of natural and man-made hazards. | FEMA |
| **Pollution, Typhoons, Coral Reef Health, Economics** | NOAA's Marine Debris Program - Hurricane Response Marine Debris Removal Fund | Coordinate the removal of the grounded derelict fishing vessel, Lady Carolina. PCRP also conducted outreach to spread awareness of the marine debris issue and proper storm preparation. | NOAA, PCRP |
| **Stormwater Runoff, Pollution** | NOAA's Coral Reef Conservation Program and Western Pacific Regional Fishery Management Council | Combined effort to develop a reef fishery atlas with final spatial data identifying issues that influence reef fisheries, including land-based pollution. Information can be useful in future efforts to prioritize geographic areas for further study or management initiatives. | NOAA, PCRP |
| **Maritime Interruptions** | Marine Transportation System Recovery Plan for the U.S. Territory of Guam and the Commonwealth of the Northern Mariana Islands (Source: USCG, 2019) | This plan takes an 'all hazards' approach and provides a common coordination framework for all parties involved, regardless of the type of event. The focus of the plan is to reopen navigable waterways to maritime commerce during the short-term recovery phase of the response to the incident. | U.S. Department of Homeland Security (DHS) – U.S. Coast Guard Sector of Guam |

Table 2-4. Current and Future Local Projects

| Problem | Project | Description | Agency |
|---|---|---|---|
| Sustainability, Economics, Natural Resources, and Development | CNMI Comprehensive Sustainability Development Plan (Source: CNMI OPD, 2021) | This updated plan documents the ten-year (2021-2030) growth visions, goals, and objectives of the CNMI's leadership, agencies, and stakeholders to work towards the shared outcome of "sustainable development". | OPD |
| Coral Reef Health, Coastal Hazards | Coral Reef Management Program | This program works to reduce local stressors and promote management, protection, and enhancement of coral reefs in the CNMI. | DCRM |
| Water Quality, Surface runoff, | Laolao Watershed Restoration | This watershed restoration project focuses on reducing land-based | DCRM |

| Problem | Project | Description | Agency |
|---|---|---|---|
| Pollution, Stormwater Management, Erosion, BMPs | Project (Source: Horsley, et al., 2020) | sources of pollution through personal action and community collaboration. | |
| Erosion, Surface Runoff, Pollution, Stormwater Management | Talakhaya Watershed Restoration Project (Source: CNMI BECQ, 2020) | This watershed restoration project focuses on protecting the Talakhaya watershed in Rota. Concerns include deforestation, erosion, development challenges and climate change. | DCRM |
| SLR, Tsunami, Development, Pollution, Erosion, Tropical Cyclones, Coral Reef Health, Surface Runoff | Public Access Enhancement | This program is committed to maintaining and enhancing public access to sea and tidal areas | DCRM |
| Coastal Erosion | Shoreline Monitoring | DCRM uses the Berger surveying method to identify, measure, and track changes within shoreline areas which provide data-driven decision making. The goal is to identify causes and impacts of coastal erosion which can better inform coastal planning and development. | DCRM |
| Erosion, Stormwater Management | Saipan Lagoon Management Plan (Source: Horsley, 2017) | The management plan outlines a strategy for DCRM to follow as part of its mission to ensure both sustainable and environmental quality of the lagoon. | DCRM |
| Economics, Sustainability | Baseline Assessment Data Collection and Analysis | The analysis involves efforts to collect and analyze baseline assessment data to support comprehensive sustainable development planning. It highlights the next steps needed in planning. | OPD |
| Economics, Sustainability | Growth Visioning Survey (Source: CNMI, OPD, 2020) | This survey allows community members to share input regarding long-term goals for growth in CNMI. | OPD |
| Economics | Garapan Revitalization Plan (Source: CNMI, OPD, 2007 and 2021) | This plan aims to transform Garapan into a premier family-friendly destination through collaboration and to alleviate challenges the area faces. | OPD |
| Economics, Sustainability, Typhoons | Comprehensive Economic Development Strategy (CEDS) | The CEDS improves coordination across CNMI agencies as well as the public and private sectors to create a comprehensive sustainable development plan for the CNMI. | OPD |

| Problem | Project | Description | Agency |
|---|---|---|---|
| SLR, Tsunami, Typhoons, Tropical Cyclones, Coastal Erosion | Shoreline Stabilization and Enhancement Plan (Source: PCRP and Horsley, 2020) | Recent studies related to shoreline change and vulnerability (in the area of Beach Road Pathway and adjacent shoreline connecting the business districts of Garapan and Susupe on Saipan) have been highlighted as an area of moderate to high concern due to a combination of factors including exposure to periodic extreme weather events, wave run-up, and sea level changes. | PCRP |
| Pollution, Typhoons, Coral Reef Health, Economics | NOAA's Marine Debris Removal Program - Hurricane Response Marine Debris Removal Fund | MINA, in partnership with multiple agencies, organizations, and businesses will coordinate the assessment, removal, and disposal of typhoon generated debris in Saipan and Tinian. | MINA |
| Climate Change, Sustainability | Micronesia Challenge -2030 | The goal of the Micronesia Challenge 2030 is to effectively conserve at least 50% of the near-shore marine resources and 30% of the terrestrial resources across Micronesia. | MINA |
| Climate Change, SLR, Coral Reef Health | Managaha Marine Conservation Area (MMCA) | This project is geared towards the local communities and off-island visitors and seeks to establish community network of environmental stewards, support and strengthen the MMCA through learning programs on biodiversity protection and climate change adaptation. | MINA |
| Water Quality, Surface runoff, Pollution, Stormwater Management, Erosion, BMPs | Saipan Beach Road Coastal Storm Risk Management Study (Source: USACE, 2020) | This study purpose is to identify and evaluate coastal storm risk management (CSRM) problems and opportunities along Beach Road, located on the western coast of the Island of Saipan. | USACE and OPD |

# 3 Watershed Planning Process

The USACE watershed planning process aims to provide a comprehensive and strategic evaluation and analysis that includes diverse political, geographic, physical, institutional, technical, and stakeholder considerations. To increase resilience to future tropical storm activity, a full range of water resources needs, and their inherent interrelatedness must be considered. Ecological impairments such as habitat loss can increase consequences of a typhoon. For example, loss of coral reef habitat may directly correlate to a reduction in the natural barrier to reduce storm surge. Likewise, upland deforestation can contribute to stream erosion and result in sedimentation in estuaries, increasing coastal storm risks to infrastructure. Unique water supply challenges and vulnerabilities may exist within a remote island environment that, when further challenged by a tropical storm, could leave people without potable water for extended periods of time.

In order to identify the full range of drivers and stressors that may contribute to increased risks associated with tropical storm activity, this WA considers all water resources needs, regardless of agency responsibilities, and develops a strategic roadmap to inform future investment decisions by multiple agencies, in coordination with local, territorial, and Federal agencies.

The CNMI WA is following the Watershed Studies Guidance outlined in the USACE ER 1105-2-102. The six-step USACE watershed planning process includes:

1. **Identify Problems and Opportunities** – Determine problems, needs and opportunities in the watershed by involving study partners, stakeholders, resource agencies, and the public.
2. **Inventory and Forecasting** – Prepare an inventory of relevant water and land resources, existing models, maps, and data. Examining anticipated future actions, assumptions and uncertainties, describe the most likely future scenarios.
3. **Identify and Screen Measures** – Develop management measures based on a feature or activity which addresses one or more of the planning objectives. Measures are then screened using constraints, expert judgment, and specific screening criteria to focus on those that will meet the planning objective.
4. **Formulate Initial Array of Strategies** – Using the measures, provide a description of alternative approaches to address identified problems and needs, emphasizing alignment of actions of Federal and local entities.
5. **Refine Initial Array and Evaluate Focused Array of Strategies –** Evaluate the alternative strategies, in consultation with study partners, to assess how effectively the strategies address the identified problems.
6. **Strategy Comparison and Selection –** Compare the strategies against one another**,** noting trade-offs between strategies, and select the best suited strategy for meeting the study goals and objectives.

The goal of this process is to improve community resiliency and improve the economic, environmental, and social outcomes of water management decisions by facilitating a common understanding of the natural resources system, allowing stakeholders to identify tradeoffs and management options. Figure 3-1. USACE Six-Step Watershed Planning Process below illustrates how the six-step watershed planning process was used to develop recommendation strategies for this WA.

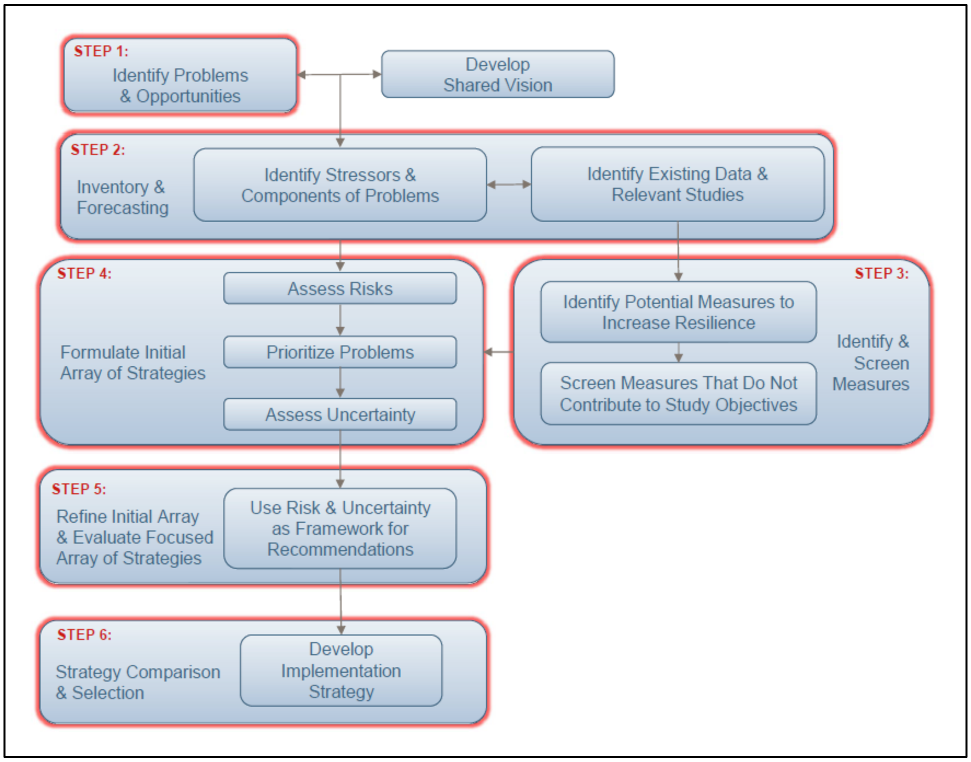
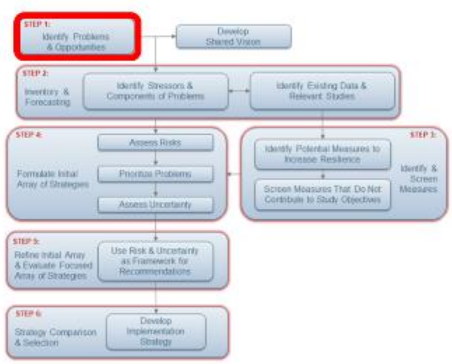



Figure 3-1. USACE Six-Step Watershed Planning Process

## 3.1 Problems



A wide range of problems stemming from both anthropogenic and weather-related drivers were identified throughout the study area of Saipan, Tinian, and Rota. Identified categories of problems include tropical storms and typhoons, coastal hazards, freshwater flooding, water quality and quantity, inland ecosystems, and tsunami. The following problem statements and their associated stressors were developed collaboratively with partners and stakeholders. For the purposes of this WA, stressors are being defined as conditions that either contribute to the problem or conditions that result from the problem.

**Problem 1:** Tropical storms and typhoons cause life safety risks, economic damages, and environmental degradation.

- *Coastal flooding and inundation of built coastal infrastructure* (defined as harbor facilities, roadways, power plants, wastewater treatment plants, and septic systems for this study) can cause erosion, environmental degradation, and damage to structures, which can result in increased risk to life safety.
- *Loss of power supply* can occur during and after tropical storm and typhoon activity, impact thousands of residents island-wide, and sometimes continue for months after the storm has passed, which can result in increased risk to life safety.
- *Severe winds* can cause damage to structures and utilities throughout an impacted area, which can result in increased risk to life safety.

- *Maritime supply chain interruptions* can result from tropical storm and typhoon activity and can increase risk to life safety, cause economic damages, and lead to food security issues.

**Problem 2:** Naturally occurring and anthropogenic stressors, including increased environmental degradation, adversely impact marine ecosystems and infrastructure in coastal areas.

- *Ocean acidification* can cause degradation of corals, economic damages, and habitat loss.
- *Increasing water temperatures* can cause degradation of corals, economic damages, and habitat loss.
- *Coral bleaching* can cause degradation of corals, economic damages, biodiversity and habitat loss.
- *RSLC* can cause economic damages and result in increased risk to coastal infrastructure and loss of habitat.
- *Land use practices* can alter vegetative cover, increase fire risk and heat stress, impact drainage patterns and water quality, and result in environmental degradation.
- *Surface runoff* can cause erosion, convey sediments, and carry pollutants that impact water quality and result in environmental degradation.
- *Coastal erosion/loss of shoreline* can result in increased risk to coastal infrastructure and habitat loss.
- *Stormwater management issues* occur when non-conforming or non-existent stormwater management infrastructure cause flooding and transport pollution sending untreated runoff to near shore waters, degrading water quality and effecting ecosystems.
- *Loss of living break water* can result in degradation of corals, shoreline vegetation, and near shore vegetation, which serves as natural infrastructure to minimize wave intensity, results in increased shoreline erosion and economic damages.
- *Nutrient loading* from land use practices, fires, agriculture, stormwater, and wastewater runoff can lead to algal blooms which can impact coral reef communities and other aquatic habitat.

**Problem 3:** Naturally occurring and anthropogenic stressors, including contamination, adversely impact water quality and supply.

- *Point and nonpoint source pollution* (including stormwater management) can impact water quality and result in environmental degradation.
- *Groundwater over pumping* can result in saltwater intrusion and reduction in recharge rates which impacts water quality and reduces water supply.
- *Unmetered water use* can encourage groundwater over pumping and result in saltwater intrusion and impacts to water quality and water supply.
- *Saltwater intrusion* can impact water quality and reduce water and food supply.
- *Water leaks in the distribution system* can encourage groundwater over pumping and result in saltwater intrusion impacts to water quality and reduces water supply.
- *Drought* can exacerbate saltwater intrusion, impact water quality, and reduce water and food supply.

**Problem 4**: Naturally occurring and anthropogenic stressors increase the risk of inland ecosystem degradation and habitat loss.

- *Invasive species* can cause habitat loss and impact inland ecosystems.

- *Wildfires* can lead to deforestation, loss of habitat, spread invasive species, decrease biodiversity, and exacerbate sedimentation.
- *Land use practices* (including stormwater management) can cause environmental degradation and habitat loss.

**Problem 5:** Heavy rainfall events that lead to flooding and erosion can cause life safety risks, economic damages, and environmental degradation.

- *Flash flooding along low lying and populated areas* can cause safety hazards, property damage, stormwater drainage overflows, inhibit evacuation, and ecologically destructive erosion.
- *Sedimentation* can result in impacts to habitats, waterways, and exacerbate riverine flooding.
- *Riverine erosion* can result in mudslides, increased risk to life safety, economic damages, and cause environmental degradation.
- *Riverine flooding* can result in increased risk to life safety and cause environmental degradation and economic damages.

**Problem 6:** Tsunamis cause life safety risks and economic damages throughout CNMI.

- *Tsunami waves* can cause life safety risks, damage to infrastructure, and flooding of coastal and low-lying areas. Although the probability of tsunamis is low, the consequences are quite high.

## 3.2 Opportunities

Opportunities are future desirable conditions that may coincide with the solutions to the identified problems in the study area. The project team identified the following opportunities for this WA:

1. Raise awareness on hazard mitigation through public education and informational campaigns.
2. Promote and support sustainable agricultural and fishing practices.
3. Promote sustainable use of terrestrial/marine ecosystems and support eco-tourism.
4. Halt and reverse habitat degradation and biodiversity loss.
5. Reduce erosive impacts of runoff and associated sedimentation to preserve wetland, aquatic, and cultural resources (medicinal plants, cultural keystone species, and sites).
6. Strengthen power infrastructure and promote energy independence to improve access to potable and palatable water and power reliability.
7. Improve access to inter-island transportation and to affordable commodities through maritime shipping.
8. Improve wastewater systems and reduce nonpoint source pollution.
9. Improve availability and sustainable management of safe and environmentally compliant water supply and sanitation.

10. Promote sustainable consumption and production patterns.

11. Strengthen the means of implementation and support partnerships for sustainable development.

12. Preserve cultural connections to the land and water resources. This includes tangible cultural heritage that can help maintain cultural identity and a sense of belonging for the indigenous Chamorro people.

13. Improve equity of vulnerable and indigenous populations within communities.

## 3.3 Planning Constraints and Considerations

There were no specific planning constraints identified for this WA.

Planning considerations represent key elements for the study team to keep in mind as the WA evolves; however, these elements will not necessarily limit the plan formulation process. The team identified the following considerations:

1. The study partners are interested in a focus on natural and nature-based features (NNBF) to address problems, when applicable.
2. This WA will focus on the areas of CNMI that fall outside of U.S. Military occupied lands, which already require the development of a comprehensive Master Plan to ensure effective long-term development and management of resources.

## 3.4 Planning Goal and Objectives

The goal of this WA is to develop a framework to increase CNMI's resilience to weather related hazards and reduce the effects of anthropogenic stressors through a focus on NNBF, where appropriate. This WA will provide a strategic roadmap to inform future investment decisions by multiple agencies (i.e., involvement by USACE, other Federal agencies, or non-Federal interests). Presidential Executive Order 13653, "Preparing the U.S. for Impacts of Climate Change" (78 FR 66817) defines resilience as, "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover from disruptions." To achieve this goal, the following objectives are identified:

1. Reduce human life loss and injuries resulting from natural hazards.

2. Increase community natural hazard preparedness and effectiveness of hazard mitigation activities.

3. Reduce damages and disruption to public and private property and areas of cultural or community importance, from flooding and coastal erosion throughout CNMI.

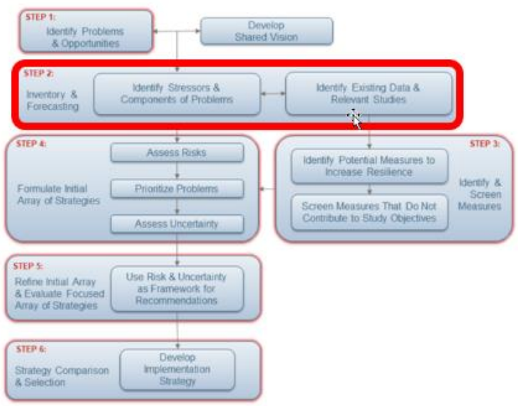
4. Restore and protect terrestrial and marine resources throughout CNMI.

5. Increase infrastructure and environmental resiliency to RSLC throughout CNMI.

6. Improve water quality and water supply for residents; increase access to potable and palatable water.

7. Increase access to affordable, reliable, sustainable, and modern energy to residents.
8. Avoid or minimize disruptions to port operations, supply chains, and local businesses.
9. Reduce environmental degradation resulting from disasters in impacted areas.
10. Build and maintain resiliency of natural, built, and human systems through safe, smart growth.

# 4 Inventory and Forecasting – Existing and Future Without-Project Conditions




The existing conditions and future without-project conditions documented in the following sections provide a baseline for evaluating and comparing future plans or management options. The existing conditions provide an inventory of the current conditions of the study area and the future without-project condition forecasts the most likely conditions expected to exist in the future if no additional actions are taken. This WA uses a 50-year period of analysis for inventory and forecasting purposes. The 50-year forecast period of analysis spans from 2022-2072. However, other agencies may have differing periods of analysis.

Appendices B-F provide additional discussion of each of the below topics and a summary of key reports utilized by the team.

## 4.1 Climate Conditions

CNMI's climate is strongly influenced by El Niño Southern Oscillation (ENSO) fluctuations. ENSO has a wet and dry phase in the western Pacific, which commences with higher rainfall, tropical storm, and typhoon activity, then migrates into drought. Frequency and longevity of ENSO events vary greatly and are still a subject of study among climatologists (Figure 4-1).

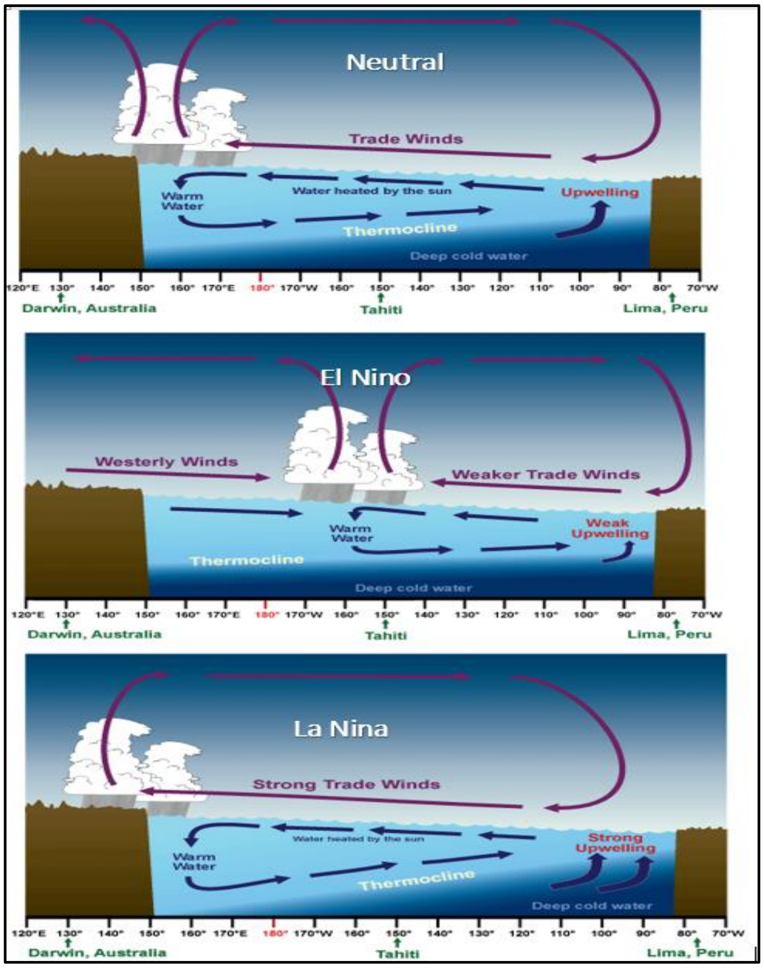



Figure 4-1. ENSO Fluctuations in the Pacific: Neutral, El Niño, and La Niña

The mean annual precipitation is 69.6 inches (NOAA and NWS, 2021). The annual number of hot days (above 88 °F) has increased from five days in the 1950s to 36 days in the 1990s. Likewise, the annual number of cool nights (below 74 °F) has dropped from roughly 35 to 15 nights over the same period (NOAA, et al., 2021). These events are projected to intensify in the Pacific due to climate change (NOAA, 2018) and are a key driver of weather hazards throughout CNMI.

Mean temperatures, number of hot days, maximum temperatures, regional sea level change, and rainfall intensity are projected to increase even with human mitigation efforts. The climate of the western North Pacific has experienced 60 years of increased temperatures. Temperatures are expected to increase 1.1 °F to 1.3 °F by 2030, 1.9 °F to 2.6 °F by 2055, and 2.7 °F to 5.1 °F by 2090. Mean annual rainfall is not projected to change significantly; however, rainfall intensities and dry and wet extremes are projected to increase (CNMI DCRM & NOAA, 2014).

Climate preparedness and resilience activities are considered and recognized in all USACE studies to ensure reliable project performance due to changing future climatic conditions. Changing climatic conditions could result in changes to storm intensity, frequency, and duration, which may potentially have wide ranging effects. Coastal effects include increased shoreline erosion and associated increased coastal storm risk. Increased rainfall intensity/duration could lead to inland hydraulic effects such as altered channel sedimentation that can increase flood elevations, increased reservoir sedimentation that reduces storage for flood control and water supply, further leading to an inability to provide necessary water pumping capacity.

The engineering analyses, consistent with ER 1100-2-8162 (Incorporating Sea level Changes in Civil Works Programs) and Engineering and Construction Bulletin 2018-14 (Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects), describe existing climatic conditions, and describe and reference some expected future change to specific coastal and hydraulic baselines. These changes in baseline conditions are based on published information (i.e., are not determined in this study) and are included for reference only. However, since no specific projects are recommended in this report due to the intent and focus of watershed assessments, no specific and direct effects due to climate change are determined. More information about the existing and future climate conditions can be found in the Engineering Appendix.

## 4.2 Land Use

According to NOAA's 2011 Coastal-Change Analysis Program, the total "developed" land area, including cropland, is 10.69% for the island of Saipan, 9% for Tinian, and 8.29% for Rota. Although these developed area totals are relatively low compared with total land mass, the degree by which human impacts may adversely affect ecosystems remains high because island infrastructure is typically located along the shoreline due to the terrain and need for harbor access. Anthropogenic activities inland are problematic as well. Land clearing for agriculture or other purposes pose threats to terrestrial habitats and upland wildlife species.

Saipan, the capitol of CNMI, is about 12 miles long and 5.5 miles wide. It is the largest and most populated island in CNMI. Residential, tourist, and commercial facilities are the most prominent activities. Casinos, hotels, shopping, aquatic recreation, and cultural heritage sites are the main tourist attractions.

Tinian is about five nautical miles southwest of Saipan, separated by the Saipan Channel. It has a land area of 39 square miles. The northern portion of Tinian is largely occupied by the U.S. Military and agricultural entities. Developed lands are more prevalent in the southern area. Garment factories, casinos, and hotels once attracted workers and tourists to Tinian, however these businesses closed in 2015. Conservation areas along with cultural and historical sites attract visitors and play a key role in maintaining cultural identity of the island's community (CNMI HPO, 2011; CNMI BECQ-DCRM, 2015).

Rota is the southernmost island of CNMI and lies approximately 40 nautical miles north-northeast of Guam. Rota is 33 square miles. Rota is the least populated area in this assessment and has many natural, historical, and cultural resources. The major population centers are Songsong and Sinapalo. Rota is known as the "Friendly Island." Tourists are attracted to Rota for exceptional bird viewing and water sports. There is one golf course on the island but no major hotels or casinos. Unlike the other islands, Rota was never invaded during World War II and thus retains much of its original limestone forests.

Land use projections for Saipan, Tinian and Rota are that the islands are likely to become more developed as economic, agricultural, and military development expands. The CNMI Comprehensive Economic Development Strategy (CEDS) documents Smart, Safe, Growth principals in planning and project prioritization to foster sustainable development. Land use management planning works to balance the needs of development with the maintenance of critical ecosystem services. The natural world provides many protective functions to the built environment for little or no cost. These services can degrade over time if natural resources are not protected, conserved, and managed. Because the islands of Saipan, Tinian, and Rota are small, land use practices need to maintain a delicate balance with the conservation and management of natural resources. Also, as the climate changes and new weather patterns develop, the level of protection provided by natural features may change. For example, as sea levels rise, waves may overtop the barrier reef with more energy, resulting in more wave-run up and beach erosion.

A complete listing of land use management considerations, recommendations, and planning support tools that aim to improve land use functions and restore, maintain, and enhance natural ecological processes and protect the communities that rely upon them are located in the CEDS 2020 Plan.

Land is also an extremely important cultural and economic resource throughout the islands. Its importance is reflected in preserving and maintaining local culture under Article XII of the CNMI Constitution, which limits acquisition of real property to persons of Northern Marianas Descent. The HPO is involved in the review of land use activities on both public and private lands, ensuring that cultural resource inventories as well as enforcing measures to preserve cultural heritage is planned before development occurs (CNMI HPO, 2011).

## 4.3 Tropical Storms & Typhoons

CNMI is located within one of the most active tropical typhoon regions in the world and experiences increased risk of storms during El Niño years. Coastal flooding and erosion are typically owed to tropical storms and typhoons. The number of tropical storms and typhoons affecting CNMI has remained constant on average over the long-term record with two to eight storms in any given year (NOAA et al., 2021). Associated coastal flood and high surf events resulting from these climatically driven hazards inundate low lying coastal communities and infrastructure. Prior to human habitation, recovery of ecosystems after damages from storms would have looked much different than today. Development has altered the natural progression of recovery. Natural storm reduction features such as forests, wetlands, and reefs have been lost and replaced by non-native flora and hardened shorelines. The change in landscape and land use has exacerbated risk for life loss and environmental degradation.

Many interrelated factors have the potential to contribute to an increase in risks associated with tropical storms and typhoons. Eustatic (worldwide) water levels, tectonic activity, and land subsidence contribute to RSLC, which may exacerbate the consequences of future tropical storms and typhoons. Portions of the world experience different ocean temperatures, currents, seismic activity (tectonics), and glacial rebound (land rises relative to sea level). The USACE (Honolulu District) estimates an increase of approximately 2.8 feet by 2070 and approximately 5.1 feet by 2100 for CNMI. RSLC for each island within CNMI is expected to be consistent with these estimates. This will lead to increased flood damages impacting already vulnerable communities and critical infrastructure.

The western island shoreline of Saipan between Tanapag Harbor and Susupe, which includes the city of Garapan, CUC power plant, and the American Memorial Park, is an area of concern for impacts from tropical storms and typhoons. It is categorized as the most vulnerable area in Saipan for RSLC and coastal erosion according to the Climate Assessment Report (CNMI DCRM & NOAA, 2014). Tinian Harbor, located on the island's southwest coastline, and the adjacent city of San Jose are vulnerable to RSLC and coastal flooding. Rota has two harbors on the Songsong peninsula. The Rota West Harbor is operated by the Commonwealth Ports Authority and is Rota's primary source of commercial imports. East Harbor is operated by the CNMI Department of Public Lands. East Harbor contains a public boat ramp and small turning basin. Adjacent to East Harbor is Mobil Marina Islands Inc., which operates a land-based fuel oil storage facility. The eastern harbor is the sole import facility for the island's fuel source, which is petroleum used for power generation and transportation (Moffatt & Nichol, 2018).

## 4.4 Coastal Areas

Coastal areas include the land and sea areas bordering the shoreline. Coastal habitats consist of coral reefs, seagrass beds, islands, lagoons and open water/pelagic areas. Coral reef ecosystems across the CNMI vary in size and composition due to natural variation in local geomorphology and wave exposure, and due to natural disturbances like typhoons and volcanic activity. The northern islands are stratovolcanoes that have formed along the tectonically active portion of the Mariana Arc, with many of the islands having erupted multiple times in recent centuries. They are all small relative to other islands, with land areas ranging from 1-13 square miles, apart from Pagan (18 square miles). These factors, combined with the strong influence of the northeast trade winds in the CNMI, together dictate that coral reefs in the northern islands are considerably less developed and host a lower number of species than those found in the older, larger, inactive southern islands. Despite less reef development and species richness, the northern marine communities are subjected to less human stress, notably fishing pressure, and pollution (Liske-Clark, 2015).

There are seven Marine Protected Areas (MPAs) in CNMI. Saipan has five MPAs, Tinian has one, and Rota has one. For maps and details of CNMI MPAs refer to Environmental Appendix D. In addition to MPAs CNMI also has designated areas of particular concern including wetlands, marshes, shorelines and streams. These areas may be viewed on the BECQ Open Data Portal. The Engineering Analysis, Appendix C, contains maps of flood zones, watersheds, and marine protected areas.

Saipan contains the largest reef area and hosts the most diverse set of coral reef habitat in CNMI. Saipan also has the largest population in CNMI which poses a threat to the health of coastal ecosystems due to human impacts. Tinian has sub-marine groundwater discharge, high wave exposure, and steep topography that contribute to low coral development. Rota's coral reefs are impaired due to fishing pressure and pollution. Common reef fish caught for food includes Surgeonfish, parrotfish, goatfish, groupers, and wrasse. As is common in populated areas, reef fish populations are depleted, as indicated by relatively small sizes of fishery species and low overall fish biomass. Climate change negatively impacts all marine ecosystems through higher temperatures, higher pH, more prolific invasive species, and diseases. Volcanic ash negatively impacts marine ecosystems by smothering benthic species and coral reefs, triggering bleaching, and causing acidification of pH levels.

Coral reef habitats help to absorb wave energy and minimize the impacts of storm surge and flooding to the densely populated coastal communities of western Saipan. However, the effects of local stressors associated with nutrient and sediment pollution are compounded by large scale, episodic stressors that degrade coral reef ecosystems, such as coral bleaching, invasive species, increasing drought, and physical damage from severe storm events. Degraded coral reefs, among other habitat types, provide limited coastal protection benefits, which increases CNMI's exposure – and potentially its vulnerability – to flooding threats. Coral bleaching and other negative impacts to reef systems are expected to increase in the future if no corrective measures are taken and as the effects of climate change continue (NOAA et al., 2018; NOAA et al., 2019; Liske-Clark, 2015). Bleached coral reef areas may still provide shoreline protection and limited habitat for years after mortality occurs and in the CNMI studies have shown recovery is possible within a short time frame (less than five years) with the presence of robust reef communities in the proximity and suitable water quality (Maynard, 2018).

Coral reef areas impacted by chronic anthropogenic stressors are less resilient to acute disturbances, such as cyclones, Crown-of-thorns Starfish (COTS) outbreaks, and temperature stress events, and can be expected to deteriorate further, potentially shifting from coral-dominated to less productive and less diverse fleshy algae and cyanobacteria dominated systems. The predicted increase in the frequency and severity of thermal stress events in the future, overfishing, and rise in ocean acidification will likely stress even the healthiest of reef systems (Liske-Clark, 2015). Adult COTS have few natural predators, although some species will prey upon them, such as Napoleon wrasse (*Cheilinus undulatus*), giant triton snails (*Charonia spp*.), titan triggerfish (*Balistoides viridescens*), starry pufferfish (*Arothron stellatus*), and harlequin shrimp (*Hymenocera picta*). A review of available literature did not point to stocking of predator species as a successful means to control COTS. Permitted removal or culling of COTS with injections of bile salts or other substances appears to be the best mitigation measure to date. However, overfishing of COTS predators, primarily the Giant Triton and *Arothron* and *Cheilinus* species, may contribute to lack of natural reef resiliency from COTS and declining biodiversity. Protection and management of all native and beneficial marine species and should be analyzed and regulated by law.

In general, future inland restoration projects could benefit both terrestrial and marine species. By focusing on revegetation and freshwater restoration, both terrestrial flora and fauna would accrue benefits. Coastal restoration projects would primarily benefit marine/estuarine species although some terrestrial species could benefit from restored nearshore habitats. With any recommended restoration project, special consideration and analyses will be required to ensure proper benefits and protective design requirements are in place for listed species.

CNMI has 31 terrestrial species listed as threatened or endangered under the Endangered Species Act (ESA) and 17 marine species. CNMI has the highest number of ESA-listed species both per unit land area and per capita of all U.S. states and territories (NOAA, 2021). In addition to corals and terrestrial plants other threated or endangered species include the Marianas Fruit Bat, Nightingale Reed-Warbler, Mariana Swiftlet, Mariana Crow, Mariana Moorhen, Micronesian Megapode, Rota White-Eye, Green Sea Turtle, Hawksbill Turtle, Humpback Whale, Loggerhead Sea Turtle, Olive Ridley Sea Turtle and Sei Whale. CNMI hosts over 1,000 species of fish, 256 species of coral (32% of all known coral), 150 species of birds – 12 of which are endemic to CNMI- and 1,029 species of plants, 244 endemic to CNMI (BECQ-DCRM, 2018).

Inundation maps are presented in the Economics Analysis, Appendix B. Habitat maps for mangroves, seagrasses, corals, and coral nurseries on the islands of Saipan, Tinian, and Rota are shown below in Figure 4-2.

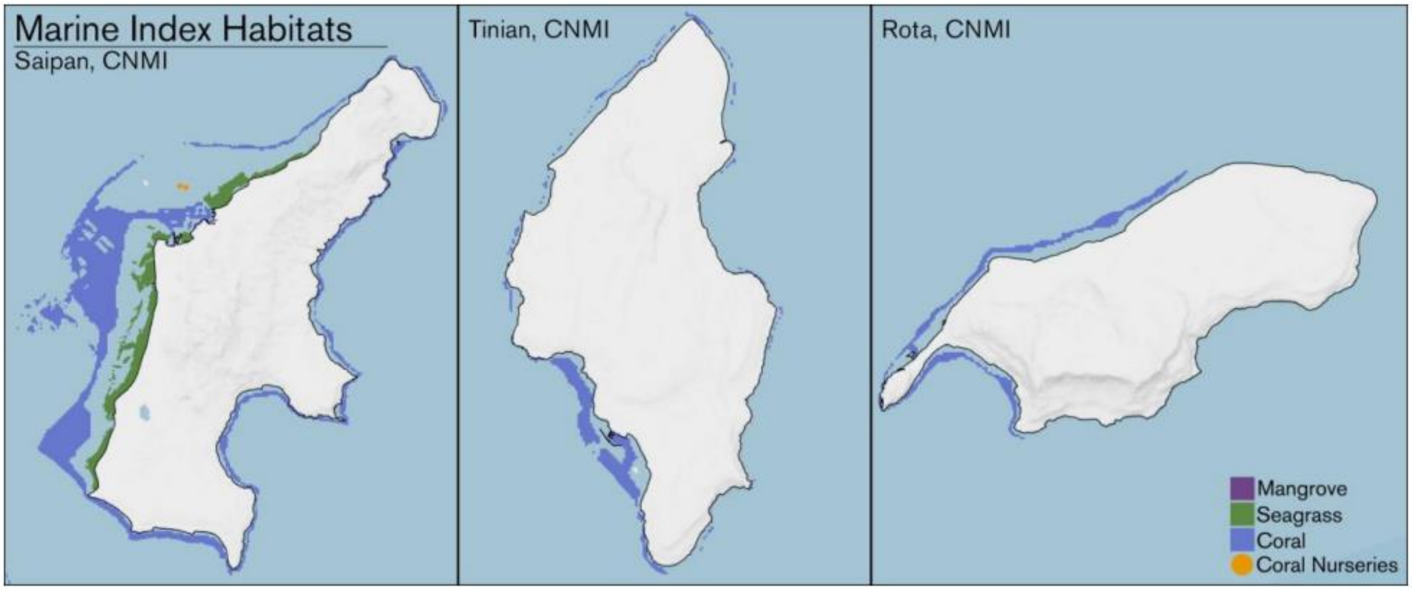



Figure 4-2. CNMI Marine Habitats (Dobson et. al, 2020)

For the past four years, the DCRM Shoreline Monitoring team have monitored nine transects within two Tinian beaches and ten transects within three Rota beaches. Based on the four-year period data collection: 78% of surveyed Tinian transects exhibited erosion while 11% are accreting and the remaining are undetermined. 40% of surveyed Rota transects exhibited accretion while the remaining 60% are eroding (DCRM Tinian and Rota, 2021).

## 4.5 Water Quality & Supply

The CUC supplies power, water, and sewer services to Saipan, Tinian, and Rota. Saipan is the only island with wastewater treatment facilities. Tinian and Rota rely on septic systems and lagoons. Though the CUC drinking water on Saipan complies with all EPA regulated contaminants and is considered safe for human consumption, most people on Saipan do not drink the water provided because they find it unpalatable due to the high chloride concentration (an unregulated contaminant). Instead, residents rely on locally produced treated bottled water or rainwater. Hotels on Saipan use reverse osmosis to provide palatable drinking water to tourists.

The primary threats to CNMI water quality include saltwater intrusion, Enterococci (fecal contamination), suspended solids, dissolved nutrients, sedimentation, land-based sources of pollution, wastewater discharge, and ammunition (heavy metals) from World War II. Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) or PFAS are human-made substances and are not naturally found in the environment. They have been used extensively in commercial goods (carpets, clothing, furniture, paper packaging for food) and in materials that are resistant to water, grease or stains such as cookware. They are also used in firefighting foams at airfields and in a number of industrial processes. Studies indicate that exposure to PFAS over certain levels may result in adverse health effects, including developmental effects to fetuses during pregnancy or to breastfed infants (e.g., low birth weight, accelerated puberty, skeletal variations), cancer (e.g., testicular, kidney), liver effects (e.g., tissue damage), immune effects (e.g., antibody production and immunity), thyroid effects and other effects (e.g., cholesterol changes) (BECQ, 2020). On June 15, 2022, EPA established new drinking water health advisories for PFAS limitations of less than 0.004 parts per trillion (ppt) for PFOA and less than 0.02ppt for PFOS. Testing by the CUC reported PFAS present in Saipan's Isley Well field at levels well above EPAs regulation (BECQ, 2020).

Potable water supplies within CNMI are limited to only groundwater sources mostly originating from rainfall. Drinking water sources vary by island. Saipan's drinking water comes from approximately 140 groundwater wells and one spring that pumps to 14 water storage tanks for distribution to villages. Total water production averages 9.5 to 10 million gallons per day according to daily well production reports. Tinian's water comes from one infiltration gallery located beneath the Makpo Wetland. Rota's drinking water comes from one main surface water source (the "Main Cave"), and three deep wells that are utilized during dry spells when the cave water spring is low (CNMI BECQ-DCRM, 2015).

Saltwater intrusion is arguably the most significant groundwater contamination issue in CNMI. The high chloride concentration and rates of ground-water production are inadequate for providing island residents with a potable and palatable 24-hour water supply and future demands are expected to be higher. High chloride concentration generally occurs for one of these reasons:

- Groundwater withdrawals
- Drought
- Depth and proximity of production wells to the aquifer
- Rising sea levels
- Subsidence
- Development and impermeable surfaces reducing groundwater recharge

Water wells are an essential resource that is vulnerable to RSLC and climatic disruptions, which may exacerbate future risks associated with water supply and quality. The water supply/delivery system within the CNMI was initially developed during the WWII era, with additional development after the Trust Territory government was ended in 1986 and the CUC began operations in 1987. Due to the age and state of the system, it is prone to leaks and nonrevenue water losses. Development within the tourism industry has increased the demands of the system, and updates are needed to improve its performance and reliability. Water loss via leaks or theft and management and maintenance challenges produce challenges for a reliable water supply in the future. Production is also vulnerable due to lack of power redundancy for pumps, physical vulnerability of the networked infrastructure, and information challenges due to lack of data availability regarding groundwater tables and freshwater inputs.

Underground storage tanks and above-ground storage tanks for fuel and chemicals provide a potential source of groundwater contamination. Landfills are also a pathway for groundwater contamination. Therefore, it is recommended that strategies and actions aggressively consider climate scenarios for data collection, during infrastructure design, and in mitigation planning (BECQ-DCRM, 2015). Previous mitigation efforts to improve water quality include groundwater and soil remediation, underground storage tank removal, and above- ground petroleum storage tanks repairs (CNMI HSEM, 2018). Impacts to well production and water supply from continued system degradation, operation vulnerabilities, increased demand, future sea level rise and saltwater intrusion would be severe and could include major economic disruptions, declining water quality, and impacts to daily life and potentially to public health.

Refer to Appendix D Environmental Analysis for discussion on water quality and Figure of streams. Visit the BECQ Public Maps, Apps and Story Maps website to see several environmental related figures and topics of interest.

## 4.6 Inland Ecosystems

Inland ecosystems consist of forests, grasslands, savannas, wetlands, caves, freshwater streams, wetlands, and lakes. These habitats are home to a unique composition of birds, invertebrates, insects, mammals, reptiles, amphibians, bats, and a variety of plant species. Forests are the most abundant and valuable terrestrial habitats in CNMI. There are four major classifications of forests in CNMI: Native Limestone, Mixed, Tangantangan, and Agroforest. Table 4-1 shows the acres of forest by island from 2016 and projected to 2035 (Willsey, Tyler et al., 2020).

Table 4-1. Forested Acres by Island

| Acres of Forest | 2016 | 2035 |
|---|---|---|
| Saipan | 17,101 | 13,456 |
| Tinian | 16,436 | 14,308 |
| Rota | 13,111 | 10,225 |

These three islands contain approximately 75% of all forested lands in CNMI, with approximately 50% being native forest. Native Limestone Forests contain a high number of native species. Mixed Forests contain both native and nonnative species. Tangantangan Forests contain the introduced Tangantangan (*Leucaena leucocephala)* tree, which was established following World War II. Agroforests contain tropical food trees.

Limestone forests are most abundant on the less populated island of Rota. Mixed forests occur in areas that were cleared for agriculture or development and have some disturbed soils. Tangantangan forests are abundant on Saipan and Tinian with small patches on Rota. Although introduced, these forests provide habitat for protected avian species such as the Nightingale reed warbler or ga ga karisu (*Acrocephalus luscinaia)* and Tinian monarch (*Monarcha takatsukasae).* Agroforests are present on Saipan, Tinian, and Rota.

The CNMI has three Integrated Watershed Management Plans (IWMPs) for adaptive 'ridge to reef' management of priority watersheds. The Garapan IWMP focuses on urban stormwater management, addressing polluted runoff from Saipan's dense center of commerce and tourism. The Lao Lao IWMP helps protect the coral of Saipan's Lao Lao Bay — a prized cultural, recreational, and tourism resource — from upland erosion and sedimentation.
The Talakahaya IWMP highlights reforestation of highly erodible soils in a remote watershed on the island of Rota. Wildfires have created large barren areas that cause erosion, reduce biodiversity, and encourage propagation of invasive species. Future conditions for inland ecosystems are likely to continue to experience degradation from wildfires, development, and pollution until IWMPs or other regulations are fully implemented.

## 4.7 Freshwater Flooding

Torrential rainfall creates flash flooding and inundation island wide (CNMI BECQ and FEMA, 2016). Mapping is incomplete for freshwater flooding; however it is reported that urban runoff during heavy rainfall events creates flooding widely occurring in low lying areas with poor stormwater management, including near coastal areas. Flash floods can inundate roads, exacerbate fire damaged terrain conditions, impede transportation, and convey sediment to near shore habitat. Intensification of tropical storms and precipitation events, as projected by the Intergovernmental Panel on Climate Change, will increase run off, flash floods, and soil erosion.

There are four active weather gages across the three islands and the NWS relies on these gages to issue flash flood warnings: Saipan has three weather gages, one at the Saipan

International Airport, one on Capitol Hill in central Saipan, and one new gage in Lao Lao; Tinian has no active weather gages; and Rota has a single weather gage at the Rota International Airport.

Most soils on the three main islands of the CNMI are of limestone origin with only a small percentage being volcanic in origin. Soils are shallow in many places, and as a result, productive areas for farming are limited. Digging too deep will result in hitting bedrock or groundwater. Erosion is a potential problem on most volcanic soils, and can be a problem in limestone areas, especially near roads or on recently cleared lands. Highly erodible soils are susceptible to washing out in large rain events which can cause flooding and sedimentation in urban areas that result in increased risk to structures and life safety (CNMI SWARS Council, 2010).

## 4.8 Tsunami

Six credible tsunamis were observed in CNMI since 1837 also occurring in 1849, 1892, 1990, 1993, and 2011. The 1849 tsunami is believed to be the only one to have caused a fatality in the region. The 2011 Tohoku earthquake (Japan/Kuril Trench) and tsunami flooded Saipan, triggering surges in neighboring Guam Apra Harbor and damaged a U.S. Navy vessel in port. The impacts to CNMI are based on the Apra Harbor gage, which recorded a 4.3-foot increase in water surface elevation.

Many coastal communities and territories of the U.S. are at risk for tsunamis, and their infrequent occurrence gives communities a false sense of security. While tsunami hazards are infrequent, their consequences can be extremely high. A tsunami may arrive within minutes, and alerts or warnings may not arrive in time. Additionally, on CNMI, all of the coastal communities impacted by coastal flooding shown in section 4.9 are also vulnerable to the impacts of tsunami.

The Pacific Tsunami Warning Center, in Honolulu, HI is the tsunami warning center serving the U.S. Pacific territories. The warning center systems provide information, direction, and updates on a territory-wide basis. Sirens are locally based; however, may not be heard due to broken equipment or if a person is indoors, outside of an audible radius, or during heavy rainfall. Sirens require continual maintenance and can be difficult to replace in remote locations. Radio, social media, texts, and NOAA weather radio can provide alternative methods, in addition to the sirens, to provide warning information to residents.

## 4.9 People and Structures at Risk

The economic analysis for the WA focuses on direct, event-based economic consequences to structures due to flooding in an existing and future scenario that will account for RSLC. The USACE Institute of Water Resources, Risk Management Center's LifeSim 2.0.1 model (LifeSim) was the analytical tool used to estimate structure damages, road inundation, and areas with population at risk (PAR). Additional details of the LifeSim analysis and methodology can be found in Appendix B - Economics and LifeSim.

The analysis year for the existing condition will be defined as the current calendar year (2022). The future analysis year will be 50 years after the existing condition year to account for the 50-year projections of RSLC in the hydraulics and hydrology data. Currently, this will be an existing condition year of 2022, and a future year of 2072.

The assessment is a screening level analysis to roughly estimate the changes between economic damages and rough order of magnitude PAR estimates that currently exist and could occur in the future as a result of RSLC. The goal of this analysis was to show changes in risk, and not exact damages for tests of feasibility such as benefit cost ratios. Since the base and future inventories and population size will be held constant in the future scenario, any changes in damages and PAR in the future scenario can be attributed solely to RSLC. It is possible that future planning and development within CNMI in accordance with the Commonwealth's vulnerability assessments and recently released Comprehensive Sustainable Development Plan (OPD, 2021), that mitigation of the impacts estimated within the LifeSim modeling could occur and future consequences could change significantly.

Visualizations from the LifeSim model below use exposed PAR, which is the PAR that physically experiences flood depths, not the broader PAR which is the population that is located within the extent of flooding without reference to flood depths. Exposed PAR is a more detailed value, and due to the limitations of the model, carries a higher level of uncertainty than PAR. Exposed PAR was used for visualizations instead of PAR due to limitations of LifeSim outputs. More detailed information regarding infrastructure at risk considered within the WA, including healthcare infrastructure, roads, energy, water supply, ports and other critical infrastructure are addressed within Appendices B, C, and D, as well as discussion of cultural resources at risk within Appendix E.

Figure 4-3 and Figure 4-4 below, show the exposure to coastal storms. Solid red indicates areas of risk that only become modeled under the future condition with RSLC. Due to its topography, the island of Tinian does not show any estimated existing or future estimated PAR to coastal flooding, however it is exposed to other coastal storm damages, such as wind and flooding from rainfall events. The mapping shows that the exposed PAR is concentrated on the low-lying areas and villages of the western shore of Saipan, which is also the areas generally associated with the higher social vulnerability ratings estimated by the Saipan Climate Change Vulnerability Assessment (DCRM, 2014).

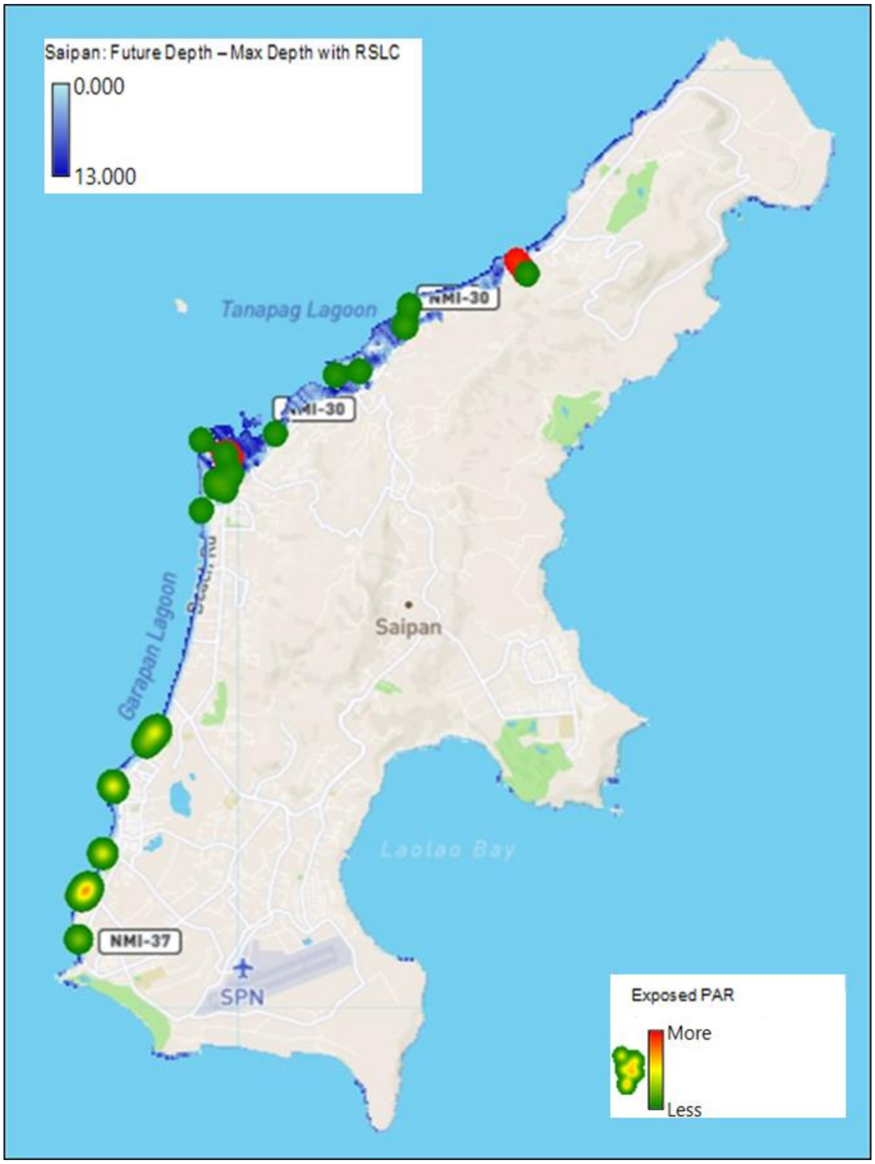



Figure 4-3. Heat Map of Areas with Exposure to Flooding for Saipan, CNMI (*Solid red indicates areas of new exposed PAR in the future scenario)*

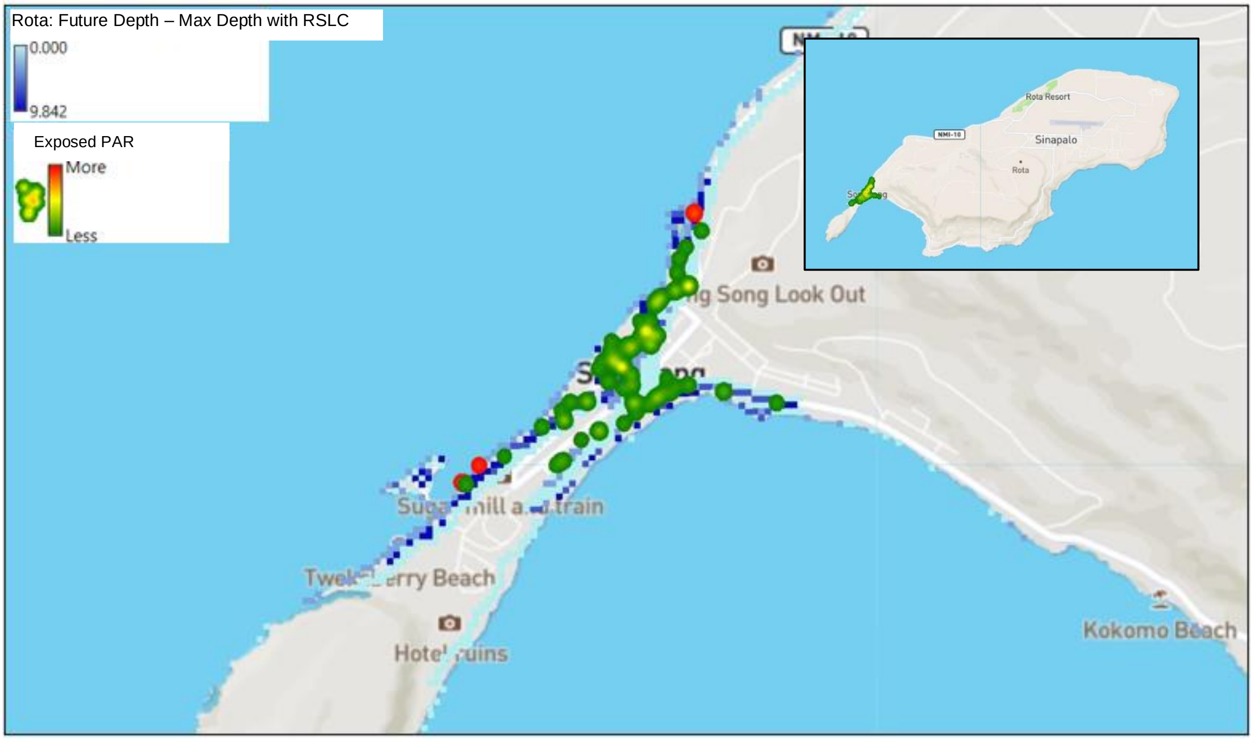



Figure 4-4. Heat Map of Areas with Exposure to Flooding for Rota, CNMI (*Solid red indicates areas of new exposed PAR in the future scenario)*

Table 4-2 shows existing PAR and how CNMI sees increases to estimated PAR under the future scenario. Seven villages are estimated to experience increased PAR in the future scenario. One of which, Ugis, on Rota, PAR is not estimated to occur until the future scenario. Also on Rota, there is an increase of PAR within the village of Liyu due to the high exposure and low elevation of the village's location on the peninsula of the island. On Saipan, the largest increase in estimated PAR is the village of San Roque. Overall, there is an estimated 16% increase of the PAR in CNMI with consideration to future RSLC.

Table 4-2. Areas and PAR Vulnerable to RSLC in the Future Scenario

| Rota | | | |
|---|---|---|---|
| Village | PAR - Existing | PAR - Future | PAR Future % Change |
| Liyu | ✓ | ✓ | 232% |
| Songsong | ✓ | ✓ | --- |
| Annex F | ✓ | ✓ | --- |
| Ugis | | ✓ | New PAR |
| Taimama | ✓ | ✓ | --- |
| **Total** | ✓ | ✓ | **23%** |
| Saipan | | | |
| Village | PAR - Existing | PAR - Future | % Change in Future for PAR |
| San Antonio | ✓ | ✓ | --- |
| San Roque | ✓ | ✓ | 30% |
| Chalan Piao | ✓ | ✓ | --- |
| Chalan Kanoa II | ✓ | ✓ | --- |
| Lower Base | ✓ | ✓ | 10% |
| San Jose (Oleai) | ✓ | ✓ | --- |
| China Town | ✓ | ✓ | --- |
| Garapan | ✓ | ✓ | 16% |
| Susupe | ✓ | ✓ | --- |
| Puerto Rico | ✓ | ✓ | --- |
| American Memorial Park | ✓ | ✓ | 14% |
| As Palacios | ✓ | ✓ | --- |
| Achugao | ✓ | ✓ | --- |
| Tanapag | ✓ | ✓ | 21% |
| **Total - Saipan** | ✓ | ✓ | **11%** |
| ***CNMI Total*** | ✓ | ✓ | ***16%*** |

Table 4-3 shows the results pertaining to structure damages, however this analysis is less about exact numbers, and more about showing which areas will experience the greatest change in the number of people at risk and are therefore vulnerable to RSLC. For example, there are an additional forty structures inundated village of Garapan in the future scenario, highlighting the vulnerability of structures in CNMI. Notably, the village of Liyu displays a very large percentage change due to the small amount of PAR in the existing condition of Liyu. Any change, even small, will appear as a large percentage change in this area.

Table 4-3. Structures Inundated Under Existing and Future Scenarios

| Rota | | | | |
|---|---|---|---|---|
| Village | Structures Inundated - Existing | Structures Inundated - Future | Additional Structures Inundated in Future | Percent Change in Future |
| Liyu | 1 | 3 | 2 | 200% |
| Songsong | 64 | 64 | 0 | --- |
| Annex F | 1 | 1 | 0 | --- |
| Ugis | | 1 | 1 | New Risk |
| Taimama | 1 | 1 | 0 | --- |
| **Total** | **67** | **70** | **3** | **4%** |
| Saipan | | | | |
| Village | Structures Inundated - Existing | Structures Inundated - Future | Additional Structures Inundated in Future | Percent Change in Future |
| San Antonio | 9 | 9 | 0 | --- |
| San Roque | 20 | 26 | 6 | 30% |
| Chalan Piao | 1 | 1 | 0 | --- |
| Chalan Kanoa II | 2 | 2 | 0 | --- |
| Lower Base | 30 | 33 | 3 | 10% |
| San Jose (Oleai) | 6 | 6 | 0 | --- |
| China Town | 1 | 1 | 0 | --- |
| Garapan | 257 | 297 | 40 | 16% |
| Susupe | 16 | 16 | 0 | --- |
| Puerto Rico | 15 | 15 | 0 | --- |
| American Memorial Park | 7 | 8 | 1 | 14% |
| As Palacios | 1 | 1 | 0 | --- |
| Achugao | 12 | 12 | 0 | --- |
| Tanapag | 56 | 68 | 12 | 21% |
| **Total** | **433** | **495** | **62** | **14%** |
| ***CNMI Total*** | ***500*** | ***565*** | ***65*** | ***13%*** |

The CNMI and its people and structures experience increased estimated PAR, structures inundated, and structure damages under the future scenario. Within the Commonwealth, new or increased PAR is estimated to occur in seven villages. One of which on Rota, Ugis, is not estimated to occur until the future scenario. On Saipan, the largest increase in estimated PAR is the village of San Roque. The island of Tinian does not show any existing or future estimate PAR. Overall, there is an estimated 16% increase to PAR due to RSLC within CNMI.

Increases of structure impacts are seen on the islands of Rota and Saipan as well. New risk is seen in Rota in the village of Ugis, and Saipan shows several dozen new structures impacted due to RSLC. Overall, there is a 13% increase in the number of structures impacted over the period of analysis.

The modeling also shows an increase in inundation of the road networks within CNMI. The majority of road inundation is estimated to occur along the western coast of Saipan, with the greatest depths (over 12 ft) expected within and between the villages of Garapan and Tanapag. On Rota, the village of Songsong also sees increases of road depths with portions of nearly all of the village's roads experiencing flooding of at least a foot. Of the 16,240 road segments within Saipan and Rota identified via OpenStreetMap, 359 road segments experience inundation under the existing scenario, with an additional 35 road segments in the future (394 in total).

## 4.10 Cultural Resources

Cultural resources are places, objects, sites, oral histories, and traditional practices that have historic or cultural significance to local individuals, communities, or even a nation. They can be viewed within watershed planning as a key component of resilience for a community by bringing together a sense of place or reflecting a people's cultural identity. An assessment of CNMI's watersheds and resources would be largely incomplete without addressing the myriad of cultural resources present throughout the landscape and its surrounding waters.

Typical inventories for cultural resources focus on preserving tangible properties such as sites, buildings, structures, objects, or districts under state, territorial, and Federal historic preservation law. This watershed assessment must also consider intangible cultural resources, which play an important role for cultural identity across the territory today. The sections below summarize the human history of CNMI.

*Summary of Prehistoric Cultural Resources*

The "prehistoric" period is understood by studying the physical evidence of human activity left behind by people or a cultural group who did not have any written records. Through a combination of archaeological research, ethnographic interviews, oral traditions, and historic documentation by Europeans during contact, a framework to understand the prehistoric temporal periods of the Northern Mariana Islands has been established. A simple two-part chronology known as the Pre-Latte Period and the Latte Period was established by archaeologists based on the location of prehistoric sites, settlement patterns, artifact typologies, changes in subsistence, and architectural features.

The Pre-Latte Period (2000 BCE to 1000 CE) begins with the early settlement of the Northern Mariana Islands 4,000 years ago. Seafaring explorers arrived from Southeast Asia bringing ceramics, canoes, domesticated animals, and cultivated crops such as banana, taro, sugarcane, breadfruit, and coconuts (CNMI HPO, 2011).

Sites from the earliest period of settlement in the Pre-Latte Period are regarded as uncommon or in poor condition. Pre-Latte sites were recorded along coastal beach environments, inland rock shelters, and caves. Archaeological fieldwork has identified unique features and artifacts at Pre-Latte sites ranging from hearths, postholes, cooking debris containing large amounts of shellfish and reef fish remains, food storage features, seafaring technologies, stone, bone, and shell ornaments, and lithic debitage from tool making activities. Large densities of fish remains at sites indicate that the Pre-Latte people relied heavily on nearshore reefs for subsistence (Reinman, 1977; Kurashina and Clayshulte, 1983; CNMI HPO, 2011).

By around 1,000 CE, archaeological evidence from the Latte Period (1000 CE to 1668 CE) signified an increase in population. This was followed by a shift in settlements expanding all across the regions of Saipan, Tinian, Rota, and Aguiguan (CNMI HPO, 2011). This major shift in settlement patterns was followed by changes in their lifeways and subsistence based on their new environment. Marine resources were identified in large densities at Latte Period sites as well as terrestrial faunal remains ranging from birds, bats, lizards, turtles, and snails. Cultivation of trees, root crops, rice, and fishing were also prevalent during this later period of settlement.

The Latte Period introduced a significant architectural stone at sites known as a *latte*. Lattes are characterized as huge capstone pillars made from limestone or basalt placed in two parallel rows and found across the Northern Mariana Island's coastlines and villages. They served as a foundation for Chamorro residential houses (CNMI HPO, 2011). Basalt grinding stones, lithic artifact scatters, quarries, water wells, rock art, caves, and ancestral burials beneath latte structures forms the material culture associated with this period. By the time European contact occurred in the mid-17$^{th}$ century, the Chamorro people have settled across the entire archipelago (CNMI HPO, 2011).

*Summary of Historic Period Resources*

The beginning of the historic period for the Northern Mariana Islands starts at 1668. Written records from the Spanish Magellan expedition documented their exploration of the islands in 1521, however it wasn't until the establishment of a Jesuit mission in Guam in 1668 that European contact for the Northern Mariana Islands intensified (CNMI HPO, 2011). Efforts made by the missionaries to colonize and convert the Chamorro people were met with resistance at Saipan and Guam (Rogers, 1995). In retaliation, the Spanish implemented a four-year *reducción* program in 1694 restricting Chamorro settlements to Guam, Saipan, and Rota (Rogers, 1995). The early 19th century also introduced Carolinian refugees who migrated to Saipan after devastating storms destroyed their homes in the Caroline Islands. Past inventories have documented Spanish mission structures, villages, remnants of buildings, archaeological deposits, and shipwrecks associated with this early period of European contact.

The Northern Mariana Islands were soon purchased by Germany in 1898. Germany intended to create an agricultural economy for the Commonwealth by exporting dried coconut meat that can be extracted into coconut oil known as copra. The Germans invested in infrastructure across the Commonwealth until 1914. Very few German period sites exist today due to major disturbances during the era of Japanese control and World War II. However, ruins exist on the surface as well as buried archaeological deposits connected to Germany's short period of agricultural development (CNMI HPO, 2011).

By 1914, the Japanese military took control of the Northern Mariana Islands and established sugarcane plantations (CNMI HPO, 2011). With World War II beginning around 1941, the Japanese constructed military structures such as airfields and naval stations in preparation for the war. Historic resources from this era of Japanese control includes farmhouses, roadways, factories, agricultural buildings, mining sites, hospitals, stores, administrative buildings, cisterns, Japanese Shinto shrines, and domestic refuse heaps.

The Pearl Harbor attack on December 7, 1941, pushed the Japanese to fortify their hold on the Northern Mariana Islands. More Japanese personnel and citizens were relocated to the island. By 1944, the majority of the population were Japanese citizens and not Chamorro or Carolinian individuals (Bowers, 1950). Large-scale destruction occurred in 1944 due to U.S. aerial and naval bombardment conducted in anticipation of U.S. marine landings. Once the islands were in

American control, airfields and military bases were established to support war operations in the Pacific and the strategic push toward the Japanese mainland. World War II historic resources make up the largest percentage of cultural and historic sites in the Northern Mariana Islands (CNMI HPO 2011), ranging from airfields, hospitals, defensive gun stations, officer housing, tunnels, caves, ammunition storage areas, equipment dumps, surface and buried scatters of military equipment, shipwrecks, plane crashes, and mass grave sites (Mckinnon 2015).

The Post-War Period saw regrowth and revegetation of large portions of the landscape which had been cleared during the war, and thus a return to thick sword grass, tangan-tangan, and tropical vegetation in many areas. Military infrastructure associated with Japanese control and World War II was largely abandoned. Chamorro communities returned to small-scale farming of the land, growing fruit trees, watermelon, tomatoes, tapioca, corn, sweet potatoes, and yams until the 1980's. Cattle ranching, originally introduced by the Spanish, resumed. In addition to small-scale farming and ranching, a tourism industry developed in the later part of the twentieth century and continues to the present. Historic districts, churches, commercial buildings, government buildings, and residences are some of the significant architectural historic resources dating to the Post-War Period (CNMI HPO, 2011).

Historic properties listed for CNMI include prehistoric and historic buildings, structures, sites, districts, objects, and traditional cultural properties. Thirty-seven historic properties are currently listed in the National Register of Historic Places (NRHP) database and spread out across Saipan, Tinian, and Rota.

*Summary of Intangible Cultural Resources*

Identifying and preserving intangible cultural resources can be a unique yet challenging opportunity to consider for this watershed assessment. The difficulty of discerning the boundary for a cultural landscape or natural feature that has cultural significance would require thorough consultation with the Chamorro cultural groups, who may refuse to disclose such sensitive information to an agency.

The National Register Bulletin 38 has addressed this issue by defining a category of protected cultural resources known as a Traditional Cultural Properties (TCP). This guidance defines a traditional cultural property as a historic property eligible for inclusion in the National Register of Historic Places because of significance associated with cultural practices or beliefs for a living community's history and maintaining their cultural identity (Parker and King, 1990).

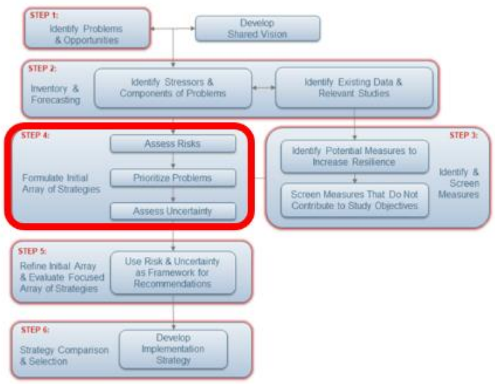
Intangible cultural resources should be considered due to the rising threat of CNMI's economic and social change as well as continued land-use development (CNMI HPO, 2011). They play a unique role in the Chamorro community's practices and beliefs, helping to maintain their cultural identity and providing a sense of place and belonging.

Although few Chamorro traditional historic properties have been identified to date, limited documentation includes certain latte sites, ancestral burials, ceremonial practices, traditional hunting areas, fishponds, plant gathering areas, trails, cultural landscapes such as geological features associated with folklore, and viewsheds from sacred locations (NPS,1998). Such intangible cultural resources should certainly be considered during planning for any water resource project and documented thoroughly, ensuring it is preserved for future generations. Understanding what traditional cultural properties exist and how they retain traditional cultural significance to the affiliated Chamorro or Carolinian groups today will also provide an opportunity for indigenous traditional ecological knowledge to be incorporated into the management of CNMI's natural and water resources. Threatened by economic and social change as well as land-use development (CNMI HPO, 2011), intangible cultural resources play a central role in the Chamorro community's practices and beliefs, which serve to maintain their cultural identity and provide a sense of place and historical continuity.

A collaborative approach and the formation of working partnerships will support a better understanding of which intangible cultural resources are most significant to Chamorros, and how traditional practices can be incorporated into the management of CNMI's heritage resources. This information can then be used to minimize and mitigate the ongoing impacts associated with economic development.

Future conditions for tangible cultural resources would include loss of research contributions to the archaeological and historic record for sites destroyed by coastal flooding, erosion, or RSLC. Economic growth through the tourism industry for tangible cultural resources is expected to decline from coastal flooding and erosion damaging the historic integrity of a cultural resource or inundation caused by RSLC making cultural resources inaccessible to cultural resource managers or the public. Intangible cultural resources are also expected to deteriorate in the future, with lack of access from coastal flooding, erosion, or RSLC altering cultural landscapes as well as keystone cultural species for the Chamorro and Carolinian people. The deterioration of CNMI's natural resources, such as coral reefs, would alter the indigenous people's social connection and traditional practices taking place across the land and its resources.

# 5 Formulate Initial Array of Strategies




In order to identify potential watershed recommendations to build resilience among CNMI's human and natural communities, a risk-based approach was taken to identify the highest risks to prioritize near-term efforts. Risks that are currently being realized within the study area with the potential for increased probability and consequences under future conditions were considered. These risks, identified and evaluated through review of existing documentation as well as a series of engagement meetings with the study partner and Federal and local stakeholders, largely fall within one or more of four categories: life loss, economic, social, and environmental. This largely aligns with benefit categories defined in the USACE Policy Memorandum "Policy Directive – Comprehensive Documentation of Benefits in Decision Documents," dated January 5, 2021, which calls for "equal consideration of economic, environmental, and social categories." The principles of this policy directive were applied to inform the risk-based prioritization of identified problems. The subsequent subsections provide details on the risk approach and prioritization assessment.

## 5.1 Risk Assessment Process & Evaluation

The risk assessment, conducted in collaboration with the project team, partners, and stakeholders, qualitatively assessed each stressor's probability of occurring and the magnitude of its consequence from an economic, life loss, social, and environmental perspective. Members of the USACE team individually performed an initial risk assessment on each of the stressors. Once completed, the ratings for each were reviewed and given a final screening by subject matter experts using professional judgement. USACE then presented the results to the study partners and stakeholders to review and provide input to ensure accuracy. The four risk metric categories (economic, life loss, social, and environmental) were evaluated based off the following criteria in sections 5.1.1 through 5.1.3.

### 5.1.1 Economic Risk

Economic risk estimates the combination of likelihood and consequences of harm to property, infrastructure, and other assets (measured in monetary units) resulting from each of the stressors. This was assessed over a 50-year forecasting period of analysis, which spans from 2022 to 2072. Table 5-1 and Table 5-2 show the evaluation criteria applied to each stressor.

Table 5-1. Qualitative Probability Metrics for Economic Impacts

| **Economic Risk – Probability** | |
|---|---|
| *Probability* | *Definition* |
| Not Likely | It is not anticipated a stressor will contribute to this risk. |
| Could Occur | It is possible a stressor could contribute to this risk. |
| Has Occurred | A stressor has contributed to this risk. |
| Has Occurred and Increasing | A stressor has contributed to this risk and is anticipated to do so again in the future. |
| Occurs Often | A stressor contributes to this risk frequently. |
| Occurs Often and Increasing | A stressor contributes to this risk frequently and is anticipated to continue to increase. |

Table 5-2. Qualitative Consequence Metrics for Economic Impacts

| **Economic Risk – Consequences** | |
|---|---|
| *Magnitude of Consequence* | *Definition* |
| No Impact | No impacts are anticipated. |
| Household Impact | Impacts are anticipated to affect a single household. |
| Town/Village Impact | Impacts are anticipated to affect a community. |
| Watershed Impact | Impacts are anticipated to affect multiple communities. |
| Commonwealth Impact | Impacts are anticipated to affect one or more islands within CNMI. |
| National Impact | Impacts are anticipated to affect the mainland U.S. and other surrounding countries/territories. |

### **5.1.2** Social and Environmental Risks

To characterize social risks, the three factors that were considered were: social connectedness, health and safety, and subsistence. The definition of social connectedness was adapted from the USACE Institute for Water Resources (IWR) 2013 "Other Social Effects: A Primer" and refers to sustaining a sense of connection to the community and neighborliness. This can include the displacement of people, business, and farms and also refers to the loss of intangible cultural resources such as folklore, traditions, language, and cultural knowledge. Health and safety refer to the risks to human health and safety including effects on security, health, safety, and emergency preparedness. The third factor used to assess social risk was subsistence, which is the ability of individuals and communities to be self-sustaining, such as reliance on natural resources to support a community and livelihoods.

To characterize environmental risk, the four factors considered were: ecosystem services impacts, habitat loss, species loss, and cultural resources loss. Ecosystem services refers to various benefits provided by certain environmental and natural resources to communities. Cultural resource loss encompasses the damage or destruction of tangible cultural resources.

The same evaluation metrics were used for both social and environmental risk assessments. The single highest ranking between factors in each risk category was carried through for the overall social and environmental risk assessments.

The following evaluation metrics shown in Table 5-3 and Table 5-4 were used to assess both the social and environmental risk.

Table 5-3. Qualitative Probability Metrics for Social and Environmental Impacts

| **Social and Environmental Risk – Probability** | |
|---|---|
| *Probability* | *Definition* |
| Not Likely | It is unlikely a stressor's occurrence will contribute to this risk. |
| Not Likely but Increasing | It is unlikely a stressor's occurrence will contribute to this risk but could happen. |
| Could Occur | It is likely a stressor's occurrence will contribute to this risk. |
| Could Occur and Increasing | It is likely a stressor's occurrence will contribute to this risk and becoming more likely. |
| Has Occurred | The stressor's occurrence has contributed to this risk. |
| Has Occurred and Increasing | The stressor's occurrence has contributed to this risk and will continue. |

Table 5-4. Qualitative Consequences Metrics for Social and Environmental Impacts

| **Social Vulnerability and Environmental Risk – Consequences** | |
|---|---|
| *Magnitude of Consequence* | *Definition* |
| Temporary Impact | It is anticipated impacts from a stressor will be temporary. Emergency response will likely be necessary to mitigate, but recovery efforts are not anticipated to be necessary. |
| Temporary Impact and Increasing | It is anticipated impacts from a stressor will be temporary and may continue to worsen over time. Emergency response will likely be necessary to mitigate, but recovery efforts are not anticipated to be necessary. |
| Long-Term Impact | It is anticipated impacts from a stressor will be long-term. Recovery is likely required to re-establish a healthy, functioning community that will sustain itself over time. |
| Long-Term Impact and Increasing | It is anticipated impacts from a stressor will be long-term and may continue to worsen over time. Recovery is likely required to re-establish a healthy, functioning community that will sustain itself over time. |
| Permanent Impacts Possible | It is anticipated impacts from a stressor will be permanent. Full recovery from impacts may not be possible. |

### 5.1.3 Life Loss Risk

Life loss risk evaluated the likelihood of a stressor occurring in any given year and the general magnitude of the life loss. The following evaluation metrics, shown in Table 5-5 and Table 5-6, were used to assess life loss risk.

Table 5-5. Qualitative Probability Metrics for Life Loss Impacts

| **Life Loss Risk – Probability** | |
|---|---|
| *Probability* | *Definition* |
| Remote | It is very unlikely a stressor will occur in any given year. |
| Low | There is a low chance a stressor will occur in any given year. |
| Moderate | There is a moderate chance a stressor will occur in any given year. |
| Likely | It is likely a stressor will occur in any given year. |
| Very Likely | It is very likely a stressor will occur in any given year. |

Table 5-6. Qualitative Consequences Metrics for Life Loss Impacts

| **Life Loss Risk – Consequences** | |
|---|---|
| *Magnitude of Consequence* | *Definition* |
| Unlikely Life Loss | It is not anticipated a stressor will result in any life loss. |
| Low Magnitude Life Loss | If a stressor occurs, it is anticipated a few lives will be lost. |
| Moderate Magnitude Life Loss | If a stressor occurs, it is anticipated more than a few lives will be lost. |
| High Magnitude Life Loss | If a stressor occurs, significant life loss is inevitable. |

## 5.2 Risk Assessment Results

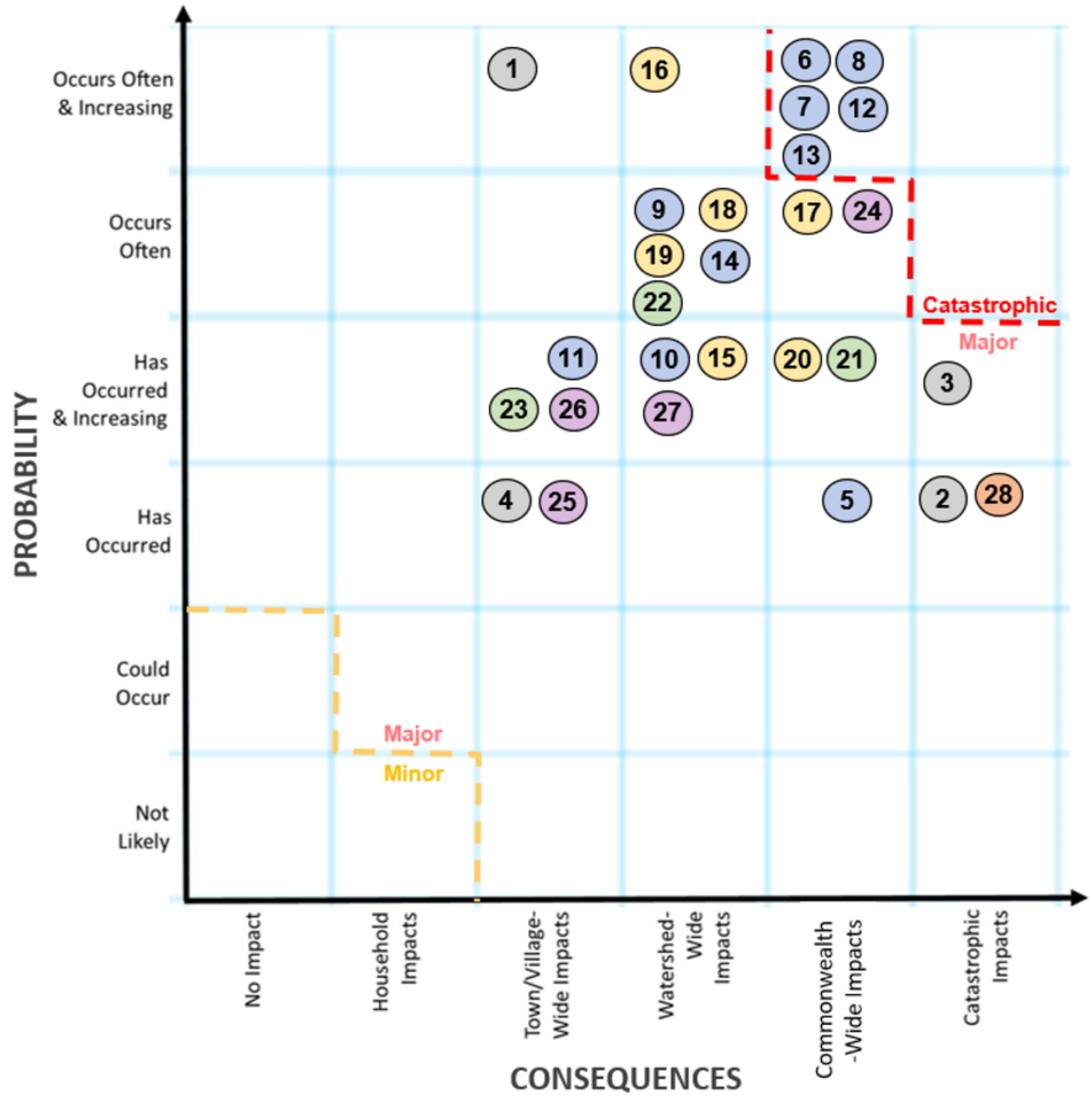
All stressors are high risk and important to address. In order to create a distinction among the stressors and their relative risk, the team developed three risk categories: minor, major, and catastrophic. The red dashed line shown in the following plots was qualitatively placed to designate the highest relative, or catastrophic, risk stressors in order to help prioritize potential future actions. For social and environmental metrics, the stressors deemed to have catastrophic risks are the ones where permanent impacts have occurred. For economic metrics, these are risks where widespread impacts occur with high frequency. For life loss metrics, highest life loss risks consider the magnitude of potential life loss and the frequency at which the stressor occurs. The range for life loss catastrophic risk spans from frequent events with low magnitude life loss to infrequent events with the potential for high magnitude life loss. All other risks are categorized as “major” or “minor” if they did not possess the highest relative risk. The categories help prioritize resiliency strategy implementation for stressors that USACE and its partners agreed were imminent.

Figure 5-1 through Figure 5-11 below show the risk assessment results. It is important to note that equal consideration was given to economic, life loss, social, and environmental risk. Stressors located anywhere in the same square at the intersection of probability and consequence have an equal risk rating.

### 5.2.1 Economic Risk

Figure 5-1 below shows the risk assessment evaluation results for economics. Increasing water temperatures, RSLC, coral bleaching, loss of living breakwater, and stormwater management are five stressors that ranked as catastrophic risks. These stressors have widespread impacts to coastal and inland ecosystems and the economy. Increasing water temperatures and RSLC are linked to climate change, which is anticipated to exacerbate these conditions. Increasing ocean temperatures can lead to the coral bleaching and loss of critical ocean habitat and ecosystem services that yield more than $100 million annually to CNMI’s economy (Grecni et al., 2021).

Various factors were considered to qualify a stressor as catastrophic, including factors outside the control of the CNMI, factors that affect the entire Commonwealth, and factors that could cause severe disruptions to primary sources of economic health for the Commonwealth, such as tourism. Stressors that rose to major are also capable of greatly impacting the economy of the CNMI; however, on a more localized, temporary, and/or infrequent level. Some stressors were categorized as major because the community has already taken steps to limit economic impacts.




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-1. Economic Risk Assessment

Figure 5-1 displays the risk assessment results for economics. Increasing water temperatures, coral bleaching, loss of a living breakwater, RSLC, and stormwater management are the five stressors that have a catastrophic risk associated with economic impacts that could affect CNMI.

Increasing water temperatures, coral bleaching, and loss of a living breakwater all adversely impact marine resources which significant support for the economy through tourism. RSLC can severely impact coastal communities and critical infrastructure, such as roads, utilities, and property, by increasing the amount of damage due to storm surge inundation and coastal erosion. Inadequate stormwater management, an issue stressed throughout CNMI, adversely impacts infrastructure, increases the amount of maintenance, and leads to water and environmental resources degradation. Current systems become easily overwhelmed by the influx of debris following a storm. Other stressors in the Coastal category, such as poor land use practices and nutrient loading, both ranked fairly high in terms of likelihood and consequences related to economic impacts; however, neither were forecasted to be catastrophic as their economic impacts are not anticipated to increase.

None of the stressors within the tropical storms and typhoons category were ranked as catastrophic. While the coastal flooding stressor has the highest probability of economic impacts in this problem category with possible irreparable damage and/or loss of property, its consequences were limited to town/village wide level. While communities have taken steps to have back-up generators on the islands for emergencies, consequences from loss of power supply remain high with impacts consisting of severe and prolonged system and service interruptions across multiple islands. Severe winds can damage both residential and commercial property, critical infrastructure, and habitat, but has not been a frequent enough occurrence to warrant a catastrophic rating at this time. Maritime supply chain interruptions may cause temporary economic impacts by restricting imports and exports, but steps have been taken to develop an emergency response plan to minimize impacts.

While water quality and supply issues have caused economic impacts with varying levels of consequences, none of the stressors in this category were ranked as catastrophic. Unmetered water use, groundwater over pumping, and leaks throughout the water distribution system led to significant revenue losses. Saltwater intrusion, exacerbated by groundwater over-pumping and RSLC, directly affects access to clean water supplies. Point and nonpoint source pollution contaminate both surface and groundwater, further limiting already scarce resources.

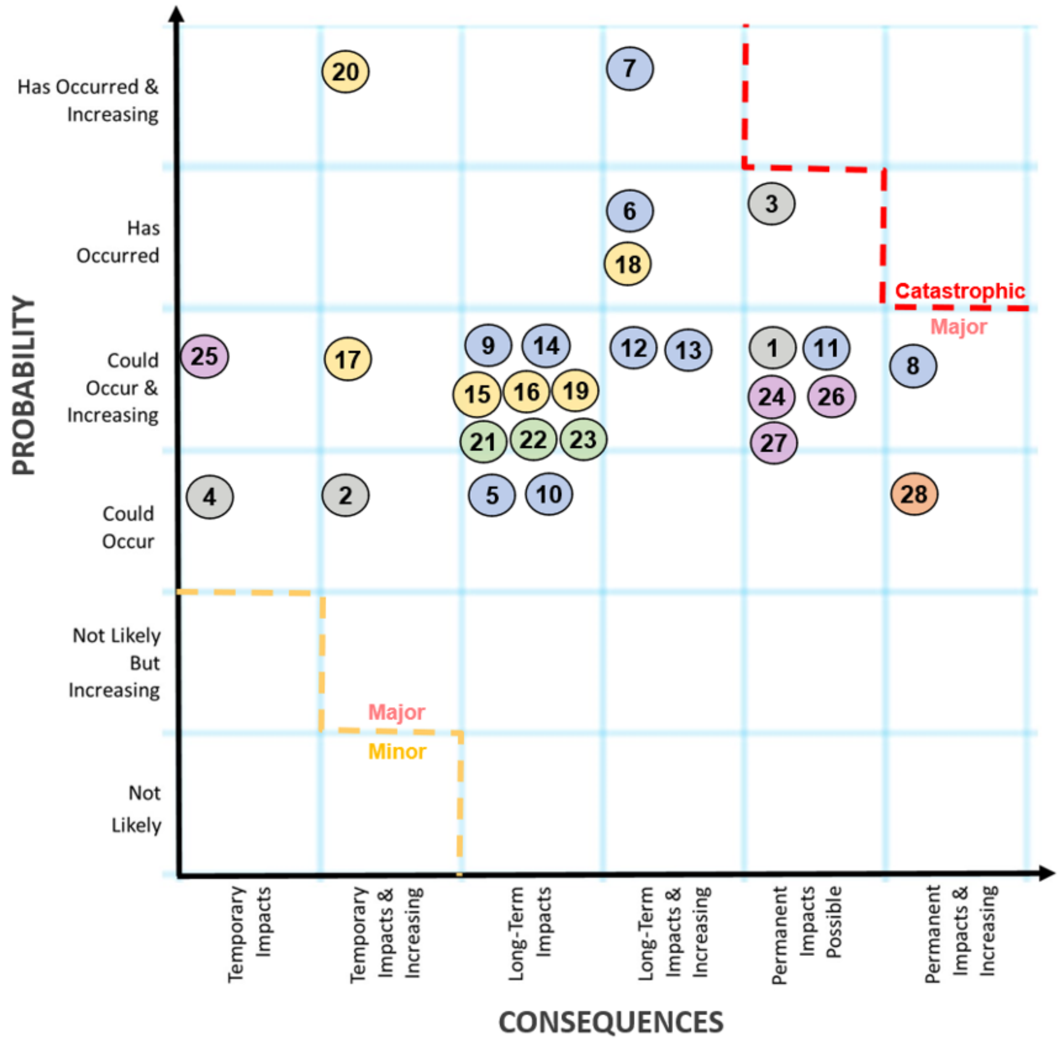
Inland ecosystem economic impacts of damages to infrastructure and the environment range from affecting a single location to watershed-wide, but none are ranked as catastrophic. Wildfires occur often from both natural and anthropogenic causes, impairing infrastructure and leading to adverse impacts to environmental and water resources. Invasive species are found throughout the islands and directly impact grazing practices, forested land production, and native aquatic organisms that support fishing livelihoods.

None of the stressors within the rainfall category were ranked as catastrophic. Stressors such as flash flooding, sedimentation, and riverine erosion occur often from storms and smaller rainfall events with varying consequences. Potential for economic impact stems from damage to infrastructure and businesses from storm events or power outages. Flooding, sedimentation, and erosion may cause economic impacts in affected areas due to inaccessibility to centers of commerce.

While tsunamis can cause widespread economic impacts due to the devastating consequences to infrastructure and life loss, this stressor was not ranked as catastrophic due to its infrequency.

### 5.2.2 Social

#### 5.2.2.1 *Social Connectedness*




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-2. Social Connectedness Risk Assessment

Figure 5-2 displays the risk assessment results for social connectedness. No stressors were considered to have catastrophic risks associated with them. Tropical storms and typhoons lead to coastal flooding that can cause significant damage and/or loss to properties and homes located near the shoreline or within the coastal plain, which can cause communities to temporarily or permanently relocate to other areas. High winds resulting from typhoons, such as Typhoon Yutu, can cause considerable damage to schools and homes leading to potential permanent displacement of both students and residents. Eroded shorelines are vulnerable to additional erosion and could lead to significant commercial and residential area losses that would force those living and working in those areas to relocate.

CNMI RSLC is expected to have permanent impacts related to displacement for certain villages. Coastal villages such as Susupe and Chalan-Kanoa were identified to be vulnerable from extreme scenarios of RSLC. Retreat from RSLC would be limited due to wetlands surrounding these villages and a large student population is expected to be displaced. This includes loss of significant recreational facilities which also serves as a high-capacity disaster recovery center for other villages on Saipan (CNMI DCRM & NOAA, 2014).

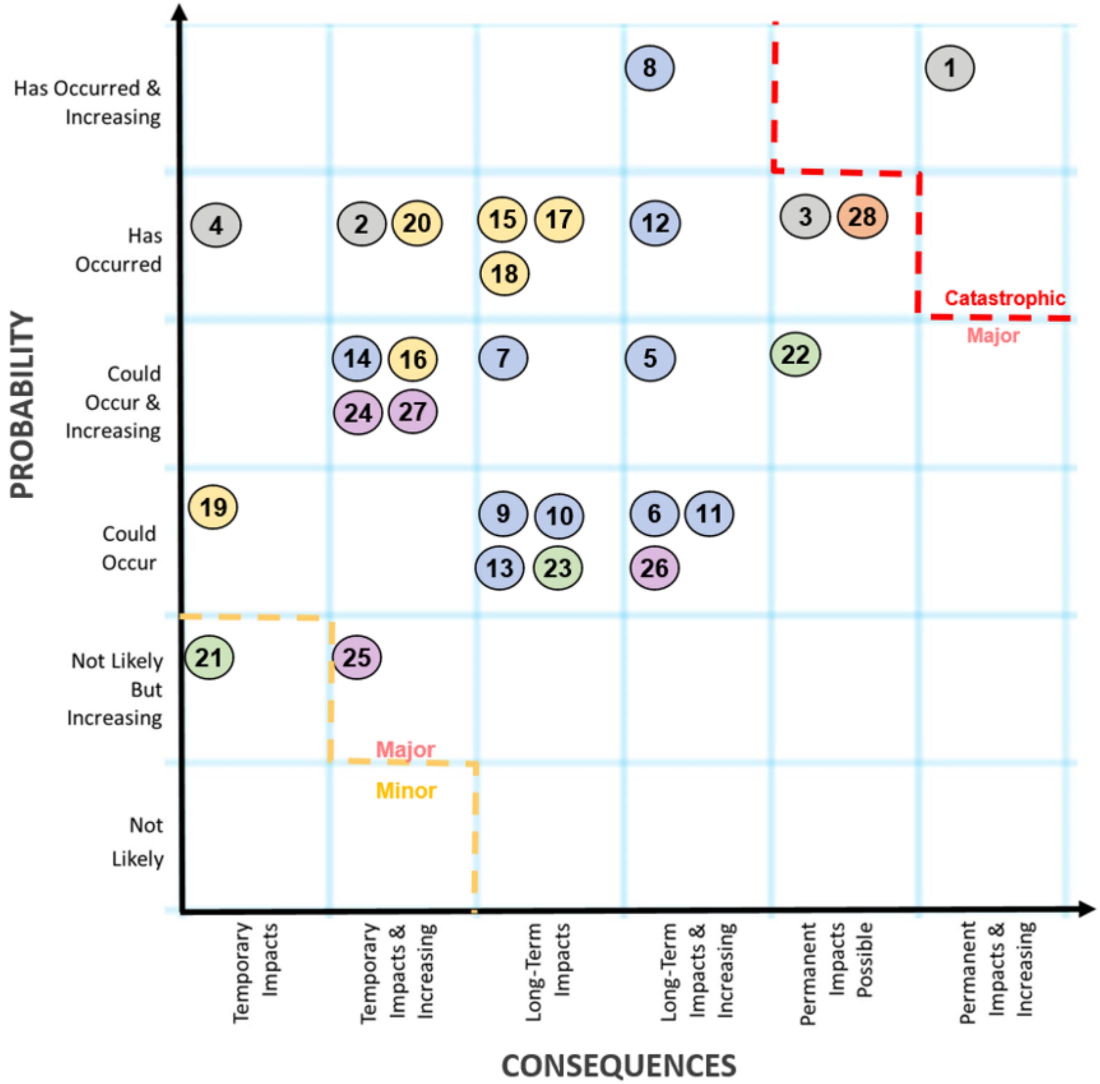
Water quality and supply is not expected to have significant displacement risk. Saltwater intrusion may have long-term consequences, particularly for farmers reliant on freshwater for their livelihood. Other stressors of water quality and supply are unlikely to cause displacement, however drought could have long-term impacts depending on length and severity. A serious drought would limit water availability, having more serious consequences for farmers. Point and nonpoint source pollution are unlikely to have any displacement impacts as water may be sourced elsewhere if contaminated.

Inland ecosystem stressors are unlikely to have significant displacement risk, although wildfires could cause long-term displacement to those living in structures on the fringe of urban areas or close to the fire source. A Community Vulnerability Assessment was performed that determined of the 424 facilities that were recorded, 114 of them were identified as vulnerable to the threat of fire (CNMI HSEM, 2018).

Social Connectedness risk ranking for rainfall related stressors was primarily focused on the length and severity of impacts. All risk factors were major due to temporary changes where recovery is expected. Flooding in CNMI mostly leads to temporary displacement when torrential rainfall creates flash flooding and inundation island-wide that can lead people to evacuate and find temporary shelter.

Tsunamis have the potential to have devastating consequences such as injury, loss of life, damage to buildings, and infrastructure in coastal zones. Should this occur, there could be severe community cohesion impacts. The consequences of tsunami-related risks are increasing with development growth.

### 5.2.2.2 *Health & Safety*




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-3. Health and Safety Risk Assessment

Figure 5-3. Health and Safety Risk Assessment displays the risk assessment results for health and safety. Coastal flooding and inundation of coastal infrastructure from tropical storms and typhoons pose catastrophic health and safety risk to communities with permanent impacts.

Floods often result in life loss largely resulting from residents not heeding warning signs and advisories to avoid driving through moving water. Flooding can also cause long-term health impacts from polluted waters. Floods also increase physiological stress as individuals navigate the loss of community members, their home, and irreplaceable possessions. Critical infrastructure including harbors, power utilities, water and wastewater treatment plants, and sewer systems can become impaired leading to import delays, loss of power and water access, and areas becoming inundated with sewage water. Power outages can lead to hospitalization prevention or supporting essential functions like providing oxygen supply if back-up generators are not installed.

None of the stressors within the coastal problem category were ranked as catastrophic, but RSLC and stormwater management have occurred with long-term impacts and increasing. Increasing RSLC can lead to health and safety risks through the impairment of critical infrastructure such as roads, power and water utilities, and critical infrastructure. In highly developed areas, stormwater runoff transports contaminants into waterways that contribute to contamination of water resources and can inundate areas leading to compromised roadways and infrastructure.

None of the stressors within the water quality and quantity category were ranked as catastrophic. Point and nonpoint source pollution can contaminate water with human or animal waste and potentially cause short-term (digestive complications) or long-term health impacts (cancer). Saltwater intrusion, unmetered water use, and groundwater over pumping currently impact drinking water availability. Power outages, from a storm or flooding event, can span from days to months and prevent electric pumps at water plants from providing drinking water to an impacted area. Saipan and Tinian have experienced disruptions to water supply following typhoons, necessitating emergency water distribution efforts and issuing water boil advisories to eliminate waterborne pathogens and minimize health and safety risks. Additionally, sedimentation can clog and subsequently close wells creating risk for temporary health and safety impacts from lack of water supply.

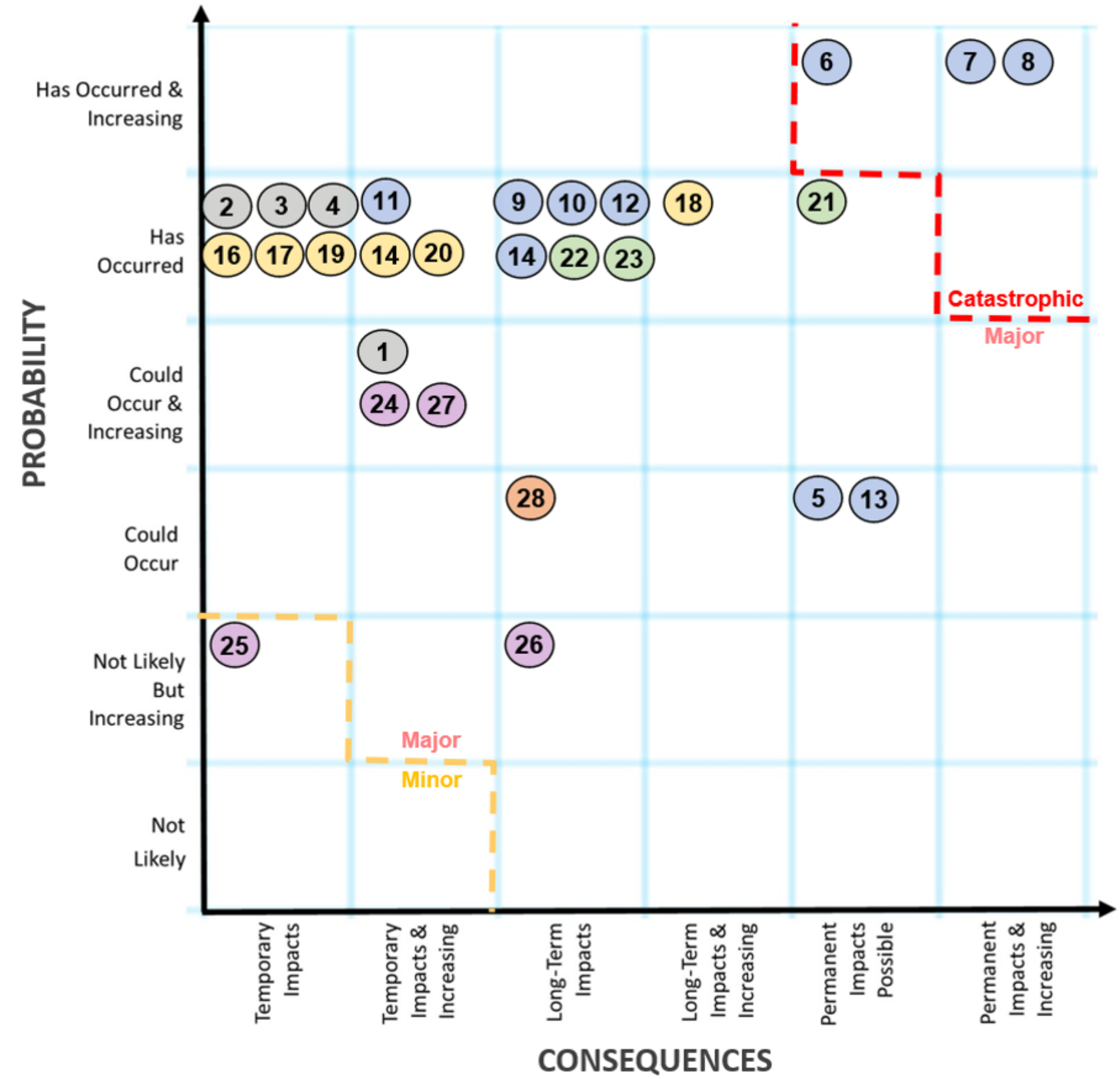
Hundreds of wildfires occur each year throughout CNMI but haven’t resulted in extensive infrastructure damage nor health and safety impacts and therefore were not ranked as catastrophic. However, with increasing tourism activity, and the expansion of residential housing into more rural areas that are considered high-risk hazard zones for wildfire, wildfire risks are also anticipated to increase with permanent impacts possible. With most fires having anthropogenic causes, increased human presence and activity in rural areas does raise concern.

None of the stressors within the rainfall category were ranked as catastrophic. While tropical storms and typhoons cause most of the flooding throughout CNMI, torrential rainfall creates flash flooding and inundated floodplains island wide, especially in low lying areas. Areas that are not directly impacted from a flood event can also experience indirect health and safety impacts. Critical infrastructure such as power utilities, water and wastewater treatment plants, and sewer systems that are impaired by coastal flooding can still impact inland areas and vice versa.

Severe winds resulting from these storm events cause health and safety risks to residents due to flying debris.

While infrequent, tsunamis pose a high risk for injuries and life loss especially for coastal and low-lying inland areas.

### 5.2.2.3 *Subsistence*




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-4. Subsistence Risk Assessment

Figure 5-4 displays the risk assessment results for subsistence. Increasing water temperatures, coral bleaching, and RSLC were the three stressors that have catastrophic risk rankings. These three stressors are connected to climate change, which is anticipated to exacerbate them. CNMI residents and the economy depend upon marine habitat for both food resources and tourism.

RSLC permanently alters and inundates coastal areas, rendering the land and habitat unusable. RSLC is occurring at a faster rate due to increasing subsidence coupled with global warming trends. Rising seas means areas further inland are being impacted by coastal flooding, nuisance flooding, and more wave action. Such events present challenges to villages, shorelines, and coastal infrastructure that may force relocation of populations in the future.

Increasing water temperature reduces overall coral health and exacerbates the frequency of bleaching events. This leaves coral vulnerable to disease, slows growth, and impacts other marine species who are dependent on them. This can lead to reduced food and tourism resources, which impairs livelihoods.

The other stressors within the coastal hazards category were not ranked as catastrophic but can cause long-term or permanent impacts to communities due to the irreparable nature of RSLC and coastal habitat degradation (loss of corals, fish, etc.). Loss of coastal habitat that has sustained locals for centuries could have permanent impacts to subsistence.

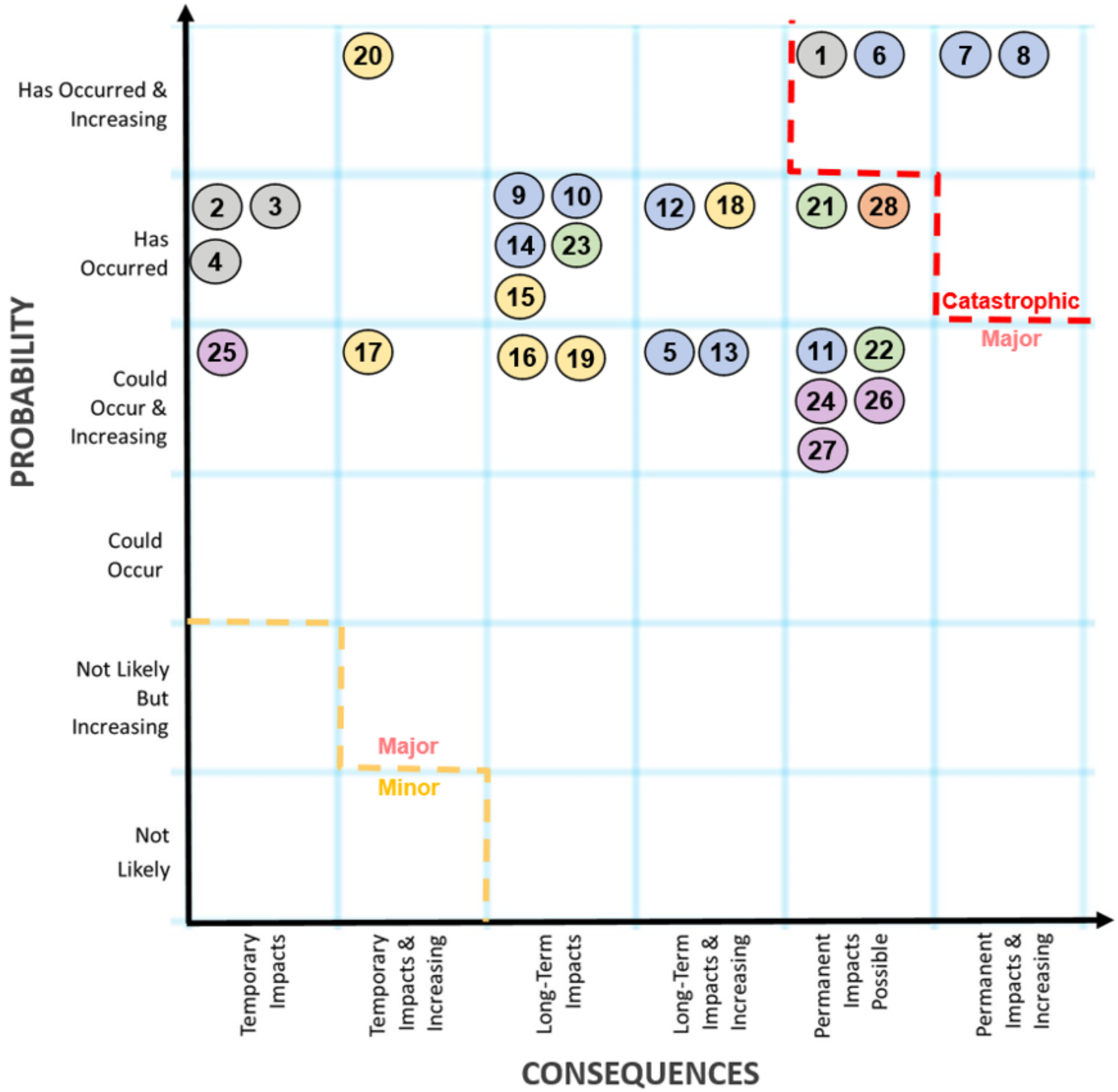
None of the stressors within the water quality and quantity category were ranked as catastrophic, but saltwater intrusion poses the highest risk to subsistence due to its long-term and increasing consequences. Groundwater over pumping and RSLC are two of the main contributors to this stressor. Once freshwater resources have been contaminated with saltwater, it is near impossible to reverse. Saltwater intrusion can permanently harm groundwater and reduce available drinking, municipal, industrial, and agricultural water supply. Despite their occurrence, the other stressors within this category were determined to have temporary or temporary and increasing consequences.

The presence of invasive species throughout inland ecosystems is of increasing concern for land use management. They are outcompeting both marine and terrestrial resources, threatening the landscape. The introduction of the scarlet gourd, an African vine of the melon family, is threatening the vegetation and ecology of Saipan and CNMI is threatened to an extent that it may diminish the beauty of the islands, which are heavily dependent on tourism. (CNMI, [HSEM], 2018)

While not ranked as having catastrophic risk, the force of a tsunami could result in permanent subsistence impacts such as loss of agricultural and natural resources. However, since tsunamis are relatively infrequent events (low probability), the overall risk to subsistence practices is reduced.

#### 5.2.2.4 *Social Vulnerability Risk Summary*

For social vulnerability risk, stressors were evaluated for each risk index: social connectedness, health and safety, and subsistence. The singular highest ranking between indices was carried through for the overall social vulnerability risk assessment. Coastal flooding and inundation of coastal infrastructure, increasing water temperatures, coral bleaching, and RSLC were all catastrophic social effects risks. The risk summary plot is shown in Figure 5-5.

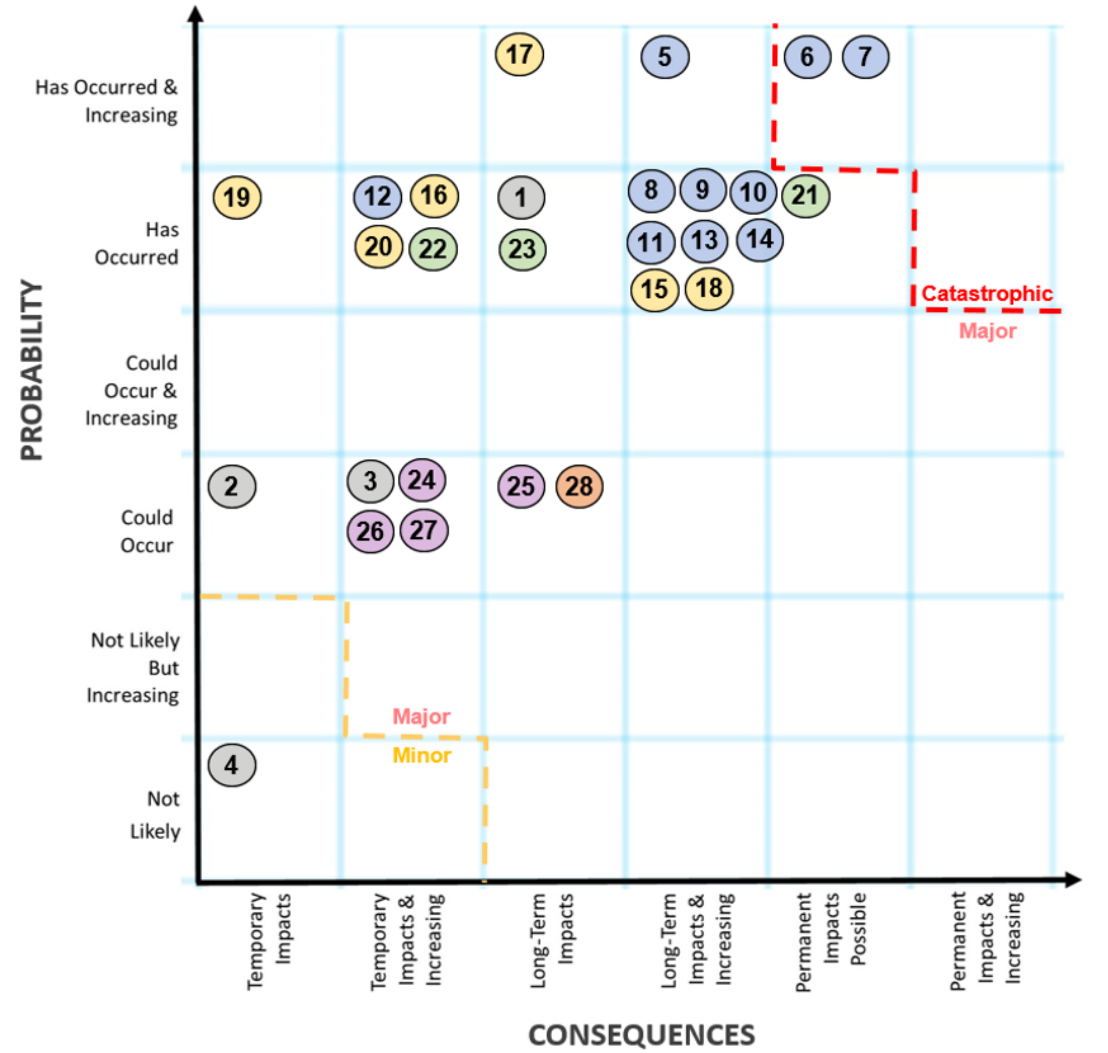



| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-5. Social Vulnerability Risk Summary

## 5.2.3 Environmental Risk

### 5.2.3.1 *Ecosystem Services*




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-6. Ecosystem Services Risk Assessment

Figure 5-6 displays the risk assessment results for ecosystem services. Increasing water temperatures and coral bleaching are the two stressors that have a catastrophic risk associated with ecosystem services with permanent impacts possible. The stressors are both in the coastal problem category and they are inherently interdependent.

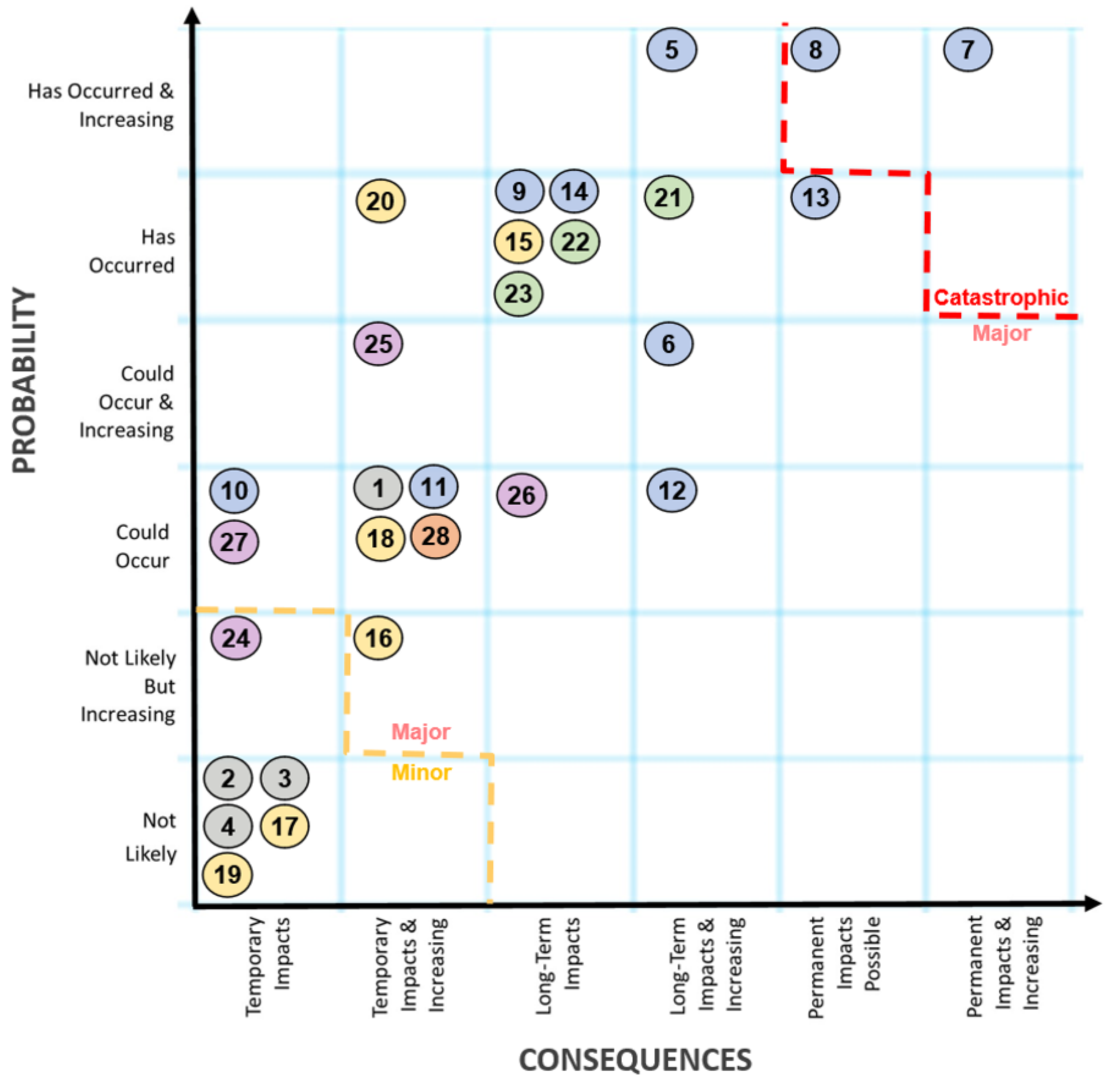
Coral reefs make up a significant piece of the coastal ecosystem and provide protection against storm surge by dissipating wave energy before it reaches the shore. Reefs also play a crucial role in eco-tourism revenue, provide essential fish habitat, food security, and avenues for traditional cultural fishing practices. Climate change, increasing water temperatures, changes in water chemistry, pollution, overfishing and other factors can lead to coral bleaching, species loss, and declining reef health. Loss of this important resource can have permanent impacts to ecosystem services.

Coastal areas throughout CNMI are subject to coastal erosion and loss of shoreline, which in the absence of storm events occur over a long period of time with gradual changes potentially resulting in significant impacts. High waves, tropical storms, human development, and climate change impacts may exacerbate erosion. Human development can lead to increased surface runoff and nutrient loading that may cause premature degradation of shorelines and disruption of vegetative materials holding the soils in place.

None of the stressors in the inland ecosystems category were ranked as catastrophic, but the encroachment of invasive species poses the greatest major risk to ecosystem services by impairing the function of native species and potentially altering ecosystem services permanently. Their presence can lead to native plant and animal extinction, reduction in biodiversity, and out-competing of limited available resources. Benefits from introduced species such as agroforests providing habitat are the exception and have been established long ago. With a small sized island, invasive species problems are severe and can wipe out or change ecosystem regimes in short order. For instance, invasive plants (scarlet gourd, chain-of-love, devil's gut vine) and other vines - *Muccuna Peruiens, Operculina spp., Ipomoea spp., Cryptostegia grandiflora, Coccinia grandis, Epipremnum aureum, Antigonon leptopus, Passiflora spp., and Mikania scandens* along with the coconut rhinoceros beetle and the brown tree snake could wipe out endemic trees and bird species.

The force of a tsunami has the potential to damage or destroy important coastal ecosystems that provide benefits such as wave attenuation, life loss reduction, shoreline protection, and species habitat. Due to both infrequency of occurrence and forecasted long-term, not permanent, impacts to ecosystem services, the tsunami stressor was not ranked as a catastrophic risk.

### 5.2.3.2 *Species Loss*




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | Tropical Storms & Typhoons |
| 3 | Severe winds | Tropical Storms & Typhoons |
| 4 | Maritime supply chain interruptions | Tropical Storms & Typhoons |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | Coastal |
| 7 | Coral bleaching | Coastal |
| 8 | Sea level rise | Coastal |
| 9 | Land use practices | Coastal |
| 10 | Surface runoff | Coastal |
| 11 | Coastal erosion/loss of shoreline | Coastal |
| 12 | Stormwater management | Coastal |
| 13 | Loss of living break water | Coastal |
| 14 | Nutrient Loading | Coastal |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | Water Quality & Quantity |
| 17 | Unmetered water use | Water Quality & Quantity |
| 18 | Saltwater intrusion | Water Quality & Quantity |
| 19 | Water leaks in the distribution system | Water Quality & Quantity |
| 20 | Drought | Water Quality & Quantity |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | Inland Ecosystems |
| 23 | Land use practices | Inland Ecosystems |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | Rainfall |
| 26 | Riverine erosion | Rainfall |
| 27 | Riverine flooding | Rainfall |
| 28 | Tsunami | Tsunami |

Figure 5-7. Species Loss Risk Assessment

Figure 5-7 displays the risk assessment results for species loss and shows that coral bleaching and RSLC pose a catastrophic risk with realized permanent impacts.

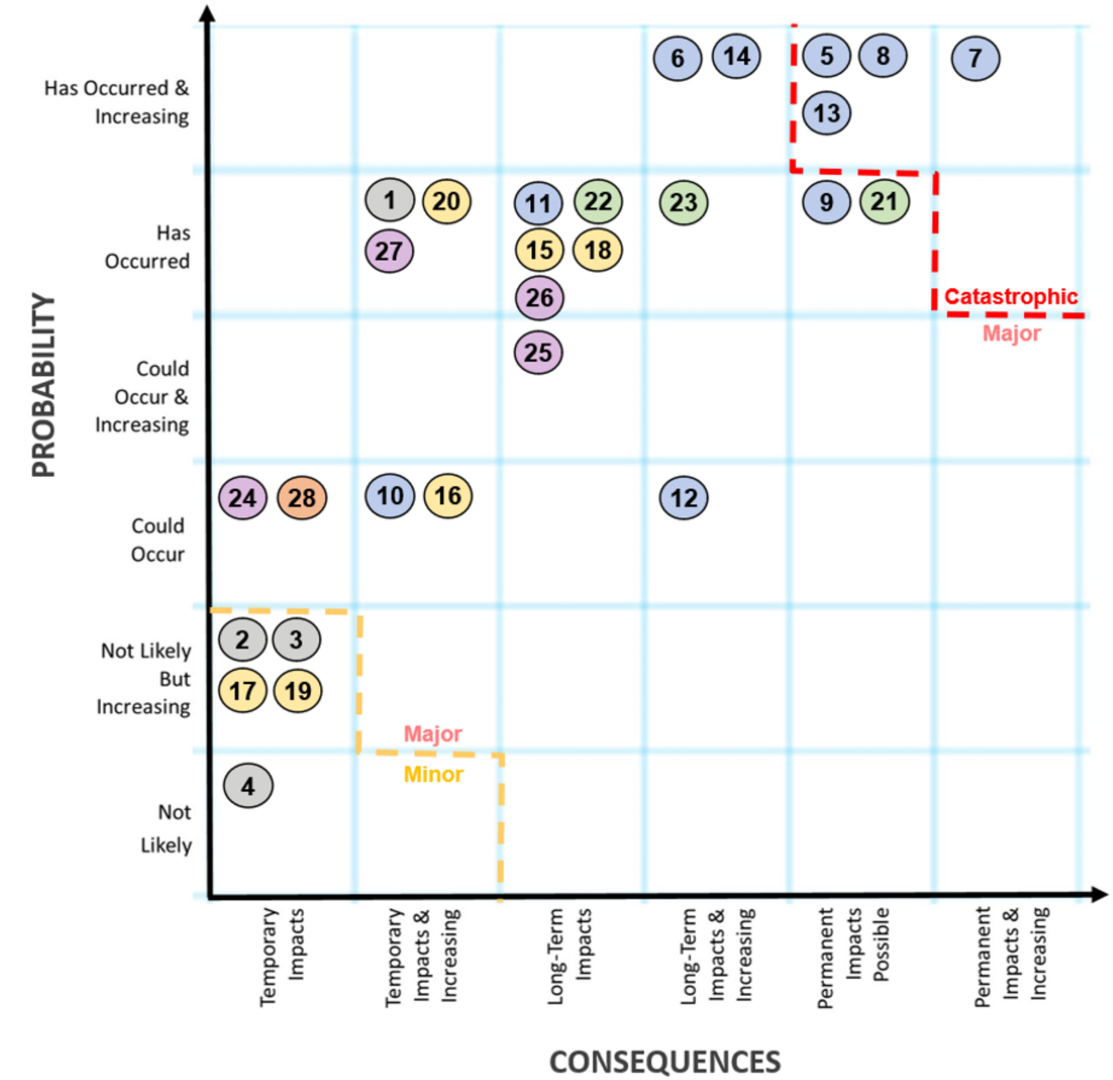
Throughout CNMI, ocean temperatures, RSLC, and acidification have increased coral stress and large-scale bleaching frequency over the last decade. Between 2013 to 2017, the CNMI had four major thermal stress and mass bleaching events, resulting in large-scale coral mortality and changes in community composition. Roughly two-thirds of the coral on CNMI has been lost since 2012 with the greatest losses occurring near Garapan and around the northern end of Saipan. RSLC can lead to permanent species loss as wave action impacts higher elevations along the shoreline. More coastal areas will be subject to increasing erosion and sedimentation, adversely impacting reefs and other nearshore marine life such as seagrasses, seaweeds, snails, algae, sponges, sea cucumbers, sea whips, anemones, and other invertebrates. A full list of species listed under the ESA can be found on NOAA's website (NOAA, 2022).

None of the stressors within the water quality and quantity category were ranked as catastrophic. However, point and nonpoint source pollution is another primary contributor to coral reef degradation with possible long-term impacts. A variety of pollutants, including sediment, organic matter, nutrients, sewage, herbicides, pesticides, petroleum products, and other substances detrimental to marine organisms can enter coastal waters through riverine discharge, stormwater runoff, and sewage outputs. The presence of these pollutants in nearshore waters is generally a result of coastal development, land clearing, burning, and other activities that alter the landscape, increasing the amount of runoff and introducing pollutants. Excess nutrients can fuel algal growth and out-compete corals by making habitat conditions unsuitable.

None of the stressors within the inland ecosystems category were ranked as catastrophic. Yet similarly to the impacts of invasive species on subsistence, invasive species are a concern to species loss as they often outcompete native species making long-term and increasing impacts possible. Terrestrial, aquatic, and marine flora and fauna species are at risk of being lost. Terrestrial species at risk include the Micronesian Megapode, Wedge-tailed shearwater, White-tailed Tropicbird, Red-tailed Tropicbird, Masked Booby, Brown Booby, Red-footed Booby, Great Frigatebird, Yellow Bittern, Pacific Reef-heron, Mariana Common Moorhen, Grey-backed Tern, Sooty tern, Brown Noody, Black Noody, Mariana Fruit Bat, Skinks, Geckos, Sea Turtles, Crabs, butterfly, damselfly, snails, sharks, fishes, and lobster (SWAP, 2015).

Species may be impacted and have lower population counts in given years where storm or other hazard events occur; however, it is unlikely that these would result in permanent species loss.

### 5.2.3.3 *Habitat Loss*




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-8. Habitat Loss Risk Assessment

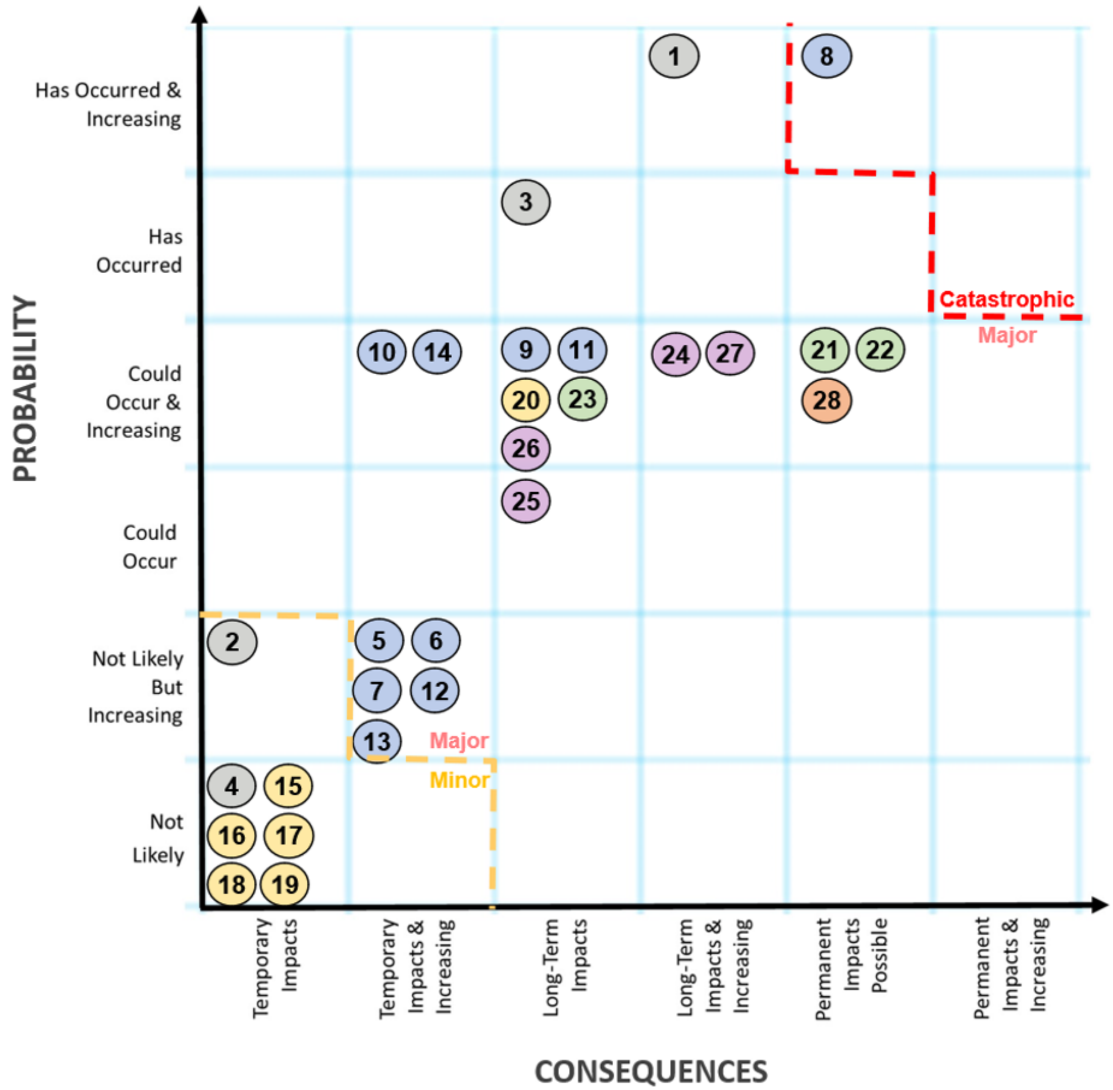
Figure 5-8 shows the risk assessment results for habitat loss. Coral bleaching, RSLC, ocean acidification, and loss of living breakwater are the four stressors that have a catastrophic risk associated with habitat loss and currently have realized permanent consequences. Land use practices, nutrient loading, invasive species, changes to water chemistry, and rising sea levels all contribute to declining habitats. RSLC is removing and migrating inland areas previously suitable for coastal habitats like mangroves and riparian vegetation. Coastal habitat like coral have experienced a decline from a multitude of disturbances including non-native crown-of-thorns starfish invasion, tropical storm events, ocean acidification, and human disturbances.

Wetlands and forests have experienced a drastic decline from development and changing environment. Other rainfall and storm stressors have possible long-term effects due to storm event impacts on the landscape and poor storm water management. Habitat recovery from floods, wildfires, landslides, sedimentation, and erosion is expected, although it may take time to recover to pre-impact conditions.

In addition to the catastrophic risks associated with coral bleaching, RSLC/subsidence and coastal habitat degradation, coastal flooding, drought, riverine flooding, surface runoff, and groundwater withdrawals may have long-term impacts on coastal habitats. Impacts from storm surge or erosion can impact habitats on or near-shore, which may take time to recover. Erosion may also be exacerbated from coastal development and land use practices such as agriculture and wildfires.

Water quality and supply have several stressors with possible long-term consequences, but none were ranked as catastrophic. For example, saltwater intrusion can lead to habitat loss if the ground water supply becomes too saline for species dependent on groundwater, like wetlands. Saltwater intrusion is increasing due to rapid subsidence and RSLC. Nutrient loading, sedimentation, and drought all affect water quality, which in turn leads to loss of habitat if species are unable to adapt to worsening conditions. For instance, nutrient loading may cause harmful algal blooms in waterways affecting aquatic habitat. Drought may dry up wetlands and other aquatic ecosystems and change ocean chemistry. Flash flooding, high winds, and poor water management are forecasted to have possible temporary impacts.

### 5.2.3.4 *Cultural Resources*




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-9. Cultural Resources Risk Assessment

Figure 5-9 displays the risk assessment results for cultural resources and shows that sea level rise poses a catastrophic risk with permanent impacts possible.

Certain water resource problems, such as loss of power supply, stormwater management, ocean acidification, and a majority of the water quality and quantity stressors would not have direct impacts to CNMI's cultural resources that would alter or destroy their historic, cultural, or traditional significance. Water resource development projects funded to solve these issues would abide by CNMI's local and federal historic preservation laws, including obtaining any necessary permits, in the event that cultural resources are impacted during their construction. Because of this assumption, water resource stressors that don't involve flooding, natural disasters, or loss of native habitats and cultural keystone species was ranked lowest by the team.

Background research identified several problems and uncertainties for cultural resources situated within the watersheds of the Northern Mariana Islands. The historic properties listed on the NRHP include sites from every temporal period discussed above and thus provide a solid backbone for historic preservation efforts. However, it is expected that many archaeological cultural resources remain undiscovered and therefore not listed on the NRHP or in the CNMI HPO database. These resources will remain unknown until ground disturbing activities expose them, likely inadvertently. The HPO is involved in the Division of Coastal Resources Management's One-Start Permit, requiring applicants to conduct surveys or have archaeological monitors present during ground disturbing work to minimize or avoid the impacts of any inadvertent finds.

Surveys and evaluations remain to be completed for much of the Northern Mariana Islands, including professional evaluations for intangible cultural resources whose historic significance is not well defined. This is true especially for certain islands that are less developed and most likely have coastal cultural resources that are endangered by flooding, RSLC, and erosion.

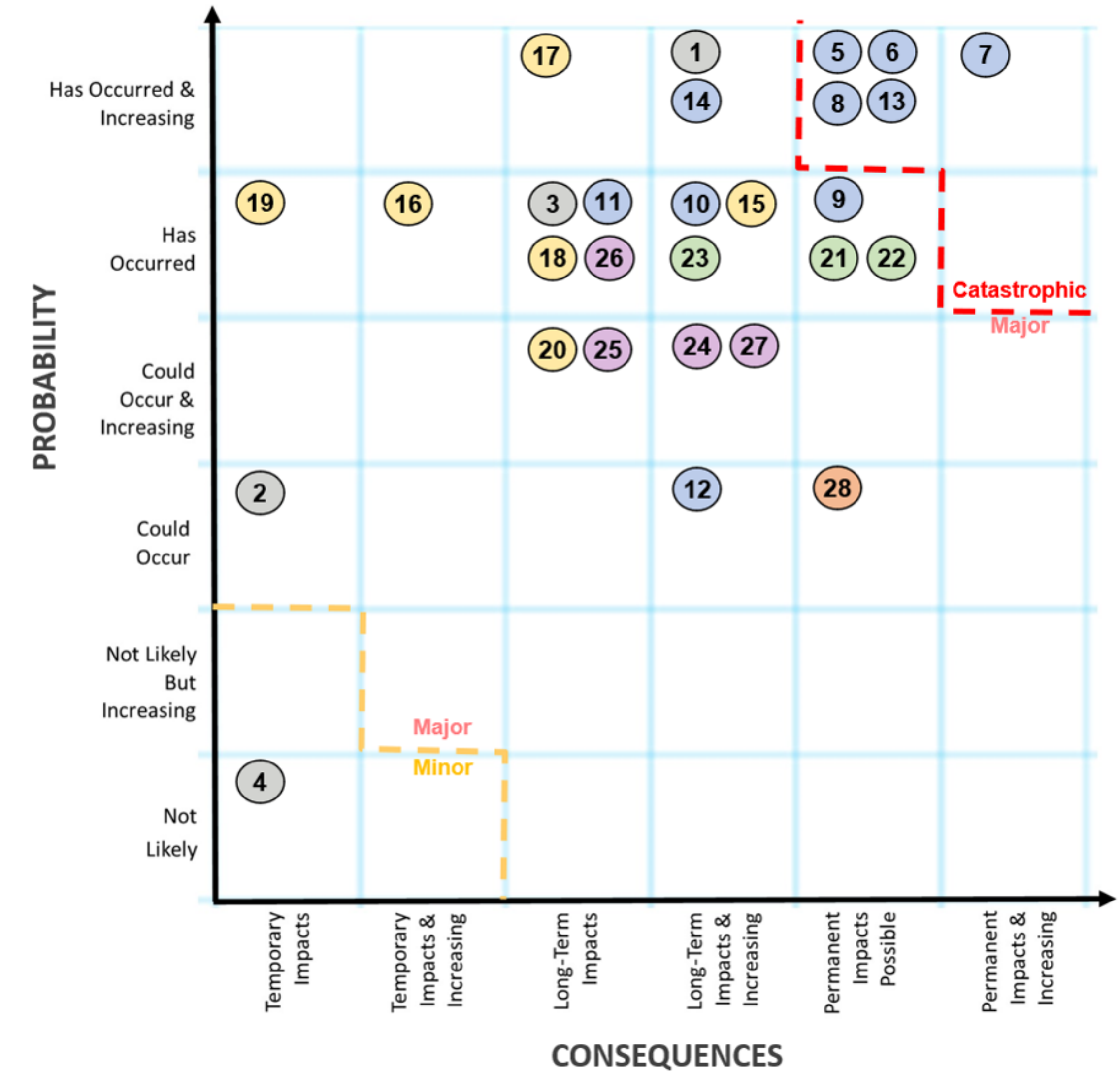
A thorough cultural resource inventory, including ethnographic fieldwork to identify intangible cultural resources, should be required when selecting a project for implementation across the watershed. Traditional cultural properties and intangible cultural heritage are assumed to be an important resource for the island with a major data gap on how they are defined. Indigenous Chamorro cultural groups are expected to have strong connections to the land, the waters, and its natural native resources. This assumption determines that coral bleaching, ocean acidification, the reduction of a living breakwater, and loss of fish habitat would impact their intangible cultural resources such as traditional fishing areas of native fish, gathering of native plant species, and maritime practices. Additionally, human activity such as point and nonpoint pollution, overfishing, and land use can impair significant cultural or traditional practices.

The location of archaeological sites depends largely upon habitation and settlement patterns, including proximity to marine or natural resources, as well as areas with traditional importance to the Chamorro people. A majority of the Pre-Latte Period sites documented in the past had relatively small site boundaries and were located along flat elevated coastal areas, near coastal lagoons, or on low terraces above beaches. Fewer sites were recorded inland. These coastal sites would potentially face permanent impacts related to RSLC and long-term impacts related to flooding and coastal erosion. However, efforts to protect these sites from flooding, as well as mitigation either through recording, excavation, and curation of characteristics that make these cultural resources historically significant before they are lost reduces the impacts to less than permanent.

While not ranked as having a catastrophic risk, tsunami damage would cause permanent impacts to sites with the potential to expose buried archaeological deposits, further exacerbate coastal erosion, or destroy a site's integrity before it can be properly inventoried and studied. Implementation of a disaster management plan to immediately assess or mitigate cultural resources after a tsunami disaster could lower the impacts from permanent to long-term. RSLC is expected to be catastrophic, due to the inaccessibility of certain cultural resources and traditional cultural landscapes that may serve as cultural heritage tourism spots or places for traditional cultural practices.

#### 5.2.3.5 *Environmental Risk Summary*

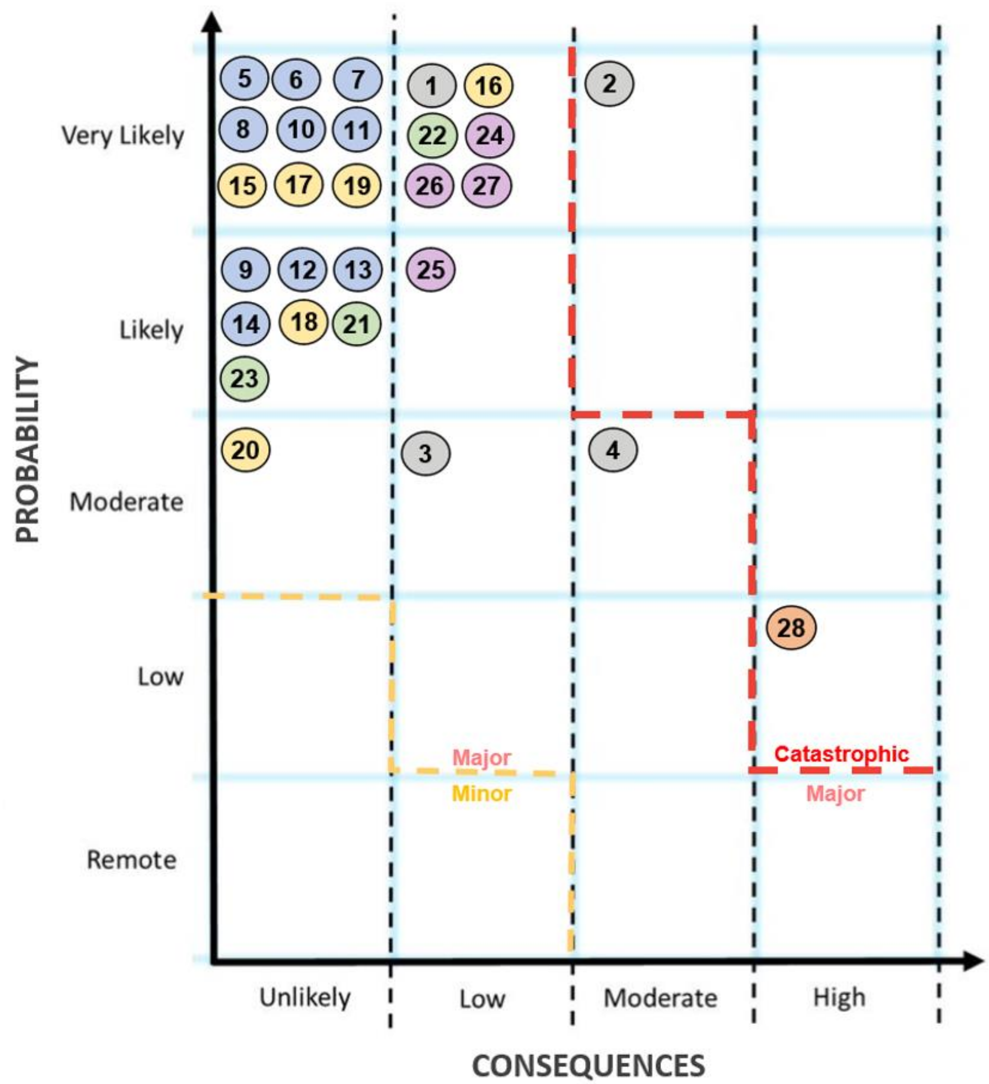
Stressors were evaluated for each environmental risk index: ecosystem services, species loss, habitat loss, and cultural resources. The single highest ranking between indices was carried through for the overall environmental vulnerability assessment. Ocean acidification, increasing water temperatures, coral bleaching, RSLC, and loss of a living break water were found to be catastrophic environmental risks. The summary plot is shown in Figure 5-10.




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-10. Environmental Risk Summary

### 5.2.4 Life Loss Risk




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
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| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
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| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-11. Life Loss Risk Assessment

Figure 5-11 displays the risk assessment results for life loss. The vertical axis shows increasing likelihood of the stressor occurring in any year, from bottom to top. The horizontal axis shows increasing consequences from left to right, measured qualitatively in terms of life loss magnitude. Stressors in the “unlikely” consequence category were not expected to result in life loss. Loss of power and tsunami are the two stressors that have a catastrophic risk associated with life loss.

Power outages pose a significant life loss risk in CNMI. Basic building operations such as lighting, security, and elevators require electricity can be compromised. Critical facilities, like healthcare, can become vulnerable and limit essential medical equipment and services, for example, medicine application, feeding, hygiene, and temperature needs. Furthermore, lifesaving operations such as life support, monitoring, diagnostic capabilities, blood services, and pharmaceutical operations require a power source to function. Many of these threats also apply to the household level.

While an infrequent occurrence, the force and mass destruction from tsunamis create the risk for high magnitude life loss. Indirect life loss risk is also high from the widespread destruction of critical facilities, roads, homes, and power supply that could occur from a tsunami.

Flash flooding, riverine flooding, and coastal flooding does occur frequently with anticipated life loss, but the magnitude of associated life loss is low and did not meet the metrics for a catastrophic risk determination. Most flood casualties are a result of driving through floodwaters, so the threat to life applies to both coastal and inland area residents. Indirect life loss risk can also result from inundation of critical infrastructure, such as water or waste wastewater treatment plants, and power utilities. Overloaded sewers can flood streets and homes with sewage whereupon downstream communities could be subjected to an inundation of polluted water.

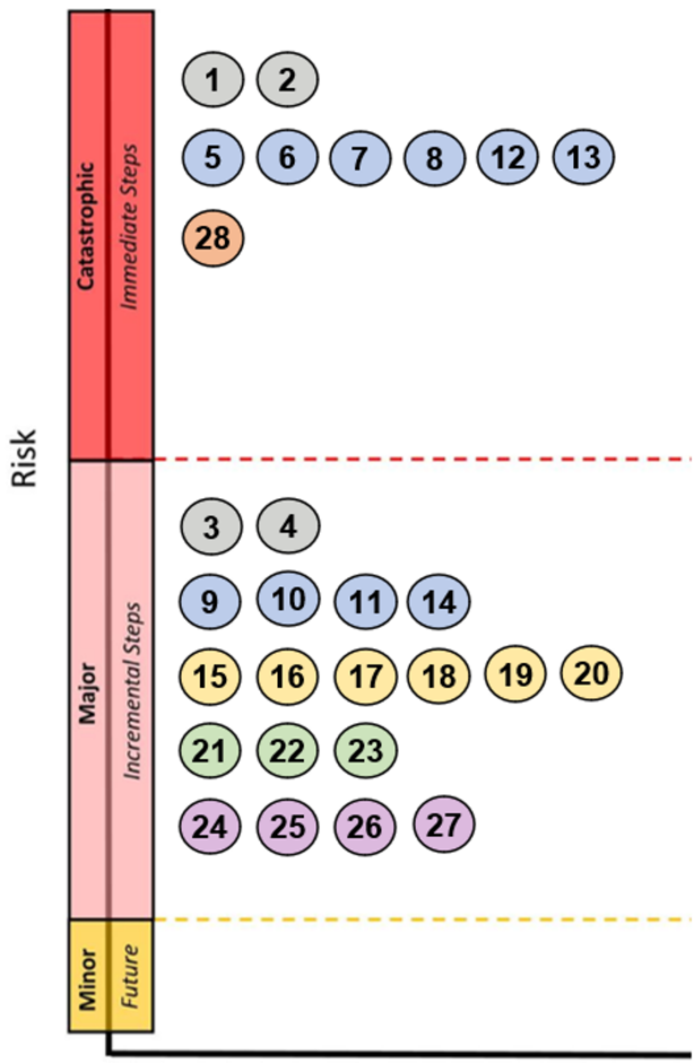
Although wildfires occur frequently, risk to life safety is relatively low because most fires happen in rural areas and not more highly populated areas. With the expansion of residential housing into more rural areas, life loss risk is anticipated to increase.

Groundwater over-pumping is currently occurring throughout CNMI and does not affect life loss. With limited and vulnerable water resources, over-pumping can lead to reduction in overall water supply and increased saltwater intrusion which can have permanent impacts on the water supply.

## 5.3 Risk Summary

Overall risk summary is shown below in Figure 5-12. The stressors found to be catastrophic in any of the risk assessment plots are coastal flooding and inundation of coastal infrastructure, loss of power supply, ocean acidification, increasing water temperatures, coral bleaching, RSLC, stormwater management, and loss of a living break water. While still critical to address, all other stressors were found to have a major risk rather than catastrophic. Since no single stressor continuously ranked within the minor relative risk category throughout each of economic, life loss, social, and environmental assessments, that category is not displayed on the final risk and uncertainty plot as shown below in Figure 5-14.

For those categorized as catastrophic, immediate steps should be taken in the near-term to reduce risks through direct actions, evaluating potential options, or filling data gaps. For those categorized as “major”, incremental steps, or a phased approach, should be taken (or continued) to reduce these significant risks.




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
| 5 | Ocean acidification | Coastal |
| 6 | Increasing water temperatures | |
| 7 | Coral bleaching | |
| 8 | Sea level rise | |
| 9 | Land use practices | |
| 10 | Surface runoff | |
| 11 | Coastal erosion/loss of shoreline | |
| 12 | Stormwater management | |
| 13 | Loss of living break water | |
| 14 | Nutrient Loading | |
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
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| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

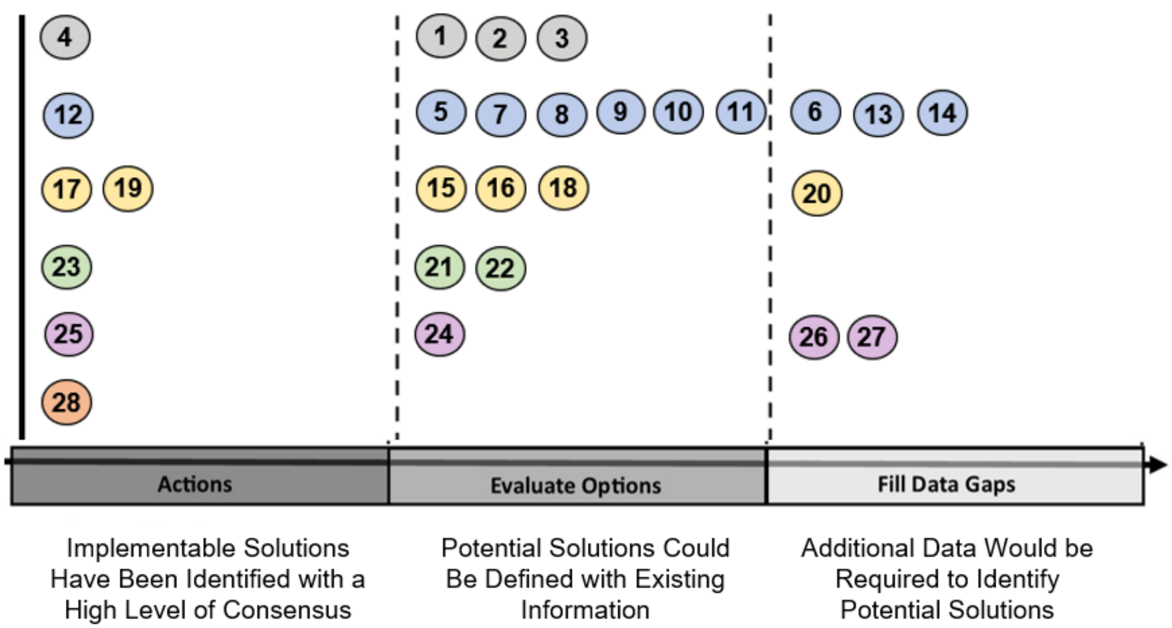
Figure 5-12. Risk Assessment Summary

## 5.4 Uncertainty Analysis

A qualitative assessment of uncertainty was also performed to help identify the appropriate type of recommendations. Uncertainty was broken down into three categories:

- ***Actions***: implementable solutions have been identified with a high level of consensus.
- ***Evaluate Options***: potential solutions could be defined with existing information.
- ***Fill Data Gaps***: additional data would be required to identify potential solutions or better define the extent or consequences.

A similar approach as the risk assessment was completed to evaluate uncertainty. Each team member assessed uncertainty based on their focused research and knowledge of possible solutions. The team scores were averaged out and validated with partner input for the final results. Figure 5-13 shows the results of the collaborative uncertainty analysis.




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
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| 12 | Stormwater management | |
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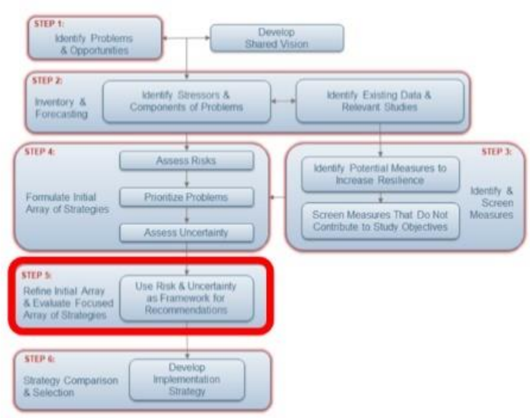
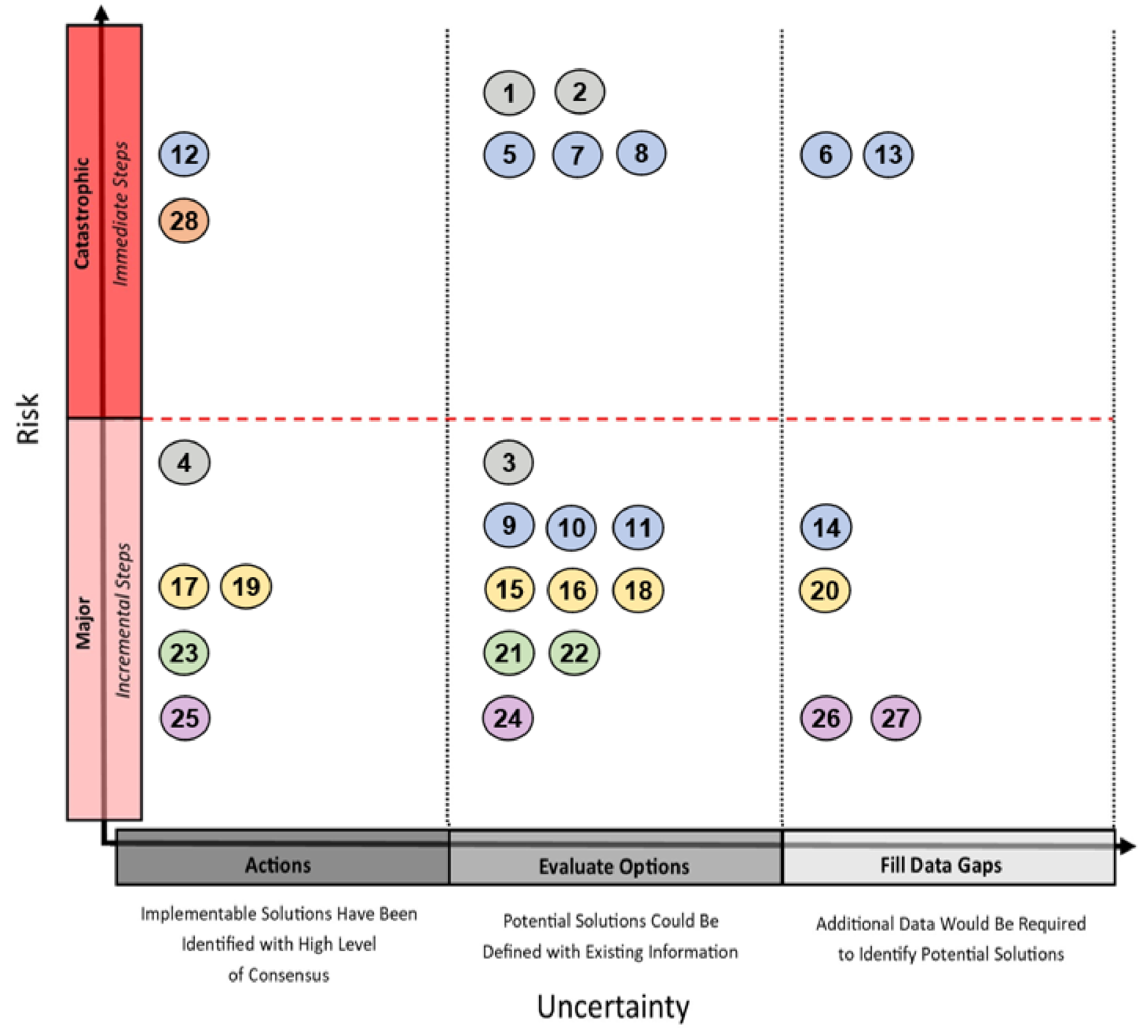
| 15 | Point and nonpoint source pollution | Water Quality & Quantity |
| 16 | Groundwater over pumping | |
| 17 | Unmetered water use | |
| 18 | Saltwater intrusion | |
| 19 | Water leaks in the distribution system | |
| 20 | Drought | |
| 21 | Invasive species | Inland Ecosystems |
| 22 | Wildfires | |
| 23 | Land use practices | |
| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-13. Uncertainty Analysis

## 5.5 Array of Recommendations




Risk and uncertainty results were used to develop a framework for the appropriate types (uncertainty-based) and timing (risk-based) for recommendations. For problems categorized as catastrophic, immediate steps should be taken to reduce risks through direct actions, evaluating potential options, or filling data gaps. For problems categorized as major, incremental steps, or a phased approach, should be taken (or continued) to reduce these significant risks. The results from the risk and uncertainty assessment placed the stressors into broad recommendation categories based off which quadrant they fell within (Figure 5-14).




| | | |
|---|---|---|
| 1 | Coastal flooding and inundation of coastal infrastructure (including harbors and roadways) | Tropical Storms & Typhoons |
| 2 | Loss of power supply | |
| 3 | Severe winds | |
| 4 | Maritime supply chain interruptions | |
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| 24 | Flash flooding along low lying and populated areas | Rainfall |
| 25 | Sedimentation | |
| 26 | Riverine erosion | |
| 27 | Riverine flooding | |
| 28 | Tsunami | Tsunami |

Figure 5-14. Risk and Uncertainty Summary

# 6 Recommendations & Implementation Strategy

Recommendations were informed by the risk- and uncertainty-based prioritization framework. For stressors with catastrophic risks and implementable solutions with a high level of consensus among agencies and stakeholders, **immediate steps or near-term actions** are recommended. For stressors with catastrophic risks, but less consensus on implementable solutions despite sufficient data and information to define potential solutions, **immediate steps or near-term evaluations** of those solutions are recommended. For stressors with catastrophic risks and known data gaps, **immediate steps to fill data gaps** through additional study and analysis are recommended.

For stressors with major risks and implementable solutions with a high level of consensus among agencies and stakeholders, **incremental steps or actions** are recommended. For stressors with major risks, but less consensus on implementable solutions despite sufficient data and information to define potential solutions, **incremental steps to evaluate** solutions are recommended. For stressors with major risks and known data gaps, **incremental steps to fill data gaps** through additional study and analysis are recommended.

## 6.1 Framing Recommendations

The risk and uncertainty assessments categorized actions that would be appropriate for the level of risk and existing knowledge and resources. Figure 6-1 below shows where each stressor fell within the broad recommendations categories.

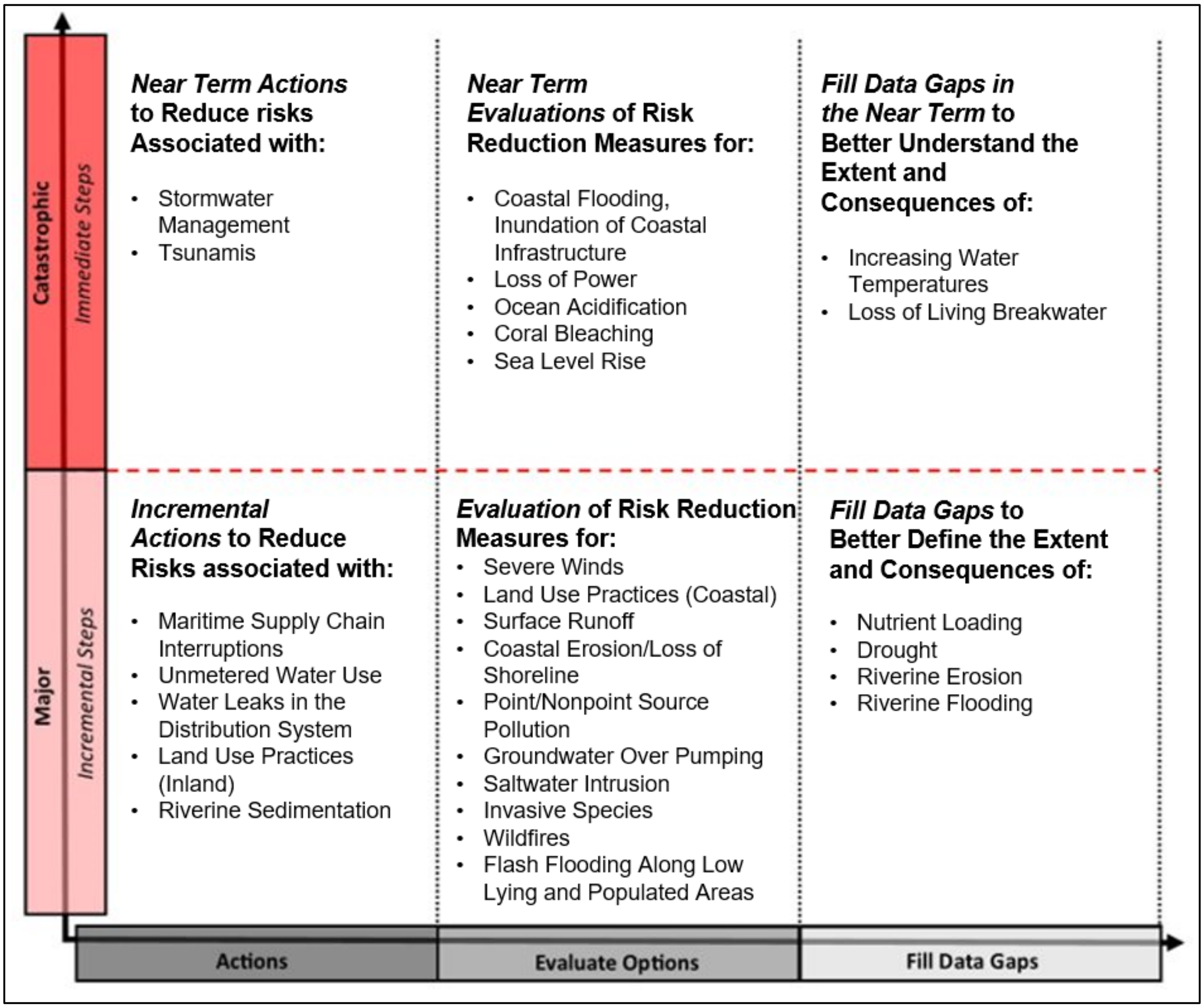
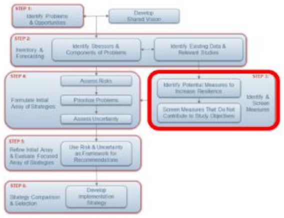
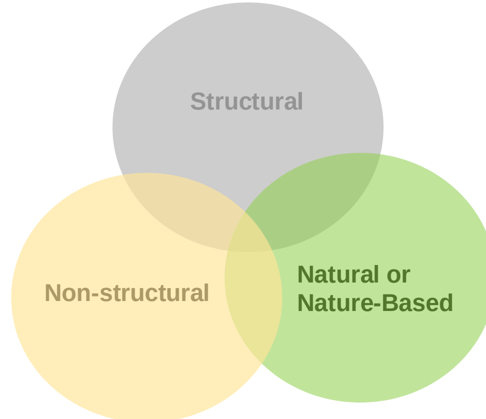



Figure 6-1. Broad Recommendation Categories According to the Risk and Uncertainty-Based Prioritization

## 6.2 Management Measures






Measures are the building blocks for recommendations. A set of NNBFs, non-structural, and structural planning measures to address problems and achieve the planning objectives was developed through synthesizing existing reports and on-going projects in CNMI (as described in Section 2.3), gathering stakeholder input, and compiling measures from subject matter experts.

Three categories of measures were identified:

- **Natural or Nature-Based Solutions**: landscape features that are used to provide engineering functions relevant to risk management, while producing additional economic, environmental, and/or social benefits. These features may occur naturally in landscapes or be engineered, constructed and/or restored to mimic natural conditions.
- **Non-Structural Measures:** activities that focus on reducing or solving problems without constructing new structures. Non-structural measures include actions such as policies, education, and/or emergency action exercises.
- **Structural Measures**: are physical modifications designed to reduce the frequency or consequence of a stressor.

Measures were evaluated during this process, and all were retained to avoid potentially discrediting pre-existing plans or projects. Instead, measures were compiled into recommendations that were formulated and prioritized through assessing the risk and uncertainty of problem categories and addressing the most critical needs based on those evaluations. The measure categories and individual measures are not mutually exclusive from one another. They were designed to work in tandem, where applicable, to provide a robust suite of different measures working together to address the issues. A list of measures can be found in Table 6-1.

Table 6-1. List of Natural or Nature-Based, Non-Structural, and Structural Measures

| Natural or Nature-Based Measures | Problem Category: Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
|---|---|---|---|---|---|---|
| **Coral Restoration and/or Preservation (incl. Coral Nursery/Propagation)** – multi-pronged approach to save and restore coral reefs. Strategies include improving habitat quality and enhancing population resilience leading to improved health and survival. This includes activities such as planting nursery-grown coral back into reefs, ensuring habitat is suitable for natural coral growth, increasing resilience to threats (e.g., climate change), and/or implementing policy for long-term protection. | ✓ | – | – | – | – | – |
| **Tide Pool Armoring** – features that mimic natural rock pools and create well-defined ecosystems that increase biodiversity while providing protection from waves and moving water. | ✓ | – | – | – | – | – |
| **Floodplain Restoration** – process which fully or partially restores significant ecosystem function, structure, and dynamic processes that have been degraded. Restoration efforts involve a comprehensive examination of the problems contributing to the system degradation and the development of alternative means for their solution. The intent of restoration is to re-establish the attributes of a naturalistic, functioning, and self-regulating system. This can reduce flood incidences, provide habitat for aquatic species, improve water quality, and increase groundwater recharge. | ✓ | ✓ | ✓ | ✓ | – | – |
| **Plant Native Vegetation Species** – process of replanting vegetation species that occur naturally in a region. This helps rebuild the soil of disturbed land for the principal purpose to rehabilitate or protect degraded land. Minimal maintenance is required, and less water is needed because they are adapted to local environmental conditions. | ✓ | ✓ | ✓ | ✓ | – | ✓ |
| **Wetland Restoration** – restoration of the physical, chemical, or biological characteristics of degraded wetlands back to their natural functions through re-establishment or rehabilitation practices. | ✓ | ✓ | ✓ | ✓ | – | – |
| **Natural Fire Breaks** – creation of a strip of bare or vegetated ground designed to create a break and prevent the progress of fires. | – | ✓ | – | – | – | – |
| **Rain Gardens** – vegetated depressions generally located along a natural slope that capture runoff from hard surfaces. They filter out pollutants from surface waters, | ✓ | ✓ | ✓ | ✓ | – | – |

| Natural or Nature-Based Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| prevent erosion, increase biodiversity, and require little to no maintenance once established. | | | | | | |
| **Divert Stormwater to Roadside Wetlands and Greenspaces** – designated areas that divert, capture, and filter stormwater. This method reduces the amount of water that enters storm drains therefore reducing the amount of contaminated water that enters rivers, lakes, and streams. | ✓ | ✓ | ✓ | ✓ | – | – |
| **Artificial Reef Structures** – artificial reef modules designed to mimic natural reefs. They are made from concrete and placed in oceans to create reef habitat. | ✓ | – | – | – | – | – |
| **Increase Marine Protected Areas** – designated areas that help protect and preserve depleted, threatened, rare, and endangered marine species and populations. They protect biodiversity, conserve cultural heritage, and support sustainable production of marine resources. | ✓ | – | – | – | – | – |
| **Mangrove Restoration** – restoration of the physical, chemical, or biological characteristics of degraded mangroves back to their natural functions through re-establishment or rehabilitation practices. Mangroves provide shoreline protection by reducing wave energy, reducing shoreline erosion, providing aquatic habitat, and storing carbon. | ✓ | – | ✓ | ✓ | – | ✓ |
| **Restoration of Groundwater Recharge Areas/Groundwater Recharge Augmentation** – recharge of groundwater occurs when rainwater and/or reclaimed water is routed to the subsurface via a natural process of the water cycle and/or through anthropogenic (man-made) processes including canals, infiltration basins, or ponds (for example). | – | – | – | ✓ | – | – |
| **Increase Carbon Storage by Increasing Forest Cover –** minimize impacts of climate change on a local level by planting or restoring land cover to the native and endemic forest. | ✓ | ✓ | – | – | – | – |
| **Beach Nourishment** – process of moving compatible sand onto an eroding shoreline to widen the existing beach. The widened shoreline provides an increased defense from coastal storms and beach erosion and protects property and infrastructure. | ✓ | – | – | – | – | ✓ |

| Non-Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| **Effective Administration of Best Management Practices** – identifying effective policies, practices, and/or procedures (i.e., management plans) to implement to reduce adverse impacts of human activity on the environment and natural resources. | ✓ | – | ✓ | ✓ | – | – |
| **Improve Land Use Planning** – identify ways to effectively enforce land use zoning to protect vulnerable populations and reduce environmental and economic impacts. | ✓ | ✓ | – | – | ✓ | – |
| **Improve Enforcement of Building Codes and Permits** – identifying effective policies, practices, and procedures to be implemented to improve building codes and require permits for either existing and/or new construction. This would improve infrastructure to better withstand storms and reduce life and safety risks. | ✓ | ✓ | – | – | – | ✓ |
| **Education and Incentives on Low Impact Development Opportunities** – offer incentives and provide educational materials to property owners and developers on benefits of low impact development to manage stormwater runoff and encourage implementation. | | – | ✓ | – | – | – |
| **Improve Policy & Education on Reducing Carbon Footprint** – identifying effective policies, practices, and procedures to be implemented for organizations and the public to lessen energy consumption and combat climate change. | ✓ | ✓ | – | – | – | – |
| **Inventory Water Leaks** – analyze the water distribution system to detect and quantify leaks. | – | – | – | ✓ | – | – |
| **Develop Water Conservation Programs** – programs designed to provide educational resources and incentives for sustainable water management. | – | – | – | ✓ | – | – |
| **Require Threshold for Percentage of Impervious Surfaces or Mitigation for New Construction** – minimize adverse environmental impacts by reducing the amount of surface water runoff from impervious surfaces. | ✓ | – | ✓ | – | – | – |
| **Education and Outreach on Sources of Water Contamination and Proper Waste Disposal** – provide educational materials and effectively communicate sources of water contamination and how to properly dispose of waste and hazardous materials. | – | – | – | ✓ | – | – |

| Non-Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| **Improve Regulation and Enforcement of Water Quality and Supply Standards** – identify effective policies, practices, and procedures to be implemented to improve water quality and supply. | – | – | – | ✓ | – | – |
| **Incentive Program to Reduce Point and Nonpoint Sources of Pollution** – provide incentives to reduce sources of pollution to preserve water and environmental resources. Incentives could include cost-sharing, financial payments, and education and technical assistance. | – | – | – | ✓ | – | – |
| **Education for Water Operators and Managers** – effective training and educational resources to better operate water system facilities and manage water resources to ensure long-term sustainability. | – | – | – | ✓ | – | – |
| **Increase Awareness and Enforcement of MPAs** – identify effective policies, practices, and/or procedures to protect MPAs. Community self-enforcement (such as a hot-line or email address) can play a critical role in the protection of these designated areas. Use buoys and signage to increase awareness of MPA boundaries to boaters and the public to preserve and prevent damage to natural habitats. | ✓ | – | – | – | – | – |
| **Water Contamination Alert System** – alert system to broadcast advisories to the public informing them of potential water contamination and immediate steps to take to remain safe. Water utility agencies would also be alerted of the contamination in the system and be able to quickly detect and respond to the issue. | – | – | – | ✓ | – | – |
| **Education on Land Use Practices to Reduce Runoff** – provide educational materials to the public on ways to reduce runoff through improved land management. This can include ending irresponsible land clearing and anthropogenic activities. | ✓ | ✓ | – | – | – | – |
| **Improve Interagency Engagement and Coordination to Promote Best Management Practices** – strengthening interagency coordination and communication to successfully implement best management practices within agencies and the public. For best results, multi-agency alignment on management and enforcement would be required. | ✓ | ✓ | – | – | – | – |
| **Education & Outreach on Wildfire Prevention** – includes effective training and educational materials on ways to reduce human-caused wildfires (i.e., hunting, cigarette butts, garbage burning, and fireworks). | – | ✓ | – | – | – | – |

| Non-Structural Measures | Problem Category: Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
|---|---|---|---|---|---|---|
| **Ballast Water Treatment** – properly treat ballast water at the port to prevent the spread of invasive species. Methods of treatment could include separation and filtration; ozone, electrical currents, or UV radiation; or chemical solutions like biocides or chlorination. | ✓ | ✓ | – | – | – | – |
| **Create a Universal Garbage Collection Task Force –** implement an effective collection system to dispose of waste and collect trash from communities to reduce pollution to the environment that harms physical habitats, transports chemical pollutants, threatens aquatic life, and interferes with human uses of river, marine and coastal environments. | ✓ | – | – | ✓ | – | – |
| **Improve Policy to Avoid, Minimize, and Offset Adverse Impacts to Sensitive Habitats** – identify effective policies, practices, and procedures to be implemented at an organizational level to reduce negative impacts to coastal resources and sensitive habitats like wetlands and mangroves. | – | ✓ | – | – | – | – |
| **Training on Land Use Monitoring and Maintenance** – create training programs for land use managers on methods to monitor the use and development of an area while also ensuring land and water compliance requirements are being met. This supports long-term sustainability and function of an area. | ✓ | – | ✓ | – | – | – |
| **Improve Enforcement on Invasive Species Management** – identify effective enforcement methods to be implemented to limit the ecological threat of invasive species through inventorying, monitoring, and eradication. | ✓ | ✓ | – | – | – | – |
| **Table-Top Exercises for Emergency First Responders** – simulated scenarios with emergency response personnel to discuss roles and response methods to a particular emergency situation. | ✓ | – | – | – | ✓ | ✓ |
| **Evacuation Signage & Maps in Public Spaces** – post evacuation signage and maps in highly visible public spaces for both locals and tourists. Include information on tsunami hazard zones, evacuation routes, and shelters in multiple languages. | – | – | – | – | ✓ | ✓ |
| **Establish Monitoring Programs to Assess Long and Short-Term Impacts of Climate Change** – establish a monitoring system that integrates satellite observations, ground-based data, and forecast models to monitor and forecast changes in the weather and climate. This can lead to improved accuracy on future trends at a local, regional, national, and global level, and provide a better understanding on climate change response | ✓ | – | – | – | – | – |

| Non-Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| **Develop GIS Database of Erosion Hotspots** – utilize geographical information systems to identify, analyze and map erosion hotspot areas to assist with land use and management decisions. | ✓ | – | ✓ | – | – | – |
| **Survey Septic Systems** – identify septic systems in need of repair and address leaching and groundwater contamination. | – | – | – | ✓ | – | – |
| **Citizen Science Projects for Invasive Species Education, Identification, and Eradication** – create a program to engage the public in data collection, analysis, and monitoring of invasive species. | – | ✓ | – | – | – | – |
| **Improve Monitoring of Illegal Dumping** – carry out strict and consistent enforcement of the CNMI anti-littering law by professional individuals and government officials to reduce illegal disposal of trash and waste by companies, the public, and agricultural entities. This could include ground inspection or satellite imagery to identify key areas, remote sensing, and use of geographic information systems. | ✓ | ✓ | ✓ | – | – | – |
| **Continued Implementation of Safe Smart Growth Principles and Comprehensive Sustainable Development Plan** – identify effective methods to encourage a mix of building types and uses, diverse housing and transportation options, development within existing neighborhoods, and robust community engagement. Smart growth strategies help preserve natural areas, foster a strong sense of community identity, and strengthen the economy. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Hazard Mapping** – routinely update hazard maps to highlight changes in risk and the extent of the hazard in an area. This information can support land use planning, mitigation, risk communication, and emergency response. | ✓ | – | ✓ | – | ✓ | ✓ |
| **Education & Outreach on Flood Insurance** – the National Flood Insurance Program offers a wide range of publications, videos, graphics, and online tools that can help policyholders, agents, and the public navigate the flood insurance process before, during and after a natural hazard. | ✓ | – | – | – | – | – |
| **Require Mitigation for Land Uses** – to offset adverse impacts to the environment from land use planning in coastal areas, limit builders and/or property owners to only take certain actions to minimize impacts. | ✓ | – | – | – | – | – |

| Non-Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| **Increase Freeboard Above Inundation** – elevate a building's lowest floor above predicted flood elevations by a small additional height (generally 1-3 feet above National Flood Insurance Program minimum height requirements). This can reduce flood insurance costs and protect homes against storm damage. | ✓ | – | ✓ | – | – | ✓ |
| **Develop Groundwater Management and Protection Plans** – sustainably manage water resources by developing comprehensive plans that identify sources of potential pollution and methods to minimize adverse impacts to caves and wells. Include information to designate and protect sources of potential groundwater recharge. | – | – | – | ✓ | – | ✓ |
| **Annual Tsunami Drills** – simulated event that provides local officials, emergency response personnel, and the public an opportunity to practice what to do in a tsunami event. | – | – | – | – | ✓ | – |
| **Scheduled Maintenance and Drain Cleaning** – preventive maintenance to maintain functionality of drainage systems and prolong their overall lifespan. | ✓ | – | ✓ | ✓ | ✓ | ✓ |
| **Resources Survey** – Conduct GIS or in-person surveys to assess available resources that can be used for future restoration and mitigation efforts. | ✓ | – | ✓ | – | – | – |
| **Designate Safe Harbor Locations** – identify locations around the island where ships can dock during an emergency. Sometimes called a 'hurricane hole,' these areas are located inland and are protected from surges and winds. | – | – | – | – | – | ✓ |
| **Increase Weather Forecasting and Technology Accuracy** – modernized technology such as weather satellites and Doppler radar helps shipping companies plan ahead and take action around inclement weather to avoid losses or delays. | – | – | – | – | – | ✓ |
| **Drought Management Plan** – defines the conditions under which a drought induced water emergency exists and specifies response actions. Developed in conjunction with local agencies to help address water usage, storage, and availability. | – | – | – | ✓ | – | – |

| Non-Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| **Drought Monitoring and Forecasting** – observation of indicators such as precipitation, temperature, streamflow, ground and reservoir water levels, and soil moisture that are used to describe drought conditions and forecast future drought trends prior to onset. | – | – | – | ✓ | – | – |
| **Climate Change Working Group** – institute an interagency working group to identify and provide sustainable solutions for communities to effectively manage and reduce the impacts of climate change. | ✓ | ✓ | – | ✓ | – | ✓ |
| **Riverine Shear Stress Analysis** – analyze the shear stress of moving water on channel beds. This can help predict sediment transport, bank erosion, and other river engineering problems that may arise in natural streams. | – | – | ✓ | – | – | – |
| **Water Recycling Program** – process by which wastewater is filtered to remove solids and then further treated to a level necessary to reuse for human consumption, irrigation, and/or commercial applications. | ✓ | – | – | – | – | – |
| **Hydrology & Hydraulics Analysis** – develop precipitation projections and hydraulic analysis to consider the adequacy and/or needs to upgrade drainage way and culvert capacity in areas vulnerable to precipitation flooding. Include consideration of retreat/relocation solutions. | ✓ | – | ✓ | – | – | ✓ |

| Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| Protect and/or Strengthen Critical Infrastructure – update critical infrastructure (ports, roads, utilities, schools, etc.) from future anticipated storm events and flooding impacts to be better retrofitted against elements. | ✓ | – | ✓ | – | – | ✓ |
| **Breakwater** – a structure constructed in the water along the shoreline that reduces the impact of waves to protect coastal areas. This can either be a traditional breakwater made from stone or concrete or a floating breakwater that has a permeable surface to convert wave power into electrical energy. | ✓ | – | – | – | – | – |
| **Sediment Capture** – a temporary settling basin installed along a waterway or low-lying area to capture eroded or disturbed soil that washes out during rainstorms. Protects the water quality of nearby streams, rivers, lakes, or bays. | ✓ | – | ✓ | – | – | – |
| **Permeable Parking Lots and Roadways** – a permeable hard surface that catches precipitation and surface runoff and directs it to either infiltrate into the ground or into a designated area rather than generating runoff. | ✓ | ✓ | – | – | – | – |
| **Engineered Mangrove Reef Walls** – sea walls designed to provide optimal conditions for oysters, tunicates, sponges, and other primary ecological producers that colonize the surface and enhance the constructed habitat. | ✓ | – | – | – | – | – |
| **Repair Leaks** – repairing leaks in the water distribution systems conserves water resources. | – | – | – | ✓ | – | – |
| **Desalinization System** – removes or reduces salts from saline water through multi-effect boiling or multi-stage flashing processes. | – | – | – | ✓ | – | – |
| **Increase Water Storage** – capture and store water resources through groundwater recharge, ponds, wetlands, tanks, water barrels, or reservoirs. | – | – | ✓ | ✓ | – | – |
| **Smart Meter Installation** – an electronic device that measures and transmits water usage data from the consumer to the provider; improves water management and provides accurate billing. | – | – | – | ✓ | – | – |
| **Wastewater Improvements (septic system upgrades, treatments plants, etc.)** – make updates to wastewater infrastructure to reduce leaching and groundwater contamination. | – | – | – | ✓ | – | – |

| Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| **Fire Road Development and Maintenance** – create unpaved roads within undeveloped urban hills, foothills, and rural areas to serve as a wildfire break and help contain fires. Due to their remote location, routine maintenance must be performed to combat adverse effects such as erosion and weed invasion. | – | ✓ | – | – | – | – |
| **Fire Stations and Lookout Tower Development** – increase the number of fire stations and lookout towers to strengthen emergency response actions and early detection of wildfires by spotting smoke from a distance. | – | ✓ | – | – | – | – |
| **Multi-Purpose Recreational Areas** – create multi-functional areas that can double as a detention pond for flood risk management and as a recreational site that can be used for sporting events, picnic areas, and walkways when dry. | – | – | ✓ | – | – | – |
| **Invasive Species Removal** – eliminate or reduce populations of plants, animals, and other living organisms that are not native to a particular area. This could be achieved with machinery or herbicide application. | – | ✓ | – | – | – | – |
| **Rainwater Catchment Systems** – collecting rainwater that falls on a site and diverting it to a tank, cistern, deep pit, aquifer, or a reservoir with percolation, so that it seeps down and recharges groundwater resources. This can help reduce flooding and soil erosion and increase water resource supplies. | – | ✓ | ✓ | ✓ | – | – |
| **Slope Drains and Terracing in Steep Terrain** – slope drains allow water to flow downward with the aid of pipes or lined channels which extend from the top to the bottom of a slope. Terracing involves leveling a hillside's ground in sections so the flat areas stack above one another like stairs. Both methods are designed to protect slopes from runoff. | ✓ | – | – | – | – | – |
| **Shoreline Armoring** – large, impermeable structures designed to protect the shore from flooding, wave attack, and erosion. They include (recurve) seawalls, bulkheads, and revetments. | ✓ | – | – | – | ✓ | ✓ |
| **Installation of Waterbars on Roads and Public Paths** – feature that helps prevent erosion on sloping roads and paths by intercepting surface water runoff and directing it into a designated drainage way. | ✓ | – | ✓ | – | – | – |
| **Establish Real-Time Weather and Stream Gaging Networks** – set up a monitoring network to provide real-time stream flow and weather data via radio and/or satellite transmission to weather and water management agencies. | – | – | ✓ | – | – | – |

| Structural Measures | Problem Category | | | | | |
|---|---|---|---|---|---|---|
| | Coastal | Inland | Rainfall Events | Water Quality & Supply | Tsunamis | Tropical Storms & Typhoons |
| **Survey and Repair Septic Systems** – evaluate septic systems in need of repair and address leaching and groundwater contamination. | – | – | – | ✓ | – | – |
| **Alternative Energy Sources** – utilizing energy sources that are not derived from fossil fuels, such as wave, wind, and solar energy**.** | – | – | – | – | – | ✓ |
| **Road Enhancements and/or Relocations** – improvement, expansion, or relocation of roads, streets, or highways to be better equipped against weather elements. | ✓ | ✓ | ✓ | – | ✓ | ✓ |
| **Improve Drainage Network** – increase the network of drains and channels that run parallel to the shoreline and provide shore protection by draining water away and protecting beach areas. The network should undergo routine maintenance to maximize functionality. | ✓ | – | – | – | – | – |

## 6.3 Potential Funding and Implementation Resources

Existing authorities will be utilized, when possible, to implement recommendations. The sections below are not an exhaustive list of all types of funding grants and programs available but describe potential funding opportunities from USACE and other agencies. Additional information may be found online by searching the authority or through coordination with agency representatives.

### 6.3.1 USACE Authorities

Below is a summary of all USACE authorities which are available for technical assistance, planning, feasibility study, or construction efforts. Most authorities require a non-Federal cost share; however, cost share waivers may be available, per Section 1156 of WRDA 1986 (33 U.S.C. 2310), as amended, for the categories of General Investigation Studies, Planning Assistance to States projects, and the Continuing Authorities Program, described below.

- **General Investigation (GI) Studies** – conducts feasibility studies related to its core mission areas of navigation, flood risk management, and ecosystem restoration, to determine if Congressional authorization and implementation of a specific Civil Works project are warranted. GIs involve jointly conducting a study with a non-Federal Sponsor and, if shown by the study to be feasible, the construction and implementation of the project. This approach requires that Congress provide an authorization to construct or implement the project. There are several types of planning studies and/or decision documents, but for the GI process the most common studies are Feasibility Studies. These include optimization of the plan(s) to be built, are equally cost-shared, and usually completed within 24-36 months. The first $100,000 is Federally funded. If the study cost exceeds $100,000, the cost share is 50 percent Federal and 50 percent non-Federal. Project implementation requires both authorization and appropriation from Congress, and the cost share is typically 65 percent Federal and 35 percent non-Federal. Requests for assistance should be submitted in the form of a Letter of Intent from a state or local government agency to USACE.

- **Section 7001 Annual Report** – utilized when study authority does not already exist for an area of interest. In Section 7001 of the Water Resources Reform and Development Act of 2014 (P.L. 113-121; 33 U.S.C. §2282d), Congress established an annual process for identifying proposals for site-specific studies and projects within USACE's water resource mission and authorities. The process includes a call for non-Federal proposals, which should be submitted to the Planning Division at the USACE District with an area of responsibility that includes the area of interest (for CNMI this is the Honolulu District). Inclusion of a proposal in a Section 7001 annual report does not provide congressional authorization or appropriation. Rather, inclusion of a proposal in a report facilitates congressional consideration of authorizing the proposal.

- **Floodplain Management Services (FPMS)** – authorized under Section 206 of the Flood Control Act of 1960 (P.L. 86-645), as amended, provides communities with technical and planning services to support effective floodplain management. FPMS efforts are often completed by Silver Jackets teams. Under the FPMS program, USACE supports both riverine and coastal flood risk reduction efforts and empowers communities to better understand their risks of flooding and develop plans to communicate and manage that risk. Activities provided under this authority include hydrologic and hydraulic technical services, general planning guidance, education and outreach materials, and National Flood Insurance Program support. Projects are typically 100% Federally funded, within limits of the authority. Requests for assistance should be in the form of a letter than includes the location and nature of the problem to be investigated.

**Silver Jackets Teams** – Silver Jackets teams across the U.S. bring together multiple state, Federal, tribal, territorial, and local agencies in partnership to learn from one another in reducing flood risk and other natural disasters. By applying their shared knowledge, the teams enhance response and recovery efforts when such events do occur. The partnerships provide an opportunity for mentoring and networking, enabling agencies to better respond and prepare for disasters as a team, and help achieve communities that are sustainable and resilient to natural disasters, especially flooding. The interagency nature of Silver Jackets teams allows for leveraging of all available resources and authorities, including those from within USACE such as FPMS, to support local flood risk management needs. Coordination between USACE, OPD, and DCRM is underway to initiate the formalization of a Silver Jackets team in CNMI.

- **Planning Assistance to States (PAS)** – two types of planning assistance are offered through the PAS program: Comprehensive Plans and Technical Assistance. Any State, or group of States, Federally recognized Tribes, and U.S. territories may partner with the Corps under the PAS program. PAS projects as cost-shared 50% Federal and 50% non-Federal. Cost-share waivers are available for up to $530,000 for U.S. territories and Federally recognized Tribes.
    - **Comprehensive Plans** – includes planning for the development, utilization, and conservation of the water and related resources of drainage basins, watersheds, or ecosystems located within the boundaries of that state, territory, or commonwealth (or a group of states/territories/commonwealths) to comprehensively address water resources challenges. The non-Federal cost share for preparation of a state comprehensive water resources plan may be provided by funds or through the provision of services, materials, supplies, or other in-kind services.
    - **Technical Assistance** – includes support of planning efforts related to the management of water resources, including the provision and integration of hydrologic, economic, or environmental data and analysis in support of water resources management and related land resources development plans. This technical assistance may not include the preparation of site-specific designs or construction. The cost-share for technical assistance may not be provided by in-kind services.
- **Engineering with Nature (EWN) Initiative** – enables more sustainable delivery of economic, social, and environmental benefits associated with infrastructure. Sustainable water resources infrastructure is achieved through the beneficial integration of engineering and natural systems. With recent advances in the fields of engineering and ecology, there is an opportunity to combine these fields of practice into a single collaborative and cost-effective approach for infrastructure development and environmental management. Triple-win outcomes are achieved throughout EWN by systematically integrating social, environmental, and economic considerations at every phase of a project. The results are innovative and resilient solutions that are more socially acceptable, viable and equitable, and, ultimately, more sustainable.

- **Regional Sediment Management (RSM) Program** – RSM is a research program which implements innovative management strategies to optimize the use of sediment and improve the management of projects. The program supports initiatives that develop and demonstrate sustainable practices that systematically increase benefits and reduce lifecycle costs for the Corps' Navigation, Flood Risk Management, and Environmental missions. RSM provides opportunities to collaborate with stakeholders and other agencies to leverage resources, share technology and data, and develop and implement innovative solutions to improve regional utilization and management of sediments. Proposals are typically solicited once per year in June and are submitted by USACE Districts. Projects do not require a non-Federal cost share, however stakeholder and partner engagement and information sharing is strongly encouraged and considered in the proposal selection process.

- **Continuing Authorities Program (CAP)** – CAP is a group of nine authorities under which USACE can plan, design, and implement certain types of water resources projects without additional project specific congressional authorization. The purpose of the CAP is to plan and implement projects of limited size, cost, scope, and complexity. The nine authorities and the water resources projects included in the program are shown below in Table 6-2. CAP Authorities.

  For all sections except Section 204 and 111, the initial feasibility phase is federally funded up to $100,000. Any remaining feasibility phase costs are shared 50/50 with the non-federal sponsor after executing a feasibility cost sharing agreement. For Section 204 projects, the Feasibility phase is performed at 100% federal cost. For Section 111 projects, the feasibility phase costs above the initial $100,000 will be cost shared in the same proportion as the cost-sharing provisions applicable to the construction of the federal navigation project causing the shore damages.

  Construction is either cost shared at 65% federal and 35% non-federal, or 75% federal and 25% non-federal, depending on the authority. Projects implemented under CAP have variable cost share requirements and limitations and a per-project federal cost limit. A pilot program for CAP projects in small or disadvantaged communities allows for full federal funding with no cost share requirement. The pilot program will apply for ten projects which meet economic criteria. CAP projects identified in Guam may qualify for this pilot program when it is implemented.

  Under the Infrastructure Investment and Jobs Act, the CAP 206 program was provided $115M for 100% Federally funded fish passage projects. Requests for assistance should be in the form of a letter describing the location and nature of the problem and requesting assistance under the program.

  **USACE International and Interagency Support (IIS)** – provides technical assistance to DoD federal agencies, state and local governments, tribal nations, private U.S. firms, international organizations, and foreign governments. Most IIS work is funded on a reimbursable basis. USACE provides engineering and construction services, environmental restoration and management services, research and development assistance, management of water and land related natural resources, relief and recovery work, and other management and technical services.

Table 6-2. CAP Authorities

| Authority | Project Purpose | Federal Project Limit (in millions (M)) |
|---|---|---|
| **Section 14**, Flood Control Act of 1946, as amended. Emergency Streambank and Shoreline Protection. | Flood risk management | $5.0M |
| **Section 103**, River and Harbor Act of 1962, as amended. Small Beach Erosion Control. | Coastal storm risk management | $10.0M |
| **Section 107**, River and Harbor Act of 1960, as amended. Small River and Harbor Improvement Projects. | Navigation improvements | $10.0M |
| **Section 111**, River and Harbor Act of 1968, as amended. Shore Damage Prevention or Mitigation. | Prevention or mitigation of shore damage caused by Federal navigation projects | $12.5M |
| **Section 204**, Water Resources Development Act (WRDA) of 1992, as amended. Regional Sediment Management. | Beneficial uses of dredged material | $10.0M |
| **Section 205**, Flood Control Act of 1948, as amended. Small Flood Control Projects. | Flood risk management | $10.0M |
| **Section 206**, Water Resources Development Act (WRDA) of 1996, as amended. Aquatic Ecosystem Restoration. | Aquatic ecosystem restoration | $10.0M |
| **Section 208**, Flood Control Act of 1954, as amended. Snagging and Clearing for Flood Control. | Removal of obstructions and clearing channels for flood risk management. | $0.5M |
| **Section 1135**, Water Resources Development Act (WRDA) of 1986, as amended. Project Modifications for Improvement of Environment. | Project modifications for improvement of the environment | $10.0M |

### 6.3.2 Other Agency and Organization Funding Opportunities

- **FEMA**
  - **Hazard Mitigation Grant Program (HMGP) –** provides funding to rebuild in a way that reduces, or mitigates, future natural hazard losses in communities. HMGP funding is authorized with a Presidential Major Disaster Declaration. The amount of funding made available to the applicant is generally 15% of the total Federal assistance amount provided for recovery from the presidentially declared disaster and is determined by the FEMA-approved Hazard Mitigation Plan.

  - **Building Resilient Infrastructure and Communities (BRIC) Competitive Grant Program –** supports hazard mitigation projects to reduce the risks from disasters and natural hazards. The BRIC program aims to categorically shift the Federal focus away from reactive disaster spending and toward proactive investment in community resilience. As a competitive grant program, applicants must apply on a yearly basis and the proposed project must have positive net benefits. BRIC encourages public infrastructure projects, projects incorporating NNBFs, and the adoption and enforcement of modern building codes.

  - **Emergency Management Performance Grant (EMPG) –** provides state, local, tribal and commonwealth emergency management agencies with the resources required for implementation of the National Preparedness System and works toward the National Preparedness Goal of a secure and resilient nation. The EMPG's allowable costs support efforts to build and sustain core capabilities across the prevention, protection, mitigation, response, and recovery mission areas.

- **USDA NRCS Pacific Island Areas**
  - **Agricultural Conservation Easement Program: Agricultural Land Easements (ALE) and Wetland Reserve Easements (WRE) –** provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits. ALE prevents conversion of productive working lands to non-agricultural uses, providing public benefits including environmental quality, historic preservation, wildlife habitat, and protection of open spaces. WRE provides habitat for fish and wildlife, improve water quality, reduce flooding, recharge groundwater, and protect biological diversity by restoring wetlands historically impacted by agricultural production.

  - **Environmental Quality Incentive Program- (EQIP) –** Provides financial and technical assistance to agricultural producers to install conservation practices that address natural resource concerns.

  - **Conservation Stewardship Program –** provides financial and technical assistance to help producers build on their conservation efforts. The program helps agricultural producers maintain and improve their conservation systems and adopt additional conservation activities to address priority resource concerns. Participants earn payments for conservation performance and steps taken to improve the resource conditions of their land.

  - **Regional Conservation Partnership Program (RCPP) –** promotes coordination of NRCS conservation activities with partners that offer value-added contributions to expand our collective ability to address on-farm, watershed, and regional natural resource concerns. Through RCPP, NRCS co-invests with partners to implement projects that demonstrate innovative solutions to conservation challenges and provide measurable improvements and outcomes tied to the resource concerns they seek to address. RCPP uses a range or on-the-ground conservation activities including land management/improvement/restoration practices, land rentals, entity- and U.S.-held easements, and public works/watersheds.

  - **Emergency Watershed Protection Program** – helps local communities recover after a natural disaster strikes. This Federal emergency recovery program offers technical and financial assistance to help local communities relieve imminent threats to life and property caused by floods, fires, windstorms, and other natural disasters that impar a watershed. Financial and technical assistance may include removal of debris from streams, reshaping and protecting eroded streambanks, establishing vegetative cover on critically eroding lands, repairing certain conservation practices, and purchasing flood plain easements.

  - **Watershed and Flood Prevention Operations Program –** provides technical and financial assistance to States, local governments and Tribes to plan and implement authorized watershed project plans for the purpose of flood prevention, watershed protection, public recreation, public fish and wildlife, agricultural water management, municipal and industrial water supply, water quality management, and watershed structure rehabilitation.

- **DHS**
  - **Department of Homeland Security Preparedness Grants –** provides funding to state, local, tribal and territorial governments, nonprofit agencies, and the private sector in building and sustaining capabilities to prevent, protect against, respond to and recover from acts of terrorism and other hazards. The total amount for each grant program is set by Congress and the allocations are made by the Secretary.

- **EPA**
  - **Agency Clean Water State Revolving Funds** – provides communities low-cost financing for a wide range of water quality infrastructure projects. Types of projects eligible to receive assistance are construction of publicly owned treatment works, nonpoint source, decentralized wastewater treatment systems, stormwater, energy efficiency, water reuse, security measures at publicly owned treatment works, and technical assistance.

  - **Water Quality Monitoring Grant Program** – also known as the Section 106 Grant Program, this grant funds efforts to enhance existing monitoring efforts and help them achieve their long-term monitoring program goals.

  - **Brownfields Technical Assistance Program –** provides technical assistance to communities and stakeholders to help address their brownfield sites, and to increase their understanding and involvement in brownfields cleanup, revitalization, and reuse.

  - **319 Grant Program –** supports a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source pollution implementation projects.

  - **Water Infrastructure Improvement for the Nation Act (WIIN Act) Grant** – addresses, supports, and improves the nation’s drinking water infrastructure. Included in the WIIN Act are three drinking water grants that promote public health and protection of the environment.

- **Bipartisan Infrastructure Law** – delivers more than $50 billion to EPA to improve the nation's drinking water, wastewater, and stormwater infrastructure. Projects eligible to receive assistance are construction of publicly owned treatment works, water reuse, security measures at publicly owned treatment works, and technical assistance.
- **Construction Grants –** provides communities with funding for water and wastewater infrastructure projects. Types of projects eligible to receive assistance are construction of publicly owned treatment works, water reuse, security measures at publicly owned treatment works, and technical assistance.
- **Sewer Overflow and Stormwater Reuse Municipal Grants** – this new grant program will provide funding for critical stormwater infrastructure projects in communities including combined sewer overflows and sanitary sewer overflows.
- **Clean Water Act 205(j)/604(b): Water Quality Management Planning** – assists in administering water quality management planning. Grant funds are used to determine the nature and extent of point and non-point source water pollution and develop water quality management plans.
- **Clean Water Act 406: Beach Monitoring and Notification Program** – supports the development and implementation of programs for monitoring and notification of risk to human health in coastal recreation waters adjacent to beaches and other similar points of access used by the public.
- **Hazardous Waste Financial Assistance Grants –** helps states and territories implement the Resource Conservation and Recovery Act to protect human health and the environment by minimizing waste generation, preventing the release of millions of tons of hazardous wastes, and cleaning up land and water.
- **National Pesticide Program** – ensures pesticides are made available for use and are properly sold, distributed, and used in a way that is protective of human health and the environment. The National Pesticide Program protects people and ecosystems that may be exposed to pesticides, through its pesticide product registration and registration review program, outreach, technical assistance, and compliance and enforcement programs.
- **Safe Drinking Water Act – Public Water System Supervision Program** – aims to protect public health by ensuring that public water systems provide safe drinking water through compliance with the national primary drinking water regulations. To protect public health and maintain direct enforcement authority, program funds will support activities such as regulation adoption, regulation implementation, enforcement, data management, etc.

- **NOAA**
  - **Coastal Management Program 309 –** occurs every five years and provides a process under "Section 309" of the Coastal Zone Management Act, as amended, for states and territories to carry out assessments to determine if funding may be available for projects relating to wetland, coastal hazards, public access, marine

debris, cumulative and secondary impacts, special area management plans, ocean resources, energy and government facility siting, and aquaculture. To be eligible for 309 funding for the next five-year period, an approved Assessment and Strategy report must be carried out by the territory (or state) by the Coastal Management Program. The "309" process calls for development of a Draft version of the Section 309 Assessment and Strategy followed by a review period, preparation of a final draft, and approval of program enhancement funding. This program is administered by the National Ocean Service.

- **Community-Based Habitat Restoration –** provides funding and technical assistance for restoration projects that ensure fish have access to high-quality habitat. The goal of these projects is to recover and sustain fisheries–particularly those species managed by NOAA Fisheries, or those listed as endangered or threatened under the Endangered Species Act. Projects range from improving access to habitat by removing dams and other barriers, to restoring coral and oyster reefs, to rebuilding coastal wetlands. This program is administered by the Office of Habitat Conservation.

- **Coral Reef Conservation Program** – provides annual funding in the form of cooperative agreements to eligible state, territorial, and commonwealth agencies for conservation projects in coral reef jurisdictions. The program provides matching awards of financial assistance that are administered as cooperative agreements, domestic grants, and spend plan Federal process. The objective is to support coral reef management and monitoring programs as well as conservation projects that seek to improve the condition of coral reef ecosystem resources. This program is administered by the Office of Coastal Management.

- **Coastal Zone Management Act** – provides for the management of the nation's coastal resources, including the Great Lakes. The goal is to "preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone.

- **Coastal Resiliency Grants** – implements projects that build resilience through sustainable ecosystem processes and functions and reduce the vulnerability of coastal communities and infrastructure from the impacts of extreme weather events, climate hazards, and changing ocean conditions. Eligible applicants are institutions of higher education, nonprofit and for-profit organizations, U.S. territories and states, Native American tribes, and local governments. Applicants must submit a pre-proposal by email to resilience.grants@noaa.gov. Full proposals will only be accepted from eligible applicants that received an invitation to submit a full proposal based on the strength of their pre-proposal. This program is administered by the National Fish and Wildlife Foundation (NFWF).

- **U.S. Integrated Ocean Observing System** – national-regional partnership that provides new tools and forecasts to improve safety, enhance the economy, and protect our environment. Integrated ocean information is available in near real time, as well as retrospectively. Easier and better access to this information is improving our ability to understand and predict coastal events - such as storms, wave heights, and sea level change.

  - **Regional Integrated Sciences and Assessments Program** – supports research teams that help expand and build the nation's capacity to prepare for and adapt to climate variability and change.

- **National Tsunami Hazard Mitigation Program (NTHMP)**
  - **Mapping and Modeling –** brings together expertise on modeling and mapping of tsunami hazards.
  - **Warning Coordination** – provides input to the operational U.S. Tsunami Warning System. Recommendations from the NTHMP help refine warning system messages, graphics, procedures, exercises, and dissemination systems so that warning system products are effective during a tsunami warning.
  - **Mitigation and Education –** works to reduce tsunami impacts primarily through education and outreach that increase awareness and encourage preparedness. It also promotes and provides guidance on other risk reduction activities, such as evacuation planning and integration of tsunami risk into land-use policy and planning

- **NFWF**
  - **Natural Coastal Resiliency Fund –** invests in conservation projects that restore or expand natural features such as coastal marshes and wetlands, dune and beach systems, oyster and coral reefs, forests, coastal rivers and floodplains, and barrier islands that minimize the impacts of storms and other naturally occurring events on nearby communities.
  - **The Coral Reef Conservation Fund –** responds to the alarming decline in both the quantity and productivity of the world's coral reef ecosystems through multiple coral conservation initiatives that aim to improve management, increase public awareness, and reduce threats to coral reefs. The program works to support reef resiliency by reducing negative impacts from unsustainable fishing and land-based pollution.

- **USGS**
  - **USGS Pacific Islands Climate Adaptation Science Center –** provides funding made available through Requests for Proposals from the USGS or from funding announcements from the University Consortium. Announcements are made available on the USGS Pacific Islands Climate Adaptation Science Center website.

    The USGS Pacific Islands Climate Adaptation Science Center identifies research priorities tied closely to the needs of natural and cultural resource managers in the Pacific Islands region. Proposals typically should focus on developing "actionable science" or knowledge that can inform or be applied to specific management challenges, locally or broadly across the Pacific Islands region.

- **USFWS**
  - **Habitat Conservation Program Planning Assistance Grants –** supports the development of new habitat conservation programs as well as the renewal or amendment of existing habitat conservation programs for species currently listed

as threatened or endangered. Species that are candidates for threatened or endangered lists may also be included.

- **ESA-Cooperative Endangered Species Conservation Fund (Section 6)** – provides grants to States and Territories to participate in a wide array of voluntary conservation projects for listed, candidate, and at-risk species on non-Federal lands. Three types of grants under this program include: Habitat Conservation Plan (HCP) Planning Assistance Grants, HCP Land Acquisition Grants, and Recovery Land Acquisition Grants. To be eligible for grant funding, States and Territories must currently have, or enter into, a cooperative agreement with the Secretary of the Interior and provide a minimum non-Federal match of 25% of the estimated program cost of approved projects.

- **Partners for Fish and Wildlife Program** – provides technical and financial assistance to landowners, managers, Tribes, corporations, schools, nonprofits interested in improving wildlife habitat on their land.

- **HUD**
  - **The Office of Community Planning and Development Disaster Resiliency Grant** – provides billions of dollars in flexible funding to help communities recover from and build resilience to climate hazards and natural disasters, particularly low- and moderate-income communities who are especially vulnerable due to current and historic discrimination and disinvestment.

  - **The Community Development Block Grant (CDBG) Program** – a flexible and widespread program reaching over 1,200 local governments in all states, territories, and commonwealths. CDBG's scope and promotion of community-specific solutions make it a powerful tool for climate resilience which requires jurisdictions to incorporate resilience to natural hazard risks into their Consolidated Plan and discuss how climate change will increase those risks and how they plan to address the impacts of climate change on low- and moderate-income residents.

  - **The Section 108 Loan Guarantee Program (Section 108)** – provides communities with a source of low-cost, long-term financing for economic and community development projects. Section 108 financing provides an avenue for communities to undertake larger, more costly projects, where they may have limited resources to invest in upfront. Section 108 can fund economic development, housing, public facilities, infrastructure, and other physical development projects, including improvements to increase their resilience against natural disasters. This flexibility of uses makes it one of the most potent and important public investment tools that HUD offers to states and local governments.

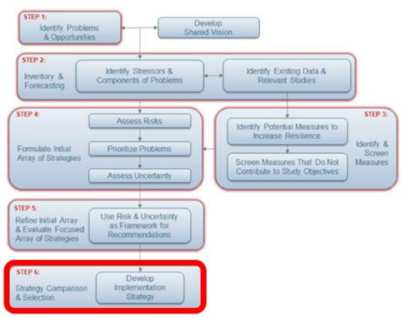
- **DOI OIA**
  - Technical Assistance Program (TAP) **–** provides grant funding for short-term projects intended to meet the immediate needs of the insular areas. TAP funding

priorities include, but are not limited to, projects that support development in the following categories: economic development, education, energy production, management control initiatives, disaster assistance, natural and cultural resources, capacity building, public safety/emergencies, health initiatives, and invasive species management.

- **University of Hawai'i (UH)**
  - **Hawaii Sea Grant –** funds research that emphasizes solution-based outcomes and applicability to pressing issues. Proposals are requested through a biennial research competition. Program development funds are also provided for select pilot projects throughout the year. Current projects address critical topics such as hazard resilience, ecosystem health, sustainable seafood, and sustainable coastal development.

- **CNMI Office of the Governor**
  - **Infrastructure and Recovery Program (IRP) –** streamlines funding for recovery and infrastructure projects throughout CNMI. As of 2021, this new program under the CNMI Governor's Office will manage nearly one billion dollars' worth of projects to be completed in the near-term.

## 6.4 Recommendations




The following sections document the recommendations and possible implementation strategies, including potential funding sources and partners. Recommendations were formulated following the risk- and uncertainty-based framework. Stressors within each category of the framework were grouped based on functional connectivity (i.e., interconnected problems should be addressed together). A combination of NNBF, non-structural, and structural measures described in Section 6.2 were explored to provide a diverse suite of resiliency options and help address stressors in each problem category.

The team held several coordination meetings with partners and stakeholders, both group and one-on-one sessions, to gain input and concurrence on the recommendations. Partners provided valuable insight into interest in recommendations and parallel on-going efforts. The study partner and other stakeholders repeatedly expressed desire for exploration and implementation of nature-based solutions. However, there may be several challenges to overcome including knowledge-based, political, and technical barriers. By using a combination of natural and conventional processes and materials, natural infrastructure can protect people, homes, and habitats.

For implementation, a combination of NNBF, nonstructural, and structural solutions along with long-term planning efforts should be explored to provide a diverse suite of resiliency options. Dependent upon on the selected recommendation, real estate requirements may be encountered, and necessary analysis and processes for use or acquisition will need to be followed. Costs included for recommendations are rough estimates and do not include real estate. Cost included for recommendations are rough estimates and are denoted by the following scale:

- $ $0-$1M
- $$ $1M-$5M
- $$$ $5M+

As discussed in Section 5.5, the risk and uncertainty results (Figure 5-14) were used to develop a framework for the appropriate types (uncertainty-based) and timing (risk-based) for recommendations. Risks identified as catastrophic have near-term recommendations for immediate steps, while risks identified as major have incremental actions for longer term steps.

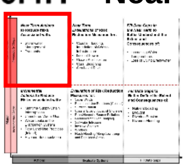
Based on the risk and uncertainty assessments, recommendations are presented in the following categories:

Catastrophic risks
- Near-term – actions
- Near-term – evaluate options
- Near-term – fill data gaps

Major risks
- Incremental – actions
- Incremental – evaluate options
- Incremental – fill data gaps

There is no obligation from the study partners or the CNMI government to implement any of the recommendations.

### 6.4.1 Near-Term Actions



Stressors listed under near-term actions have the highest risk and lowest implementation uncertainty, although additional level of analysis may be warranted prior to implementation. Actions identified for these stressors have a high level of consensus, and should be prioritized as soon as possible, ideally within five years.

Stressors evaluated as near-term actions include:

- Stormwater Management
- Tsunamis

#### 6.4.1.1 *Stormwater Management*

A significant source of surface water contamination throughout the study area is from stormwater runoff. Due to impervious surfaces preventing infiltration directly into the ground, moving water picks up contaminates as it travels downslope. Effective stormwater management will reduce runoff from rainwater into roadways and waterways and redirect it into a well-maintained drainage system. Recommendations and practices outlined in the CNMI and Guam Stormwater Management Manual (Witten Group, Inc., 2006) and the CNMI Comprehensive Sustainable Development Plan (OPD, 2021) should be followed. Table 6-3 below shows near-term actions for stormwater management.

Table 6-3. Near-Term Actions for Stormwater Management

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| Engineering with Nature | Wetland Restoration and Bioswales: Develop areas to direct and capture runoff and perform natural water filtration processes in steep terrain areas to remove contaminants before entering water systems or recharging groundwater resources. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that Indigenous Traditional Ecological Knowledge (ITEK) can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: EPA, NFWF, NRCS, USACE CAP 206, USFWS<br><br>Potential Partners: BECQ-DCRM, Dept. of Community and Cultural Affairs-HPO, Dept. of Land and Natural Resources (DLNR), EPA, NRCS, USACE, USFWS |
| | Rainwater Catchment Systems for Groundwater Recharge: Install infrastructure to utilize precipitation that can help recharge groundwater resources and reduce surface runoff. | Estimated Cost: $$<br><br>Potential Funding: EPA, FEMA<br><br>Potential Partners: BECQ-DEQ, DPW, NRCS |
| | Rain Gardens: Create rain gardens in developed areas that capture runoff from hard surfaces and filter out pollutants from surface waters, prevent erosion, increase biodiversity, and require little to no maintenance once established. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA, USACE CAP Sect. 204 or 206, USACE RSM<br><br>Potential Partners: BECQ-DCRM, DLNR, EPA, USFWS, NRCS |
| Drainage System Improvements | Scheduled Maintenance and Drain Cleaning: Continued upkeep of storm drains in urban areas to maintain water flow and prevent backups. | Estimated Cost: $<br><br>Potential Funding: USACE CAP 208<br><br>Potential Partners: DPW, EPA, OPD |
| | Sediment Capture: Install sediment capture tanks in urban or steep terrain areas to intercept large sediment debris and capture sediment before being released into waterways. | Estimated Cost: $$<br><br>Potential Funding: EPA, NRCS<br><br>Potential Partners: BECQ-DCRM, DLNR, DPW, EPA, NRCS |

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| | Improve Drainage Network: Identify locations of the network within urban or steep terrain areas that need to be updated or replaced to maintain and/or improve its functionality. | Estimated Cost: $$<br><br>Potential Funding: EPA, HUD, IRP<br><br>Potential Partners: BECQ, DPW |

#### 6.4.1.2 *Tsunamis*

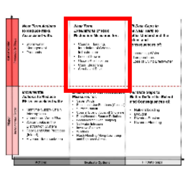
Although an uncommon occurrence, tsunamis pose a significant risk to human lives, health and safety, the environment, homes, and critical infrastructure. Strong waves and flooding can last for several hours in a tsunami. Presently, the CNMI receives tsunami warnings from the Pacific Tsunami Warning System that will send out a Tsunami Watch to areas that may be impacted within the hour. Despite all tsunami activity in the Pacific being detected, fatalities have resulted due to residents not heeding warnings. The CNMI Office of Homeland Security and Emergency Management (HSEM) does conduct tsunami preparedness drills with students to exercise tsunami response and evacuation in case of an event. Table 6-4 below shows recommendations for tsunamis.

Table 6-4. Near-Term Actions for Tsunamis

| Tsunami | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| Education & Outreach | Natural Hazard Related Signage and Maps in Public Spaces: Ensure updated evacuation routes, safe zones, shelter locations, and preparedness steps are visible in public spaces and accessible to people in multiple local languages, who are hard of hearing, and/or sight impaired. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, NTHMP, OIA, UH, USACE Silver Jackets<br><br>Potential Partners: American Red Cross (ARC), CNMI Dept. of Public Safety (DPS), CNMI HSEM, FEMA, NOAA, OPD, USACE Silver Jackets |
| Emergency Preparedness | Annual Tsunami Drills: Routinely practice community-wide drills with all age levels to ensure proper preparedness. | Estimated Cost: $<br><br>Potential Funding: FEMA, NTHMP, OIA, USACE Silver Jackets<br><br>Potential Partners: CNMI DPS, CNMI HSEM, CNMI Public School System, FEMA, NOAA, OPD, USACE Silver Jackets |

| Tsunami | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| | Tsunami Table-Top Exercises for Emergency Responders: Host interactive exercises with emergency personnel agencies and local leaders to practice simulated events to improve response efficiency and to ensure responsibilities are clearly identified. | Estimated Cost: $<br><br>Potential Funding: FEMA, NTHMP, OIA, USACE Silver Jackets<br><br>Potential Partners: ARC, BECQ-DCRM, CNMI DPS, CNMI HSEM, Dept. of Community and Cultural Affairs-HPO, FEMA, NOAA, OPD, USACE Silver Jackets |
| Risk Analysis | Hazard Mapping: Routinely update hazard maps to highlight changes in risk and the extent of the hazard in an area. This information can support land use planning, mitigation, risk communication, and emergency response. | Estimated Cost: $<br><br>Potential Funding: FEMA, NTHMP, OIA, UH, USACE FPMS, USACE Silver Jackets<br><br>Potential Partners: BECQ-DCRM, CNMI HSEM, Dept. of Community and Cultural Affairs-HPO, FEMA, NOAA, NRCS, USACE Silver Jackets |
| Policy / Improve Land Use Planning | Continued Implementation of Safe Smart Growth Principles and Comprehensive Sustainable Development Plan: Implement requirements to ensure organizations are following plans and procedures outlines in existing documents to help with long-term sustainability. | Estimated Cost: $<br><br>Potential Funding: DHS, HUD, OIA<br><br>Potential Partners: BECQ-DCRM, CNMI Zoning Offices, Governor's Council of Economic Advisors, OPD |
| | Improve Land Use Planning: Due to the potential life safety and economic risks, institute zoning and/or building codes to minimize risk. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, OIA<br><br>Potential Partners: BECQ-DCRM, CNMI Zoning Offices, DPW, OPD |

### 6.4.2 Near-Term Evaluation of Options



Stressors deemed appropriate for evaluating options in the near-term have catastrophic risk and moderate levels of implementation uncertainty. Additional studies are needed to better understand the problem or to identify recommended plans. Studies should be initiated in the near-term, ideally within zero to five years and target implementation within five to ten years.

Stressors that require near-term evaluations are:

- Coastal Flooding and Inundation of Coastal Infrastructure
- Loss of Power
- Ocean Acidification
- Coral Bleaching
- Sea Level Rise

#### 6.4.2.1 *Coastal Flooding and Inundation of Coastal Infrastructure, Loss of Power*

Tropical storms and typhoons, which often lead to flooding, are a common occurrence throughout CNMI and their frequency and intensity are anticipated to be exacerbated by climate change. Due to the encroachment of development along the coast and into the floodplain, recurring flooding is capable of undermining critical infrastructure related to shipping, transportation, utilities, and communications, which can lead to day- to month-long outages.

CNMI endured loss of power following tropical storms and typhoons. Vulnerable power supplies can lead to severe consequences such as major economic disruptions, declining water resources (pumps and wells cannot operate), effects to daily life, and potential public health issues. Diversifying CNMI's energy portfolio and strengthening renewable energy standards, which would all support the developing Comprehensive Energy Plan, would strengthen resiliency throughout the islands. Recommendations and practices outlined in the CNMI Comprehensive Sustainable Development Plan should be followed.

Near-term efforts should begin to evaluate options for reducing potentially catastrophic risks associated with these two stressors. A combination of nature-based, non-structural, and structural measures should be considered to build long-term resiliency (Table 6-5).

Table 6-5. Near-Term Option Evaluation for Coastal Flooding, Inundation of Coastal Infrastructure, and Loss of Power

| **Tropical Storms & Typhoons** | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| Ecosystem Restoration | Plant Native Vegetation Species: Plant durable native vegetation to help anchor topsoil, absorb water, and reduce runoff and erosion into waterways and drainage systems. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: NRCS, USACE CAP Sect. 206, USFWS<br><br>Potential Partners: BECQ-DCRM, Dept. of Community and Cultural Affairs-HPO, DLNR, EPA, NRCS, USACE, USFWS |
| Beach Enhancement | Beach Nourishment: Add sand to eroded beach areas to increase beach widths and reduce erosion. This helps to create an erosion buffer, and sand can be either dredged from nearby areas or transported in from an outside area. | Estimated Cost: $$<br><br>Potential Funding: NFWF, USACE CAP Sect. 103 or 204, USACE RSM<br><br>Potential Partners: BECQ-DCRM, DLNR, EPA, Dept. of Community and Cultural Affairs-HPO, PCRP |

| Tropical Storms & Typhoons | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| Emergency Preparedness | Storm Event Table-Top Exercise for Emergency Responders: Host interactive exercises with emergency personnel, community leaders, and agencies to practice simulated storm events to improve response efficiency and to ensure responsibilities are clearly identified. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, OIA, USACE Silver Jackets<br><br>Potential Partners: ARC, BECQ-DCRM, CNMI DPS, CNMI HSEM, FEMA, NOAA, OPD, USACE |
| | Climate Change Working Group: Institute an interagency working group to identify and provide sustainable solutions for communities to effectively manage and reduce the impacts of climate change. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, NOAA, UH<br><br>Potential Partners: BECQ-DCRM, DLNR-DFW, EPA, FEMA, NOAA |
| Risk Analysis | Hazard Mapping: Routinely update hazard maps to highlight changes in risk and the extent of the hazard in an area. This information can support land use planning, mitigation, risk communication, and emergency response. | Estimated Cost: $<br><br>Funding: FEMA, NOAA, OIA, UH, USACE FPMS, USACE Silver Jackets<br><br>Potential Partners: BECQ-DCRM, CNMI HSEM, Dept. of Community and Cultural Affairs-HPO, FEMA, NOAA, NRCS, USACE |
| Education and Outreach | Education and Outreach on Emergency Preparedness, Evacuation Routes, and Safe Zones: Outreach to the public to ensure they have an emergency kit ready to go with essential items in case of power outages or flood evacuations. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, OIA, UH, USACE Silver Jackets<br><br>Potential Partners: BECQ-DCRM, CNMI HSEM, CNMI DPS, FEMA, NOAA, OPD, USACE |
| | Natural Hazard Related Signage and Maps in Public Spaces: Ensure updated evacuation routes, safe zones, and preparedness actions are visible in public spaces and accessible to people in multiple local languages, who are hard of hearing, sight impaired. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, OIA, UH, USACE Silver Jackets<br><br>Potential Partners: CNMI-HSEM, FEMA, NOAA, OPD, USACE |

| Tropical Storms & Typhoons | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| | Flood Insurance: Provide the public with educational materials and webinars on ways to determine where the flood zone areas are and the benefits of purchasing flood insurance. | Estimated Cost: $<br><br>Potential Funding: FEMA, USACE Silver Jackets<br><br>Potential Partners: CNMI HSEM, FEMA, OPD, USACE |
| Flood Protection Study | Increase Freeboard Above Inundation: Conduct a study to determine the critical flood elevations and then what the additional height buildings would need to be raised to protect life safety, reduce flood damages, and lower insurance costs. | Estimated Cost: $$<br><br>Potential Funding: FEMA, USACE CAP Sect. 205, USACE GI<br><br>Potential Partners: FEMA, OPD, USACE |
| Critical Infrastructure Protection | Recurve Sea Wall: Study and assess the construction of a sea wall that deflects waves, thus reducing wave overtopping. This will help protect the shore and coastal infrastructure from flooding and erosion. | Estimated Cost: $$<br><br>Potential Funding: FEMA, HUD, NOAA, USACE CAP Sect. 205<br><br>Potential Partners: BECQ-DCRM, DLNR, FEMA, MINA, OPD, PCRP, USACE |
| | Road Enhancements and/or Relocations: Update roads to be better equipped for various weather elements, which can include permeable pavement to minimize standing water, reduce runoff, and promote groundwater recharge. Relocation of roadways out of hazard zones can significantly reduce the threat to critical routes. | Estimated Cost: $$<br><br>Potential Funding: FEMA, HUD<br><br>Potential Partners: DPW, BECQ-DCRM, OPD, USACE |
| | Protect and/or Strengthen Critical Infrastructure: Update critical infrastructure (ports, roads, utilities, schools, etc.) from future anticipated storm events and flooding impacts to be better retrofitted against elements. | Estimated Cost: $$-$$$<br><br>Potential Funding: FEMA, HUD, IRP, USACE CAP Sect. 107<br><br>Potential Partners: BECQ-DCRM, Commonwealth Ports Authority, CUC, DPW, OPD, USACE |
| Policy | Continued Implementation of Safe Smart Growth Principles and Comprehensive Sustainable Development Plan: Implement requirements to ensure organizations are following plans and procedures outlines in existing documents to help with long-term sustainability. | Estimated Cost: $<br><br>Potential Funding: DHS, HUD, OIA<br><br>Potential Partners: BECQ-DCRM, CNMI Zoning Offices, EPA, Governor’s Council of Economic Advisors, OPD |

| Tropical Storms & Typhoons | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| | Improve Enforcement of Building Codes and Permits: Work with local experts to examine how building requirements can be met by developers to ensure infrastructure is safe and maintained against coastal weather impacts. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, OIA<br><br>Potential Partners: BECQ-DCRM, OPD, CNMI Zoning Offices, DPW, EPA |
| | Improve Monitoring of Illegal Dumping: Carry out strict and consistent enforcement of the CNMI anti-littering law by professional individuals and government officials to reduce illegal disposal of trash and waste by companies, the public, and agricultural entities. | Estimated Cost: $$<br><br>Potential Funding: EPA<br><br>Potential Partners: BECQ-DCRM, BECQ-DEQ, DLNR, DPW, EPA, OPD |
| Diversify Energy Sources | Alternative Energy Sources: Identify and implement renewable energy sources (i.e., solar, wind, wave, methane from wastewater treatment) to support energy goals in reducing diesel fuel usage and improving the affordability of power sources without compromising power system reliability. | Estimated Cost: $$$<br><br>Potential Funding: DOE, EPA, FEMA, IRP<br><br>Potential Partners: CUC, DOE, DPW, EPA, OPD |

#### 6.4.2.2 *Relative Sea Level Change, Coral Bleaching, and Ocean Acidification*

Resources affected by these three stressors, all interrelated, are at increased risk of environmental degradation and vulnerable to naturally occurring and anthropogenic activities. With climate change expected to continue increasing, the impacts of each of these stressors on the built and/or natural environment is also expected to be exacerbated. Rising sea levels present direct challenges to CNMI's villages, shorelines, and coastal infrastructure. Increasing ocean water temperatures pose an imminent threat to near-shore environments and coral reefs, including coral bleaching. Coral bleaching is expected to increase at a relatively quick rate in the Western Pacific, with bleaching occurring on an annual basis before 2050 (CNMI HSEM, 2018). Additionally, improvements in stormwater management can help reduce contaminants, which can also lead to bleaching, from entering waterways leading to the ocean. Ocean acidification, resulting from GHG emissions, leads to adverse impacts to marine life, including coral.

Near term efforts should begin to evaluate options for reducing potentially catastrophic risks associated with RSLC, coral bleaching, and ocean acidification. An integrated, multi-purpose approach is warranted to identify and evaluate the full spectrum of potential actions that could be taken by Federal and local agencies to reduce risks (Table 6-6).

Table 6-6. Near-Term Option Evaluation for Coastal Hazards

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| Ecosystem Restoration | Coral Reef, Mangrove, and Wetland Restoration: Further define ecosystem enhancement/green infrastructure possibilities (studies and pilot projects) including restoring mangroves, coral reefs (including nurseries and propagation), and wetlands in high priority areas, permeable greenspaces, and/or areas suitable for submerged/artificial reef pilot projects. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NFWF, NOAA, UH, USACE CAP Sect. 206, USFWS<br><br>Potential Partners: BECQ-DCRM, Dept. of Community and Cultural Affairs-HPO, DLNR, EPA, USACE, USFWS |
| | Increase Carbon Storage by Increasing Forest Cover: Minimize impacts of climate change on a local level by planting or restoring at least 10% land cover to the native and endemic forest. | Estimated Cost: $<br><br>Potential Funding: NFWF<br><br>Potential Partners: BECQ-DCRM, BECQ-DEQ, DLNR, EPA, OIA |
| Ecosystem Protection | Climate Change Analysis: Establish monitoring programs to assess long- and short-term impacts of climate change. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA<br><br>Potential Partners: BECQ-DCRM, Dept. of Community and Cultural Affairs-HPO, DLNR-Department of Fish and Wildlife (DFW), EPA, FEMA, MINA, NOAA, OPD, Planning and Development Advisory Council |
| | Coral Restoration and/or Preservation (incl. Coral Nursery/Propagation): Save and restore coral reefs through a multi-pronged approach. Strategies include improving habitat quality and enhancing population resilience leading to improved health and survival. This includes activities such as planting nursery-grown coral back into reefs, ensuring habitat is suitable for natural coral growth, increasing resilience to threats (e.g., climate change), and/or implementing policy for long-term protection. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NFWF, NOAA, UH, USFWS, USACE CAP Sect. 206<br><br>Potential Partners: BECQ-DCRM, EPA, NFWH, NOAA, USACE, USFWS |

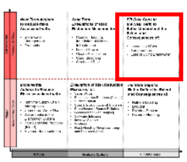
| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| | Marine Protected Areas: Increase the number of MPAs and their awareness through identifiable boundary markers, buoys, or signage. | Estimated Cost: $<br><br>Potential Funding: NFWF, NOAA<br><br>Potential Partners: BECQ-DCRM, DLNR-DFW, EPA, USFWS |
| Beach Enhancements | Beach Nourishment: Add sand to eroded beach areas to increase beach widths and reduce erosion. This helps to create an erosion buffer and sand can be either dredged from nearby areas or transported in from an outside area. | Estimated Cost: $$<br><br>Potential Funding: NFWF, USACE CAP Sect. 103 or 204, USACE RSM<br><br>Potential Partners: BECQ-DCRM, DLNR, EPA, Dept. of Community and Cultural Affairs-HPO, PCRP |
| Emergency Preparedness | Hazard Mapping Updates: Perform analysis to determine forecast RSLC and update mapping. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, OIA, UH, USACE FPMS, USACE Silver Jackets<br><br>Potential Partners: BECQ-DCRM, CNMI HSEM, Dept. of Community and Cultural Affairs-HPO, FEMA, NOAA, USACE |
| | Natural Hazard Related Signage and Maps in Public Spaces: Ensure updated evacuation routes, safe zones, and preparedness steps are visible in public spaces. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, OIA, UH, USACE Silver Jackets<br><br>Potential Partners: BECQ-DCRM, FEMA, NOAA, USACE |
| | Climate Change Working Group: Institute an interagency working group to identify and provide sustainable solutions for communities to effectively manage and reduce the impacts of climate change. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, NOAA, UH<br><br>Potential Partners: BECQ-DCRM, DLNR- DFW, EPA, FEMA, NOAA |
| Policy / Improve Land Use Planning | Improve Enforcement on Building Codes and Permits: Mandate requirements to be met to ensure infrastructure is safe and maintained against coastal weather impacts. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, OIA<br><br>Potential Partners: BECQ-DCRM, CNMI Zoning Offices, DPW |

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| | Continue Implementation of Safe Smart Growth Principles and Comprehensive Sustainable Development Plan: Implement requirements to ensure organizations are following plans and procedures outlines in existing documents to help with long-term sustainability. | Estimated Cost: $<br><br>Potential Funding: DHS, HUD, OIA<br><br>Potential Partners: BECQ-DCRM, CNMI Zoning Offices, EPA, Governor's Council of Economic Advisors, OPD |
| | Improve Monitoring of Illegal Dumping: Carry out strict and consistent enforcement of the CNMI anti-littering law by professional individuals and government officials to reduce illegal disposal of trash and waste by companies, the public, and agricultural entities. | Estimated Cost: $<br><br>Potential Funding: EPA<br><br>Potential Partners: BECQ-DCRM, BECQ-DEQ, DLNR, DPW, EPA, OPD |
| Education and Outreach | Flood Insurance: Provide the public with educational materials and webinars on ways to determine where the flood zone areas are and the benefits of purchasing flood insurance. | Estimated Cost: $<br><br>Potential Funding: FEMA, USACE Silver Jackets<br><br>Potential Partners: CNMI HSEM, FEMA, OPD, USACE |
| | Flood Risk Awareness and Floodplain Mapping: Raise awareness of flood risk in a particular area through public outreach. Conduct floodplain mapping or hazard assessments to identify at risk areas. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, USACE Silver Jackets, USACE FPMS, UH<br><br>Potential Partners: FEMA, NOAA, OPD, USACE |
| Flood Protection Study | Increase Freeboard Above Inundation: Conduct a study to determine the critical flood elevations and then what the additional height buildings would need to be raised to protect life safety, reduce flood damages, and lower insurance costs. | Estimated Cost: $$<br><br>Potential Funding: FEMA, USACE CAP Sect. 205, USACE GI<br><br>Potential Partners: USACE, FEMA, OPD |

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| Structural Enhancements and Processes | Flood Break Floating Breakwater: Assess and construct a structure along the shoreline, instead of directly on the shoreline to act as a permeable breakwater that could be made from local material. The structure could also be used to convert wave power into electrical energy while reducing wave impact on the shoreline and coastal infrastructure, including harbors. | Estimated Cost: $$-$$$<br><br>Potential Funding: FEMA, IRP, NOAA<br><br>Potential Partners: FEMA, DLNR, MINA, OPD, PCRP |
| Critical Infrastructure Protection | Protect and/or Strengthen Critical Infrastructure: Update critical infrastructure (ports, roads, utilities, schools, etc.) from future anticipated storm events and flooding impacts to be better retrofitted against elements. | Estimated Cost: $$-$$$<br><br>Potential Funding: DOT, EPA, FEMA, HUD, IRP, USACE CAP Sect. 14 or 205<br><br>Potential Partners: CUC, DPW, EPA, OPD |

### 6.4.3 Near-Term Fill Data Gap

Stressors that possessed a high level of uncertainty in the identified solutions require a more detailed understanding of the problem before initiating a study or project. Steps should be taken to fill the data gaps within the next zero to five years followed by an initiation of a study or implementation of a program performed within five to ten years, if possible.



Stressors with identified data gaps that should be addressed in the near-term are:

- Increasing Water Temperatures
- Loss of Living Breakwater

#### 6.4.3.1 *Increasing Water Temperatures, Loss of a Living Breakwater*

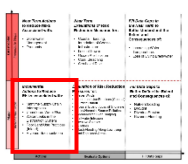
Increasing sea level surface temperatures pose imminent threats to the near shore environments and coral reefs throughout the islands. The decline of the overall health to these habitats can lead to a decrease in both ecosystem value and tourism appeal.

Living breakwater provides significant ecological value and contributes to the economy through tourism, while reducing risks associated with coastal flooding, coastal erosion, and loss of shoreline. The ecological and monetary value of the living breakwater should be quantified from a multi-purpose perspective. Further data should be collected in the near term to better understand and document the current and projected impacts to the existing living breakwater along the shoreline to inform potential solutions (Table 6-7).

Table 6-7. Near Term Data Gaps for Increasing Water Temperatures and Loss of Living Breakwater

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Partners and Funding** |
| Ecosystem Restoration | Coral Reef, Wetland, and Shoreline Restoration: Further define ecosystem enhancement/green infrastructure possibilities (studies and pilot projects) including restoring coral reefs (including nurseries and propagation), wetlands, and shoreline vegetation in high priority areas, permeable greenspaces, and/or areas suitable for submerged/artificial reef pilot projects. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NFWF, USACE CAP Sect. 103 or 206, USACE GI, USFWS, UH<br><br>Potential Partners: BECQ-DCRM, Dept. of Community and Cultural Affairs-HPO, DLNR, EPA, USACE, USFWS |
| | Increase Carbon Storage by Increasing Forest Cover: Minimize impacts of climate change on a local level by planting or restoring at least 10% land cover to the native and endemic forest. | Estimated Cost: $<br><br>Potential Funding: NFWF, NRCS<br><br>Potential Partners: BECQ-DCRM, BECQ-DEQ, DLNR, EPA, OIA |

### 6.4.4 Incremental Actions



Recommendations categorized as incremental actions have a low level of implementation uncertainty and pose a major risk, rather than catastrophic risk recommendations, on which the study mainly focused. As such, recommendations for incremental actions and studies and filling data gaps do not have potential partners listed.

These recommendations should initiate implementation within zero to ten years. These problems are important to address in the near-term to reduce economic, social, and environmental risks. However, with limited resources, these recommendations may be taken as incremental steps to make continuous progress towards enhancing resiliency.

Stressors with solutions categorized as incremental actions include:

- Maritime Supply Chain Interruptions
- Unmetered Water Use
- Water Leaks in the Distribution System
- Land Use Practices (Inland)
- Riverine Sedimentation

#### 6.4.4.1 *Maritime Supply Chain Interruptions*

Due to CNMI's remote location and on-island resource limitations, CNMI is dependent on maritime shipping to provide imports. During tropical storms and typhoons, harbor infrastructure can be damaged and/or access to the port restricted. This disrupts the supply chain and prevents critical supplies from reaching the islands. In conjunction with the following recommendations, the Marine Transportation System Recovery Plan is a key document outlining procedures to reduce impacts (Table 6-8).

Table 6-8Table 6-8. Incremental Actions for Maritime Supply Chain Interruptions

| Tropical Storms & Typhoons | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Emergency Preparedness | Emergency Planning: Identify alternative shipping routes and have emergency resource reserves (i.e., water, non-perishable food, etc.) on the island. Ensure the Maritime Transportation Systems Recovery Plan is updated. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, USACE Silver Jackets |
| Alternative Docking Locations | Safe Harbor Locations: Identify alternative location around the island where ships can dock during an emergency. This will ensure resources are delivered and minimize congestion and back-ups. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, OPD |
| Weather Forecasting | Increase Weather Forecasting and Technology Accuracy: Invest in modernized technology to help shipping companies forecast and adjust due to inclement weather to minimize losses or delays. Tracking and predicting storms will allow for the most efficient actions to be taken. | Estimated Cost: $<br><br>Potential Funding: FEMA, NOAA, USGS |
| Critical Infrastructure Protection | Protect and/or Strengthen Critical Infrastructure: Update critical infrastructure (ports, roads, utilities, schools, etc.) from future anticipated storm events and flooding impacts to be better retrofitted against elements. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA, FEMA, HUD, IRP, USACE CAP Sect. 107, USACE GI |

#### 6.4.4.2 *Unmetered Water Use, Water Leaks in the Distribution System*

Unmetered water use and water leaks in the distribution systems are considered non-revenue water, which is water that has been released into the water distribution systems but is 'lost' before it makes it to the end user. These are two significant issues CNMI faces when managing its water supply that led to significant economic losses. These issues are the result of outdated and unmaintained water supply infrastructure. Additionally, inaccurate metering leads to water theft by users pumping groundwater above their allocations. The current loss rate is estimated to be approximately 200 million gallons per month (Nimbus Environmental Services, 2018). To improve resiliency, updating infrastructure and identifying locations of leaks will be an effective and immediate way to improve long-term water supply resources. In addition to the agreed upon solutions provided below in Table 6-9, recommendations and practices outlined in the CNMI Comprehensive Sustainable Development Plan should be followed and the several data gaps outlined in the Guidance Manual for Smart, Safe Growth acknowledged due to the complexity and magnitude of these issues.

Table 6-9. Incremental Actions for Unmetered Water Use, Water Leaks in the Distribution System

| Water Quality & Quantity | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Ecosystem Restoration | Restoration of Groundwater Recharge Areas: To supplement water loss, restore areas to support groundwater recharge and enhance water supply. | Estimated Cost: $<br><br>Potential Funding: EPA, NFWF, NRCS, USACE CAP Sect. 206 |
| Education and Outreach | Water Conservation Programs: Provide education to residents on sustainable water activities and the benefits of high efficiency, water saving appliances for homes, business, and agricultural practices. Provide rebates or an incentive to justify changes. | Estimated Cost: $<br><br>Potential Funding: EPA, NRCS, OIA, USACE PAS |
| Enhanced Water Supply Management | Smart Meter Installation: Update metering technology to accurately track water usage to reduce non-revenue water and better monitor water supply. | Estimated Cost: $<br><br>Potential Funding: EPA, IRP |
| | Inventorying Water Leaks: Utilize modeling and other technology to analyze the existing water distribution system and quantify and locate leaks. | Estimated Cost: $<br><br>Potential Funding: BOR, EPA, IRP |
| Policy | Continued Implementation of Safe Smart Growth Principles and Comprehensive Sustainable Development Plan: Implement requirements to ensure organizations are following plans and procedures outlines in existing documents to help with long-term sustainability. | Estimated Cost: $<br><br>Potential Funding: DHS, HUD, OIA |
| | Improved Regulation & Enforcement of Water Quality and Supply Standards: Identify effective policies, practices, and procedures to be implemented to improve water quality and supply. | Estimated Cost: $<br><br>Potential Funding: EPA |
| Structural Enhancement | Retrofit or replace current water distribution system infrastructure to minimize water leaks. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA, HUD, IRP, NRCS, OIA |

#### 6.4.4.3 *Land Use Practices (Inland)*

To reduce inland habitat degradation resulting from land use practices and maximize the limited space on each of the islands, a combination of planning, policy, nature-based solutions were identified. Consideration should be given to strengthening land use planning and enforcement efforts and environmental enhancements (Table 6-10).

Table 6-10. Incremental Actions for Land Use Practices (Inland)

| **Inland Ecosystems** | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Ecosystem Restoration | Floodplain and Wetland Restoration: Conduct a study or restoration project to help connect the land to the floodplain, support aquatic habitat, and enhance groundwater recharge. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NRCS, USACE CAP Sect. 106, USACE EWN, USACE GI, USACE PAS, USFWS |
| Engineering with Nature | Rain Gardens: Implement rain gardens downslope of urban areas to capture and filtrate surface runoff and reduce erosion. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA |
| Policy/Improved Land Use Practices | Improve Land Use Planning: Identify and implement Safe, Smart Growth Principles and the Comprehensive Sustainable Development Plan requirements to effectively zone and use land efficiently to accommodate competing needs, provide recreation, and reduce adverse land and water quality impacts. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK and thorough cultural resource survey can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: DHS, EPA, HUD, OIA |
| | Improve Enforcement on Building Codes and Permits: Mandate requirements for developers to minimize impermeable surfaces which can lead to increased surface water runoff and habitat impacts. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, OIA |
| | Require Mitigation for Land Use: Implement requirements to mitigate land use practices to offset adverse impacts. | Estimated Cost: $<br><br>Potential Funding: EPA |
| | Effective Administration of Best Management Practices: Identify requirements and proper enforcement of organizations and the public to support sustainable use. | Estimated Cost: $<br><br>Potential Funding: EPA, HUD, OIA |

| Inland Ecosystems | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| | Create Threshold for Percentage of Impervious Surfaces for New Construction or Require Mitigation: Set limits on impervious surface areas to minimize surface water runoff and associated adverse impacts. | Estimated Cost: $<br><br>Potential Funding: IRP, USACE CAP Sect. 205, USACE FPMS |
| Risk Analysis | Hazard Mapping: Routinely update hazard maps to highlight changes in risk and the extent of the hazard in an area. This information can support land use planning, mitigation, risk communication, and emergency response. | Estimated Cost: $<br><br>Potential Funding: FEMA, OIA, USACE FPMS, USACE, Silver Jackets, UH |
| Education and Outreach | Interagency Engagement and Coordination to Promote Best Management Practices: Interagency collaboration to take a unified approach in promoting best management practices. | Estimated Cost: $<br><br>Potential Funding: BECQ-DCRM, OPD |
| | Training on Land Use Monitoring and Maintenance: Include training on methods to monitor the use and development of an area while also making sure the upkeep and compliance requirements are being met. This supports long-term sustainability and function of an area. | Estimated Cost: $<br><br>Potential Funding: EPA, NRCS |
| Community Services | Create A Universal Garbage Collection Task Force: Implement an effective trash collection system to reduce illegal dumping and pollution that contaminated water resources and ecosystem habitats. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA, HUD, OIA |

#### 6.4.4.4 *Riverine Sedimentation*

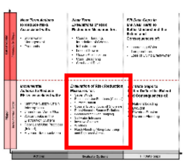
Riverine sedimentation resulting from rainfall events can lead to reduced stream channel storage capacity. This can have cascading negative impacts on in-channel and surrounding aquatic habitat, increase flood risk for adjacent communities, and clog urban stormwater drainage systems. The recommendations are composed of a combination of structural, nonstructural, and nature-based measures, which could reduce the consequences of recurring occurrences of sedimentation associated with rainfall and riverine systems (Table 6-11).

Table 6-11. Incremental Actions for Riverine Sedimentation

| Rainfall Events | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Ecosystem Restoration | Native Vegetation and Wetland Restoration: Study and implement ecosystem/nature-based enhancements including planting native resilient vegetation and developing wetland areas. These areas can slow the flow of water, which reduces erosion and provides an opportunity for groundwater recharge. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NRCS, USACE EWN, USACE CAP Sect. 206, USACE GI, USACE PAS, USFWS |
| Sheer Stress Analysis | Riverine Shear Stress Analysis – Analyze the sheer stress of moving water on channel beds to help forecast sediment transport, bank erosion, and other river engineering problems that may arise in natural streams. | Estimated Cost: $<br><br>Potential Funding: NRCS, USACE CAP Sect. 204, USACE RSM |
| Training | Training on Land Use Monitoring and Maintenance: Provide training to local agency staff on effective ways to monitor the use and development of an area while also making sure the proper upkeep and compliance requirements are being met. This supports long-term sustainability and function of an area. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: EPA, NRCS |
| Policy/Improved Land Use Planning | Effective Administration of Best Management Practices: Identify requirements and proper enforcement for organizations and the public to support sustainable use. Utilize existing Integrated Watershed Management Plans. | Estimated Cost: $<br><br>Potential Funding: HUD, OIA |
| | Improve Land Use Planning: Identify and implement Safe, Smart Growth Principles and Comprehensive Sustainable Development Plan requirements to effectively zone and use land efficiently to accommodate competing needs, provide | Estimated Cost: $<br><br>Potential Funding: DHS, HUD, OIA |

| Rainfall Events | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| | recreation, and reduce adverse land and water quality impacts. | |
| Drainage System Improvements | Scheduled Maintenance and Drain Cleaning: Continue upkeep of storm drains in urban areas to maintain water flow and prevent backups. | Estimated Cost: $<br><br>Potential Funding: USACE CAP Sect. 208 |
| | Sediment Capture: Install sediment capture tanks in urban or steep terrain areas to intercept large sediment debris and capture sediment before being released into waterways. | Estimated Cost: $$<br><br>Potential Funding: EPA, NRCS |
| | Divert Stormwater to Roadside Wetlands and Green Spaces: Redirect water to designated greenspaces to capture sediment and reduce impacts to stormwater drainage systems. | Estimated Cost: $$<br><br>Potential Funding: EPA, FEMA, NRCS, USACE CAP Sect. 204 or 206, USACE RSM |
| | Improve Drainage Network: Identify areas of the network that need to be updated or replaced to maintain and/or improve its functionality. | Estimated Cost: $$<br><br>Potential Funding: EPA, HUD, IRP |

### 6.4.5 Evaluation of Options



Incremental studies should be initiated within zero to five years with implementation targeted for within five to ten years or sooner if possible. Studies should first further investigate the stressor then determine the most effective solution(s) and implementation strategy to achieve resiliency.

Stressors to pursue as incremental evaluations are:

- Severe Winds
- Land Use Practices (Coastal), Surface Runoff
- Surface Runoff
- Coastal Erosion/Loss of Shoreline
- Point/Nonpoint Source Pollution
- Groundwater Over Pumping
- Saltwater Intrusion
- Invasive Species
- Wildfires
- Flash Flooding Along Low Lying and Populated Areas

#### 6.4.5.1 *Severe Winds*

Severe winds associated with tropical storms and typhoons can cause structural damage to buildings, loss of power, and increase life safety risks. To minimize these impacts, near-term incremental steps should be taken to further evaluate solutions. Increasing infrastructure resiliency and educating the public on steps to take to protect themselves and their property are important (Table 6-12).

Table 6-12. Option Evaluation for Severe Winds

| Tropical Storms & Typhoons | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Emergency Preparedness | Education and Outreach on Emergency Preparedness: Advise the community on ways to protect and secure homes and businesses from high winds to minimize damage and health and safety risks. | Estimated Cost: $<br><br>Potential Funding: FEMA, USACE Silver Jackets |
| Policy | Improve Enforcement on Building Codes and Permits: Mandate requirements on new and existing development to strengthen structural integrity against strong winds. Resilient materials should be utilized, including concrete, anchor bolts, durable siding, wind-resistant roofing, and re-enforced doors and framing. | Estimated Cost: $<br><br>Potential Funding:<br>EPA, FEMA, HUD, OIA |

#### 6.4.5.2 *Land Use Practices (Coastal), Surface Runoff, Coastal Erosion/Loss of Shoreline*

Land practices and surface runoff are interconnected and largely result from anthropogenic activities such as urban development. An increase in hard, impermeable surfaces prevents water infiltration and exacerbates surface runoff and sedimentation. Coastal areas are home to sensitive aquatic and marine ecosystems which can be adversely impacted as a result.

Erosion and loss of shoreline is a naturally occurring process that will likely be exacerbated by RSLC. Commercial, residential, recreational, and tourism along the coastline are at increased economic, environmental, and social risks, which is cause for concern. Due to the proximity of the shoreline to critical infrastructure and vulnerable populations, an integrated, multi-purpose approach is warranted to identify and evaluate the full spectrum of site-specific actions that could be taken by Federal and local agencies (Table 6-13).

Table 6-13. Option Evaluation for Land Use Practices (Coastal), Surface Runoff, Coastal Erosion/Loss of Shoreline

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Ecosystem Restoration | Coral Reef, Wetland, Vegetation, Mangrove Restoration: Further define ecosystem enhancement/green infrastructure possibilities (studies and pilot projects) including restoring coral reefs (including nurseries and propagation), wetlands, native resilient plant species, and mangroves in high priority areas, permeable greenspaces, and/or areas suitable for submerged/artificial reef pilot projects. To ensure restoration projects have a high likelihood of success the following site-specific actions should be considered; evaluation of proper management protection exists and is enforced, conditions such as water quality, soil characterization, availability of adequate environmental factors (sunlight, shade, nutrients, flows, chemistry, etc.), and develop adaptive management and monitoring plans for any constructed restoration project. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NOAA, NRCS USACE CAP Sect. 206, USACE EWN, USACE GI, USFWS |
| | Plant Native Vegetation Species: Identify key areas of deforestation and restore with native tree species to provide habitat, reduce flood risk, and erosion. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NRCS, USACE CAP Sect. 206, USACE GI, U.S. Forest Service (USFS), USFWS |
| Engineering with Nature | Engineer Reef Walls and Artificial Reef Structures: Construct ecofriendly artificial reef modules and reef walls that will provide marine habitat for many species. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: FEMA, IRP, NOAA, NRCS, USACE EWN |
| | Rain Gardens: Implement rain gardens downslope of urban areas to capture and filtrate surface runoff and reduce erosion. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA |
| Beach Enhancement | Beach Nourishment: Add sand to eroded beach areas to increase beach widths and reduce erosion. This helps to create an erosion buffer and sand can be either dredged from nearby areas or transported in from an outside area. | Estimated Cost: $$<br><br>Potential Funding: NFWF, USACE CAP Sect.103 or 204, USACE RSM |

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Drainage System Improvements | Sediment Capture: Redirect runoff to designated greenspaces to capture sediment and reduce impacts to stormwater drainage systems. In steep areas, slope drains and install terracing to reduce erosion. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NRCS |
| Policy/Improved Land Use Planning | Improve Enforcement on Building Codes and Permits: Mandate requirements for developers to minimize impermeable surfaces which can lead to increased surface water runoff and habitat impacts. | Estimated Cost: $<br><br>Potential Funding: FEMA, HUD, OIA |
| | Create Threshold for Percentage of Impervious Surfaces for New Construction or Require Mitigation: Set limits on impervious surface areas to minimize surface water runoff and associated adverse impacts. | Estimated Cost: $<br><br>Potential Funding: IRP, USACE CAP Sect. 205, USACE FPMS |
| | Effective Administration of Best Management Practices: Identify requirements and proper enforcement for organizations and the public to support sustainable use. Utilize existing Integrated Watershed Management Plans. | Estimated Cost: $<br><br>Potential Funding: HUD, OIA |
| | Improve Land Use Planning: Identify and implement Safe, Smart Growth Principles to effectively zone and use land efficiently to accommodate competing needs, provide recreation, and reduce adverse land and water quality impacts. | Estimated Cost: $<br><br>Potential Funding: DHS, HUD, OIA |
| Engagement and Outreach | Increase Outreach and Enforcement of Marine Protected Areas: Raise awareness to the public through events | Estimated Cost: $<br><br>Potential Funding: NOAA |
| | Education on Land Use Practices to Reduce Runoff: Reduce adverse impacts to the environment by helping landowners and developers better understand the impacts land use activities can have. | Estimated Cost: $<br><br>Potential Funding: EPA, USACE Silver Jackets, USFS |
| | Interagency Engagement and Coordination to Promote Best Management Practices: Interagency collaboration to take a unified approach in promoting best management practices. | Estimated Cost: $<br><br>Potential Funding: BECQ-DCRM, OPD |
| Erosion Analysis | Assess and Develop GIS Database of Erosion Hotspots: Analyze current land use trends and conditions to identify high risk area to help inform land use management and decision making. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA, NRCS |

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| | Sediment Transport Study and Regional Sediment Management Plan: Utilize sediment modeling techniques to evaluate the movement and deposition of sediment to detect and forecast erosion hotspots. Develop a regional sediment management plan outlining best management practices and effective solutions for areas such as the Saipan Lagoon. This will be critical information to help inform beach nourishment efforts and future development along shorelines. | Estimated Cost: $<br><br>Potential Funding: EPA, NRCS, USACE CAP Sect. 206, USACE RSM |
| | Shoreline Armoring, Recurve Sea Wall, Tidepool Armoring: Further define structural opportunities (studies and pilot projects) to construct structural features to reduce the impacts of waves and minimize coastal erosion and provide habitat. | Estimated Cost: $-$$<br><br>Potential Funding: FEMA, IRP, NOAA, USACE CAP Sect. 111, USACE EWN, USACE GI |
| Structural Enhancements | Road Enhancements and/or Relocations: Update roads and parking lots with permeable material to minimize surface runoff. | Estimated Cost: $-$$<br><br>Potential Funding: DOT, IRP |

### 6.4.5.3 *Point/Nonpoint Source Pollution, Groundwater Over Pumping, Saltwater Intrusion*

Options for reducing social, environmental, and economic risks associated with the impacts of point and nonpoint source pollution and saltwater intrusion on groundwater resources and groundwater over pumping should be evaluated to identify site specific recommendations to reduce these risks. A combination of nonstructural and structural measures has been incorporated into the following actions shown in Table 6-14.

Table 6-14. Incremental Actions for Point/Nonpoint Source Pollution, Groundwater Over Pumping, Saltwater Intrusion

| Water Quality & Quantity | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Engineering with Nature | Divert Stormwater to Roadside Wetlands and Greenspaces: Designate areas that divert, capture, and filter stormwater to reduce the amount of water that enters storm drains. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA, NRCS, USACE CAP Sect. 204 or 206, USACE EWN, USACE RSM, USFWS |
| Training & Education | Improve Water Conservation Education and Training: Develop educational material and programs to help residents, landowners, and water operators and managers learn about the impacts of over pumping and ways to integrate long-term resilient water use practices into practices. | Estimated Cost: $<br><br>Potential Funding: EPA, USACE Silver Jackets |

| Water Quality & Quantity | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| | Improve Education on Sources of Water Contamination and Proper Waste Disposal: Develop educational material to help residents and landowners learn about the environmental impacts of improper waste disposal and sources of contamination. Identify best practice options to implement. | Estimated Cost: $<br><br>Potential Funding: EPA, USACE Silver Jackets |
| Policy/ Improved Land Use Planning | Effective Administration of Best Management Practices: Widely distribute and update existing groundwater management plans to keep current and address protection to cave and well water resources. | Estimated Cost: $<br><br>Potential Funding: EPA, USACE Silver Jackets, USACE PAS |
| | Identify areas critical for groundwater recharge and supply and contaminated areas in need remediation. Develop management plans/policy to protect groundwater and avoid contaminated areas while working on remediation. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA |
| | Strengthen Implementation of Water Quality Standards: Work with local water managers to develop effective methods to ensure healthy water quality standards are being met. Utilize Water Management Plans. | Estimated Cost: $<br><br>Potential Funding: EPA |
| Alert System | Install a Water Contamination Alert System: Implement an integrated, real-time alert system that will broadcast advisories to the public of potential water contamination and actions to stay safe. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA, IRP |
| Community Services | Create a Universal Garbage Collection Task Force: To reduce point and nonpoint source pollution, set up community trash services to provide designated areas and services to properly dispose of hazard waste and trash. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA, IRP |
| Septic System Analysis | Survey Septic Systems: Evaluate the current septic tank system to identify any leaks or repairs needed to reduce contaminate leaching into groundwater resources. | Estimated Cost: $<br><br>Potential Funding: EPA |
| Structural Enhancements | Desalinization System: Construct a desalinization plant to convert saline water into freshwater. | Estimated Cost: $$$<br><br>Potential Funding: EPA, IRP |
| | Wastewater Improvements: Evaluate the wastewater system to identify risk-prone areas and repair. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA |

#### 6.4.5.4 *Invasive Species, Wildfires*

Resulting from both natural and anthropogenic causes, invasive species and wildfires have caused ecosystem and habitat degradation throughout the islands. To reduce the environmental, economic, and social risks associated with the impacts of these two stressors, site specific recommendations should be evaluated (Table 6-15).

Table 6-15. Incremental Actions for Invasive Species and Wildfires

| Inland Ecosystems | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Emergency Preparedness | Climate Change Working Group: Institute an interagency working group to identify and provide sustainable solutions for communities to effectively manage and reduce the impacts of climate change. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA, NOAA |
| Ecosystem Restoration | Vegetation Restoration: Plant native resilient vegetation species to help anchor topsoil, absorb water, and provide native habitat. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $$<br><br>Potential Funding: NRCS, USACE EWN, USACE FPMS, USFWS |
| | Invasive Species Management: Enforce invasive species management through monitoring and checkpoints (including ballast water treatment). Remove areas of invasive species infestation and replant with native species. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $-$$<br><br>Potential Funding: OIA, NRCS, USBR, USFS |
| Wildfire Prevention | Wetland Restoration: Increase wetland area which provides natural habitat and natural fire breaks. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: EPA, NFWF, NRCS, USACE CAP Sect. 206, USACE PAS, USFWS |
| | Increase Fire Stations and Lookouts: Evaluate wildfire-prone areas to increase resources to improve wildfire detection and emergency response. | Estimated Cost: $<br><br>Potential Funding: DHS, FEMA, HUD, IRP, OIA |
| | Fire Road Development and Maintenance: Develop roads throughout wild-fire prone areas to provide fire breaks and easy access for first responders. Include invasive species management/prevention plan and signage on how to identify and report invasive species sightings. | Estimated Cost: $-$$<br><br>Potential Funding: DHS, FEMA, HUD, IRP, OIA |
| Community Engagement | Interagency Engagement and Coordination to Promote Best Management Practices: Interagency collaboration to take a unified approach in promoting best management practices on land use and management. | Estimated Cost: $<br><br>Potential Funding: BECQ-DCRM, OPD |

| Inland Ecosystems | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| | Citizen Science Projects for Invasive Species Education, Identification, and Eradication: Initiate a community program for volunteers to help with data collection, analysis, and monitoring invasive species. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: USFS, USFWS |
| | Wildfire Education and Outreach: Provide educational materials to the public on wildfire prevention resulting from anthropogenic causes. Give actional steps to take to reduce risks. | Estimated Cost: $<br><br>Potential Funding: FEMA, USACE Silver Jackets |
| Policy | Improve Policy to Avoid, Minimize, and Offset Adverse Impacts to Sensitive Habitats: Providing protections areas such as wetlands will help ensure their protection and continued benefits in the ecosystem. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $<br><br>Potential Funding: NRCS, OIA |

#### 6.4.5.5 *Flash Flooding Along Low Lying and Populated Areas*

Near term efforts should begin to evaluate options to reduce potentially catastrophic risks associated with flash flooding, which occurs frequently due to high rainfall, steep slopes, and poor stormwater management. Further evaluation is needed to identify site specific recommendations to reduce these risks (Table 6-16).

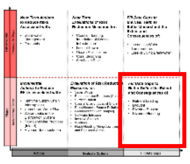
Table 6-16. Incremental Actions for Flash Flooding

| Rainfall Events | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Engineering with Nature | Rainwater Catchment Systems for Groundwater Recharge: Install infrastructure to utilize precipitation that can help recharge groundwater resources and reduce surface runoff. | Estimated Cost: $$<br><br>Potential Funding: EPA, FEMA |
| Ecosystem Restoration | Plant Native Resilient Vegetation Species: Plant durable native vegetation to help anchor topsoil, absorb water, and reduce runoff and erosion into waterways and drainage systems. Collaborate with indigenous Chamorro and Carolinian cultural groups to ensure that ITEK can be incorporated or is considered. | Estimated Cost: $$<br><br>Potential Funding: EPA, NRCS, USACE EWN, USACE FPMS, USFWS |

| Rainfall Events | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Drainage System Improvements | Scheduled Maintenance and Drain Cleaning: Continued upkeep of storm drains in urban areas to maintain water flow and prevent backups. | Estimated Cost: $<br><br>Potential Funding: USACE CAP Sect. 208 |
| | Divert Stormwater to Roadside Wetlands and Green Spaces: Redirect water to designated greenspaces to capture sediment and reduce impacts to stormwater drainage systems. | Estimated Cost: $$<br><br>Potential Funding: EPA, FEMA, NRCS, USACE CAP Sect. 204 or 206, USACE EWN, USACE RSM |
| | Incentives and Education on Low Impact Development Opportunities: Offer incentives and provide educational materials to property owners and developers on benefits of low impact development to manage stormwater runoff to encourage implementation. | Estimated Cost: $$<br><br>Potential Funding: EPA |
| | Improve Drainage Network: Assess the network to identify areas that need to be updated or replaced to maintain and/or improve its functionality. | Estimated Cost: $$<br><br>Potential Funding: EPA, HUD, IRP |
| Education & Outreach | Natural Hazard Related Signage and Maps in Public Spaces: Ensure updated evacuation routes, safe zones, and preparedness steps are visible in public spaces. | Estimated Cost: $<br><br>Potential Funding: FEMA, OIA, USACE Silver Jackets, UH |
| Risk Analysis | Hazard Mapping: Routinely update hazard maps to highlight changes in risk and the extent of the hazard in an area. This information can support land use planning, mitigation, risk communication, and emergency response. | Estimated Cost: $<br><br>Potential Funding: FEMA, OIA, USACE FPMS, USACE Silver Jackets, UH |
| Flood Protection Study | Increase Freeboard Above Inundation: Conduct a study to determine the critical flood elevations and then what the additional height buildings would need to be raised to protect life safety, reduce flood damages, and lower insurance costs. | Estimated Cost: $$<br><br>Potential Funding: FEMA, USACE CAP Sect. 205, USACE GI |
| Policy | Improve Monitoring of Illegal Dumping: Carry out strict and consistent enforcement of the CNMI anti-littering law by professional individuals and government officials to reduce illegal disposal of trash and waste by companies, the public, and agricultural entities. | Estimated Cost: $$<br><br>Potential Funding: EPA |

| Rainfall Events | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| | Create Threshold for Percentage of Impervious Surfaces for New Construction or Require Mitigation: Set limits on impervious surface areas to minimize surface water runoff and associated adverse impacts. | Estimated Cost: $<br><br>Potential Funding: IRP, USACE CAP Sect. 205, USACE FPMS |
| Real-Time Gaging Networks | Establish Real-Time Weather and Stream Gaging Networks: Implement technology to monitor real-time weather and stream flow conditions. This will contribute to warning advisories, archive data for future studies. | Estimated Cost: $<br><br>Potential Funding: FEMA, USGS |
| Structural Enhancements | Multi-Purpose Areas: Evaluate the benefits of developing multi-functional areas that can double as recreational and detention spaces to reduce flood risk in low-lying areas. | Estimated Cost: $-$$<br><br>Potential Funding: NRCS, USACE CAP Sect. 205, USACE GI, USACE PAS |
| | Waterbars on Roads and Public Paths: Divert runoff at identified locations to minimize erosion on sloping ground. | Estimated Cost: $<br><br>Potential Funding: FEMA, USACE CAP Sect. 204 or 205, USACE RSM |

### 6.4.6 Fill Data Gaps



Recommendations categorized as filling data gaps address stressors that require a more detailed understanding of the problem before initiating a study or project. Steps should be taken to fill these data gaps in the near-term (zero to five years) with initiation of a study or implementation of a program taken in incremental steps (five to ten years or sooner if possible).

Stressors identified as requiring filling data gaps include:

- Nutrient Loading
- Drought
- Riverine Erosion
- Riverine Flooding

#### 6.4.6.1 *Nutrient Loading*

Data gaps regarding nutrient loading should be filled to reduce environmental and health and safety risks associated with nutrient loading. Further information is needed to better understand its magnitude and contributing sources within the watershed. Increased stream monitoring, septic tank assessments, and evaluations of agricultural activity are actions that should be taken (Table 6-17).

Table 6-17. Fill Data Gaps for Nutrient Loading

| Coastal | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Policy | Improve Monitoring of Illegal Dumping: carry out strict and consistent enforcement of the CNMI anti-littering law by professional individuals and government officials to reduce illegal disposal of trash and waste by companies, the public, and agricultural entities. | Estimated Cost: $$<br><br>Potential Funding: EPA |
| Septic System Analysis and Repairs | Improve Wastewater Infrastructure (septic system upgrades, treatments plants, etc.): Make updates to wastewater infrastructure to reduce leaching and groundwater contamination. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA, HUD, IRP, OIA |
| | Survey Septic Systems: Evaluate the current septic tank system to identify any leaks or repairs needed to reduce contaminates leaching into groundwater resources. | Estimated Cost: $<br><br>Potential Funding: EPA |
| Stream Monitoring | Increase Stream Monitoring: Routinely collect data from waterways to build a database on nutrient levels at a local and watershed level. | Estimated Cost: $<br><br>Potential Funding: USGS |

#### 6.4.6.2 *Drought*

Although nearly impossible to eliminate the effects of drought, steps can be taken to fill existing data gaps to obtain a better understanding of its impacts. The long-term impact of droughts on water supply and the economy are still uncertain, but the goal is to reduce long-term vulnerability through actions focused on increasing water supply and storage, developing a drought management plan, and improved drought forecasting (Table 6-18).

Table 6-18. Fill Data Gaps for Drought

| Water Quality and Quantity | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Drought Planning | Drought Monitoring and Forecasting: Closely track surface and groundwater resources, climate data, soil data, etc., to develop a wholistic approach to help forecast future drought trends prior to its onset. | Estimated Cost: $<br><br>Potential Funding: USGS |
| | Drought Management Plan: Develop a drought management plan in conjunction with local agencies to help address water usage, storage, and availability. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA, USACE PAS, USACE Silver Jackets |

| Water Quality and Quantity | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| | Climate Change Working Group: Institute an interagency working group to identify and provide sustainable solutions for communities to effectively manage and reduce the impacts of climate change. | Estimated Cost: $<br><br>Potential Funding: EPA, FEMA |
| Structural Enhancements | Improve Water Supply: Retrofit or replace current water distribution system infrastructure to minimize water leaks. Locations can be identified by taking inventory. | Estimated Cost: $$-$$$<br><br>Potential Funding: EPA, FEMA, HUD, IRP |
| | Increase Water Storage: Study and conduct project to capture and store water resources through groundwater recharge, ponds, wetlands, tanks, reservoirs, and water barrels. | Estimated Cost: $-$$<br><br>Potential Funding: EPA, NRCS, USACE PAS |

### 6.4.6.3 *Riverine Erosion, Riverine Flooding*

CNMI is vulnerable to riverine flooding and erosion. Steps should be taken to fill existing data gaps to obtain a better understanding of their impacts (Table 6-19).

Table 6-19. Fill Data Gaps for Riverine Erosion and Riverine Flooding

| Rainfall Events | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Engineering with Nature | Rainwater Catchment Systems for Groundwater Recharge: Install infrastructure to utilize precipitation that can help recharge groundwater resources and reduce surface runoff. | Estimated Cost: $$<br><br>Potential Funding: EPA, FEMA |
| Hydrology and Hydraulics Analysis | Conduct a Hydrology and Hydraulics Analysis: Develop precipitation projections and hydraulic analysis to identify areas prone to flooding and consider the adequacy and/or needs to upgrade drainage way and culvert capacity in areas vulnerable to precipitation flooding. Include consideration of retreat/relocation solutions. | Estimated Cost: $<br><br>Potential Funding: EPA, USACE FPMS, USACE PAS, USACE Silver Jackets |
| Real-Time Gaging Networks | Establish Real-Time Weather and Stream Gaging Networks: Implement technology to monitor real-time weather and stream flow conditions. This will contribute to warning advisories, archive data for future studies. | Estimated Cost: $<br><br>Potential Funding: FEMA, USGS |

| **Rainfall Events** | | |
|---|---|---|
| **Focus** | **Recommendation** | **Potential Funding** |
| Flood Protection Study | Increase Freeboard Above Inundation: Conduct a study to determine the critical flood elevations and then what the additional height buildings would need to be raised to protect life safety, reduce flood damages, and lower insurance costs. | Estimated Cost: $$<br><br>Potential Funding: FEMA, USACE CAP Sect. 205, USACE GI |
| Critical Infrastructure Protection | Protect and/or Strengthen Critical Infrastructure: Update critical infrastructure (ports, roads, utilities, schools, etc.) from future anticipated storm events and flooding impacts to be better retrofitted against elements. | Estimated Cost: $$-$$$<br><br>Potential Funding: DOT, EPA, FEMA, HUD, IRP, USACE CAP Sect. 205 |

## 6.5 Implementation Strategy

To help prioritize limited time and resources, a general timeline for recommendation implementation is provided in Table 6-20 and Table 6-21. Recommendations reflect the level of readiness to implement with a greater emphasis put on accelerating implementation of recommendations for catastrophic risks. The timeline provided is an estimate based on the urgency of addressing the stressor and possible implementation roadblocks, such as knowledge gaps, local approval, and funding (determined through the uncertainty analysis). Generally, near-term actions should be implemented within five years. Near-term evaluation options should be evaluated within zero to five years and implemented as soon as possible thereafter. Incremental actions should be implemented as soon as possible (zero to ten years) but may require additional time to implement as the corresponding stressor was assessed to be a major risk. Evaluating options to address major stressors should occur within zero to ten years with implementation occurring soon thereafter.

Table 6-20. Near-term Strategies

| Priority | Stressor | Recommendation Focus Area | 0-5 years | 5-10 years | 10+ years |
|---|---|---|---|---|---|
| *Near-Term Actions* | Stormwater Management (Table 6-3) | Engineering with Nature | Implement | – | – |
| | | Drainage System Improvements | Implement | – | – |
| | Tsunamis (Table 6-4) | Education and Outreach | Implement | – | – |
| | | Risk Analysis | Implement | – | – |
| | | Emergency Preparedness | Implement | – | – |
| | | Policy/Improved Land Use Planning | Implement | – | – |
| *Near-Term Evaluation of Options* | Coastal Flooding, Inundation of Coastal Infrastructure, Loss of Power (Table 6-5) | Ecosystem Restoration | Evaluate | Implement | – |
| | | Beach Enhancement | Implement | – | – |
| | | Risk Analysis | Evaluate | Implement | – |
| | | Emergency Preparedness | Implement | – | – |

| Priority | Stressor | Recommendation Focus Area | 0-5 years | 5-10 years | 10+ years |
|---|---|---|---|---|---|
| | | Education and Outreach | Implement | – | – |
| | | Flood Protection Study | Evaluate | Implement | – |
| | | Critical Infrastructure Protection | Evaluate | Implement | – |
| | | Policy | Implement | – | – |
| | | Diversify Energy Sources | Implement | Implement | – |
| | RSLC, Coral Bleaching, and Ocean Acidification (Table 6-6) | Ecosystem Restoration | Evaluate | Implement | – |
| | | Ecosystem Protection | Evaluate | Implement | – |
| | | Beach Enhancement | Implement | – | – |
| | | Emergency Preparedness | Implement | – | – |
| | | Policy / Improved Land Use Planning | Evaluate | Implement | – |
| | | Education and Outreach | Evaluate/ Implement | – | – |
| | | Flood Protection Study | Evaluate | Implement | – |
| | | Structural Enhancements and Processes | Evaluate | Implement | – |
| | | Critical Infrastructure | Evaluate | Implement | – |
| *Data Gaps to be Filled in the Near-Term* | Increasing Water Temperatures, Loss of a Living Break Water (Table 6-7) | Ecosystem Restoration | Fill Data Gaps/ Evaluate | Evaluate/ Implement | Implement |

Table 6-21. Incremental Strategies

| Priority | Stressor | Recommendation Focus Area | 0-10 years | 10-15 years | 15+ years |
|---|---|---|---|---|---|
| *Incremental Actions* | Maritime Supply Chain Interruptions (Table 6-8) | Emergency Preparedness | Implement | – | – |
| | | Alternative Docking Locations | Implement | – | – |
| | | Weather Forecasting | Implement | – | – |
| | | Critical Infrastructure Protection | Implement | Implement | – |
| | Unmetered Water Use, Water Leaks in the Distribution System (Table 6-9) | Ecosystem Restoration | Evaluate | Implement | – |
| | | Education and Outreach | Implement | – | – |
| | | Enhanced Water Supply Management | Implement | Implement | – |
| | | Policy | Implement | Implement | – |
| | | Structural Enhancement | Implement | Implement | Implement |
| | Land Use Practices (Inland) (Table 6-10) | Ecosystem Restoration | Evaluate | Implement | – |
| | | Engineering with Nature | Evaluate | Implement | – |
| | | Policy/Improved Land Use Planning | Implement | Implement | – |
| | | Risk Analysis | Evaluate | Implement | – |
| | | Education and Outreach | Implement | – | – |
| | | Community Services | Implement | Implement | – |
| | Riverine Sedimentation (Table 6-11) | Ecosystem Restoration | Evaluate | Implement | – |
| | | Sheer Stress Analysis | Evaluate | Implement | – |
| | | Training | Implement | Implement | – |
| | | Policy/Improved Land Use Planning | Implement | Implement | – |
| | | Drainage System Improvements | Evaluate | Implement | Implement |
| *Incremental Evaluation of Options* | Severe Winds (Table 6-12) | Emergency Preparedness | Implement | Implement | – |
| | | Policy | Evaluate | Implement | Implement |
| | Land Use Practices (Coastal), Surface Runoff, Coastal Erosion/Loss of Shoreline | Ecosystem Restoration | Evaluate | Implement | Implement |
| | | Engineering with Nature | Evaluate | Implement | Implement |
| | | Beach Enhancement | Evaluate | Implement | Implement |
| | | Drainage System Improvements | Evaluate | Implement | Implement |

| Priority | Stressor | Recommendation Focus Area | 0-10 years | 10-15 years | 15+ years |
|---|---|---|---|---|---|
| | (Table 6-13) | Policy/Improved Land Use Planning | Evaluate/ Implement | Implement | Implement |
| | | Engagement and Outreach | Evaluate/ Implement | Implement | Implement |
| | | Erosion Analysis | Evaluate | Implement | Implement |
| | | Structural Enhancements | Evaluate | Implement | Implement |
| | Point/Nonpoint Source Pollution, Groundwater Over Pumping, Saltwater Intrusion (Table 6-14) | Training and Education | Evaluate/ Implement | Implement | Implement |
| | | Engineering with Nature | Evaluate | Implement | Implement |
| | | Policy/Improved Land Use Planning | Evaluate/ Implement | Implement | Implement |
| | | Alert System | Evaluate/ Implement | Implement | Implement |
| | | Community Services | Evaluate/ Implement | Implement | Implement |
| | | Septic System Analysis | Evaluate | Implement | Implement |
| | | Structural Enhancements | Evaluate | Implement | Implement |
| | Invasive Species, Wildfires (Table 6-15) | Ecosystem Restoration | Evaluate | Implement | Implement |
| | | Emergency Preparedness | Evaluate/ Implement | Implement | Implement |
| | | Wildfire Prevention | Evaluate | Implement | Implement |
| | | Community Engagement | Evaluate | Implement | Implement |
| | | Policy | Evaluate/ Implement | Implement | Implement |
| | Flash Flooding Along Low Lying and Populated Areas (Table 6-16) | Ecosystem Restoration | Evaluate | Implement | Implement |
| | | Engineering With Nature | Evaluate | Implement | Implement |
| | | Drainage System Improvements | Evaluate | Implement | Implement |
| | | Education & Outreach | Evaluate/ Implement | Implement | Implement |
| | | Risk Analysis | Evaluate | Implement | Implement |
| | | Flood Protection Study | Evaluate | Implement | Implement |
| | | Policy | Evaluate/ Implement | Implement | Implement |
| | | Real-Time Gaging Networks | Evaluate | Implement | Implement |
| | | Structural Enhancements | Evaluate | Implement | Implement |
| | | Policy | Fill Data Gaps | Evaluate | Implement |

| Priority | Stressor | Recommendation Focus Area | 0-10 years | 10-15 years | 15+ years |
|---|---|---|---|---|---|
| *Data Gaps to be Filled in Incremental Steps* | Nutrient Loading (Table 6-17) | Septic System Analysis and Repairs | Fill Data Gaps | Evaluate | Implement |
| | | Stream Monitoring | Fill Data Gaps | Evaluate | Implement |
| | Drought (Table 6-18) | Drought Planning | Fill Data Gaps | Evaluate | Implement |
| | | Structural Enhancements | Fill Data Gaps | Evaluate | Implement |
| | Riverine Erosion, Riverine Flooding (Table 6-19) | Hydrology and Hydraulics Analysis | Fill Data Gaps | Evaluate | Implement |
| | | Engineering with Nature | Fill Data Gaps | Evaluate | Implement |
| | | Real-Time Gaging Networks | Fill Data Gaps | Evaluate | Implement |
| | | Flood Protection Study | Fill Data Gaps | Evaluate | Implement |
| | | Critical Infrastructure Protection | Fill Data Gaps | Evaluate | Implement |

# 7 Conclusion

The purpose of this WA is to assist with future decision-making and strategic planning in CNMI to rehabilitate and improve the resiliency of infrastructure and natural resources, while reducing risks to human life and property from future natural hazards. This comprehensive document incorporates the best available scientific literature and robust stakeholder engagement across local and Federal stakeholders.

The prioritized list of recommendations addresses the problem categories, explores the opportunities, and meets the study objectives while adhering to special considerations. Table 7-1 displays how the recommendations fulfill the study objectives, which include:

1. Reduce human life loss and injuries resulting from natural hazards.
2. Increase community natural hazard preparedness and effectiveness of hazard mitigation activities.
3. Reduce damages and disruption to public and private property, areas of cultural or community importance, from flooding and coastal erosion throughout CNMI.
4. Restore and protect terrestrial and marine resources throughout CNMI.
5. Increase infrastructure and environmental resiliency to RSLC throughout CNMI.
6. Improve water quality and water supply for residents.
7. Increase access to potable and palatable water and affordable, reliable, sustainable, and modern energy to residents.
8. Avoid or minimize disruptions to port operations, supply chain, and local businesses.
9. Reduce environmental degradation resulting from disasters in impacted areas.
10. Build and maintain resiliency of natural, built, and human systems through Safe, Smart Growth.

The USACE Principles of Resilience (prepare, absorb, recover, and adapt) were incorporated in Figure 7-1 to identify which resilience principles were achieved for each recommendation.

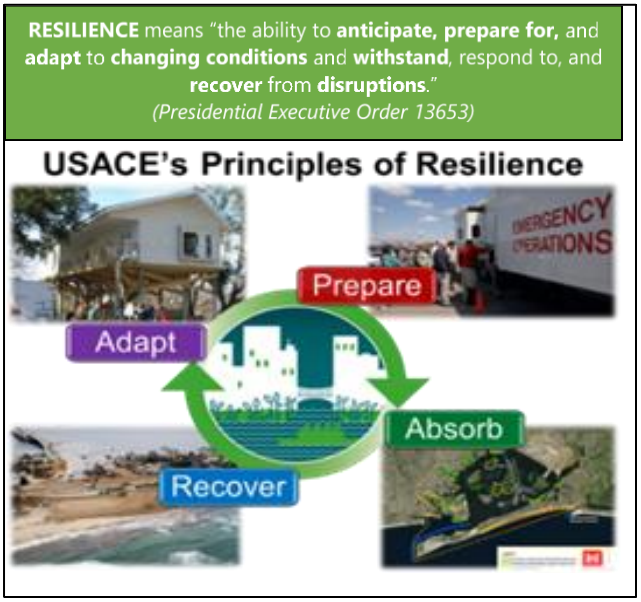



Figure 7-1. USACE Resiliency Principles

**Prepare –** Considers the needs of a community or system to better withstand future disruptions.

**Absorb –** Enhances the ability of a community or system to endure a disruption and limit subsequent damage. This principle can also be used as an opportunity to consider adding system component robustness, redundancy, and increased reliability.

**Recover –** Stresses wise and rapid repair or functional restoration of a community or system following a disruption.

**Adapt –** Considers modifications to a project component or system that maintains or improves future performance based on lessons learned from previous events.

Lastly, the recommendations presented in this document align with many of the goals set forth in the CNMI's Comprehensive Sustainable Development Plan (listed below). This planning document provides a strategic roadmap on the ten-year (2021-2030) growth visions, goals, and objectives of the CNMI to work towards sustainability development and serves as a guidance document for the CNMI agencies and stakeholders. Table 7-1 identifies which goal(s) each recommendation meets through this effort.

Goal 4 - Inclusive Education: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Goal 6 - Clean Water and Sanitation: Ensure availability and sustainable management of water and sanitation for all.

Goal 7 - Affordable and Clean Energy: Ensure access to affordable, reliable, sustainable, and modern energy for all.

Goal 9 - Industry, Innovation, and Infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.

Goal 11 - Sustainable Cities and Communities: Make cities and human settlements inclusive, safe, resilient, and sustainable.

Goal 12 - Sustainable Production and Consumption: Ensure sustainable consumption and production patters.

Goal 13 - Climate Action: Take urgent action to combat climate change and its impacts.

Goal 14 - Sustainable Use of Ocean Resources: Conserver and sustainable use oceans, seas, and marine resources for sustainable development.

Goal 15 - Sustainable Terrestrial and Nearshore Resources: Protect, restore, and promote sustainable use of terrestrial and near shore ecosystems, sustainably manage forests, and preserve and halt degradation of biodiversity and resources of particular concern in the CNMI.

Goal 17 - Partnerships: Strengthen the means of implementation and support partnerships for sustainable development.

Table 7-1. Recommendations Addressing the Objectives

| Priority | Stressor | Recommendation | Obj. 1 | Obj. 2 | Obj. 3 | Obj. 4 | Obj. 5 | Obj. 6 | Obj. 7 | Obj. 8 | Obj. 9 | Obj. 10 | Resiliency Principle | CSDP Goal(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Near-Term Actions* | Stormwater Management | Engineering with Nature | – | – | ✓ | ✓ | – | ✓ | ✓ | – | ✓ | ✓ | Absorb, | 6, 9, 11 |
| | | Drainage System Improvements | – | ✓ | ✓ | ✓ | – | – | – | – | – | ✓ | Prepare, Absorb, Recover, Adapt | 6, 9, 11 |
| | Tsunamis | Education and Outreach | ✓ | ✓ | – | – | – | – | – | – | – | – | Prepare | 4 |
| | | Risk Analysis | – | – | ✓ | – | ✓ | – | – | – | ✓ | – | Prepare, Adapt | 9, 11 |
| | | Emergency Preparedness | ✓ | ✓ | – | – | – | – | – | – | – | – | Prepare | 4 |
| | | Policy/Improved Land Use Planning | ✓ | ✓ | ✓ | – | – | – | – | – | – | ✓ | Prepare, Adapt | 9, 11 |
| *Near-Term Evaluate Options* | Coastal Flooding, Inundation of Coastal Infrastructure, Loss of Power | Ecosystem Restoration | – | – | ✓ | ✓ | ✓ | – | – | – | ✓ | – | Absorb, Recover | 14, 15 |
| | | Beach Enhancement | – | – | ✓ | ✓ | ✓ | – | – | – | ✓ | – | Recover | 14, 15 |
| | | Emergency Preparedness | ✓ | ✓ | – | – | – | – | – | – | – | – | Prepare | 4 |
| | | Risk Analysis | – | – | ✓ | – | ✓ | – | – | – | ✓ | – | Prepare, Adapt | 9, 11 |
| | | Education and Outreach | ✓ | ✓ | – | – | – | – | – | – | – | – | Prepare | 4 |
| | | Flood Protection Study | ✓ | ✓ | ✓ | – | ✓ | – | – | – | – | – | Prepare, Adapt | 9, 11 |
| | | Critical Infrastructure Protection | ✓ | ✓ | ✓ | – | ✓ | – | – | ✓ | – | ✓ | Prepare, Absorb, Recover, Adapt | 9, 11, 13 |
| | | Policy | ✓ | ✓ | ✓ | – | ✓ | – | – | – | – | ✓ | Prepare, Adapt | 9, 11 |

| Priority | Stressor | Recommendation | Obj. 1 | Obj. 2 | Obj. 3 | Obj. 4 | Obj. 5 | Obj. 6 | Obj. 7 | Obj. 8 | Obj. 9 | Obj. 10 | Resiliency Principle | CSDP Goal(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Diversify Energy Sources | ✓ | ✓ | – | – | – | – | ✓ | ✓ | – | – | Prepare, Absorb, Adapt | 7 |
| | RSLC, Coral Bleaching, and Ocean Acidification | Ecosystem Restoration | – | – | – | ✓ | ✓ | – | – | – | ✓ | – | Absorb, Recover | 13, 14, 15 |
| | | Ecosystem Protection | – | – | – | ✓ | ✓ | – | – | – | – | – | Absorb, Adapt | 13, 14, 15 |
| | | Beach Enhancement | – | – | ✓ | ✓ | ✓ | – | – | – | ✓ | – | Recover | 14, 15 |
| | | Emergency Preparedness | ✓ | ✓ | – | – | – | – | – | – | – | – | Prepare | 4 |
| | | Policy / Improved Land Use Planning | – | – | ✓ | ✓ | ✓ | – | – | – | – | ✓ | Prepare, Adapt | 9, 11 |
| | | Education and Outreach | ✓ | ✓ | – | – | – | – | – | – | – | – | Prepare | 4 |
| | | Flood Protection Study | ✓ | ✓ | ✓ | – | ✓ | – | – | – | – | – | Prepare, Adapt | 9, 11 |
| | | Structural Enhancements and Processes | – | – | – | ✓ | ✓ | – | – | ✓ | ✓ | – | Prepare, Absorb, Adapt | 9, 11, 13 |
| | | Critical Infrastructure | ✓ | ✓ | ✓ | – | ✓ | – | – | ✓ | – | ✓ | Prepare, Absorb, Recover, Adapt | 9, 11, 13 |
| *Near-Term Data Gap Options* | Increasing Water Temperatures, Loss of a Living Break Water | Ecosystem Restoration | – | – | – | ✓ | ✓ | – | – | – | ✓ | – | Absorb, Adapt | 13, 14, 15 |
| *Incremental Actions* | Maritime Supply Chain Interruptions | Emergency Preparedness | – | – | – | – | – | – | ✓ | ✓ | – | – | Prepare | 4 |
| | | Alternative Docking Locations | – | – | – | – | – | – | – | ✓ | – | – | Prepare, Adapt | 9 |

| Priority | Stressor | Recommendation | Obj. 1 | Obj. 2 | Obj. 3 | Obj. 4 | Obj. 5 | Obj. 6 | Obj. 7 | Obj. 8 | Obj. 9 | Obj. 10 | Resiliency Principle | CSDP Goal(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weather Forecasting | – | – | – | – | – | – | – | ✓ | – | – | Prepare | 9 |
| | | Critical Infrastructure Protection | – | – | ✓ | – | ✓ | – | – | ✓ | – | – | Prepare, Absorb, Recover, Adapt | 9, 11 |
| | Unmetered Water Use, Water Leaks in the Distribution System | Ecosystem Restoration | – | – | – | – | – | ✓ | ✓ | – | – | – | Absorb, Adapt | 14, 15 |
| | | Education and Outreach | – | – | – | – | – | ✓ | ✓ | – | – | ✓ | Prepare | 4, 6 |
| | | Enhanced Water Supply Management | – | – | – | – | – | ✓ | ✓ | – | – | ✓ | Prepare, Absorb, Adapt | 6, 11 |
| | | Policy | – | – | – | – | – | ✓ | ✓ | – | – | ✓ | Prepare, Adapt | 6, 9, 11 |
| | | Structural Enhancement | – | – | – | – | – | ✓ | ✓ | – | – | ✓ | Prepare, Absorb, Adapt | 6, 9, 11 |
| | Land Use Practices (Inland) | Ecosystem Restoration | – | – | – | ✓ | – | ✓ | – | – | – | – | Absorb, Adapt | 15 |
| | | Engineering with Nature | – | – | – | ✓ | – | – | – | – | ✓ | – | Absorb, Adapt | 15 |
| | | Policy/Improved Land Use Planning | – | – | – | ✓ | – | – | – | – | – | ✓ | Prepare, Adapt | 9, 11, 12 |
| | | Risk Analysis | – | – | – | ✓ | – | – | – | – | – | – | Prepare, Adapt | 9 |
| | | Education and Outreach | – | – | – | ✓ | – | – | – | – | – | – | Prepare | 4 |
| | | Community Services | – | – | – | ✓ | – | ✓ | – | – | – | – | Prepare, Absorb | 4 |
| | Riverine Sedimentation | Ecosystem Restoration | – | – | – | ✓ | – | ✓ | – | – | ✓ | – | Absorb, | 15 |
| | | Sheer Stress Analysis | – | – | – | ✓ | – | – | – | – | ✓ | – | Prepare | 9 |
| | | Training | – | – | – | – | – | – | – | – | – | ✓ | Prepare | 4 |

| Priority | Stressor | Recommendation | Obj. 1 | Obj. 2 | Obj. 3 | Obj. 4 | Obj. 5 | Obj. 6 | Obj. 7 | Obj. 8 | Obj. 9 | Obj. 10 | Resiliency Principle | CSDP Goal(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Policy/Improved Land Use Planning | – | – | – | – | – | – | – | – | – | ✓ | Prepare, Adapt | 9, 11 |
| | | Drainage System Improvements | – | ✓ | – | ✓ | – | – | – | – | – | ✓ | Prepare, Absorb, Recover Adapt | 6, 9, 11 |
| *Evaluate Options* | Severe Winds | Emergency Preparedness | ✓ | ✓ | – | – | – | – | – | ✓ | – | – | Prepare | 4 |
| | | Policy | ✓ | ✓ | – | – | – | – | – | ✓ | – | ✓ | Prepare, Adapt | 9, 11 |
| | Land Use Practices (Coastal), Surface Runoff, Coastal Erosion/Loss of Shoreline | Ecosystem Restoration | – | – | ✓ | ✓ | – | – | – | – | ✓ | – | Absorb, Adapt | 14, 15 |
| | | Engineering with Nature | – | – | ✓ | ✓ | – | – | – | – | ✓ | – | Absorb, Adapt | 11, 12, 14, 15 |
| | | Beach Enhancement | – | – | ✓ | ✓ | – | – | – | – | ✓ | – | Recover | 14, 15 |
| | | Drainage System Improvements | – | – | ✓ | – | – | – | – | – | ✓ | – | Prepare, Absorb, Recover Adapt | 6, 9, 11 |
| | | Policy/Improved Land Use Planning | – | – | ✓ | – | – | – | – | – | – | ✓ | Prepare, Adapt | 6, 9, 11 |
| | | Engagement and Outreach | – | – | ✓ | ✓ | – | – | – | – | – | – | Prepare | 4, 17 |
| | | Erosion Analysis | – | – | ✓ | – | – | – | – | – | ✓ | – | Prepare, Adapt | 9 |
| | | Structural Enhancements | – | – | – | – | – | – | – | – | – | ✓ | Prepare, Absorb, Recover Adapt | 9, 11 |
| | Point/Nonpoint Source Pollution, Groundwater | Training and Education | – | – | – | ✓ | – | ✓ | ✓ | – | – | – | Prepare | 4 |
| | | Engineering with Nature | – | – | – | ✓ | – | ✓ | ✓ | – | – | – | Absorb, Adapt | 6, 9, 11, 15 |

| Priority | Stressor | Recommendation | Obj. 1 | Obj. 2 | Obj. 3 | Obj. 4 | Obj. 5 | Obj. 6 | Obj. 7 | Obj. 8 | Obj. 9 | Obj. 10 | Resiliency Principle | CSDP Goal(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Over Pumping, Saltwater Intrusion | Policy/Improved Land Use Planning | – | – | – | – | – | ✓ | ✓ | – | – | ✓ | Prepare, Adapt | 6, 9, 11 |
| | | Alert System | ✓ | – | – | – | – | ✓ | – | – | – | – | Prepare, Adapt | 9, 11 |
| | | Community Services | – | – | – | ✓ | – | ✓ | – | – | – | – | Prepare | 4 |
| | | Septic System Analysis | – | – | – | – | – | ✓ | ✓ | – | – | – | Prepare, Adapt | 6, 9 |
| | | Structural Enhancements | – | – | – | – | – | ✓ | – | – | – | ✓ | Prepare, Absorb, Recover Adapt | 6, 9, 11 |
| | Invasive Species, Wildfires | Ecosystem Restoration | – | – | – | ✓ | – | – | – | – | – | – | Absorb, Adapt | 15 |
| | | Emergency Preparedness | ✓ | ✓ | – | – | – | – | – | ✓ | ✓ | – | Prepare | 4 |
| | | Wildfire Prevention | ✓ | ✓ | – | ✓ | – | – | – | – | – | – | Prepare, Absorb, Adapt | 9, 11, 15 |
| | | Community Engagement | – | ✓ | – | – | – | – | – | – | – | ✓ | Prepare | 4, 17 |
| | | Policy | – | – | – | ✓ | – | – | – | – | – | ✓ | Prepare, Adapt | 9, 11 |
| | Flash Flooding Along Low Lying and Populated Areas | Ecosystem Restoration | – | – | – | ✓ | – | – | – | – | ✓ | – | Absorb, Adapt | 15 |
| | | Engineering with Nature | – | – | – | ✓ | – | ✓ | – | – | ✓ | – | Absorb, Adapt | 15 |
| | | Drainage System Improvements | ✓ | ✓ | ✓ | – | – | – | – | ✓ | – | ✓ | Prepare, Absorb, Recover Adapt | 6, 9, 11 |
| | | Education & Outreach | ✓ | ✓ | – | – | – | – | – | – | – | – | Prepare | 4 |
| | | Risk Analysis | ✓ | ✓ | ✓ | – | – | – | – | ✓ | – | – | Prepare | 9 |
| | | Flood Protection Study | ✓ | ✓ | ✓ | – | – | – | – | – | – | – | Prepare | 9 |

| Priority | Stressor | Recommendation | Obj. 1 | Obj. 2 | Obj. 3 | Obj. 4 | Obj. 5 | Obj. 6 | Obj. 7 | Obj. 8 | Obj. 9 | Obj. 10 | Resiliency Principle | CSDP Goal(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Policy | – | – | – | ✓ | – | – | – | – | – | ✓ | Prepare, Adapt | 9, 11 |
| | | Real-Time Gaging Networks | ✓ | ✓ | ✓ | – | – | – | – | – | – | – | Prepare | 9, 11 |
| | | Structural Enhancements | – | – | ✓ | ✓ | – | – | – | – | ✓ | – | Prepare, Absorb, Recover Adapt | 6, 9, 11 |
| *Fill Data Gaps* | Nutrient Loading | Policy | – | – | – | ✓ | – | – | – | – | – | – | Prepare, Adapt | 6, 9, 11 |
| | | Septic System Analysis and Repairs | – | – | – | – | – | ✓ | ✓ | – | – | – | Prepare, Absorb, Recover Adapt | 9 |
| | | Stream Monitoring | – | – | – | – | – | ✓ | – | – | – | – | Prepare | 9 |
| | Drought | Drought Planning | – | ✓ | – | – | – | ✓ | ✓ | – | – | – | Prepare | 9 |
| | | Structural Enhancements | – | – | – | – | – | ✓ | ✓ | – | – | ✓ | Prepare, Absorb, Recover Adapt | 9, 111 |
| | Flash Flooding Along Low Lying and Populated Areas | Hydrology and Hydraulics Analysis | ✓ | ✓ | ✓ | – | – | – | – | – | – | ✓ | Prepare, Adapt | 9 |
| | | Engineering with Nature | – | – | – | ✓ | – | ✓ | – | – | – | – | Absorb, Adapt | 15 |
| | | Real-Time Gaging Networks | ✓ | ✓ | ✓ | – | – | – | – | – | – | – | Prepare | 9, 11 |
| | | Flood Protection Study | ✓ | ✓ | ✓ | – | – | – | – | – | – | – | Prepare, Adapt | 9 |
| | | Critical Infrastructure Protection | – | – | ✓ | – | – | – | – | ✓ | – | ✓ | Prepare, Absorb, Recover Adapt | 9, 11 |

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