UVA | FRANK BATTEN SCHOOL of LEADERSHIP and PUBLIC POLICY

TECHNICAL REPORT

Flowing Towards Resilience: Managing Floods for Cleaner Water in Port Vila, Vanuatu

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Disclaimer

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

University of Virginia Honor Code

On my honor as a University of Virginia student, I have neither given nor received unauthorized aid on this assignment.

Jenny Ha Tran
April 2024

List of Figures and Tables

Acronyms

ADB	**Asian Development Bank**
DEPC	**Department of Environmental Protection and Conservation (Vanuatu)**
DFAT	**Department of Foreign Affairs and Trade (Australia)**
EWB	**Engineers Without Borders**
GCF	**Green Climate Fund**
GI	**Green Infrastructure**
LID	**Low-Impact Development**
MIA	**Ministry of Internal Affairs (Vanuatu)**
MIPU	**Ministry of Infrastructure and Public Utilities (Vanuatu)**
NbS/NBS	**Nature-based Solutions**
NGO	**Non-governmental Organizations**
SLA	**Service level agreement**
WASH	**Water, Sanitation and Hygiene**
WSUD	**Water-sensitive Urban Design**

CONTENTS

Executive Summary

Vanuatu, a small island developing state in the South Pacific, frequently faces the harsh reality of intense natural disasters. Due to its location and topography, Vanuatu is particularly vulnerable to climate change's adverse impacts, ranging from floods, droughts, and heatwaves to tropical cyclones, earthquakes, and tsunamis (Climate Risk Country Profile - Vanuatu - Vanuatu, 2021). These frequent and intensifying natural disasters are leading to significant environmental and public health challenges.

In the 2022-2023 tropical season, Vanuatu suffered from five tropical cyclones, causing "severe damage to housing, infrastructure, agriculture, and aquaculture, and impacted an estimated 250,000 people" (End of South Pacific Cyclone Season Report 2022-2023 - Vanuatu | ReliefWeb, 2023). The increase in frequency and intensity of cyclones leads to more frequent flooding events, resulting in worsening water quality, especially in rapidly urbanizing areas. The Emten Lagoon region, located on the border of the capital city of Port Vila, has been identified as a priority area due to its growing population and the lack of sufficient resources and infrastructure to manage the impacts of stormwater runoff and pollution effectively. Without prompt interventions, the quality of life of populations surrounding the Lagoon will continue to worsen due to unhygienic living conditions and contact with contaminated water sources.

This report is prepared for Engineers Without Borders Australia (EWB Australia), an Australian non-profit organization with 20 active chapters internationally that aims to improve the wellbeing and quality of life of marginalized communities through education and implementation of sustainable engineering solutions (Engineers Without Borders Australia, n.d.). EWB Australia has been working to enhance climate resilience in Vanuatu and particularly in Port Vila since 2016, focusing on improving sanitation in challenging environments. Given EWB Australia's existing program portfolio, this project is relevant and can contribute policy solutions to further EWB's missions to improve the quality of life in Vanuatu.

To address water quality and stormwater management issues in the Emten Lagoon region, the project has explored both technical and policy alternatives. Technical alternatives include (1) the construction of retention ponds for stormwater runoff designed to reduce and filter stormwater before it reaches the Lagoon and (2) the implementation of low-impact development (LID) plans integrating green infrastructure to manage and filter stormwater runoff effectively. Policy alternatives encompass (3) an incentive program designed to bolster household-level green infrastructure adoption and (4) a public education campaign aimed at promoting sustainable stormwater management practices.

The evaluation of these alternatives is grounded in five critical criteria: effectiveness, financial feasibility, operational feasibility, sustainability, and equity. Using evidence from existing literature, case studies, and interviews with local stakeholders and experts, this report recommends EWB Australia initiate an Incentive Program for Green Infrastructure Adoption, targeting household-level implementation of sustainable practices. Specifically, through EWB Australia in Vanuatu and with the support of local communities, households would receive resources to implement small-scale green infrastructure, including rain gardens, vegetable gardens, and/or green roofs to reduce flood-water flow-through and filter stormwater. Following the implementation of this household-based solution, the next step involves rolling out low-impact development infrastructural projects, including the systematic construction of larger-scale infrastructure around the Emten Lagoon. This phased strategy combines immediate, actionable policy interventions with long-term, sustainable technical solutions to most effectively and sustainably improve the quality of life for residents in the Emten Lagoon area.

About the Client

The client is Engineers Without Borders Australia, an Australian non-profit organization with 20 active chapters, "operating nationally and internationally with the published aim of improving the quality of life of disadvantaged communities through education and the implementation of sustainable engineering projects." One of the three main goals of the organization is to support Sustainable Development Goal #6 – clean water and sanitation for all ("Water, Sanitation & Hygiene Project - Engineers Without Borders," n.d.). Currently, EWB has multiple Water, Sanitation & Hygiene (WASH) projects in Vanuatu aiming to improve water, sanitation, and hygiene for local people. Water quality improvement has long been a top priority for EWB; therefore, this project fits into the current strategic plan for the organization in Vanuatu ("Vanuatu," n.d.).

EWB is interested in addressing the stormwater runoff management issue in the Emten Lagoon, Port Vila after having successfully alleviated water quality issues in other areas in Vanuatu. Since EWB has the technical solutions to the stormwater runoff problems but lacks the policy mechanisms to implement these technical solutions on the ground, this project serves as the nexus to make technical, engineering solutions become effective and widespread.

engineers
without borders
australia

I. Problem Statement

Vanuatu ranks first on the world's disaster risk list, according to the Pacific Response to Disaster Displacement Project ranking (Pacific Response to Disaster Displacement Urban Case Study, n.d.). From tropical cyclones to earthquakes, Vanuatu has suffered from natural disasters in one form or another in every month of 2023 ("Magnitude 6.3 Earthquake Strikes Vanuatu Islands Region," 2023; Mishra, 2023). During one week in April 2023, the country suffered two Category 4 cyclones which left 80% of its population without power, food, and stable water supplies (S. Wilson, 2023). Due to the increase in the quantity and frequency of storms and cyclones, Vanuatu islands are constantly faced with the aftermath of natural disasters. These disasters lead to increases in flooding events, consequently causing worsening water quality in catchment areas due to pollutants and erosion from the flood flow (Miller, 2023).

Subsequently, adverse climate impacts have driven Vanuatu residents across 83 islands to migrate to bigger cities for safety and economic opportunities (Climate Risk Country Profile - Vanuatu - Vanuatu, 2021; Climate "Tragedy," 2022). Particularly, the suburban area outside of the capital city, Port Vila, has urbanized quickly over the past two decades. According to the Urban Resilience Hub, from 1999 to 2009, the population of Port Vila increased by more than 50 percent, followed by a slower but consistent growth rate over the past decade (Port Vila, 2023). Specifically, the area that many migrants reside in surrounds the Emten Lagoon, the second-biggest lagoon in Port Vila (see Figure 1). The geographic characteristics of this lagoon set it up for frequent flooding with its low-terrain location and a narrow channel for flood water (often contaminated) to exit out to the sea. Therefore, climate-related internally displaced migrants and local residents near the Emten Lagoon often live in low-quality environments and informal settlements, facing challenges in hygiene and sanitation.

Intensifying rainfall and extreme weather events in Port Vila, Vanuatu have led to more frequent flooding, which diminishes water quality in the Emten Lagoon catchment area surrounded by quickly urbanizing areas, causing reduced quality of life for many local residents *(Fraser, 2021; Greater Port Vila Urban Resilience Project, 2020; MacKenzie et al., 2022).*

II. Background

1. Study Area: Emten Lagoon, Port Vila, Vanuatu

Geographical Setting

The Emten Lagoon is a catchment area on the Efate Island in Shefa, one of the six provinces in Vanuatu. The Lagoon lies in the suburban area of Port Vila, Vanuatu's capital city, surrounded by Montmartre and Ekasup localities (see Figure 1). The Lagoon is connected via a narrow channel with the Erakor Lagoon, which is directly connected to Port Vila (see Figure 1).

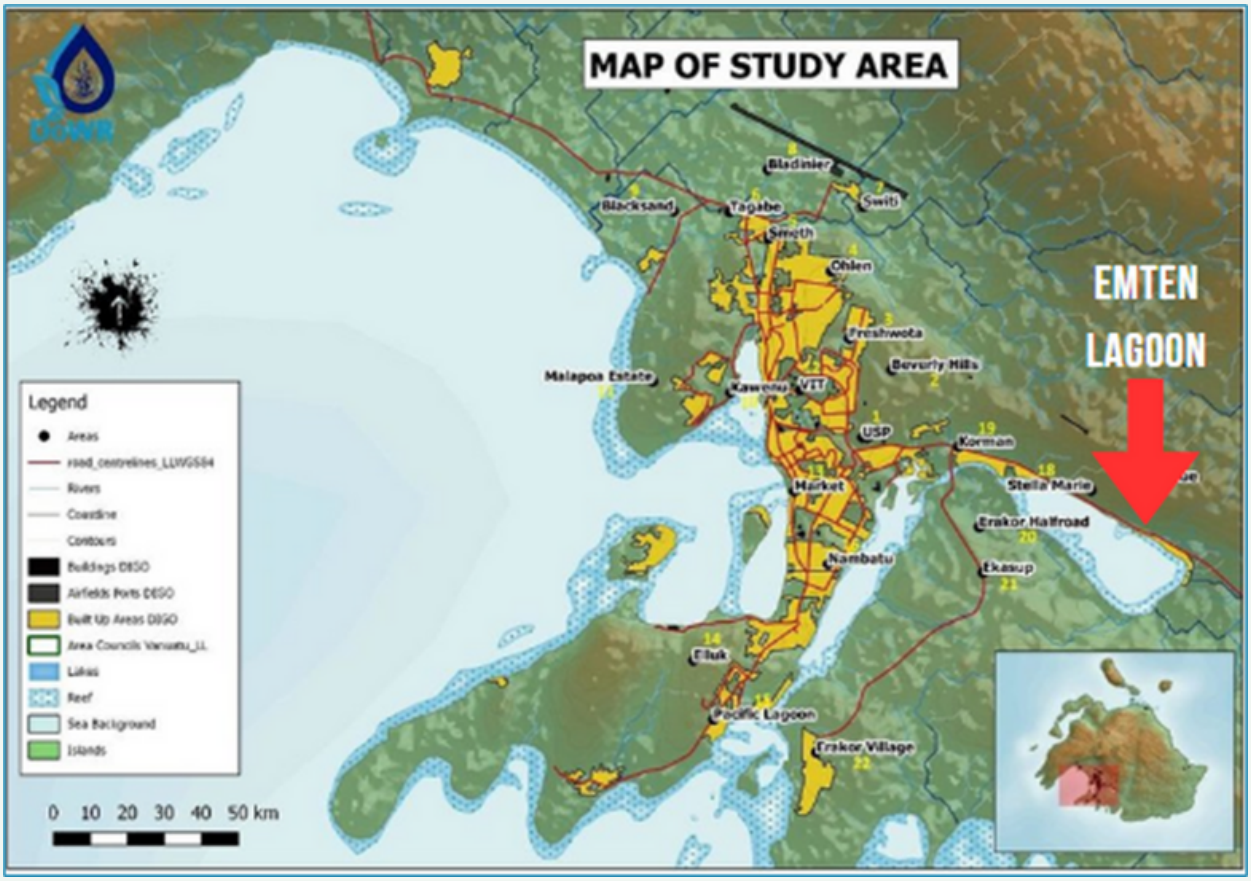


Figure 1. Modified Map of Study Area (Kotra et al., 2017)

The area surrounding the Lagoon closer to Port Vila and Montmartre is more developed and tourism-oriented, while areas on the Ekasup edge mostly include informal settlements (see Appendix D for photos of developments around Emten Lagoon). As these areas are urbanizing, there are still various bare land slots and unplanned and underdeveloped housing, especially along the Ekasup-side shoreline (see Figure 2).

Figure 2. Google Earth photo of Study Area, reflecting Montmartre and Ekasup shorelines (Google Earth).

Climate

Vanuatu's climate ranges "from wet tropical in the northern islands [...] to the dryer subtropical in the southern extremes of the archipelago" (World Bank Climate Change Knowledge Portal, n.d.). Vanuatu's tropical-subtropical climate is demonstrated by high humidity levels and relatively high temperatures. The average measured annual rainfall range is from 1,500 mm in the subtropical zones to over 4,000 mm in the wet tropical zones (World Bank Climate Change Knowledge Portal, n.d.). The average temperature is 21-27 degrees Celsius, except for Port Vila which witnesses a range of temperature from below 20 degrees Celsius to 30 degrees Celsius (World Bank Climate Change Knowledge Portal, n.d.). Both temperature and annual rainfall rates are expected to rise significantly in the future with annual rainfall rising to approximately 2300mm (see Figure 3) and temperature rising by at most 2.9 degrees Celsius by the end of the 21st century (Climate Risk Country Profile - Vanuatu - Vanuatu | ReliefWeb, 2021).

Being a part of the tropical-subtropical climate, Vanuatu is also prone to natural disasters, especially tropical cyclones. During the hot and wet season from November to April, Vanuatu suffers from the tropical cyclone season. The entire area of Vanuatu experiences "about 2-3 cyclones in a cyclone season, and the greatest frequency is in January and February," which makes up "20 to 30 cyclones per decade, with 3 to 5 causing severe damage" (Vanuatu Meteorology & Geo-Hazard Department - Tropical Cyclone, n.d.).

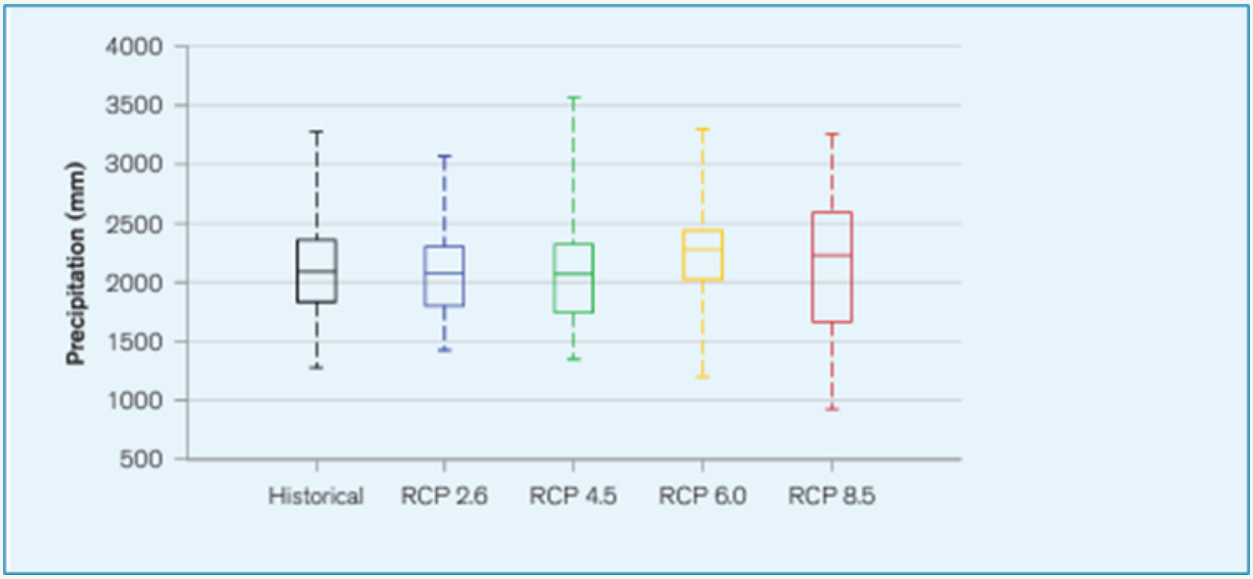


Figure 3. Projected average annual rainfall in Vanuatu 2080-2099 (World Bank Climate Change Knowledge Portal, n.d.)

2. Outcome of Interest: Improved Water Quality

The outcome of interest is improved water quality from stormwater entering the Emten Lagoon area. A study conducted by the Department of Water Resources in Vanuatu concluded in 2020 that the water in the lagoon is toxic with "harmful Escherichia coli (E. coli) bacteria and algae" (Hakwa, 2021). The water has since been unsafe for drinking, swimming, and fishing. Residents have been reporting that children around these areas are contracting illnesses from interacting with the contaminated water (Hakwa, 2021).

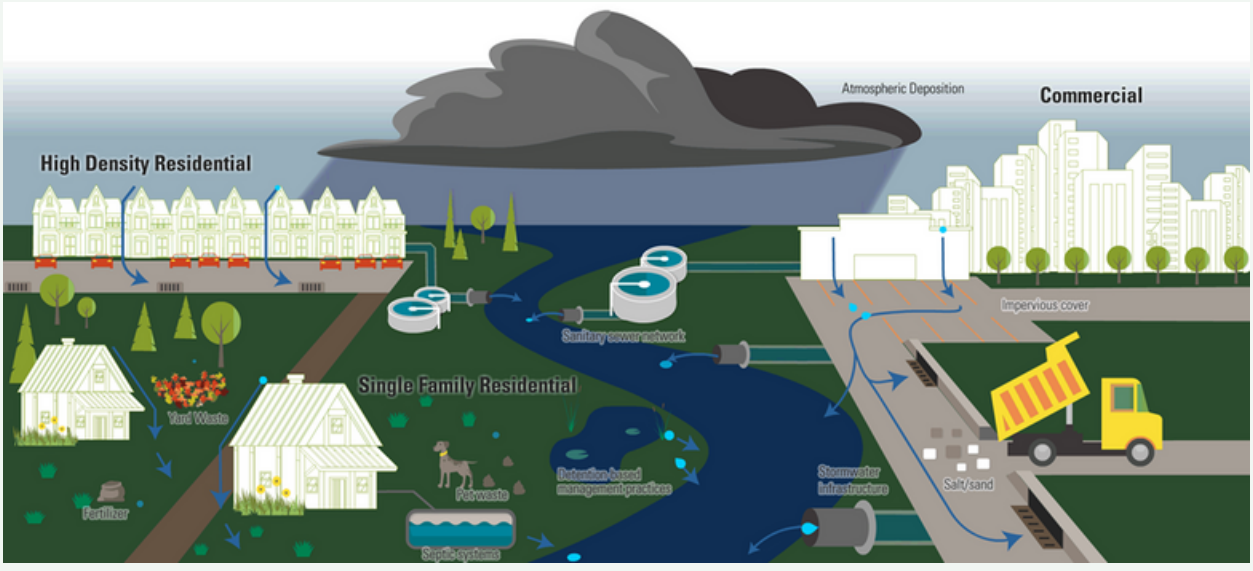


Figure 4. Impact of Stormwater Runoff on Water Quality (Stormwater Runoff in Urban Watersheds | U.S. Geological Survey, n.d.)

3. Relevant Causes to Declining Water Quality

a. Stormwater Runoff

One of the main mechanisms through which stormwater impacts water quality is sediment and pollutant carriage (Talbot et al., 2018). As climate change causes more frequent and intense rainfall events, the amount of stormwater runoff also increases, causing flooding in catchment areas (i.e., areas on lower terrains that can catch and store water from rainfalls like ponds, lakes, and lagoons). Beyond causing flooding, the increased rainfall also carries along debris which includes road erosions and wastes from agricultural, industrial, and residential activities into the catchment (Talbot et al., 2018). Therefore, households surrounding these catchment areas suffer from contaminated water floods, resulting in multiple safety issues including water-borne illnesses. Various organizations worldwide, including the Asian Development Bank and the Intergovernmental Panel on Climate Change have predicted that extreme rainfall events will increase in frequency and intensity in Vanuatu over the next decade (Greater Port Vila Urban Resilience Project, 2020; Port Vila, 2023). Increasing rates of rainfall will cause a significant increase in stormwater runoff, carrying more pollutants and sediments into catchment areas in all Vanuatu regions, including Port Vila.

b. Urbanization

In Vanuatu, climate disasters have contributed to the uninhabitability of many rural or peri-urban areas by depleting crucial resources like housing, clean water, and economic opportunities (Davies, 2023). When faced with constant displacement, rural Vanuatu residents have to leave their "home islands" to head for urban areas, causing the urbanization rate to be approximately 3% each year (Petrou & Connell, 2017; Rawlings, 1999). The urbanization population has almost doubled over the past two decades (Vanuatu Urban Population 1960-2023, n.d.). This trend will likely continue and accelerate in the future with severing climate change impacts. The area of interest for this project, Shefa, is one of the fastest urbanizing in Vanuatu as the province has the capital city Port Vila (Komugabe-Dixson et al., 2019). Therefore, urbanization is a relevant barrier to stormwater management in Port Vila, Vanuatu.

c. Waste Management Issues

An important factor that causes declining water quality in this region is issues in waste management. According to a review of the sanitation and hygiene status in Vanuatu conducted in 2022, "34% of Vanuatu households have access to basic sanitation with the majority using unimproved or limited sanitation service, less than 1% of individuals defecating in the open, and just 25% of Vanuatu households have a basic handwashing facility at home" (Rand et al., 2022). Therefore, a major factor causing worsening water quality near residential areas is household waste. On top of household wastes, agricultural and industrial activities from areas upstream also contribute to additional pollution of catchment areas. While the industrial and agricultural activities in Vanuatu are not upscaled enough to be the source of all pollutants and sedimentation according to an Australian Aid Program report, it is worth noting that there are still industrial and agricultural enterprises significantly contributing to sedimentation into the Lagoon (Nath et al., 2006) (see Appendix D).

While these are all relevant causes contributing to worsening water quality, which is the outcome of interest, the main root cause that this project focuses on is increased stormwater runoff. Below are justifications for this focus area.

First, EWB Australia's Vanuatu program is interested in the impact of climate change, which causes extreme weather events and subsequently, flooding in the region. Other projects that EWB Australia has developed and invested in Vanuatu have focused on rural and peri-urban regions, which have targeted waste management capabilities. Therefore, it would be reasonable for the organization for this project to target stormwater runoff instead of waste management issues.

Second, the government of Vanuatu has already developed relatively concrete legislative frameworks to address waste management issues. In the early 2000s, the government created various legislation on agricultural and sanitation practices in rural areas to address rural water quality issues (Vanuatu National Water Policy 2017 – 2030. | FAOLEX, 2017). In the last decade, Vanuatu has also developed multiple legislation and directives to address industrial pollution (e.g., the 2013 Pollution (Control) Act which requires businesses to acquire pollution and land use permits) (Department of Environmental Protection & Conservation - Pollution Control Act, 2013). Meanwhile, the current policy landscape lacks urban and climate-related water management policies. Therefore, it is reasonable to focus on climate-driven and urban-focused key root causes, which means solving stormwater (from flooding) management issues in newly urbanized areas.

4. Stakeholder Mapping

The relevant stakeholders of water quality issues in catchment areas of Vanuatu are featured in an Ecosystem Map (Figure 5). The client, EWB Australia, and the problem of declining water quality are placed in the middle of the map.

Government (public-sector) stakeholders are key to this issue. On the left-hand side, public sector stakeholders at the national level are listed. The Department of Environmental Protection and Conservation (DEPC) is the main agency in charge of implementing and managing/monitoring stormwater water quality issues, i.e., DEPC is the main decision-maker. They collaborate with peer departments to implement policies and provide policy suggestions to Parliament. These peer departments include the Department of Water Resources (collaborator on water resource management issues), the Department of Fisheries (collaborator on water quality for aquatic species), the Department of Climate Change (collaborator on flooding predictions and mitigation), the Department of Public Health (collaborator on health and sanitation issues affected by declining water quality), and the Department of Internal Affairs (collaborator on administrative aspects of implementation). All these departments work with and under the initiative leadership of the Department of Environmental Protection and Conservation to address stormwater management problems. At the provincial/municipal level, there are councils partially voted in by residents and partially appointed by the Department of Internal Affairs. The city council reports to the provincial council, and local committees report to the city or village councils.

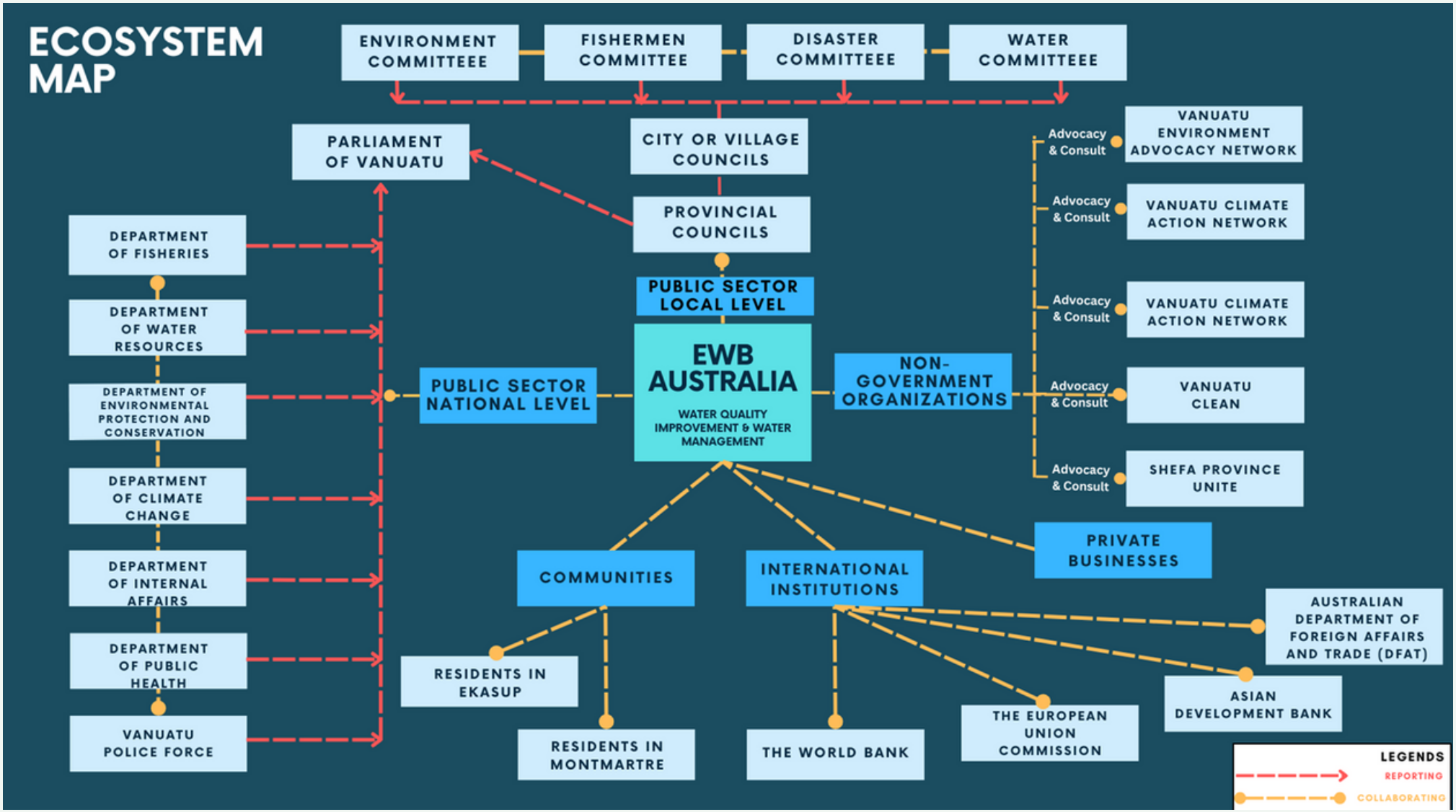


Figure 5. Ecosystem Map - EWB Australia and Water Quality Issue in Port Vila, Vanuatu

The second group of stakeholders with significant influence is the communities themselves, featured on the lower-left side of the Map. They communicate and advocate for environmental issues to local governments and serve as an awareness-raising channel for policy implementation. They are also targets for government grants for environmental protection and conservation (Vanuatu Environmental Advocacy Network Become CEPF Recipients, 2023).

The third stakeholder group is non-profit and non-governmental organizations (NGOs), featured on the right-hand side. These organizations include Vanuatu Clean, Vanuatu Environment Advocacy Network, and Shefa Province Unite, which are active in environmental advocacy and pollution clean-ups. NGOs and communities work closely with each other wherein NGOs provide funding for pollution clean-up campaigns or educate residents on environmental issues. NGOs also work closely with the government both at the local and national levels to provide funding for public sector projects and consult the Vanuatu government on both technical and policy solutions for issues that the government is facing.

The final group consists of international stakeholders, which include international governments, organizations, and financial institutions. International organizations and governments such as the Asian Development Bank (ADB), the World Bank, the EU, the Australian Department of Foreign Affairs and Trade (DFAT), and Aid partners play crucial roles in development projects in Vanuatu. They are crucial in the devising and funding process of development projects.

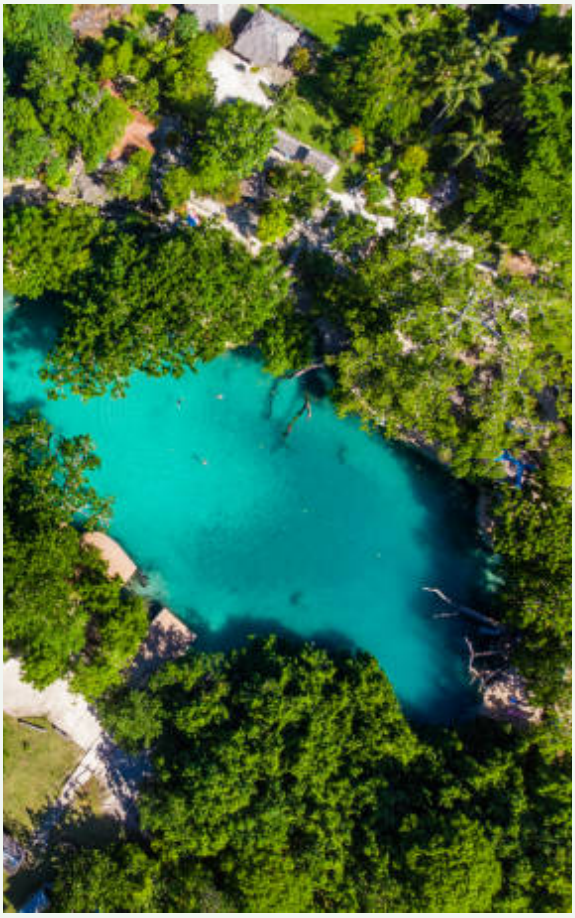
Overall, this section has provided the background information on the problem and reasoning for the project's focus on addressing stormwater management in Vanuatu. Appendix C provides a short infographic on the problem statement and relevant background information for reference. In addition, this section has provided a preliminary stakeholder mapping for the water quality issues in the Emten Lagoon region.

III. Review of Relevant Existing Legislation and Regulations

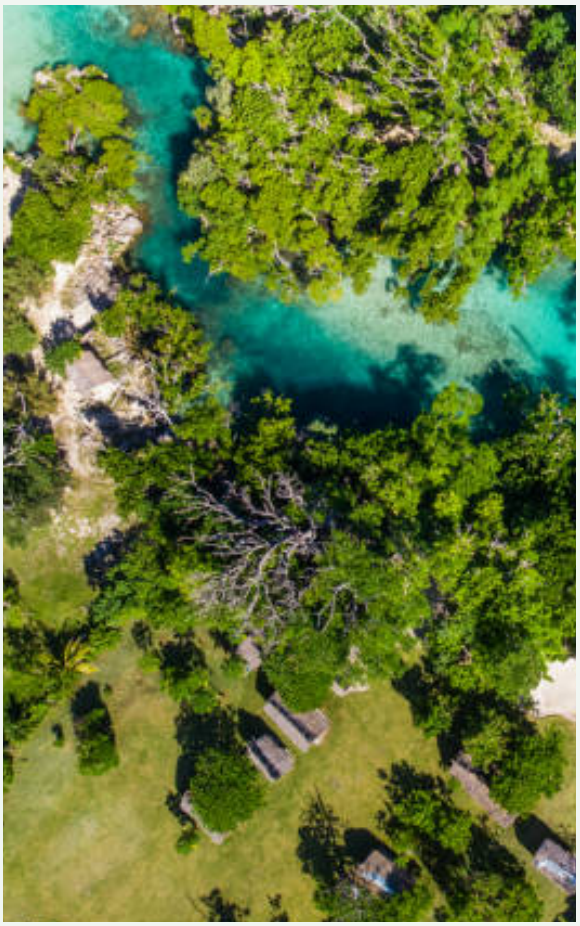
The Vanuatu Infrastructure Strategic Investment Plan 2015-2024 states that water and sanitation infrastructure development for urban water supply and sanitation falls under the jurisdiction of the Ministry of Infrastructure and Public Utilities (MIPU), Ministry of Internal Affairs (MIA), and Ministry of Land and Natural Resources (Vanuatu Infrastructure Strategic Investment Plan 2015 – 2024. | FAOLEX, n.d.). The Plan specifies that new infrastructural projects need to satisfy a set of criteria which include: (1) Suitability of scale and status with the affected community, (2) Operational sustainability; (3) Policy framework for economic and social development; (4) Financial and economic impact (Vanuatu Infrastructure Strategic Investment Plan 2015 – 2024. | FAOLEX, n.d.). There are no specific requirements or current plans to construct new grey infrastructure to target the management of stormwater-related issues at present.

The Vanuatu National Plan 2016-2030 states the government's will and determination to develop Vanuatu's potential as a "world leader in blue-green growth and sustainable development" (Vanuatu 2030, n.d.). The government plans to "capitalize on the rapid advances in technology and innovation that can complement traditional knowledge to better utilize our natural assets on land and at sea to ensure our food security, maintain our cultural identity, and enhance our economic prospects" (Vanuatu 2030, n.d.). The Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030 encourages the implementation and financing of alternative green solutions to Vanuatu's climate problems (The Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030 - Climate Change Laws of the World, n.d.). Besides the National Plan 2016-2030 and the Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030, there is minimal legislation that particularly targets the adoption and implementation of green infrastructure in Vanuatu at the national level. The Environmental Management and Conservation Act, the Water Resources Management Act, the Coastal Zone Management Act, the National Climate Change and the National Disaster Risk Reduction and Management Plan all have abstract stipulations to encourage sustainable practices to protect the lived environment but also do not specifically mention the adoption or implementation of green infrastructure (Physical Planning Act (Cap. 193). | FAOLEX, n.d.; Water Resources Management Act 2002 (Cap. 281). | FAOLEX, n.d.).

The Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030 specify that stakeholders including national and local governments, the private sector, NGOs, and other organizations need to provide climate change and natural disaster knowledge and information to "enable informed decision-making for planning, development and disaster operations and development of accurate community awareness tools" (The Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030 - Climate Change Laws of the World, n.d.). The directives identified in the Policy focus on enhancing the standards for the issuance and distribution of climate change and natural disaster risk information and knowledge. The Policy also encourages the exploration and enhancement of knowledge-sharing systems to raise public awareness of climate and natural disaster risks, which aligns with the goals of public education programs mentioned in this section of the report.



Finally, output-based programs or incentive programs have also been part of the country's policies to address climate change issues. Particularly, the Vanuatu Framework for Climate Services stated that service level agreement (SLA) can serve as an essential output-based tool to increase the provision of climate services by both government and non-governmental stakeholders (Vanuatu Framework for Climate Services - Climate Change Laws of the World, n.d.). SLA is "a contract between a service provider and the end user that defines the level of service expected from the service provider"(Vanuatu Framework for Climate Services - Climate Change Laws of the World, n.d.). In the case of climate services and the context of this project, SLAs can apply (as part of incentive programs) to households adopting sustainable practices as the "provider" and being compensated for their actions to reduce climate risks for their entire community, and the entire country.



IV. Technical Solutions: Evidence and Choice of Alternatives

This section presents the existing technical solutions to address increased stormwater runoff and provides a preliminary assessment of their effectiveness based on existing evidence from academic literature and case studies of each solution implementation in geographical locations similar in climate vulnerability and resilience needs to the Emten Lagoon area (see Appendix A: Summary of Existing Solutions). Then, it proposes two technical solutions most appropriate for the Emten Lagoon region.

1. Evidence of Existing Technical Solutions

a. Infrastructural solutions: Grey Infrastructure

Traditional infrastructural solutions to stormwater management fall into the category of grey infrastructure. Grey infrastructure in the stormwater management context is defined as "traditional stormwater infrastructure in the built environment such as dams, gutters, drains, pipes, and retention basins" (Green and Grey Infrastructure Research | US EPA, n.d.). These are all infrastructural developments to stop the water flow (e.g., dams or check dams), reduce flow-through rate (e.g., dams, drains, pipes), or keep the flown-down water in a certain location (e.g., retention basins, detention ponds).

The listed measures have been effective in reducing and filtering stormwater runoff for decades. For instance, dams are successful in reducing flooding risk by approximately 20% on average via flow-through rate reduction (Boulange et al., 2021). Check dams, a series of small, temporary dams built-in channels or ditches, have been proven to be effective in preventing erosions from getting into catchment areas (Kang et al., 2013). Additionally, studies have shown that retention basins or detention ponds (i.e., artificial ponds with surrounding vegetation) are highly effective at "remediate runoff [...] and remove contaminants" before they enter other waterways (Birch et al., 2006; Hogan & Walbridge, 2007).

While grey infrastructure has been proven effective in managing stormwater runoff thus far, there are concerns about its effectiveness going forward. First, the scale of existing grey infrastructure might not be adequate to manage increases in stormwater runoff resulting from worsening climate change. Experts have warned that "with climate change, even dams that currently meet the expectations set upon their construction decades ago may be inadequate to meet safety standards in the future" (Kondolf & Yi, 2022). Hence, there is a global need to expand or renovate existing grey infrastructure. However, grey infrastructure in general is costly both financially and administratively, especially for developing countries (Wu, 2016). Therefore, despite being highly effective, implementation of these solutions is a significant hurdle for governments worldwide, particularly for Vanuatu as a small island developing state.

CASE STUDY: SEA WALLS IN LAMI TOWN, FIJI

Lami Town is a town next to Fiji's capital city Suva. Given its geographical location on the eastern coastal shore of Fiji, Lami Town is "particularly vulnerable to flooding from heavy rains and storm surges" (Rao et al., 2013). Lami Town also faces rapid urbanization leading to a growing population suffering from the climate impacts in this region, mostly residing in informal settlements. Lami Town, in many ways, is facing similar problems that households around the Emten Lagoon region are facing with intensifying flooding from natural disasters.

To alleviate climate adverse effects, the government of Fiji and Lami Town have constructed a series of sea walls to prevent sea-level rise from causing flooding in Lami Town. Sea walls are a series of walls built (often from cement, rocks, or tires) to stop the flood flow from reaching impacted populations (see Figure 6). While proven to be effective in reducing flooding in Fiji, sea walls, a type of grey infrastructure, are also significantly more costly in comparison to other green infrastructure considered including replantation of mangroves and stream buffers or reduction of upland logging and coral extractions (Rao et al., 2013). According to a thorough economic analysis comparing the costs and benefits of these solutions, building sea walls demonstrated the lowest benefit-cost ratio due to the high costs of construction and maintenance (Rao et al., 2013).

Figure 6. Sea Walls in Fiji (Schipper, 2022)

b. Nature-based Solutions & Green Infrastructure

In recent years, nature-based solutions (NBS) have become quickly developed and highly effective in assisting with stormwater management efforts. NBS are defined as "actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature" (Nature-Based Solutions | IUCN, n.d.). The most popular NBS used in stormwater management belongs to the category of green infrastructure. Green infrastructure (GI) is "a strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services and enhance biodiversity" (Green Infrastructure, n.d.). In the context of stormwater management, GI is any approach to restore and leverage functions of the natural landscape, soil, and vegetation to manage stormwater. Examples of approaches include but are not limited to green roofs, rain barrels and cisterns, permeable pavements, bioretention areas, vegetated swales or dry swales, curb and gutter elimination, vegetated filter strips, sand, and organic filters, constructed wetlands, riparian buffers (US EPA, 2015) [1]. This section on the GI approach in its entirety and focus on its current usage and effectiveness assessment.

Any approach to address the problem must be effective in reducing stormwater runoff flow-through rate and filtering the runoff before it flows into the catchment. Overall, GI serves both functions but at a limited capacity. Specifically, the extent to which GI is successful in reducing stormwater runoff depends on the "size of the storm event, including event duration and peak flow intensity" (C. Li et al., 2019; Tao et al., 2017).

Evidence suggests that GI successfully reduces and filters runoff in storm events globally. For instance, green roofs have been found to outperform traditional stormwater-control roofs in reducing stormwater runoff by up to 65% on average (Green Roofs, n.d.; C. Li et al., 2019; Santos et al., 2022). During significant storm events, green roofs can retain from 30% to 50% of the total captured rainfall volume according to a green roof experimental test in the UK (Stovin et al., 2012). These results show that green roofs are generally effective in reducing stormwater runoff and perform slightly worse in bigger storm events. Another commonly used GI in stormwater management, especially in urban settings, is rain gardens. A rain garden is 30% more absorbent compared to a conventional lawn. They are effective in "removing up to 90% of nutrients and chemicals and up to 80% sediments from rainwater runoff" (All About Rain Gardens – What They Are & How to Build One, n.d.; Chaffin et al., 2016; C. E. Wilson et al., 2014).

Based on existing empirical evidence, stand-alone GI is effective in reducing and filtering stormwater runoff in comparison to the status quo of no intervention or small-scale traditional infrastructure. They are the most effective during smaller weather events when combined with existing grey infrastructure or when combined (C. Li et al., 2019). The evidence on this is abundant and reliable given the various experiments conducted on the effectiveness of GI worldwide. Given its low-cost and small-scale nature, GI would also be adaptable in developing country settings like Vanuatu.

[1] See Appendix B for detailed definitions of each type of GI.

CASE STUDY: NATURE-BASED SOLUTIONS IN KOA HILL, HONIARA, SOLOMONS ISLANDS

Honiara is a city that lies on the southern coast of the Solomon Islands facing "a range of climate-related and natural hazards with impacts exacerbated by shortcomings in urban development, infrastructure, and urban governance" (McEvoy et al., 2023). Koa Hill, an informal settlement in Honiara, is similar to the Emten Lagoon area as it is highly vulnerable to flooding and also consists of a quickly growing population.

To deal with flooding issues and enhance community resilience to flooding, various NBS projects have been planned and piloted. To provide an example, an urban (rain) garden has been piloted in the area of Koa Hill which is in "the immediate flood danger zone" (McEvoy et al., 2023). This garden is effective in partially reducing stormwater from flowing into the community households and has been simultaneously serving as a public space for community gatherings (see Figure 8) (McEvoy et al., 2023).

Figure 7. Rain gardens in Koa Hill constructed by community members (McEvoy et al., 2023)

However, GI poses significant implementation and maintenance challenges. The construction of certain types of GI, such as green roofs or green walls, requires extensive engineering and construction expertise as well as frequent maintenance (Liberalesso et al., 2020). They also incur high upfront and maintenance costs (Liberalesso et al., 2020). Therefore, the take-up of GI, especially large-scale interventions, requires careful consideration from all relevant stakeholders. An overview of how GI can address stormwater issues can be found in Figure 8.

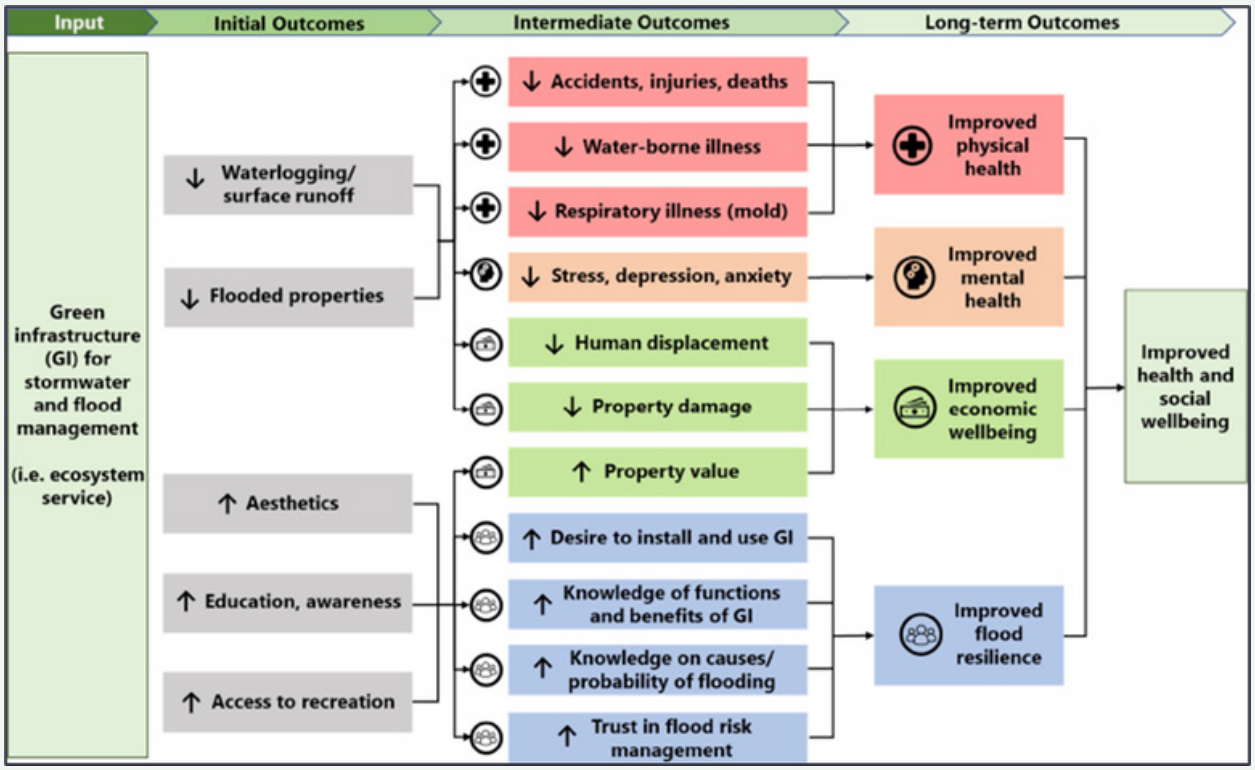


Figure 8. Analysis of how Green Infrastructure (GI) addresses stormwater management issues (Venkataramanan et al., 2019)

c. Combined solutions

Existing research suggests that GI is optimized when combined with existing grey measures like traditional infrastructural development such as dams or retention basins. Two examples of combined solutions that have been increasingly pursued by cities globally in recent times are low-impact development (LID) and Water Sensitive Urban Design (WSUD). Both LID and WSUD have demonstrated effectiveness in reducing and filtering stormwater runoff, contributing to improved water quality and reduced urban flooding. Some literature may refer to LID and WSUD interchangeably if mention WSUD plans only include green infrastructure development. Both LID and WSUD aim to minimize the impact of stormwater runoff by combining different existing solutions with new, low-impact integrations.

i. Low-impact development (LID)

Low-impact development refers to "systems and practices that use or mimic natural processes" or the combination of GI with each other to manage and filter stormwater runoff rates (C. E. Wilson et al., 2014; Yang et al., 2020). LID techniques, such as permeable pavements, green roofs, rain gardens, and bio-retention basins, are designed to slow down stormwater flow, encourage infiltration, and remove pollutants through natural processes (C. Li et al., 2019; Yang et al., 2020). In a study on an urbanizing catchment in China, Qin et al. (2013) found that LID techniques are more effective in reducing runoff than conventional stormwater management designs during heavier storm events.

ii. Water Sensitive Urban Design (WSUD)

WSUD is an approach to planning and design incorporating stormwater management objectives to create a sustainable and resilient urban environment (Meng et al., 2022; Wu et al., 2023). In a study conducted in an urbanized catchment in Sydney, Australia, WSUD has been found to consistently achieve the largest flood volume reduction of up to 50% in big storm events when compared with grey and green infrastructure individually (Wu et al., 2023). Another study was conducted in Parma, Italy in which the authors investigated the impact of the integration of green roofs and permeable pavements on increasing flooding resilience (Dada et al., 2021). The results from this paper indicate that the integrated approach which included "soft engineering hydraulic strategies" combined with green roofs and porous pavements resulted in improved urban flooding resilience (Dada et al., 2021). Essentially, WSUD ensures a comprehensive approach to stormwater management, providing cities with a more resilient and sustainable framework for addressing the challenges of urbanization, climate change, and water resource management. While there have been concerns about WSUD being ineffective for big catchment areas of more than 1000 hectares, since Emten Lagoon is much smaller, this is not a relevant concern (Meng et al., 2022). Therefore, WUSD might be the most reasonable and sustainable technical solution to effectively solve Vanuatu's stormwater management problem.

A major challenge in the implementation of any innovative solution to stormwater management, including GI, LID, and WSUD, is how to design effective policies to boost the transition from traditional technical solutions to these innovations. A set of principles for policy design aiming at successful implementation was derived from a series of global case studies conducted by researchers at the Institute of Sustainability and Innovation at Victoria University, Australia. The principles are as follows:

- **"Policies need to be clear in drivers and objectives. With these factors, policies, and legislation supporting the transition from traditional to innovative solutions would be well-supported by a "wide variety of stakeholders in the community" (Sharma et al., 2018);**
- **Enabling legislation across all levels from local to national is key to giving legitimacy and coordination in the implementation of innovative solutions;**
- **Local government needs to be the empowered implementer and there needs to be coordination across different agencies and stakeholder groups;**
- **Technical support and sustainable funding resources are key to the success in the implementation of innovative solutions;**
- **The successful implementation of innovative solutions is reliant on community education and support" (Sharma et al., 2018).**

With this framework in mind, the following section provides evidence of policy alternatives that have been successful in the past in facilitating the implementation of technical solutions mentioned in this section.

2. Technical Alternative Choices for Emten Lagoon, Port Vila

a. Technical Alternative 1: Build retention ponds for stormwater runoff

Under this alternative, the City of Port Vila would build retention ponds (see Figure 9) to redirect and reduce the amount of stormwater runoff into the Lagoon. These retention ponds can be built within 5-10 km of the perimeter of the shoreline of the Lagoon along the flow-through direction. These ponds would serve as a support system for the Lagoon itself by either storing stormwater or filtering runoff before stormwater flows into the Lagoon. Retention ponds have been proven effective in various settings, but especially in extreme storm events, as exemplified by studies conducted across the United States (Miller, 2023; Rivers, 2022). Worldwide, retention ponds have been widely used to reduce flooding, especially in countries that face frequent and extreme flooding events like Japan or the Netherlands (Chan et al., 2022).

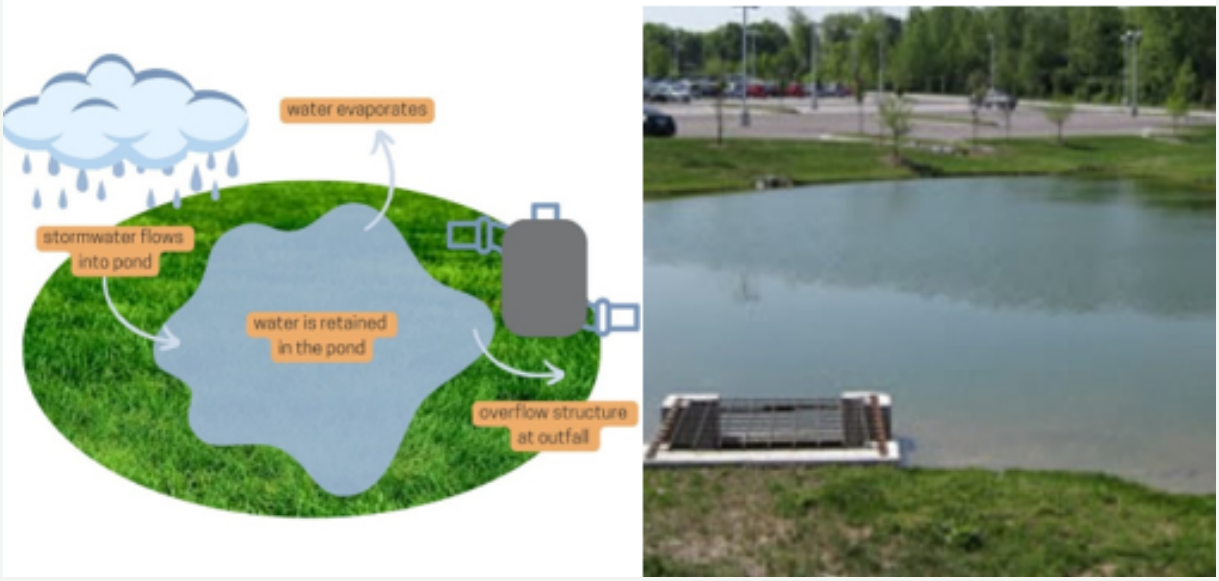


Figure 9. How retention ponds work (Google Photos)

Since this alternative proposes a series of infrastructural developments, the government of Vanuatu and particularly the City of Port Vila, in conjunction with the assistance of EWB, would be the main actors responsible for the implementation and costs. More detailed development plans and consultation with the Department of Urban Affairs and Planning would determine areas that benefit from these developments the most. It is anticipated that this alternative will be rolled out over a relatively long period as it involves many infrastructure projects. The engineering details on the design and implementation of this alternative will be included in a separate, follow-up phase to this project by the EWB team.

b. Technical Alternative 2: Implementing low-impact development plans

To resolve the stormwater runoff issue around the Emten Lagoon, the government of Port Vila can adopt and combine LID techniques, such as permeable pavements, green roofs, rain gardens, and bio-retention basins, that are designed to slow down stormwater flow, encourage infiltration, and remove pollutants through natural processes (C. Li et al., 2019; Yang et al., 2020). Low-impact development (LID) plans aim to combine green infrastructure to manage and filter stormwater runoff rates (C. E. Wilson et al., 2014; Yang et al., 2020). Currently, Port Vila is following the Vanuatu National Environment Policy and Implementation Plan 2016-2030 (Vanuatu Government, 2015). This plan details that the country needs to increase access and implementation (without disturbance of protected areas) of green infrastructure. Therefore, this proposed alternative suggests a plan to actualize this policy objective in the Emten Lagoon area.

To lower the rate of stormwater runoff into the Lagoon and filter stormwater flow-through, the Port Vila City Council can consider building bio-retention basins or rain gardens (see Figures 10 and 11) along the shoreline of the Lagoon to reduce the amount and flow-through rate of stormwater runoff. Bio-retention basins are different from regular retention ponds in that they focus both on storing stormwater and filtering stormwater of pollutants by combining the pond design with "vegetation, organic matter, engineered soils, and at times an underdrain system" (Water Conservation Technologies, n.d.). Bio-retention basins have been proven effective in reducing flooding from intense rain as well as filtering stormwater runoff into the main streams. They are commonly used in areas prone to flooding such as Cape Cod, Massachusetts, or different provinces in Singapore ("Bioretention," 2015; Liao, 2019).

Figure 10. Bio-retention basin in Kellangh, Singapore (Google Photos)

Figure 11. Bio-retention basin in Cape Cod, Massachusetts, the U.S. (Google Photos)

Under this LID plan, bio-retention basins can also be combined with permeable pavements along the roads surrounding the Lagoon. By design, these pavements allow rainwater to permeate directly into the ground instead of flowing into rivers and lakes. Permeable pavements have been proven to reduce flooding effectively in China and Australia, for instance (Hu et al., 2018; Iqbal et al., 2022). For example, in China, permeable pavements were found to have "reduced total surface runoff by 1–40% and peak flow by 7–43%" across various provinces and under 12 different tested scenarios (Iqbal et al., 2022).

This alternative aims to benefit the entire population surrounding the Emten Lagoon as, if implemented properly, it would efficiently lower the flooding frequency and improve runoff quality. In turn, this plan would improve the quality of life for all residents of Port Vila around the lagoon. The costs incurred by this plan would have to be covered by either the City of Port Vila, the national government of Vanuatu, or international/NGO funding. Since the water quality of the Lagoon has been worsening for up to three years, in combination with increasing flooding intensity and frequency, this plan needs to be adopted as soon as possible.

Photo Credit: Green Climate Fund

V. Policy Solutions: Evidence and Choice of Alternatives

1. Evidence of Existing Policy Solutions

a. Public goods control regulations

These are policies that focus on controlling the use of public spaces to minimize stormwater runoff and pollution. These regulations often involve restrictions on land development, zoning laws, building codes, or compliance-monitoring measures that mandate the implementation of green infrastructure and best management practices (BMPs) to mitigate stormwater issues. These policies accompany the implementation and enhance the effectiveness of GI and LID to address stormwater management issues.

Public control regulations have proven to be effective in reducing stormwater runoff and improving water quality. By mandating the implementation of green infrastructure, these regulations facilitate the natural infiltration of water, reducing the burden on traditional stormwater systems. A prime example of public good control regulations is land-use and zoning laws. Land use and land-use changes have extremely complex impacts on urban water resources where land use significantly affects runoff water quality (L. Li et al., 2021). Therefore, many cities worldwide have implemented land-use and zoning laws to either require the addition of GI or LID on certain land areas or protect these areas from further urban development. Land-use changes to increase the proportion of green spaces and permeable roads have been found to "reduce runoff pollution and improve runoff water quality" (L. Li et al., 2021). In another study in Madison, Wisconsin, the authors have found that municipal regulation changes to tighten urban development standards can result in a 30% reduction in runoff volume in residential areas (Stone & Bullen, 2006).

Overall, existing research suggests that increasing regulations on land use to protect land from development and increasing GI implementation are correlationally effective in reducing and cleaning stormwater runoff. However, few studies provide the causal link between these regulations and stormwater management efficacy. Current studies have mostly investigated the impact of land development on increased stormwater runoff velocity and pollution. Therefore, more research needs to be conducted to determine whether land use regulations can directly improve stormwater management.

b. Public education and outreach

Public education and outreach initiatives increase awareness among the general public, businesses, and communities about the importance of stormwater management. These policies often involve workshops, community events, and educational campaigns to inform people about the impacts of stormwater runoff, ways to reduce pollution, the importance of sustainable water management practices, and existing programs to manage stormwater runoff.

Public education and outreach initiatives are crucial to fostering a sense of responsibility and encouraging behavioral changes among individuals and communities (Campbell, 2006). In the stormwater management context, informed individuals would be more likely to follow best practices to address increased stormwater runoff. A study conducted in Melbourne, Australia found that an education campaign over 8 months successfully reduced litter loads in stormwater and enhanced public knowledge about stormwater management programs (Taylor et al., 2007). Other studies have amplified this outcome, suggesting that educational campaigns and workshops are effective and less costly measures to promote best practices in stormwater management (Fore, 2013; Porse, 2013). Currently, in Vanuatu, various community engagement projects are funded by NGOs like EWB to promote the use of sustainability measures to address climate change impacts. Therefore, public education and outreach might be suitable for stormwater management in Vanuatu.

c. Incentive programs

Incentive programs are policies to provide financial or non-financial incentives to encourage property owners, businesses, and individuals to adopt stormwater management practices. These incentives can include tax breaks, grants, rebates, and technical assistance for GI installations.

Incentive programs have demonstrated their effectiveness in promoting the adoption of sustainable stormwater management practices. For instance, in the U.S., both stormwater management fees and grants to control stormwater runoff have worked successfully to reduce flooding and runoff pollution (Hammer, 2018; Novaes & Marques, 2022; Zhao et al., 2019). Incentive programs might also provide revenue for local governments. However, in the context of Vanuatu where there might be governance capacity limitations, the implementation and monitoring of incentive programs is potentially challenging. As an NGO, EWB can likely address such challenges by assisting in funding and capacity building. Further coordination with the client and local government stakeholders would be required to properly evaluate the effectiveness of this policy alternative.

2. Policy Alternative Choices for Emten Lagoon, Port Vila

a. Policy Solution 1: Incentive program to increase household-level green infrastructure adoption

This alternative proposes that Port Vila, in conjunction with the assistance of EWB, start an output-based incentive program, with the output being that households will adopt small-scale green infrastructure such as rain gardens, green roofs, vegetation gardens, or reforestation of surrounding areas. These small-scale projects, when implemented together, can reduce significant amounts of stormwater runoff. There are multiple designs for incentive programs to implement green infrastructure, which include grants, rebates, awards programs, or matching program designs. Incentive programs have been widely adopted in the developing world to roll out household-level interventions to address social issues (UNDP Incentive Systems, n.d.). Therefore, it is appropriate to consider an incentive program as an alternative in the context of this project.

According to the latest report, Port Vila has 11,000 households with approximately 40% "residing outside of the administrative boundaries" and approximately 50% "assumed to not have access to improved sanitation" (Port Vila, 2023). For this report, the targeted population would include people living in suburbs outside of the city boundaries and under sanitation standards, making a total of approximately 5,000 households. The program would target about 10% of the population for implementation, which would be approximately 500 households that are the closest in proximity to the Lagoon area [2]. The program would run for 1-2 years to encourage implementation and observe the potential impact of green infrastructure on changing water quality and the well-being of residents.

Given the socioeconomic status of residents around the Lagoon, which consists of people living in expanding informal settlements, a grant or awards program to encourage adoption would be most appropriate (Federation, 2013). The grant would provide financial support to allow households in closest proximity to the Lagoon to purchase and implement a small-scale green infrastructure solution (such as a rain garden or a green roof). The estimated cost of one rain garden ranges from 0 to 100 US dollars [3] (ICPRB et al., n.d.; Step 1, n.d.), which is not a small investment in Ni-Vanuatu Vatu (Fore, 2013) [4]. Therefore, at the first stage of the program, the grant would provide a small grant to incentivize households to adopt small-scale, lower-cost green infrastructure. The key actors in the implementation of this program can be either the government of Vanuatu or EWB in conjunction with the Port Vila City Council. Given that household-scale green infrastructure is limited in its capacity to fully address large-scale issues like extreme flooding, this alternative must be rolled out immediately.

[2] Number of households affected was confirmed through an interview with community initiatives.

[3] Cost to implement = Size for effective rain garden (sq. ft.) x Cost per sq. ft.

[4] Exchange rate used: 1 USD = ~119 VUV

b. Policy Solution 2: Public education campaign on sustainable stormwater management practices

This alternative proposes a public education campaign on sustainable stormwater management practices and the role of green infrastructure in addressing flooding and rainwater runoff. This campaign would involve sending out information and organizing workshops with local village councils on the guidelines for flooding events, introduction to the role of nature-based solutions to reduce stormwater runoff, and information on access to these solutions (which are mostly green infrastructure). Some green infrastructure may pose a financial and/or technical knowledge challenge for implementation without assistance from experts. However, some solutions require minimal expertise for implementation and/or maintenance. The project would focus on educating residents about small-scale, easy-to-implement solutions such as rain gardens or simplified green roofs to minimize the financial and knowledge challenges faced by implementers.

Public education has been proven a successful policy tool to enhance public awareness and in many cases, increase adoption rates of sustainable practices among the general public (Fore, 2013). Given that in many studies, public and community leadership have been successful in changing the general public's awareness and behaviors, this solution is suitable for the social and political context in Vanuatu (Fore, 2013). NGOs and advocacy groups in the local area of Port Vila can assist the government in forming this public education campaign, which will include: (1) a series of workshops on flooding guidelines and nature-based solutions introductions, (2) infographics sent out to communities at the household level, and (3) a training session for local government leaders on improving public awareness on stormwater runoff issues.

Photo Credit: Green Climate Fund

VI. Assessment Criteria

While many relevant causes are contributing to worsening water quality in the Emten Lagoon, the priority focus for evaluation of policy alternatives is *effectiveness in reducing the effects of flooding on water quality*. Practicality is also crucial to any project's success, especially in countries and communities lacking and in dire need of resources. Given the context of this project, any proposal needs to be *operationally and financially feasible* to be successfully adopted by the government, both at the national and local levels. In addition, since this project operates in Vanuatu, a developing country that continuously faces disasters, *sustainability* is a key assessment criterion. Finally, since EWB is a non-profit organization focused on assisting marginalized communities worldwide, any project supported by EWB would highly emphasize *equity*. Any proposed alternative needs to consider the community's capacity and the project's impact on the livelihood of the communities it targets. These criteria are organized and tailored to the two sets of solutions: technical and policy alternatives.

***Tables 1 and 2* provide detailed definitions, measurement metrics, and sources of evidence for each criterion set used for technical solutions and policy solutions to the proposed problems.**

Table 1. Criteria Matrix for Technical Alternatives

Criteria	Definition	Measurement Sub-Criteria	Source of Evidence
Effectiveness	This solution can effectively improve the water quality in Emten Lagoon.	How many pollutants in stormwater (e.g., metal pollutants, E. Coli, or bacteria in general) will the implemented solution reduce?	**Secondary data:** Scientific literature
		How much stormwater flow will the implemented solution reduce?	
Operational Feasibility	Relevant stakeholders have the administrative, logistical, and legislative capacity necessary to implement and maintain this solution.	Human resources	**Primary data:** Stakeholder interviews **Secondary data:** Scientific literature & admin. data
		Legislation	
		Willingness	
		Technical knowledge and skills	
Financial Feasibility	There are existing sources of funding for the implementation and/or maintenance of this solution.	Existence of funding resources	**Primary data:** Stakeholder interviews **Secondary data:** Historical funding data (national and international)
		Willingness to fund	
Sustainability	This alternative provides a long-lasting impact on water quality.	Resilience/Adaptivity to natural disasters and climate change	**Primary data:** Expert interviews **Secondary data:** Scientific literature
		Monitoring/Maintenance demands in the long term	

Table 2. Criteria Matrix for Policy Alternatives

Criteria	Definition	Measurement Metric	Source of Evidence
Effectiveness	This solution effectively improves the water quality in Emten Lagoon.	What percents of households participate in / take up this solution? (measured by uptake rate)	**Secondary data:** Scientific literature
		How many percents of households have adopted new sustainable behaviors after the program?	
Operational Feasibility	Relevant stakeholders have the capacity necessary to implement and maintain this solution.	Human resources	**Primary data**: Stakeholder interviews **Secondary data:** Scientific literature & admin. data
		Legislation	
		Willingness	
		Technical knowledge and skills	
Financial Feasibility	There are existing sources of funding for the implementation and/or maintenance of this solution.	Existence of funding resources	**Primary data**: Stakeholder interviews **Secondary data:** Historical funding data (national and international)
		Willingness to fund	
Sustainability	This alternative provides a long-lasting impact on water quality.	Durability of policy/program to political, social, and financial change	**Primary data**: Expert interviews **Secondary data:** Scientific literature
		Community integration with program	
Equity	The solution allows all interested participants the opportunity to access the benefits of the program.	Can interested participants take part in the program?	Scientific literature
		Do all participants receive equitable benefits from the program?	

1. Operational Feasibility

This criterion applies to both technical and policy alternatives.

a. Definition:

This criterion focuses on measuring the operational capacity of the government (national and local) to implement and maintain each alternative. Particularly, the focus is to assess whether relevant stakeholders have the administrative, logistical, and legislative capacity necessary to implement and maintain a proposed solution.

b. Measurement:

This report measures the administrative and legislative capabilities of relevant stakeholders to build and maintain suggested infrastructural projects. The sub-criteria involved are human resources (i.e. number of staff involved in implementation and availability of staff), existing and potential supporting legislation (i.e., whether there are existing laws and regulations, if they are supportive, and if they have impacts on implementation), implementation willingness (i.e., whether relevant stakeholders are willing to implement this solution), and technical knowledge and skills required (i.e., whether relevant stakeholders have the skills necessary to implement the solution).
The sources of evidence include existing legislation, staffing schemes, and government project implementation plans. These secondary data resources demonstrate whether there is supporting legislation and sufficient human resources to implement each alternative and whether staff have the qualifications to do so. The main evidence for implementation willingness and supporting evidence for other listed metrics will be derived from interviews with experts and local stakeholders.

Each alternative would be ranked high, medium, and low in operational feasibility. Each alternative will be ranked in each of the sub-criteria: human resources, legislation, willingness, and technical knowledge and skills under this criterion as high (denoted (++)), medium (denoted (+-)), and low (denoted (--)). The rationales for ranking a solution high, medium, or low in operational feasibility are presented in Appendix C, Table 1.

The final operational feasibility level ranking will be the combined ranking of four sub-criteria. The ranking score denotations using plus (+) and minus (-) signs allow for the summation of rankings, where we follow that one plus (+) cancels out one minus (-) score. The alternative solution with the highest summed score will have the most (+) in its score and will be recommended. The rankings of each alternative in each sub-criterion can be relevant for stakeholders when they want to prioritize a certain alternative given its ranking on a specific sub-criterion.

2. Financial feasibility

This criterion applies to both technical and policy alternatives.

a. Definition:

This criterion measures whether there is funding available or willingness to fund the implementation and maintenance of any proposed solution.

b. Measurement:

To measure financial feasibility, this report assesses the government of Vanuatu's willingness to pay for the solution, including the national government and the Port Vila City Council. The report also evaluates international institutions' willingness to fund the solution including but not limited to the World Bank, the European Commission, the Asian Development Bank, and the Australian Department of Foreign Affairs and Trade (DFAT). Non-government organizations may also have resources to fund proposed solutions.

To find evidence for the financial feasibility assessment, budgetary plans at both the national and local levels were reviewed to identify whether the government is currently allocating funds to similar projects and whether funding is available to spend on suggested alternatives. Consideration of similar projects will be assessed per each alternative solution (both technical and policy solutions). Examples of relevant similar projects include nature-based solutions' implementation/incentive projects, stormwater management and water quality improvement projects, and environmental education campaigns. This report also reviews historical funding and protocol documents to identify foundations for international organizations to provide funding for the proposed alternative.

Similarly to operational feasibility, each alternative would be ranked high (++), medium (+-), and low (--). The rationales for ranking a solution high, medium, or low in operational feasibility are presented in Appendix C, Table 2. The final financial feasibility level ranking would be the combined ranking of two sub-criteria. The rankings of each alternative in each sub-criterion can be relevant for stakeholders when they want to prioritize a certain alternative given its ranking on a specific sub-criterion.

3. Effectiveness

a. For technical alternatives:

i. Definition:

This criterion measures the extent to which the alternatives reduce (1) pollutants in stormwater flowing into the Emten Lagoon area and (2) stormwater runoff rates. This is the outcome of interest that this project sets out to resolve.

ii. Measurement:

This report measures the effectiveness of an intervention in reducing runoff rates of stormwater by demonstrating the percent decrease in water flowing through or into a certain catchment area during a flooding event. Effectiveness in pollution reduction is shown through the percentage decrease in pollutants in the stormwater flow or catchment area after implementing the solutions. Relevant pollutants include metal elements and bacteria, both in general and specifically Escherichia coli (E. Coli), the bacteria that Emten Lagoon is confirmed to be polluted with, according to findings from a study by the Vanuatu Department of Water Resources (Fraser, 2021). Reducing flow-through rates is a measure to show how a solution slows down the rates at which flood water flows into the catchment area.

An ideally effective alternative would result in a higher percentage of reduction in flow-through rates and pollutants post-implementation. However, an alternative might be more efficient in reducing the flow-through rate than another while being less effective in reducing pollutant rates. In this case, to compile the Technical Effectiveness Index, this assessment would weight pollutant reduction higher because the outcome of interest is water quality [5]. Based on consultation with relevant stakeholders and existing research, this report will use the following formula to calculate the Technical Effectiveness Index:

Technical Effectiveness Index = (0.7)x(Pollutant reduction rates) + (0.3)x(Flow-through reduction rates)

The solution with the higher Effectiveness Index score is recommended.

[5] This weighting follows the Point Allocation method in Multi-criteria Decision Analysis, which is when "a decision-maker allocates a certain number of points to each criterion. The more points a criterion receives, the greater its relative importance" (Croeser et al., 2021; Odu, 2019). Given that there are only two criteria in this case, according to Croeser et al. (2021), the "default hierarchical weights were 50% for first priority, 25% for second priority, 5 % for third priority and 10 % for fourth priority. If less than four priorities were nominated, weights were scaled proportionately." Therefore, in this case, with two criteria, the first-priority criterion, pollution reduction rates, is approximately 2.3 times as important as the second criterion, flow-through reduction rates.

b. For policy alternatives:

i. Definition:

This criterion will measure the effectiveness of each suggested policy in increasing residents' participation in sustainable behaviors in response to flooding events, which contributes to improving water quality in the Emten Lagoon (Fore, 2013).

ii. Measurement:

This report measures participation by two main sub-criteria: program uptake rates and the percentage of program participants engaging in more sustainable behaviors. First, program uptake rates are assessed by documenting the uptake rates (in percent) of similar programs in comparable contexts. Uptake can be defined as participation in the program or having received benefits from the program to any extent. These projected uptake rates would be in the percentage of the total number of households surrounding Emten Lagoon (who are the most exposed to Emten Lagoon water quality issues). For this project, projected uptake rates will be reported only for the first year of implementation. Second, this report evaluates changed behaviors by investigating evaluation studies of similar programs in the past in comparable contexts. Behaviors that this report draws from for evaluation include (1) enhanced understanding of the use of nature-based solutions in flooding mitigation and adaptation or (2) voluntary uptake of the program without the program's support. Similar programs this report draws from in its evaluation include sanitation enhancement, water quality improvement, and flooding-related incentive and public education programs in small-island developing states in Vanuatu specifically and in other small-island developing states in the South Pacific.

Similarly to operational feasibility, each alternative is ranked high (++), medium (+-), and low (--). The rationales for ranking a solution high, medium, or low in operational feasibility are presented in Appendix C, Table 3.

The final policy effectiveness level ranking is the combined ranking of two sub-criteria. The ranking score denotations using plus (+) and minus (-) signs allow for the summation of rankings, where we follow that one plus (+) cancels out one minus (-) score. The alternative solution with the highest summed score will have the most (+) in its score and will be recommended. The rankings of each alternative in each sub-criterion can be relevant for stakeholders when they want to prioritize a certain alternative given its ranking on a specific sub-criterion.

4. Sustainability

a. For technical alternatives:

i. Definition:

This criterion will measure the ability of the suggested technical solution to have a long-lasting impact on water quality improvement in the Emten Lagoon area.

ii. Measurement:

This report measures this criterion by evaluating two sub-criteria: (1) whether the solution is resilient or adaptive to natural disasters and climate change and (2) whether it requires monitoring and maintenance over time. To operationalize this criterion, this report reviews existing data on the resilience and adaptability level of each solution in past natural disaster events. Specifically, it also documents cases in which similar solutions have survived challenges posed by flooding, heatwaves, sea-level rise, and storms/cyclones, which are commonly faced with climate issues in Vanuatu.

Similarly to the feasibility criteria, each alternative is ranked high (++), medium (+-), and low (--). The rationales for ranking a solution high, medium, or low in sustainability are presented in Appendix C, Table 4.

The final operational feasibility level ranking would be the combined ranking of two sub-criteria. The ranking score denotations using plus (+) and minus (-) signs allow for the summation of rankings, where we follow that one plus (+) cancels out one minus (-) score. The alternative solution with the highest summed score will have the most (+) in its score and will be recommended. The rankings of each alternative in each sub-criterion can be relevant for stakeholders when they want to prioritize a certain alternative given its ranking on a specific sub-criterion.

b. For policy alternatives:

i. Definition:

This criterion will measure the ability of the suggested technical solution to have a long-lasting impact on water quality improvement in the Emten Lagoon area. Particularly, this criterion measures the proposed policy or program's ability to withstand changing political, social, and financial conditions over time.

ii. Measurement:

This measurement involves evaluating two sub-criteria: (1) whether the suggested policy or program would be likely to be in effect for a long period, through different political, social, and financial or funding conditions, and (2) community integration of the policy solution. To operationalize this criterion, factors such as the policy's flexibility to adapt to new information or conditions, its reliance on stable or diversified funding sources, and its alignment with long-term societal values and goals are crucial. Such assessment will be conducted through analysis of stakeholder interviews. Additionally, the assessment also includes a review of legal and institutional frameworks to ensure the policy's enforceability over time. For a policy or program to be successful, community acceptance and eventual voluntary uptake of the policy or program without incentives are very important. Communities are the key because they are the main program beneficiaries and drivers of change to the outcome of interest. To measure the likelihood that a community would accept and integrate a policy or program, the report draws on existing evaluation of similar programs (including sanitation enhancement, water quality improvement, and flooding-related incentive and public education programs in small-island developing states in Vanuatu specifically and in other small-island developing states in the South Pacific).

Similarly to the feasibility criteria, each alternative is ranked high (++), medium (+-), and low (--). The rationales for ranking a solution high, medium, or low in sustainability are presented in Appendix C, Table 5.

The final operational feasibility level ranking would be the combined ranking of two sub-criteria. The ranking score denotations using plus (+) and minus (-) signs allow for the summation of rankings, where we follow that one plus (+) cancels out one minus (-) score. The alternative solution with the highest summed score will have the most (+) in its score and will be recommended. The rankings of each alternative in each sub-criterion can be relevant for stakeholders when they want to prioritize a certain alternative given its ranking on a specific sub-criterion.

5. Equity

This criterion is tailored for policy alternatives only.

a. Definition:

This criterion measures whether and how each alternative would bring equitable access and benefits to all residents immediately residing around the Emten Lagoon regardless of their socioeconomic status, property ownership, or employment status.

b. Measurement:

This report assesses the equity implications of each policy using secondary data on similar programs in Vanuatu on accessibility and the impact of these programs on different stakeholder groups. Similar programs this report draws from in its evaluation include sanitation enhancement, water quality improvement, and flooding-related incentive and public education programs in small-island developing states in Vanuatu specifically and in other small-island developing states in the South Pacific.

The two main sub-criteria to measure equity implications are accessibility to policy or program and the amount and type of benefits received by participants. Accessibility can be defined as the ability of residents from different socioeconomic statuses, property ownership, or employment status to access and receive benefits from the program. A program is considered equitable if the program is inclusive in its design and provides significant benefits relative to other options. In addition, a program is only equitable if it allows opportunities of access for those most affected and most disadvantaged as the result of the worsening water quality. Vice versa, a program that is not equitable only targets niche populations and does not provide significant benefits to participants. Each sub-criteria is measured through rationale listed in Appendix C, Table 6.

VII. Key Findings

This section highlights the key findings of the analysis and evaluation of each proposed solution based on the given set of criteria. The detailed evaluation can be found in the Annex attached at the end of this report.

Technical Solution 1: Building a Series of Retention Ponds surrounding the Lagoon

When evaluated against the proposed set of criteria for technical solutions, retention ponds overall perform at the medium-low level on all criteria. Because of the infrastructural-focused nature of retention ponds, they require levels of technical skills and human resources that local communities and the government of Port Vila cannot provide as of now. In addition, existing supporting legislation and demonstration of willingness are vague and use indirect language. Therefore, it is difficult to predict whether there is a supportive legislative environment for this solution to be implemented. Retention ponds also do not perform well on financial feasibility given that it requires a relatively significant amount of funding for implementation and maintenance. While proven effective in reducing stormwater flow-through rates and filtering flood water, retention ponds are not resilient to damage caused by natural disasters.

Technical Solution 2: Low-impact Development Plan with Bio-Retention Basins and Permeable Pavements

The proposed LID plan, which combines bio-retention basins (in the form of rain gardens, vegetation gardens, green roofs, etc.) and permeable pavements in areas surrounding the Lagoon, performs medium-high overall on the assessment criteria. While this solution does require human resources, the technical skills required are relatively low as the implementation process involves mostly skills that communities have already adopted in their day-to-day activities. In addition, because this solution is a combination of different green infrastructure techniques, it optimizes the effectiveness of all techniques involved. The most significant strength of LID implementation is that it is highly sustainable. Bio-retention basins and permeable pavements are nature-based solutions, which by design are resilient to natural disasters.

Policy Solution 1: Incentive Program for Adoption of Household-level Green Infrastructure	*Policy Solution 2: Public Education Campaign*
The proposed incentive program performs well in the criteria list. The greatest strength of the incentive program is its efficiency and minimal technical requirements. Most importantly, this program brings financial and sustainability benefits to communities most impacted by the worsening water quality. A key limitation of this proposal is that it requires funding from international organizations; however, the amount of funding required can be acquired from existing funding opportunities, and there are abundant opportunities available based on this report's analysis.	**The proposed public education campaign was given an overall medium assessment score based on the evaluation process. The campaign does not require significant human resources or specific technical skills, and there is existing, detailed legislation that would support the implementation of this flooding resilience campaign. Two key weaknesses of this proposed solution are: (1) public education campaigns have not resulted in significant behavioral changes in the past in Vanuatu, and (2) given its short-term nature, it is unlikely that this education campaign would have a long-term impact.**

Photo Credit: Toda Peace Institute

VIII. Outcome Matrix

Based on the information provided by the analysis, Table 3 presents an outcome matrix that summarizes and demonstrates the recommended solutions. Alternatives highlighted in *green* are recommended.

Table 3. Outcome Matrix

Criteria	Technical Solutions		Policy Solutions	
	Retention Ponds	***Low-Impact Development***	***Incentive Programs***	*Education Campaign*
Operational Feasibility	*Low (--)*	**Medium (+-)**	***High (++)***	*High (++)*
Financial Feasibility	*Low (--)*	***Medium (+-)***	***High (++)***	*High (++)*
Effectiveness	*0.185**	***1.446****	***High (++)***	*Low (--)*
Sustainability	*Low (--)*	***Medium (+-)***	***High (++)***	*Low (--)*
Equity	*N/A*	*N/A*	***Yes***	*Yes*

NOTES:

***Numerical values are Effectiveness indices that serve ranking purposes**

Red indicates low criteria score, Yellow indicates medium criteria score, and Green indicates high criteria score.

IX. Recommendations

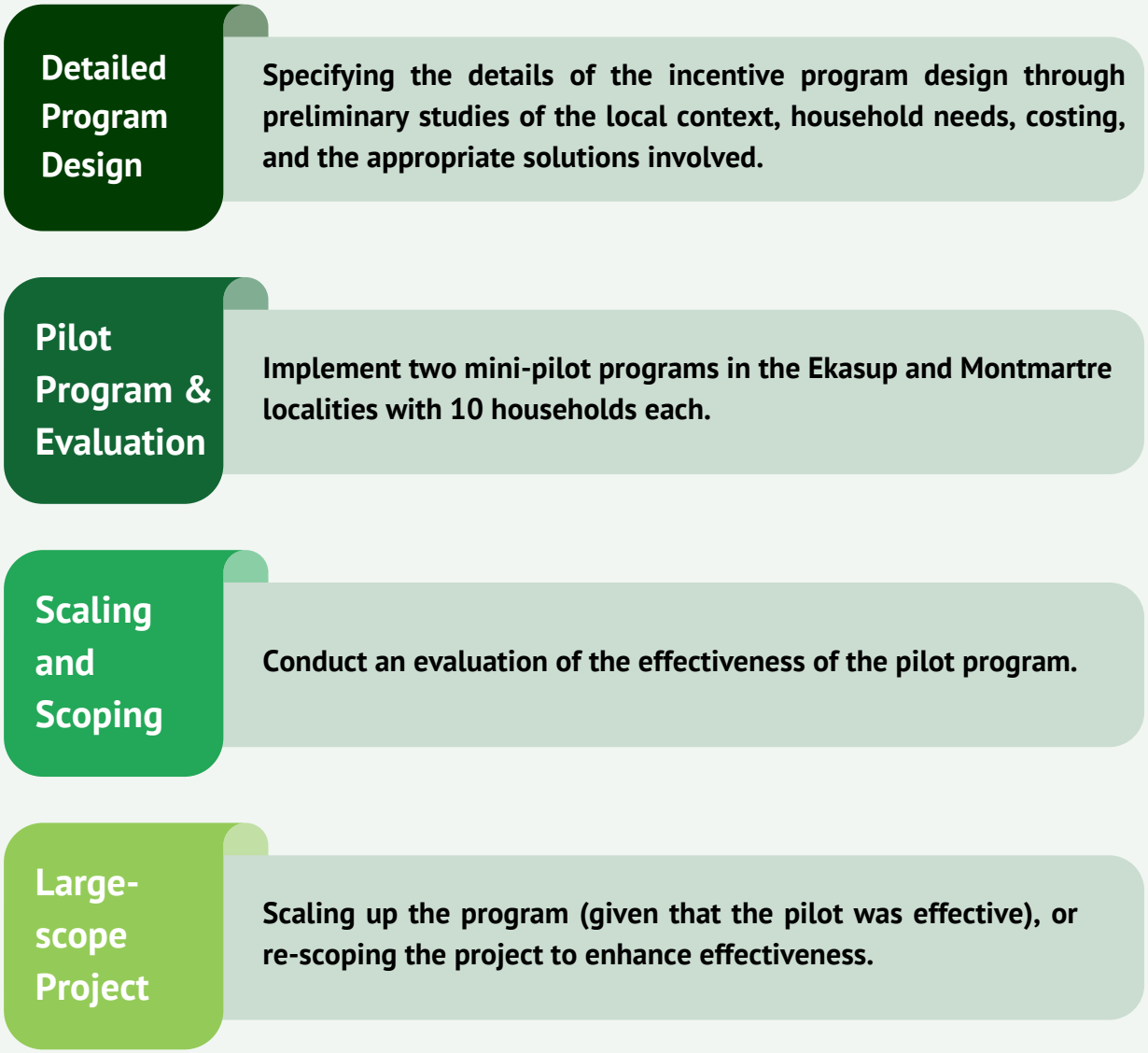
Based on the performance of each proposed solution on the assessment criteria, the recommendations are as follows. Between the two technical solutions, implementing a low-impact development plan to integrate rain gardens (i.e. bio-retention basins) and permeable pavements is more achievable for the local context at Emten Lagoon. Between the two policy solutions, this report recommends an incentive program to encourage households to adopt sustainable behaviors, which may involve building their own rain gardens, vegetation gardens, green roofs, and revegetating or reforesting areas surrounding their communities.

First, initiating the Incentive Programs for Green Infrastructure Adoption aligns with the preferences of residents in Port Vila and similar developing countries who respond well to incentives. This approach allows for quicker and more widespread community involvement, addressing immediate concerns related to stormwater management. Subsequently, implementing Low-Impact Development (LID) projects utilizing EWB's engineering solutions provides a more comprehensive and long-term solution. This phased approach ensures that community engagement and awareness are established before introducing large-scale engineering interventions. This sequence aims to optimize the effectiveness of both technical and policy solutions for sustainable and lasting impact on water quality around the Emten Lagoon.

X. Implementation

After thorough evaluation based on predetermined criteria, it is recommended that a sequential implementation strategy be adopted for optimal results. The initial focus should be on the implementation of an Incentive Program for Green Infrastructure Adoption due to its potential to quickly garner community participation. People in Port Vila, and similar developing regions, often respond positively to incentives, making this policy option more feasible and quicker to implement, according to interviews with stakeholders. The main steps of the Incentive Program implementation plan are presented in Figure 12.

Figure 12. Implementation Steps



Subsequently, following the success of the incentive program, the implementation of Low-Impact Development Plans is recommended. Leveraging the technical expertise and engineering solutions offered by organizations like Engineers Without Borders (EWB), this phase will involve the deployment of green infrastructure such as bio-retention basins and permeable pavements to further enhance stormwater management around the Emten Lagoon. This approach ensures a comprehensive and sustainable strategy to tackle water quality issues while aligning with the community's capacity and preferences.

In accordance with these suggested programs, it is highly recommended that EWB engages in discussions with governmental stakeholders to foster policy reforms that help create a nurturing environment for climate resilience initiatives. For instance, the adoption and enforcement of the proposed Bill for the Drainage Act of 2017, which provides a legislative framework for the "planning, design, construction and maintenance of public drainage systems" would be very helpful in painting a full picture of the requirements for progress in climate resilience development.

By recommending a phased approach, this strategy aims to strike a balance between immediate action and long-term, sustainable solutions, taking into consideration the socio-economic landscape and the unique challenges faced by communities in the Emten Lagoon area. This adaptable and sequential plan maximizes the potential for success, community engagement, and lasting positive impacts on water quality.

APPENDIX A.
Summary of Existing Solutions

Table 1. Technical solutions to stormwater runoff reduction			
Type of solutions	Solutions	Relevant legislation	Potential Funding
Infrastructural solutions	Dams	Physical Planning Act (Cap. 193)	FDI, WB Loans, Government funds
	Retention basins / Detention ponds	Physical Planning Act (Cap. 193)	FDI, WB Loans, Government funds
Non-infrastructural solutions	Nature-based solutions (green infrastructure)	Physical Planning Act (Cap. 193)	GCF, EU (e.g. Horizon), DFAT funds
Combined solutions	Low-impact Development (LID)	Physical Planning Act (Cap. 193); Pollution Control Act No.10 of 2013;	GCF, EU (e.g. Horizon), DFAT funds
	Water Sensitive Urban Development (WUSD)	Physical Planning Act (Cap. 193); Pollution Control Act No.10 of 2013; Vanuatu National Environment Policy and Implementation Plan 2016-2030	GCF, EU (e.g. Horizon), DFAT funds

Table 2. Adaptive (Policy) solutions to stormwater runoff reduction			
Type of solutions	**Solutions**	**Relevant legislation**	**Potential Funding**
Externality control & monitoring	Land use planning and zoning regulations	Land Lease Act (Cap 163); Land reform Act [CAP123]	FDI, WB Loans, Government funds, GCF, EU (e.g. Horizon), DFAT funds
	Waste management compliance regulations	Waste Management Act No. 24 of 2014; Pollution Control Act No.10 of 2013	FDI, WB Loans, Government funds, GCF, EU (e.g. Horizon), DFAT funds
Public education and outreach	Communication plans, ad campaigns, and information distribution	Vanuatu National Environment Policy and Implementation Plan 2016-2030	NGOs funding, GCF, EU (e.g. Horizon), DFAT funds
	Education of existing programs/legislation	Vanuatu National Environment Policy and Implementation Plan 2016-2030	NGOs funding, government funds
Incentive programs	Tax credits for good stormwater management practices	Environment Management and Conservation Act No.12 of 2002	FDI, WB Loans, Government funds, GCF, EU (e.g. Horizon), DFAT funds
	Financial incentives (mostly through grants) to adopt technical solutions	Environment Management and Conservation Act No.12 of 2002	FDI, WB Loans, Government funds, GCF, EU (e.g. Horizon), DFAT funds

APPENDIX B.
Types of Green Infrastructure

Green Route	Arboreal interventions	Carbon capture	SUDs	Flood actions	Water treatment	Green/ Permeable pavements
Smart soils	Pollinators	Vertical GI	Horizontal GI	Pollutant filters	Resting areas	Urban farming

The section below describes each type in more detail:

1. Green routes include green pathways for recreational, public health and well-being; and transportation linkages.
2. Arboreal interventions include shade trees, cooling trees, planting and renewal urban trees, arboreal areas around urban areas, trees re-naturing parking.
3. Carbon capture initiatives include urban carbon sinks.
4. Sustainable drainage systems (SUDs) include grassed swales and water retention pounds, suds for green bike lanes/parking; and rain gardens.
5. Flood actions include urban catchment forestry, hard drainage-flood prevention, unearthed water courses, channel re-naturing, and floodable parks.
6. Water treatments include green filter areas; and natural wastewater treatments.
7. Green pavements include hard drainage pavements, green pavements, green parking pavements, cycle-pedestrian green pavement, and cool pavement.
8. Smart soils include enhanced nutrient management and releasing soil, smart soil production in climate-smart urban farming precincts, and smart soil as substrate.
9. Pollinators include pollinator verges and spaces (walls/vertical, roofs), natural pollinator modules, and compacted modules.
10. Vertical green installations include fences, noise barriers, façades with climbing plants, hydroponic façades, and vertical mobile gardens.
11. Horizontal GI includes floating gardens, green covering shelters, electro wetlands, green roofs, and green shady structures.
12. Pollutant filters include green filter areas and urban garden bio-filters.
13. Resting areas include a parklet or pocket park and green resting areas.
14. Urban farming includes climate-smart greenhouses, wastewater treatment by using by-products, urban orchards, community composting, and small-scale urban livestock.

APPENDIX C. Ranking Rationale for Each Evaluation Criterion

This evaluation follows the Multi-criteria Decision Analysis models provided by (1) the online IUCN NBS Self-assessment Tool (The IUCN Online Self-Assessment Tool for Nature-Based Solutions, 2024) and (2) the Multi-criteria-analysis (MCA) Helsinki Metropolitan Area Council (YTV)) (Practical Evaluation Tools for Urban Sustainability, n.d.). The ranking score denotations using plus (+) and minus (-) signs allow for the summation of rankings, where we follow that one plus (+) cancels out one minus (-) score. The alternative solution with the highest summed score will have the most (+) in its score and will be recommended.

Table 1. Operational feasibility ranking rationale

Sub-criteria	High (++)	Medium (+-)	Low (--)
Human resources	Relevant stakeholders have or can provide enough human resources (in quantity) to actualize the solution.	There are some human resources for implementation, but not sufficient.	There are no human resources to implement the solution.
Technical knowledge and skills	Human resources (provided by relevant stakeholders) have full technical knowledge and skills necessary to implement this solution.	Human resources have some levels of technical knowledge and skills for implementation but still need training or external support.	Human resources have very minimal to no technical knowledge and skills for solution implementation.
Legislation	There is full legislative support through the existence of current policies or there are proposed initiatives for policy advocacy) for the solution.	There is some kind of legislative support, but the language of legislation is vague or there are not enough supporting regulations to implement the solution. There is some level of policy advocacy for the solution, but no action items.	There is no legislative support for the solution.
Willingness	Relevant stakeholders show full willingness to implement this solution and advocate for the initiative.	Relevant stakeholders show some kind of willingness but do not guarantee agreement to implement the solution.	Relevant stakeholders show little to no willingness to implement solutions.

Table 2. Financial feasibility ranking rationale

Sub-criteria	High (++)	Medium (+-)	Low (--)
Existence of funding resources	There are sources of existing funding for the solution specifically.	There are sources of funding for the types of projects that are in the category of the proposed solution (including green infrastructure, infrastructure development, household support incentive programs, and/or public education funds).	There is no funding for the solution specifically or for the types of projects that are in the category of the proposed solution (including green infrastructure, infrastructure development, household support incentive programs, and/or public education funds).
Willingness to fund	Relevant stakeholders show full willingness to fund the project (either verbally in interviews or through published strategic plans).	Relevant stakeholders show some willingness to fund the solution, but the language is high-level and vague (either verbally in interviews or through published strategic plans).	Relevant stakeholders show low to no willingness to fund the project (either verbally in interviews or through published strategic plans).

Table 3. Effectiveness Ranking Rationale for Policy Alternatives

Sub-criteria	High (++)	Medium (+-)	Low (--)
Uptake	The uptake rate is high (>70%) among the targeted population.	The uptake rate is moderate (30-60%) among the targeted population.	The uptake rate is low (<30%) among the targeted population.
Behavior change	The program completely changed all participating households' behavior; households implemented nature-based solutions.	The program somewhat changed households' behavior; some participating households implemented nature-based solutions.	The program did not change households' behavior; no household implemented nature-based solutions.

Table 4. Sustainability Ranking Rationale for Technical Alternatives

Sub-criteria	High (++)	Medium (+-)	Low (--)
Resilience/ Adaptivity to Natural Disasters and Climate Change	The solution is highly adaptive to all-natural disasters or climate change adverse impacts.	The solution is resilient and adaptive to some but not all natural disasters or adverse climate events.	The solution is not at all resilient to natural disasters or adverse climate events.
Maintenance / Monitoring requirements	The solution does not require maintenance or monitoring.	The solution requires some level of maintenance or monitoring.	The solution requires continuous and rigorous maintenance and monitoring.

Table 5. Sustainability Ranking Rationale for Policy Alternatives

Sub-criteria	High (++)	Medium (+-)	Low (--)
Durability through political, social, and financial changes	The solution is highly durable to political, social, and financial changes.	The solution is durable to some level of political, social, and financial changes.	The solution stops working immediately if there is a minor political, social, and financial change.
Community integration likelihood	Communities can and will voluntarily integrate this solution.	Communities show a willingness to integrate this solution but cannot integrate the solution without adequate support.	Communities do not want to or cannot integrate programs/policies.

Table 6. Equity Ranking Rationale for Policy Alternatives

Sub-criteria	***Equitable***	***Not Equitable***
Is the program accessible by all, especially most disadvantaged/affected populations?	**Yes**	**No**
Does the program provide meaningful, usable benefits for participants	**Yes**	**No**

APPENDIX D.
Photos of Development Surrounding Study Area

Photo courtesy of Dr. Andrew MacKenzie, Australian National University

For a more resilient Vanuatu.

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Annex.
Detailed Assessment of Proposed Solutions

1. Technical Solution 1: Building Retention Ponds

***Description*:** This solution involves building a series of retention ponds surrounding the Emten Lagoon Area.

1.1. Operational Feasibility

Sub-criteria	Ranking Rationale	Ranking
Human resources	The construction and maintenance of retention ponds require skilled personnel in engineering and water management (*Operation and Maintenance of Stormwater Ponds - Minnesota Stormwater Manual*, n.d.). Currently, community organizations on the ground are willing to provide the human resources necessary to participate in the construction process. In an interview, a local community initiative group expressed that: *"[…] Communities themselves and community-initiative groups can [implement the solution], just with some training and support."*[1] At the government level, there are no designated human resources in the Department of Climate Change to engage in this solution's implementation process.[2] Projects like these would fall under the supervision of the Vanuatu Project Management Unit, where staffs are also already assigned to ongoing projects (*Vanuatu Project Management Unit: What We Do*, 2024). Thus, there are no targeted human resources for this project, but there are some availabilities in the government, NGOs, and community initiatives to take on this project.	**Medium (+-)**

[1] *Interview with Community Initiatives.*
[2] *Communication with Client.*

Technical knowledge and skills	Currently, the government is not focused on actualizing technical solutions themselves; rather, they are focused on policy formation and enforcement. There also lacks coordination across different government departments to engage in any infrastructure-focused solution. The government would also need to rely on NGOs and other external support channels for this project development. NGOs on the ground often also serve as the nexus between local needs and international experts and provide resources such as training and information session for local stakeholders, instead of having the specific technical skills themselves to implement a solutions.[3] Communities in their current capacity do not have the technical knowledge and skills necessary to implement this solution. They do not know about the solution at all and have never heard about it prior to communication related to this project. Any technical knowledge and skills for implementation would need to come from external training.[4]	**Low (--)**
Legislation	The Vanuatu National Plan 2016-2030 states the government's will and determination to develop Vanuatu's potential as a "world leader in blue-green growth and sustainable development" (*Vanuatu 2030*, n.d.), which indirectly supports the development of solutions to address climate change impacts like retention ponds. While environmental regulations and land-use planning for sustainable development legislation are available in Vanuatu in general as well as Port Vila, there are no specific stipulations related to retention ponds. This means there are no specific constraints, but there are also no specific regulations supporting the construction of retention ponds specifically. Compliance with Vanuatu's environmental regulations and land-use planning is achievable but requires coordination with local authorities.	**Medium (+-)**
Willingness	Communities show willingness to implement any solution to improve the current water quality issues surrounding the Lagoon.[5] The government has also shown support at strategic level. However, since this solution suggests an intervention rather on the larger-scale, it would be difficult	**Low (--)**

[3] *Communication with Client and Observation of NGO activities in Port Vila.*
[4] *Interview with Community Initiatives*
[5] *Interview with Community Initiatives*

	to gather government or NGOs buy-in due to the potential logistical challenges (e.g., bringing in experts, gather constructors, budgeting, etc.). Currently, there are many infrastructure projects near and around the Lagoon directly producing construction waste.[6] Since the construction of a series of retention ponds involves relatively long-term infrastructure development, might face local opposition because communities may assume that such constructions will lead to more waste, not less.	
Total Ranking		**Low (--)**

1.2. Financial Feasibility

Sub-criteria	**Ranking Rationale**	**Ranking**
Existence of funding resources	Funding would primarily come from the government budget and potentially international aid. The availability of funds and commitment to allocating resources will determine financial feasibility. Given its current lack of resources, funding a major infrastructural project like this series of retention ponds would be highly challenging for the Vanuatu government (*Vanuatu Infrastructure Strategic Investment Plan 2015 – 2024.* | *FAOLEX*, n.d.). Current funding for infrastructural investment from international organizations have also been targeted for on-going projects; therefore, it would be challenging to divert these funds towards building new retention ponds (*Vanuatu Infrastructure Strategic Investment Plan 2015 – 2024.* | *FAOLEX*, n.d.).	**Low (--)**
Willingness to fund	Both local and international stakeholders have expressed a commitment to funding sustainable environmental infrastructure projects. Both the Vanuatu 2030 –The People's Plan for National Sustainable Development and the Port Vila Greening Master Plan have demonstrated a commitment to invest in sustainable infrastructure projects (MacKenzie et al., 2022; *Vanuatu 2030*, n.d.). However, these documents remain high-level and strategic, and thus reasonably do not contain languages specifically mentioning the building of retention ponds. Similarly, over the past few years, the EU, the Green Climate Fund, and governments of Australia, Canada, and New Zealand have provided millions of dollars to invest in Vanuatu's infrastructure projects to specifically improve water quality and climate resilience	**Medium (-+)**

[6] Interview with Community Initiatives.

	(Green Climate Fund, 2016, 2022; IUCN, 2022). These organizations show willingness to fund nature-based solutions projects to enhance climate resilience in Vanuatu, but there has yet to be a specific mention of retention ponds in their funding announcements. In addition, the potential **costs** of implementing a series of retention ponds might pose a challenge in convincing relevant stakeholders. This solution is often implemented in big cities with many resources for sustainability infrastructure-development. For instance, Amsterdam spent $2 million dollar on a water retention project to prevent flooding through retention gardens and ponds (Wendland, 2020). They also require continuous maintenance, which would increase the implementation costs (Northwest, n.d.) and in turn decrease willingness to provide funding. Therefore, with the scope of impact of this solution at and around the Emten Lagoon, requiring major upfront funding and continued maintenance support would be challenging.	
Total Ranking		**Low (--)**

1.3. Effectiveness[7]

Pollutant reduction

According to reviewed literature, "measured bacteria removal efficiencies in sedimentation or wet retention ponds ranged from 15% to 20% (Krometis et al. 2009) to 56% and 86% (Mungasavalli and Viraraghavan 2006) to 42% to 99% (Clary et al. 2008). Literature review studies cite average sedimentation pond bacteria removal rates of 65% [...] (Schueler and Holland 2000) and 70% (Pennington et al. 2003)" (Tilman et al., 2011). Since there needs to be detailed designs and assessment of how many ponds to be built and where they will be built, we cannot provide an exact projection of pollutant reduction rate. At the initial phase, it is reasonable to assume that the ponds would have a modest impact on reducing water sediments coming to the Lagoon. Thus, this report will use the 15% - 20% range of effectiveness in pollutant reduction as the projected effectiveness measure.

Flow-through rates reduction

A study of a series of retention ponds in Arkansas, the United States found that they "decrease peak-flow runoff by about 15 percent" (Haggard & Scott, 2015). Another study found that "peak flows are reduced at a rate of 11.16–22.67%" (Abduljaleel et al., 2023). A study conducted in Fiji found that retention ponds, when combined with existing infrastructure, can further reduce flooding rates by 13% (Airlangga Mardjono, 2022). Even though there are many other studies on flow-through rates reduction, based on credible simulations provided by U.S.-based studies and the study in Fiji, which is similar to Vanuatu in the climate context, this report chooses to use 15% as the reference effectiveness measure.

[7] Note: The effectiveness of a solution in reducing pollutants and flow-through rate can be reasonably applied across different settings. Therefore, this section draws from effectiveness studies of similar technical solutions in different settings worldwide.

Technical Effectiveness Index for Retention Ponds = (0.7)x(20%) + (0.3)x(15%) = 0.185

1.4. Sustainability

Sub-criteria	**Ranking Rationale**	**Ranking**
Resilience/ Adaptivity to Natural Disasters and Climate Change	Resilience to natural disasters, particularly cyclones and storms, is moderately achievable with a well-designed system of retention ponds (Hogan & Walbridge, 2007). This is true for all retention pond systems, and since this is a technical solution, if implemented properly, retention ponds should also be relatively resilient to natural disasters in the Port Vila context. Retention ponds can provide water for irrigation and other subsistence activities, which can prove useful in helping residents adapt to climate change (Staccione et al., 2021). However, because of the infrastructural requirements, it is difficult to move or modify retention ponds to more optimal locations if necessary due to climate conditions. This is true to all retention ponds, including if they are constructed in the Emten Lagoon area.	**Medium (+-)**
Maintenance / Monitoring requirements	Retention ponds require frequent monitoring and maintenance (Northwest, n.d.). If left without maintaining, they can get clogged and might result in even worse water quality flowing into the Emten Lagoon catchment.	**Low (--)**
Total Ranking		**Low (--)**

2. Technical solution 2: Implementing a LID Plan

***Description*:**
This solution involves implementing a low-impact development plan, which involves constructing bio-retention basins/rain gardens and permeable pavements on the shore of the Emten Lagoon Area.

2.1. Operational Feasibility:

Sub-criteria	**Ranking Rationale**	**Ranking**
Human resources	To implement a LID plan, planners and implementers are required. NGOs and government department, especially the Department of Environmental Protection & Conservation, Department of Climate Change, and Department of Urban Affairs and Planning have experts who can develop a LID plan for Port Vila and the Emten Lagoon area specifically. However, a challenge is that since the water quality issue of the Lagoon lies under the jurisdiction of many government	**Medium (+-)**

	departments, none have taken the lead in solving this issue.[10] Thus, there are no staff designated for this project. In the implementation process, communities are essential. While community initiative groups are eager to implement any project necessary to help improve the water quality, they are limited as well in human resources for this specific project as they also have ongoing initiatives of their own. There are contractors available for the implementation of this solution, but they are not easily found in the local region.[11]	
Technical knowledge and skills	The LID techniques involved in this plan do not require high levels of technical knowledge and skills for implementation. During a discussion with local community initiative groups, they have confirmed that they have never heard of this solution. However, after describing the techniques involved, they expressed that they could implement rain gardens, vegetation gardens, and permeable pavements if provided training and financial support.[12]	**Medium (+-)**
Legislation	The adoption of LID plans aligns with existing policies, including the Vanuatu Infrastructure Strategic Investment Plan 2015 – 2024 and Vanuatu 2030 – the People's Plan (*Vanuatu 2030*, n.d.; *Vanuatu Infrastructure Strategic Investment Plan 2015 – 2024. | FAOLEX*, n.d.). However, to effectively implement this plan may require specific additional regulations regarding land use and green infrastructure. Coordination with local authorities for compliance is thus essential.	**Medium (+-)**
Willingness	The government of Port Vila has shown willingness to implement ecosystem-based adaptation plans, according to the Port Vila Urban Greening Master Plan (MacKenzie et al., 2022). Therefore, we can assume government support for a more specific plan to integrate green infrastructure into the Emten Lagoon area, which is an essential part of Port Vila experiencing pollution and in need of sustainable solutions. Community groups have also demonstrated that they would be cooperative in implementing green infrastructure listed under this solution.[13]	**Medium (+-)**
Total Ranking		**Medium (+-)**

2.2. Financial Feasibility

Sub-criteria	**Ranking Rationale**	**Ranking**
Existence of funding resources	Similar to retention ponds, LID plans are well-supported in strategic plans of the government and international organizations because the elements of the LID plan are green infrastructure. This is exemplified by the funding to design and implement the Port Vila Greening Master Plan by the European Union under the Intra-ACP GCCA+ Pacific Adaptation to Climate Change and Resilience Building (PACRES) Program (*Development of Port Vila Urban Greening Masterplan Underway | News | Dailypost.Vu*, n.d.). Therefore,	**Medium (+-)**

	even though there is no specific language to support a LID plan as of now, there are sources of funding to develop and implement a LID plan as the next step to implement the Port Vila Greening Master Plan.	
Willingness to fund	Both local and international stakeholders have expressed a commitment to funding sustainable initiatives involving green infrastructure in Vanuatu. Since 2018, Vanuatu has been receiving US $28 million dollars address its climate change issues. Similar to the retention ponds development, there have been funding announcements by the Green Climate Fund, the EU, and governments of Australia, Canada, and New Zealand to invest in Vanuatu's green infrastructure projects to specifically improve water quality and climate resilience (Green Climate Fund, 2016, 2022; IUCN, 2022). The difference between this solution and the construction of retention ponds is that this requires significantly less funding. To develop and implement LID plans require funding for a detailed design and planning process but does not require exorbitant funding. In this particular case, green infrastructure involved include rain gardens and permeable pavements, which cost significantly less to implement compared to retention ponds. Therefore, overall there is a high willingness and possibility of funding for LID plans for Port Vila.	**High (++)**
Total Ranking		**Medium (+-)**

2.3. Effectiveness[8]

Pollutant Reduction:
LID plans are highly effective in reducing pollutants in stormwater runoff. According to Ahiablame et al. (2012), "a large number of studies have credited bioretention as a best management practice capable of reducing [up to] 99 % of sediment and nutrient losses (e.g., Davis et al. 2006; Hunt et al. 2006; Dietz 2007; Line and Hunt 2009; Roy-Poirier et al. 2010; Table1)." Specifically, bio-retention basins or rain gardens have been shown to reduce 70% to 99% of bacteria, specifically improving E. Coli by 17%. Applying these findings to the Emten Lagoon context, this report assumes the lower-bound effectiveness measure in pollutant reduction of 70%. This means, 70% of pollutants in stormwater flowing through the retention basin would be kept in the basin. In addition, permeable pavements have been found to reduce E. Coli in stormwater flowing through them by 98-99% (Tota-Maharaj & Scholz, 2010).

Flow-through Rates Reduction:

[8] Note: The effectiveness of a solution in reducing pollutants and flow-through rate can be reasonably applied across different settings according to consultation with engineering experts. Therefore, this section draws from effectiveness studies of similar technical solutions in different settings worldwide.

LID plans, by design, reduce flow-through rates effectively. Bio-retention basins or rain gardens have been shown to reduce stormwater runoff volume by 40 % to 97 % according to studies conducted in Maryland and North Carolina (Ahiablame et al., 2012). Permeable pavements are effective in reducing 50% to 93% of runoff rates. Applying these findings to the Emten Lagoon context, this report assumes the lower-bound effectiveness measure in flow-through rates reduction of 40% for rain gardens and 50% for permeable pavements.

Therefore, the Technical Effectiveness Index can be calculated as follows:

Technical Effectiveness Index for Bio-retention Basins = (0.7)x(70%) + (0.3)x(40%) = 0.61
Technical Effectiveness Index for Permeable Pavements = (0.7)x(98%) + (0.3)x(50%) = 0.836
Total Technical Effectiveness Index = 0.836 + 0.61 = 1.446

2.4. Sustainability

Sub-criteria	**Ranking Rationale**	**Ranking**
Resilience/ Adaptivity to Natural Disasters and Climate Change	LID plans exhibit high sustainability. Green infrastructure components, if well-designed, can withstand natural disasters like cyclones and storms (OECD, 2018). The green infrastructure this report discusses, which includes rain gardens, vegetation gardens, permeable pavements, and/or revegetation/reforestation, are nature-based and can last indefinitely, especially if people continue to tend to them. Communities in Vanuatu have taken multiple initiatives to start and tend to nature-based solutions, such as planting hundreds of mangroves to protect soil and water resources.[9] Green infrastructure components can also serve multiple functions, enhancing water quality and potentially providing food and water resources for households, proving that they are adaptive to sustainability needs of local communities. Components of LID can also be moved if physical areas are impacted by climate change (Pour et al., 2020).	**High (++)**
Maintenance / Monitoring requirements	The green infrastructure involved in this LID plan would require maintenance and monitoring. Rain gardens require "weekly watering and weeding when the garden is first planted, followed by annual mulching, pruning, and replacing any dead or diseased plants. Rain gardens also should be inspected regularly for potential erosion problems and sediment accumulation" (*Maintaining a Rain Garden | Rhode Island Department of Environmental Management*, n.d.). Permeable pavements, on the other hand, do not require frequent maintenance (Antunes et al., 2018). Since these are	**Medium (+-)**

[9] Interview with Community Initiative.

	technical aspects of the solution, the same assessment can be made for similar solutions implemented in Vanuatu.	
Total Ranking		**High (++)**

3. Policy Solution 1: Incentive Program

***Description*:**
This solution involves designing and implementing an incentive program to encourage households in the Emten Lagoon area to implement nature-based solutions at the household level, which include rain gardens, vegetation gardens, green roofs, and reforestation/revegetation.

3.1. Operational feasibility:

Sub-criteria	**Ranking Rationale**	**Ranking**
Human resources	Since the program requires distributing financial incentives to households and follow up on incentivized behavior changes, there needs to be human resources for these two parts of the program implementation. EWB Vanuatu has conducted incentive programs in the past with the same scale, indicating that there are human resources necessary to implement this program.[10] In addition, community initiative groups at the Emten Lagoon area have expressed approval of the program and committed human resources in the implementation the program. They have also clarified that households would voluntarily take part in this project and directly engage with NGOs to access the program, which would reduce the need for human resources in the outreach process.[11]	**High (+-)**
Technical knowledge and skills	There is some technical knowledge and skills required for this public education campaign. To effectively implement the program, NGO staffs need to have the necessary skills to distribute incentives and monitor outcomes. Human resources involved also needs understand the local socioeconomic, cultural, and political context to engage with communities and promote the program.	**Medium (+-)**
Legislation	There is no specific legislation required to implement an incentive program in Port Vila or in Vanuatu in general. NGOs implementing this program would need to follow local rules and regulations to legally operate in the country.	**High (++)**

[10] Communication with Client.
[11] Interview with Community Initiative.

Willingness	In Vanuatu, the most successfully community programs are "locally-led"; thus, community willingness is the most important to consider in this solution (Westoby et al., 2020). Communities have repeatedly expressed that they need funding resources to support sustainable initiatives. Therefore, there is high willingness to adopt among community members and households. Government support is also shown through strategic plans as mentioned in the previous sections.	**High (++)**
Total Ranking		**High (++)**

3.2. Financial feasibility

Sub-criteria	**Ranking Rationale**	**Ranking**
Existence of funding resources	An incentive program is likely to attract funding from various sources, including government budgets and international aid. Currently, there are multiple international grants available among NGOs on the ground in Vanuatu that can provide incentives for adoption of more sustainable practices. For instance, Save the Children recently collaborated with the Green Climate Fund to initiate the Vanuatu Community-based Climate Resilience Project worth nearly USD 37 million, which "includes a GCF grant of over USD 26 million, with additional co-financing from the Governments of Vanuatu and Australia and Save the Children Australia" (Green Climate Fund, 2022b). This funding is going towards rehabilitating agricultural and polluted land by planting new vegetation to enhance climate resilience. Besides the Green Climate Fund, the EU and the Australian government have been continuously providing funding for small incentive-based programs to enhance resilience. Therefore, there are current funds available for this program.	**High (++)**
Willingness to fund	Given the financing history of international organizations in small island developing states like Vanuatu, many incentive programs have been funded and will continue to be funded here. International organizations are key funders and have repeatedly provided funding and shown a commitment to funding these projects, exemplified by the World Bank's 2020 Incentive Program Development Policy Grant aimed at designing and implementing incentive programs in developing countries. Hence, there is certain willingness to fund programs like this in Vanuatu.	**High (++)**
Total Ranking		**High (++)**

3.3. Effectiveness

Sub-criteria	**Ranking Rationale**	**Ranking**

Uptake	Given that the households in the region are in need of support for climate adaptation, uptake will be high (>70%) because the program's financial benefits.[12]	**High (++)**
Behavior change	Monetary incentives have been proven effective in changing targeted populations' behaviors (Nguyen-Van et al., 2021). In Vanuatu specifically, NGOs including EWB has conducted successful incentive programs in the past, leaving in many households with sanitary living standards. Therefore, we can expect similar results in this program.	**High (++)**
Total Ranking		**High (++)**

3.4. Sustainability

Sub-criteria	**Ranking Rationale**	**Ranking**
Durability through political, social, and financial changes	This program is not dependent on government funding, which enhances its durability through political changes. However, the success of the program is dependent on community support and financial resources provided by international organizations. In Vanuatu, while there are many resources for funding, there are also multiple funding targets. Therefore, the program may not receive funding for a long period of time given other competing needs in different communities other than the Lagoon (Nations, n.d.).	**Medium (+-)**
Community integration likelihood	Based on interviews with local stakeholders, it can be inferred that communities would be willing and able to integrate any type of solution that would improve the water quality in the Lagoon, especially if provided with a small incentive. They do understand that the water quality in the Lagoon directly affects their lifestyle and well-being. They have been integrating other solutions started by local initiative groups, including periodical garbage collection on and around the Lagoon. Therefore, if the solutions prove effective, it would be highly likely integrated into communities' daily activities.	**High (++)**
Total Ranking		**High (++)**

3.5. Equity

Given the suggested design of this program, households that are most affected by the worsening water quality would be prioritized for accessibility. Households that are interested in participating in the program would be able to access the program. In addition, these are communities that are historically racially and socio-economically disadvantaged. Allowing them

[12] Interview with Stakeholders.

access to this program prior to other populations further from the lake-shore ensures equitable access to the program. In addition, benefits provided in the form of financial incentives would significantly help households improve their quality of life by adopting sustainability practices (Federation, 2013).

4. Policy Solution 2: Public Education Campaign

***Description*:**
This solution involves implementing a public education campaign to encourage households in the Emten Lagoon area to implement sustainable behaviors in response to flooding.

4.1. Operational Feasibility:

Sub-criteria	Ranking Rationale	Ranking
Human resources	Implementing a public education campaign involves collaboration with NGOs and advocacy groups. High operational feasibility is attributed to existing local support. Advocacy groups, or community initiatives, have been voluntarily conducting public education campaigns to enhance citizen awareness of water quality issues and potential solutions. The Erakor Bridge Youth Association has been able to form a group of 70 people involved in door-to-door education and mobilization of households to engage in more sustainable activities to improve the water quality.[14] Therefore, local communities are a reliable source of human resources for this program.	**High (++)**
Technical knowledge and skills	There is some technical knowledge and skills required for this public education campaign. Since the campaign would mostly involve distributing information designed to target communities in the Emten Lagoon, human resources involved in this campaign needs understand (1) the local socioeconomic, cultural, and political context, and (2) the solutions being educated to the communities.	**Medium (+-)**
Legislation	Currently, there are not proper legislation regarding education campaigns yet, according to communications with the Department of Internal Affairs. However, NGOs and local community initiatives have already conducted public education campaigns of their own in the past, proving that this option is somewhat feasible (Nations, n.d.).	**Medium (+-)**
Willingness	Community initiatives show some willingness to continue with public education campaigns. Since they have been conducting education campaigns in the past, they have not shown commitment to a new campaign as of now.[15] The Departments have also shown willingness to continue educating the public through their ongoing education campaigns, therefore, it is uncertain whether they are willing to provide support for a new education campaign specific to the Lagoon area.	**Medium (+-)**
Total Ranking		**High (+-)**

4.2. Financial feasibility

Sub-criteria	Ranking Rationale	Ranking
Existence of funding resources	NGOs and advocacy groups have funding for public education campaigns within climate resilience and sustainability grants. Currently, there are funding opportunities from the Green Climate Find through Oxfam in Vanuatu and directly through the Climate Information Services for Resilient Development Planning in Vanuatu (Van-CIS-RDP) program (Fund, 2016; *Vanuatu NGO Climate Change Adaptation Program | Department of Economic and Social Affairs*, n.d.).	**High (++)**
Willingness to fund	The willingness to fund is assessed as medium given that a lot of community initiatives are already carrying out public education campaigns for very little to no cost. In a discussion with local communities, we learn that community initiative leaders have been going door-to-door and hosting information session to educate the locals on sustainability practices.[17] However, there are still multiple sources of funding available and international organizations such as the UNFCCC and the OECD are encouraging funding projects to raise awareness to climate change in small-island developing states (OECD, 2023; *Opening: Enhancing the Capacity of Small Island Developing States for Climate Action and Ambition | UNFCCC*, n.d.).	**Medium (+-)**
Total Ranking		**High (++)**

4.3. Effectiveness

Sub-criteria	Ranking Rationale	Ranking
Uptake	Given that the public education campaign is free-of-charge, there are no barriers to uptake. However, since public education campaigns have been quite abundant in the area, another public education campaign may not receive as much attention as expected.[13]	**Medium (+-)**
Behavior change	Community initiatives have reported low effectiveness of their public education campaigns regarding behavior changes. After their waste collection campaign, residents were still dumping trash directly into the catchment area. Therefore, the effectiveness to change behaviors are low. They provide great nudges for behavior changes but are weak in actually affecting change.	**Low (--)**
Total Ranking		**Low (--)**

4.4. Sustainability

Sub-criteria	Ranking Rationale	Ranking

[13] Interview with Stakeholders.

Durability through political, social, and financial changes	While not dependent on financial resources (because this option is relatively low-cost), as communities and the government change social or political priorities, public education campaigns may not be pursued over a long period of time. Given that sustainability is a big concern but not the only one Vanuatu faces, as the news cycle move, the priority to implement the education campaign may change. There have been many public education campaigns in the past by the Department of Climate Change, but these are often one-off events and long-term public education is often provided by community volunteers (*Vanuatu NGO Climate Change Adaptation Program | Department of Economic and Social Affairs*, n.d.; Westoby et al., 2020).	Medium (+-)
Community integration likelihood	In the past, in Port Vila especially, communities have experienced many public education campaigns. However, the integration of these campaigns into daily activities and behaviors is minimal; it is not expected that residents will take on the public education role. In addition, efforts to enhance public education through door-to-door outreach by community initiative groups in Vanuatu have been faced with ignorance and/or rejection.[14] Therefore, expecting community integration would be somewhat unrealistic.	**Low (--)**
Total Ranking		**Low (--)**

4.5. Equity

Because the public education campaign is open to all residents of Emten Lagoon, any households that are interested in learning about nature-based solutions and live in proximity of the Lagoon would be able to access the information provided by the campaign. The information would also come in various forms, ranging from posters to online information, making it easy for access for all. However, simply providing information does not mean that households have the adequate means to implement sustainability projects. Therefore, the benefits received for targeted communities in this case may not be as meaningful as financial or in-kind incentives. Overall, the program would be relatively equitable when implemented in the Lagoon area.

[14] Interview with Community Group.

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