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Multi-Hazard Action Plan for Marinduque: Addressing Cascading Risks from Typhoon-Aggravated Mining Structure Degradation and Water Contamination

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Abstract:

This action plan was developed to strengthen disaster risk reduction and management in the Province of Marinduque by addressing cascading risks associated with typhoons, flooding, degraded mining structures, and possible water contamination. As an island province in the MIMAROPA Region, Marinduque is exposed to hydrometeorological hazards such as typhoons, heavy rainfall, flooding, landslides, and storm surges. These hazards may interact with the long-term environmental legacy of former mining operations, particularly in areas connected to the Boac River, Mogpog River, and Calancan Bay. Such interaction can result in sediment movement, possible contamination of water sources, public health exposure, livelihood disruption, and increased pressure on local emergency response and recovery systems.

The action plan is anchored on the four thematic areas of Philippine Disaster Risk Reduction and Management: disaster prevention and mitigation, disaster preparedness, disaster response, and disaster rehabilitation and recovery. It also considers local risk conditions, community perceptions, existing DRRM capacities, contingency planning gaps, environmental health concerns, and the operational realities of an island province. The proposed interventions include strengthening water quality surveillance, establishing provincial water testing capacity, improving monitoring of mining-related environmental risks, enhancing contingency planning and preparedness exercises, activating Emergency Operations Center and Incident Management Team arrangements, expanding WASH and health surveillance measures, and supporting long-term environmental and livelihood recovery.

The plan emphasizes that Marinduque's risk context should not be viewed only as a typhoon or flood concern. Instead, it requires a multi-hazard and cascading-risk approach that links environmental monitoring, public health protection, emergency coordination, community preparedness, and Build Back Better recovery. Through coordinated implementation by provincial, municipal, barangay, national agency, academic, civil society, private and community stakeholders, the action plan seeks to support safer, healthier, and more resilient communities in Marinduque.

Keywords — Disaster Risk Reduction and Management, DRRM, Cascading Risks, Typhoon, Flooding, Mining Legacy, Water Contamination, Environmental Health, Marinduque.

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I. INTRODUCTION

The Philippines is highly exposed to disaster risks due to its geographic location, archipelagic setting,

and regular exposure to tropical cyclones, heavy rainfall, flooding, landslides, storm surges, earthquakes, and other hazards. These risks are intensified by climate change, environmental degradation, poverty, limited access to basic services, and uneven local capacities for preparedness, response, and recovery. In island provinces, disaster impacts can be more difficult to manage because severe weather events may disrupt transport, communication, supply chains, health services, water systems, and emergency logistics *[1]-[3]*.

Marinduque is an island province in the MIMAROPA Region composed of six municipalities: Boac, Buenavista, Gasan, Mogpog, Santa Cruz, and Torrijos. Its communities, infrastructure, livelihoods, and ecosystems are exposed to recurring hydrometeorological hazards, particularly typhoons, heavy rainfall, flooding, landslides, and storm surges. The province's river systems, coastal barangays, upland areas, and reliance on agriculture, fisheries, and natural resources make disaster risk reduction and management (DRRM) a continuing development priority *[4]-[6]*.

Disaster risk in Marinduque is also shaped by the long-term environmental legacy of former mining operations. The Marcopper mining disasters and related mining activities affected the Boac River, Mogpog River, and Calancan Bay, leaving continuing concerns related to contaminated sediments, degraded river systems, affected coastal and marine ecosystems, and possible public health and livelihood impacts *[7]-[11]*. During extreme rainfall and flooding, these conditions may interact with degraded mining structures, silted waterways, contaminated sediments, and local water systems, creating cascading impacts involving possible water contamination, public health exposure, livelihood disruption, evacuation concerns, relief and water, sanitation, and hygiene (WASH) needs, emergency logistics, and longer-term recovery challenges *[3], [7]-[11]*.

The Multi-Hazard Action Plan for Marinduque was developed to assist in addressing these compound and cascading risks through a structured, localized, and integrated disaster risk management approach. It focuses on strengthening systems that can anticipate, monitor, prepare for, respond to, and recover from possible cascading impacts arising from typhoon-aggravated mining structure degradation and water contamination. The plan is anchored on the four thematic areas of Philippine DRRM: disaster prevention and mitigation, disaster preparedness, disaster response, and disaster rehabilitation and recovery *[1], [12]*.

Through this action plan, the Provincial Government of Marinduque, municipal and barangay local governments, national government agencies, technical institutions, civil society organizations, and communities can strengthen environmental monitoring, water quality surveillance, contingency planning, emergency coordination, health and WASH response, livelihood protection, and Build Back Better recovery. The plan highlights the need for a multi-hazard and cascading-risk perspective in local DRRM, particularly where natural hazards interact with long-standing environmental and mining-related risks.

II. RESEARCH METHODS

The action plan was developed using a descriptive and action-planning approach that combined document review, local risk analysis, stakeholder inputs, and synthesis of proposed programs, projects, and activities. This approach was used to examine cascading risks associated with typhoons, flooding, degraded mining structures, possible water contamination, public health exposure, livelihood disruption, and recovery needs in Marinduque. Secondary data were reviewed from national, regional, provincial, and technical sources, including DRRM plans, development and physical framework plans, environmental and mining-related documents, technical studies, policy frameworks, and reports on the Marcopper mining legacy.

Primary inputs were gathered through local consultations, survey responses, and coordination with concerned DRRM stakeholders. These inputs helped validate community perceptions, preparedness gaps, response and recovery concerns, and operational challenges faced by provincial, municipal, and barangay actors. The findings were analyzed through situational, Political, Economic, Social, Technological, Environmental, and Legal (PESTEL), and Strengths, Weaknesses, Opportunities, and Challenges (SWOC) analyses, which informed the formulation of goals, objectives, outcomes, priority programs, projects, and activities

(PPAs), and monitoring and evaluation arrangements under the four thematic areas of the Philippine DRRM System.

III. SITUATIONAL ANALYSIS

A. Risk and Exposure Context

Marinduque's disaster risk profile is shaped by its island geography, river systems, coastal settlements, upland terrain, and dependence on natural-resource-based livelihoods. The province is composed of six municipalities—Boac, Buenavista, Gasan, Mogpog, Santa Cruz, and Torrijos—and has communities located along riverine, coastal, and upland areas. These areas are exposed to typhoons, heavy rainfall, flooding, rain-induced landslides, storm surges, drought, earthquakes, liquefaction, tsunamis, earthquake-induced landslides, and volcanic hazards *[4], [5]*.

Flooding and rainfall-related hazards are among the most relevant concerns for the action plan because they can affect settlements, agricultural lands, transport routes, evacuation movement, water systems, and emergency response operations. Marinduque has several river systems, including the Boac and Mogpog river systems, which are closely linked to local livelihoods, drainage, agriculture, water resources, and downstream communities *[4], [5], [9], [10]*. During strong typhoons and prolonged rainfall, these river systems may experience swelling, siltation, erosion, and flooding that can disrupt community safety and basic services.

The province's exposure is further complicated by the long-term environmental legacy of former mining operations. Areas connected to Boac River, Mogpog River, and Calancan Bay continue to be associated with concerns related to mine tailings, contaminated sediments, degraded ecosystems, and affected water and livelihood resources *[7]-[11]*. These conditions are significant because heavy rainfall and flooding can disturb sediments, worsen erosion, and increase the possibility of water quality concerns in nearby and downstream communities.

The resulting risk is therefore not limited to direct typhoon and flood impacts. In mining-affected areas, hydrometeorological hazards may potentially interact with degraded mining structures, silted waterways, contaminated sediments, and local water systems. This interaction can create cascading effects involving possible water contamination, public health exposure, livelihood disruption, evacuation concerns, relief and WASH needs, and longer-term recovery requirements *[3], [7]-[11]*.

Vulnerable groups may experience these impacts more severely. Farmers and fisherfolk can lose income when agricultural lands, river systems, and coastal waters are affected. Low-income households may have limited resources for preparedness, evacuation, water treatment, and recovery. Children, older persons, pregnant women, persons with disabilities, and individuals with existing health concerns potentially face higher risks during evacuation, exposure to unsafe water or sediments, and post-disaster service disruption.

This risk and exposure context shows the need for an integrated action plan that links disaster risk reduction, environmental monitoring, public health protection, water safety, emergency coordination, and recovery planning. For Marinduque, strengthening resilience requires preparing not only for typhoon and flood hazards, but also for the cascading consequences that may arise when these hazards interact with mining-related environmental risks.

B. PESTEL Analysis

The PESTEL analysis identifies the political, economic, social, technological, environmental, and legal factors that may influence the implementation of the Multi-Hazard Action Plan for Marinduque. These factors provide the broader context for understanding the province's capacity to address cascading risks from typhoons, flooding, mining-related environmental degradation, and possible water contamination.

Political. DRRM in Marinduque operates within established provincial, municipal, and barangay governance structures. The presence of the Provincial DRRM Council (PDRRMC), Municipal DRRM Councils (MDRRMCs), local DRRM offices, and response clusters provides an institutional foundation for planning, coordination, and emergency operations *[1], [4], [12], [13]*. However, the implementation of specialized actions for mining-related environmental risks requires strong coordination among local governments, Department of Environment and Natural Resources-Mines and Geosciences Bureau

(DENR-MGB), Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB), Department of Health (DOH), Office of Civil Defense (OCD), Department of the Interior and Local Government (DILG), technical institutions, and community stakeholders. Sustained political commitment, inter-agency coordination, and continuity of programs across planning and budget cycles are necessary to ensure that risk reduction measures are not limited to immediate disaster response.

Economic. Marinduque's local economy depends significantly on agriculture, fisheries, small enterprises, transport, and natural-resource-based livelihoods. Typhoons, flooding, and possible contamination events can affect farms, fishing grounds, markets, roads, water systems, and household income *[4], [5], [9]*. The cost of environmental monitoring, laboratory testing, river rehabilitation, WASH support, response logistics, and livelihood recovery may also place pressure on local government resources. This highlights the need to align the action plan with the Local DRRM Fund, annual investment plans, sectoral budgets, national agency programs, and possible partnerships with academic, civil society, and private sector actors.

Social. Community awareness and participation are essential to the success of the action plan. Residents in exposed areas may already be familiar with typhoons, flooding, and evacuation procedures, but mining-related contamination risks require clearer public communication, stronger trust-building, and more accessible advisories. Vulnerable groups, including children, older persons, persons with disabilities, pregnant women, fisherfolk, farmers, and low-income households, may face greater risks due to limited mobility, livelihood dependence, health concerns, and reduced capacity to recover. Social acceptance of evacuation, water safety advisories, health monitoring, and livelihood interventions will depend on timely information, community engagement, and transparent decision-making.

Technological. The plan requires stronger technical systems for hazard monitoring, water quality surveillance, emergency communication, mapping, information management, and reporting. Existing early warning and communication systems provide a foundation for preparedness, but cascading risks involving possible contamination require additional tools and technical protocols. These include water testing capacity, sediment and river monitoring, GIS-based risk mapping, referral systems for laboratory confirmation, data management for health surveillance, and communication platforms for public advisories. Strengthening technological capacity is important for timely detection, evidence-based decision-making, and coordinated response.

Environmental. Marinduque's environmental context is shaped by hydrometeorological hazards, river systems, coastal ecosystems, upland slopes, and the long-term effects of former mining operations. Heavy rainfall and flooding can contribute to erosion, siltation, sediment movement, and possible contamination of water sources *[3], [7]-[11]*. Degraded mining structures, contaminated sediments, and affected river and coastal ecosystems have the potential to intensify disaster impacts in communities near Boac River, Mogpog River, and Calancan Bay. These conditions reinforce the need for integrated environmental monitoring, ecosystem-based rehabilitation, riverbank stabilization, mangrove restoration, and long-term risk reduction measures.

Legal. The action plan is supported by the Philippine DRRM Act of 2010, local DRRM planning requirements, environmental regulations, public health mandates, and the roles of national and local agencies in disaster risk reduction, environmental management, and health protection *[1], [12]*. Existing laws provide a strong basis for contingency planning, risk assessment, emergency response, water quality monitoring, environmental protection, and rehabilitation. However, implementation depends on the translation of legal mandates into operational protocols, funded programs, agency coordination, and regular monitoring. Strengthening compliance, clarifying institutional roles, and integrating the proposed actions into local plans and budgets will be essential for sustainability.

C. SWOC Analysis

The SWOC analysis highlights the strengths, weaknesses, opportunities, and challenges that influence Marinduque's capacity to implement a multi-hazard action plan for cascading risks. It shows that the province has an existing DRRM foundation, but also needs stronger technical, institutional, and operational systems for mining-related environmental

emergencies and possible water contamination events.

Strengths. Marinduque has established DRRM structures at the provincial, municipal, and barangay levels. The presence of the PDRRMC, MDRRMCs, Provincial DRRM Office (PDRRMO), Municipal DRRM Offices (MDRRMOs), response clusters, Emergency Operations Center (EOC) or operations center arrangements, and Incident Command System (ICS), early warning practices, and local disaster planning processes provides an institutional basis for implementation *[1], [4], [12], [13]*. The province also has practical experience in preparing for and responding to typhoons, flooding, evacuation, relief operations, and post-disaster assessments. These existing mechanisms can be used as entry points for integrating mining-related environmental monitoring, WASH preparedness, health surveillance, and recovery planning.

Weaknesses. Despite these strengths, several gaps limit the province's capacity to address cascading risks. Local systems are generally more prepared for familiar hydrometeorological hazards than for compound events involving possible water contamination, contaminated sediments, heavy metal exposure, and degraded mining structures. Technical capacity for environmental monitoring, local water testing, laboratory referral, health surveillance, and risk communication remains limited *[4], [8], [9], [11]*. Equipment, trained personnel, data management systems, and specialized protocols for suspected contamination events also need to be strengthened. These gaps may delay verification, advisories, response decisions, and recovery planning during emergencies.

Opportunities. The action plan can build on existing national and local policy frameworks, including the Philippine DRRM Act, local DRRM plans, environmental regulations, health mandates, and annual investment planning processes. Partnerships with DENR-MGB, DENR-EMB, DOH, OCD, DILG, academic institutions, civil society organizations, and technical experts can strengthen evidence generation, environmental monitoring, public health support, and community-based preparedness. There are also opportunities to integrate ecosystem-based and nature-based measures such as riverbank stabilization, watershed protection, mangrove rehabilitation, and other rehabilitation efforts into local development, DRRM, climate change adaptation, and environmental management programs.

Challenges. Implementation may be affected by recurring typhoons, extreme rainfall, flooding, island logistics, transport disruptions, limited local resources, and competing development priorities. Mining legacy issues also involve complex institutional mandates and long-term environmental, health, livelihood, and accountability concerns *[7]-[11]*. During emergencies, the province may need to address evacuation, relief, safe water, WASH, health monitoring, environmental assessment, transport, and livelihood protection at the same time. Sustaining the action plan will therefore require continuous coordination, funding, technical support, public trust, community participation, and regular updating of protocols based on monitoring results and lessons learned.

Overall, the SWOC analysis shows that Marinduque does not need to build a completely new disaster risk management system for cascading risks. Rather, it needs to strengthen and adapt its existing DRRM mechanisms so that these can address the additional demands of mining-related environmental hazards, possible water contamination, health exposure, and long-term recovery.

IV. SUMMARY OF GOALS, OBJECTIVES, AND PPAs

The Multi-Hazard Action Plan for Marinduque is organized according to the four thematic areas of Philippine DRRM: disaster prevention and mitigation, disaster preparedness, disaster response, and disaster rehabilitation and recovery. The goals and objectives respond to the province's cascading risk context, particularly the interaction of extreme rainfall, flooding, degraded mining structures, contaminated sediments, water systems, health exposure, and livelihood disruption.

Goal 1: Disaster Prevention and Mitigation

To reduce the risk of environmental contamination and flood-related impacts arising from the interaction of extreme rainfall events and degraded mining structures in Marinduque by

reducing vulnerabilities and exposure and enhancing the capacities of communities.

The prevention and mitigation component focuses on reducing contamination, sedimentation, erosion, and flood exposure in priority riverine and coastal communities. It strengthens early detection, environmental monitoring, water quality verification, sediment management, and ecosystem-based disaster risk reduction in areas where typhoons and flooding may interact with mining-related environmental risks.

Objective 1.1: To establish and strengthen an early detection and environmental monitoring system for mining-related water contamination risks in the Boac, Mogpog, and Sta. Cruz river systems from 2027 to 2030.

Outcome: Water quality monitoring and early detection systems for mining-related contamination risks were established in priority river systems and exposed communities.

This objective centers on building a connected system for surveillance, verification, reporting, and public advisory issuance during heavy rainfall, flooding, or suspected contamination events. It includes water quality surveillance and early warning in the Boac, Mogpog, and Sta. Cruz river systems; use of water-level and turbidity sensors in priority monitoring points; and preparation of reporting procedures and advisory protocols. A Provincial Water Testing Laboratory Service will also be established to support basic microbiological, physico-chemical, and environmental screening, while referral arrangements will be maintained for specialized tests beyond provincial capacity.

To strengthen the technical basis for monitoring, the plan also provides for heavy metal contamination risk assessment in the Boac and Mogpog river systems. This assessment will identify priority monitoring points, affected river sections, exposed communities, and appropriate prevention and mitigation measures, while also supporting orientation and risk communication for communities linked to Calancan Bay.

Objective 1.2: To reduce sedimentation, erosion, and flood exposure in downstream and coastal communities of Boac, Mogpog, and Sta. Cruz through managed river rehabilitation and ecosystem-based DRR by 2030.

Outcome: Downstream and coastal communities were better protected from sedimentation, erosion, and flood-related impacts through managed river rehabilitation and ecosystem-based DRR measures.

Risk reduction under this objective addresses both riverine and coastal pathways of exposure. In the Boac and Mogpog river systems, managed ecological dredging or desilting will be undertaken in technically identified downstream sections, subject to assessment, permitting, environmental safeguards, sediment characterization, and monitoring. Available sediment estimates for Boac River and Mogpog River provide a practical basis for treating sedimentation as both a disaster risk reduction and environmental rehabilitation concern *[8]-[11]*.

Along the Calancan Bay coastline, mangrove improvement and maintenance will support coastal protection, fisheries recovery, and long-term ecosystem rehabilitation. Planting, maintenance, survival monitoring, and Bantay Bakawan teams will help strengthen community-based protection while reducing coastal erosion, wave impacts, and storm surge exposure.

Goal 2: Disaster Preparedness

To strengthen provincial, municipal, barangay, and community preparedness for typhoon-induced flooding, mining-related contamination risks, and related cascading impacts through planning, capacity building, early warning, risk communication, and pre-arranged resource mobilization.

The disaster preparedness component strengthens the capacity of provincial, municipal, barangay, and community systems to anticipate and prepare for flooding, mining-related environmental exposure, water contamination, and related public health risks. It focuses on institutional preparedness, contingency planning, simulation exercises, risk communication, community orientation, market mapping, and partnerships for critical services and technical augmentation.

Objective 2.1: To update and institutionalize provincial and municipal preparedness protocols for mining-related water contamination and environmental emergencies by 2030.

Outcome: Preparedness planning and inter-local government unit (LGU) coordination mechanisms for mining-related water contamination and environmental emergencies were strengthened at the provincial and municipal levels.

Preparedness planning will be strengthened by updating the Provincial DRRM Plan and supporting the integration of mining-related water contamination concerns into municipal DRRM plans. A dedicated contingency plan for flooding and mining-related water contamination scenarios will define warning triggers, activation levels, response cluster roles, technical agency coordination, public advisory procedures, WASH actions, safe water measures, health surveillance, and resource mobilization.

These arrangements will be tested through tabletop, functional, and full-scale exercises. Each exercise will serve a different purpose: tabletop exercises will assess decision-making and role clarity; functional exercises will test information flow, EOC reporting, resource requests, and inter-LGU coordination; and full-scale exercises will examine field deployment, WASH and health support, assessment procedures, and coordination with technical agencies.

Objective 2.2: To strengthen the capacity of MDRRMCs to guide community preparedness actions for flooding and mining-related water contamination emergencies starting 2027.

Outcome: MDRRMCs of Sta. Cruz, Boac, and Mogpog were capacitated to guide barangays and communities on preparedness actions for flooding and mining-related water contamination emergencies.

At the community level, the plan translates technical risk information into practical preparedness guidance. Information, education, and communication (IEC) and orientation materials will cover flooding, water safety, contamination risks, household preparedness, evacuation guidance, protective actions, and reporting of unusual river conditions or health symptoms. Annual municipal IEC caravans will be conducted in exposed riverine and coastal barangays in Boac, Mogpog, and Sta. Cruz, with priority attention to farmers, fisherfolk, schools, women, older persons, persons with disabilities, barangay officials, and other community groups. To make the messages easier to apply, the IEC strategy will distinguish actions before, during, and after flooding or suspected contamination events.

Objective 2.3: To establish and strengthen provincial partnerships for critical services, supplies, and technical augmentation needed for flooding and mining-related water contamination emergencies by 2027.

Outcome: Partnerships for critical services, supplies, and technical augmentation were established to support preparedness and continuity of public services for flood and mining-related water contamination emergencies.

Because some emergency needs cannot be arranged only during response, the plan provides for market mapping and pre-disaster agreements with critical service providers and suppliers. These include water suppliers, transport providers, pharmacies, food suppliers, logistics providers, and other local providers that may be needed when municipal resources are stretched.

The province will also establish augmentation agreements with external stakeholders for environmental assessment, water testing, public health surveillance, WASH support, technical advisories, and response logistics. These agreements will clarify contact persons, activation procedures, service standards, request processes, mobilization timelines, reporting expectations, and coordination channels before an emergency occurs.

Goal 3: Disaster Response

To ensure timely, coordinated, inclusive, and technically informed emergency response during typhoon, flooding, and suspected contamination events affecting Marinduque communities.

The disaster response component focuses on saving lives and meeting the immediate subsistence, health, WASH, protection, and safety needs of affected communities during and immediately after flooding and suspected mining-related water contamination emergencies. It strengthens provincial coordination, technical support to affected municipalities, rapid assessment, public information, and life-saving augmentation when municipal capacities are exceeded.

Objective 3.1: To improve and support MDRRMC capacities for timely disaster response, coordinated assessment, and real-time reporting during flood and contamination-related emergencies.

Outcome: Timely provincial response coordination and technical support were provided to affected MDRRMCs during flood and mining-related water contamination emergencies.

The response system begins with activation and coordination. When flooding or suspected contamination affects more than one municipality or requires support beyond ordinary local response arrangements, the Provincial Incident Management Team (IMT) or Area Command Team will be activated to support operational planning and incident action planning. The Provincial EOC will serve as the main hub for situation reporting, resource tracking, response cluster coordination, technical referral, and public information. Rapid Damage Assessment and Needs Analysis (RDANA) will be expanded to include WASH, water quality testing, and environmental safety assessment so that early response decisions are informed by both humanitarian and technical findings. Public advisories and situation reports will provide verified information on flood conditions, unsafe water sources, avoidance of floodwater or sediments, evacuation guidance, hygiene precautions, health consultation, and testing or assessment updates.

Objective 3.2: To support the timely delivery of life-saving, WASH, health, and protective services to communities affected by flooding and mining-related water contamination in Boac, Mogpog, and Sta. Cruz during disaster response operations.

Outcome: Life-saving and protective services were provided to affected communities in Boac, Mogpog, and Sta. Cruz during flood and mining-related water contamination emergencies.

When municipal capacities are exceeded, provincial augmentation will support evacuation, search and rescue, emergency transport, relief, WASH, safe water, health surveillance, and temporary shelter needs. Priority attention will be given to flood-prone riverine and coastal barangays, older persons, children, pregnant women, persons with disabilities, and households with limited mobility or resources. This response component recognizes that cascading emergencies require simultaneous action on evacuation, rescue, safe water, hygiene, health monitoring, shelter, logistics, and environmental safety.

Goal 4: Disaster Rehabilitation and Recovery

To restore and improve facilities, livelihoods, living conditions, and organizational capacities of communities affected by flooding and water contamination arising from degraded mining structures during extreme rainfall events, while reducing future disaster risks in accordance with the Build Back Better principle.

The disaster rehabilitation and recovery component focuses on restoring and improving the facilities, livelihoods, water systems, ecosystems, and community capacities affected by flooding and possible mining-related water contamination. It applies the Build Back Better principle by ensuring that recovery actions do not only replace what was damaged, but also reduce future risk, strengthen public health safeguards, support livelihood continuity, and improve environmental conditions in affected riverine and coastal areas.

Objective 4.1: To strengthen post-disaster recovery planning and learning systems in communities affected by flooding and mining-related water contamination.

Outcome: Post-disaster recovery planning and learning systems were strengthened and used to guide rehabilitation and recovery priorities.

Recovery decisions will be guided by Post-Disaster Needs Assessment (PDNA), rehabilitation and recovery planning, and post-disaster learning reviews. The PDNA will assess damages, losses, service disruptions, and recovery needs across affected sectors, while also considering contamination-related concerns such as affected water sources, possible exposure to contaminated sediments, health concerns, livelihood impacts, and the need for continued environmental monitoring. The Rehabilitation and Recovery Plan will identify priority programs, responsible offices, funding sources, timelines, and monitoring arrangements. After-action reviews will then document lessons from warning, evacuation, EOC activation, public advisories, RDANA, WASH support, health

surveillance, laboratory referral, relief distribution, environmental monitoring, and technical agency coordination, which could be used to improve future DRRM planning.

Objective 4.2: To strengthen environmental rehabilitation and risk reduction in the Boac and Mogpog river systems and Calancan Bay through physical and biological remediation measures.

Outcome: Priority riverine and coastal areas were rehabilitated through risk-informed environmental recovery and ecosystem-based measures.

Environmental recovery will combine riverbank stabilization, bioengineering, and coastal ecosystem rehabilitation. In the Boac and Mogpog river systems, the plan proposes vegetative stabilization, vetiver planting, slope protection, and other appropriate nature-based or hybrid measures to reduce erosion, limit further sediment movement, and protect downstream communities. In Calancan Bay, continued mangrove and coastal ecosystem rehabilitation will support storm surge buffering, fisheries recovery, biodiversity, and community-based environmental stewardship.

To sustain these gains, rehabilitation outputs will be integrated into provincial and municipal development, DRRM, climate change adaptation, and environmental management plans.

Objective 4.3: To strengthen socio-economic recovery among affected communities through health protection, safe water restoration, and livelihood support.

Outcome: Affected households and communities were supported through health, safe water, and livelihood recovery measures that reduce future vulnerability.

Socio-economic recovery will focus on three linked areas. First, health monitoring and referral will support communities with possible exposure to contaminated floodwater, sediments, or unsafe water sources. Second, safe water restoration will include assessment of affected systems, emergency provision of safe water, disinfection or rehabilitation of local sources, water quality testing, and public advisories. Third, livelihood recovery will support affected farmers, fisherfolk, small enterprises, and low-income households through assistance guided by PDNA findings, environmental advisories, local risk conditions, and the recovery of riverine, coastal, and ecosystem resources that sustain livelihoods.

The PPAs proposed under the four goals form an integrated set of interventions for addressing the cascading risks examined in this study. Prevention and mitigation measures strengthen early detection, water quality monitoring, sediment management, and ecosystem-based risk reduction in areas where extreme rainfall and flooding may interact with degraded mining structures, contaminated sediments, and affected river and coastal systems. Preparedness actions improve contingency planning, risk communication, community readiness, and pre-arranged partnerships for safe water, WASH, health, logistics, and technical support. Response interventions support coordinated EOC activation, rapid assessment, public advisories, and life-saving augmentation during flooding or suspected contamination events. Rehabilitation and recovery measures then link environmental rehabilitation, safe water restoration, health monitoring, and livelihood support so that affected communities can recover while reducing future exposure.

These PPAs also show that the four DRRM thematic areas are cross-cutting rather than separate or strictly sequential. Environmental monitoring informs preparedness, response advisories, and recovery planning; preparedness arrangements support faster response and more organized rehabilitation; response assessments provide the evidence base for recovery; and rehabilitation measures reduce future exposure and strengthen prevention. Taken together, the PPAs provide a practical pathway for strengthening Marinduque's capacity to manage typhoon-related, mining-linked, and water contamination risks in a more anticipatory, coordinated, and risk-informed manner.

V. MONITORING AND EVALUATION

Monitoring and evaluation will ensure that the Multi-Hazard Action Plan for Marinduque is implemented according to its intended objectives, outputs, timelines, and institutional responsibilities. The PDRRMO will serve as the overall coordinating office, while concerned lead offices will track PPAs under their respective mandates. These include PG-

ENRO, PHO, PPDO, PEO, PSWDO, PAgriO, MDRRMOs, municipal offices, barangay councils, national government agencies, academic institutions, civil society organizations, and service providers.

Monitoring will cover both implementation progress and operational readiness. Key areas include the functionality of water quality surveillance systems, establishment of provincial water testing capacity, completion of heavy metal risk assessments, implementation of river and coastal rehabilitation measures, updating of plans and contingency protocols, conduct of simulation exercises and IEC activities, completion of market mapping and service agreements, EOC and IMT activation, RDANA and PDNA conduct, situation reporting, public advisories, WASH and health support, safe water restoration, livelihood recovery, and documentation of lessons learned.

Evaluation will assess whether the implemented actions contribute to improved preparedness, faster coordination, better technical decision-making, safer water and WASH response, stronger environmental monitoring, and more risk-informed recovery. Findings should be consolidated through the PDRRMO and presented to the PDRRMC as part of regular DRRM monitoring and planning processes. Results should also inform updates to the Provincial DRRM Plan, municipal DRRM plans, contingency plans, rehabilitation and recovery plans, annual investment programming, Local DRRM Fund Investment Plan, response protocols, IEC materials, supplier agreements, and future preparedness exercises.

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