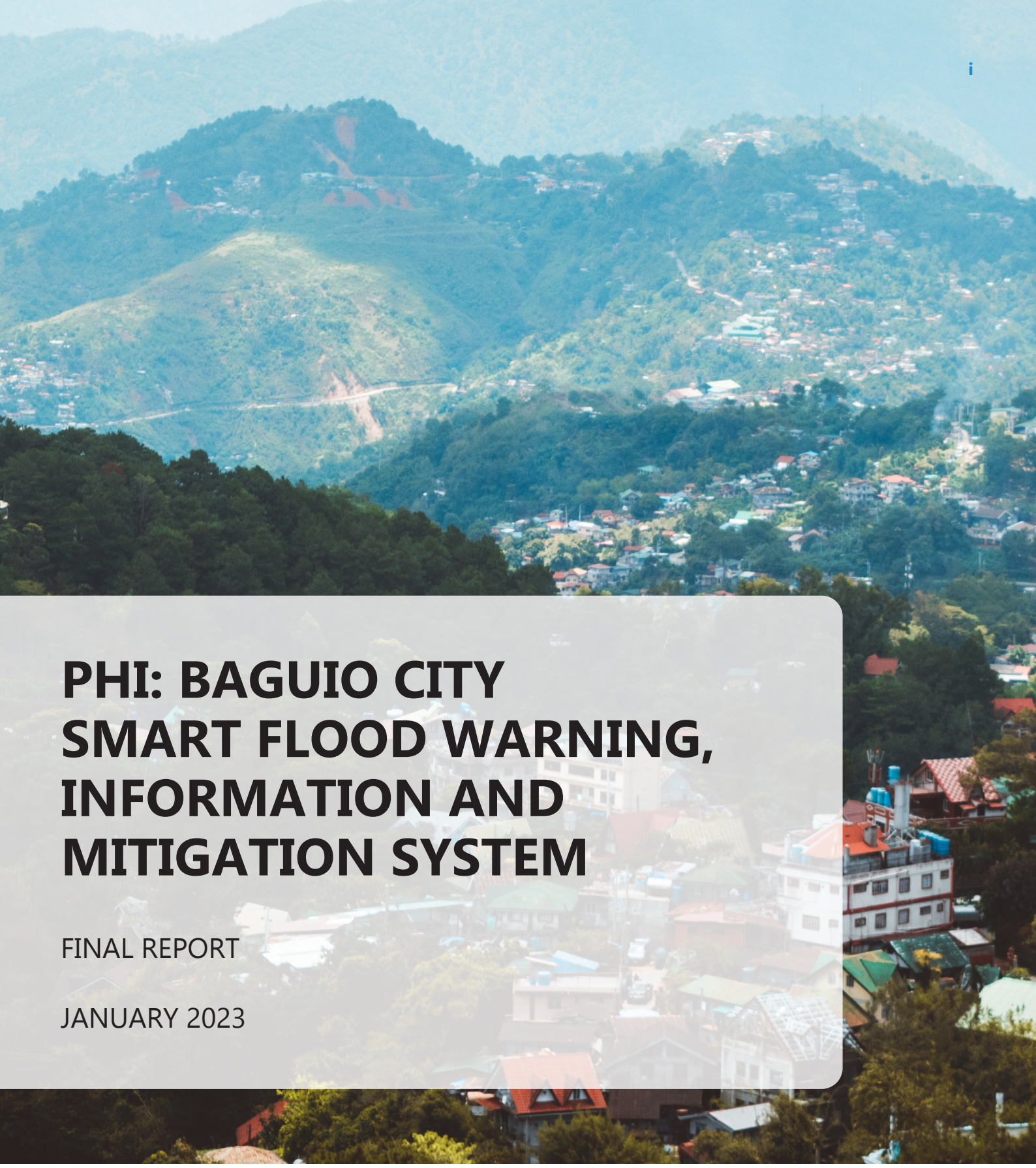

PHI: BAGUIO CITY SMART FLOOD WARNING, INFORMATION AND MITIGATION SYSTEM

FINAL REPORT

JANUARY 2023

ASEAN AUSTRALIA SMART CITIES TRUST FUND
Asian Development Bank

Australian Government
Department of Foreign Affairs and Trade

ADB

Source: Adobe Stock

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AASCTF	ASEAN Australia Smart Cities Trust Fund
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BDRRMC	Barangay Disaster Risk Reduction and Management Committee
CAR	Cordillera Administrative Region
CCA	Climate Change Adaptation
CDRRMC	City Disaster Risk Reduction and Management Council
CDRRMO	City Disaster Risk Reduction and Management Office
CEO	City Engineer's Office
CMC	Crisis Management Committee
CPDO	City Planning and Development Office
CSO	Civil Society Organisation
CSWDO	City Social Welfare and Development Office
D&O	Dissemination and Outreach
DDO	Data Dissemination and Outreach
DFAT	Department of Foreign Affairs and Trade (Australia)
DILG	Department of the Interior and Local Government
DOST	Department of Science and Technology (Philippines)
DOST-ASTI	DOST Advanced Science and Technology Institute
DOST-CAR	DOST Cordillera Administrative Region
DRR	Disaster Risk Reduction

DRRM	Disaster Risk Reduction and Management
EWS	Early Warning System
FEWS	Flood Early Warning System
GESI	Gender Equality and Social Inclusion
GIS	Geographic Information System
HSO	Health Services Office
ICT	Information and Communications Technology
LGBTQ+	Lesbian, Gay, Bisexual, Transsexual, Queer and other
LGU	Local Government Unit
LVO	Local Volunteer Observer
MITD	Management Information Technology Division
NDRRMA	National Disaster Risk Reduction and Management Authority
NDRRMC	National Disaster Risk Reduction and Management Council
NEDA	National Economic and Development Authority
OPCEN	Baguio City Emergency Operation Center
OTJ	On-the-job (Training)
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDAO	Persons with Disabilities Office
PIO	Public Information Office
SCCC	Smart City Command Center
SOP	Standard Operating Procedures

EXECUTIVE SUMMARY

The occurrence of flooding and landslides, both regular phenomena in Baguio City, threaten Baguio's sustained and long-term economic development. Baguio City is considered the "summer capital of the Philippines", attracting 1.8 million tourists in 2018, with an annual growth rate of ca. 16%. By being exposed and having a high vulnerability to climate hazards, combined with the expansion of impervious paved areas within the city and its surroundings, Baguio is experiencing increasing runoff volumes and flood damages. All these impacts are expected to be compounded by climate change, which will very likely cause an increase in the frequency and intensity of rainfall events and further exacerbate pluvial and fluvial flooding and rain-induced landslides.

In April 2019, the Asian Development Bank (ADB) approved the establishment of the ASEAN Australia Smart Cities Trust Fund (AASCTF or the Fund) under the Urban Financing Partnership Facility, with financing provided by the Government of Australia, through its Department of Foreign Affairs and Trade (DFAT).

The ADB, through the AASCTF, supported Baguio City in implementing the Smart Flood Early Warning, Information and Mitigation System project. The project assisted the city with both the planning for flood mitigation and the delivery of the services of flood early warning and responses, using smart technologies. The project outcome has been improved flood early warning system, responses, and mitigation measures of Baguio City. It had three outputs: (i) smart flood early warning information system (FEWS) established and operational; (ii) real-time data capture system established in four river basins in Baguio City; and (iii) flood mitigation action plan prepared.

This report is the Final Report of the Baguio City Smart Flood Warning, Information, and Mitigation System, and is the 10th report produced in the project. The report summarizes the project achievements, findings and outputs and presents recommendations for further activities to enhance long-term sustainability.

The FEWS has been developed with Baguio Local Government Unit (LGU) and other key stakeholders to improve community disaster preparedness, raise awareness, and ensure ownership. A highly technical, smart, and resilient IT framework to house the system has been established using MIKE OPERATIONS by DHI, a state-of-the-art software product for model-based forecasting. Although the FEWS has been fully installed at the LGU servers, it was not possible to complete online testing and operational acceptance during the 2022 monsoon with the key reasons being delays in obtaining data from stakeholder organizations, data quality issues, unforeseen delays in construction, installation and commissioning of real-time stations.

The focus on building capacities at local level has been a fundamental driver throughout the project. The 'Targeted Capacity Building Programme to Enhance Delivery of a Sustainable FEWS' was implemented in 2022, in an effort to further solidify and enhance program effectiveness and sustainability. A total of eleven (11) trainees from the LGU and local/regional public institutions completed the program and form the FEWS O&M team, who will be in charge of operating and maintaining the FEWS. The 3-module Capacity Building Program was led by DHI and supported by Ramboll, focusing on giving the trainees a general understanding of Flood Early Warning Systems and training in the different types of DHI software used in the FEWS for Baguio.

Following the completion of the pilot project, it is recommended to initiate a project consolidation phase to ensure long-term sustainability of the FEWS. In the proposed consolidation phase, the necessary finetuning, troubleshooting, testing and feedback loops will be executed and the capacities within the established FEWS O&M team will continue to increase through on-the-job training and implementation of standard operating procedures. The overall purpose of the consolidation phase is for the FEWS O&M group to be fully ready to launch the system publicly and operate it independently utilizing the FEWS as an active risk mitigation instrument for Baguio City.

1. INTRODUCTION

Source: Ramboll

1.1 ASEAN AUSTRALIA SMART CITIES TRUST FUND PROGRAMME

In April 2019, the Asian Development Bank (ADB) approved the establishment of the ASEAN Australia Smart Cities Trust Fund (AASCTF or the Fund) under the Urban Financing Partnership Facility, with financing provided by the Government of Australia, through its Department of Foreign Affairs and Trade (DFAT). The Fund's envisioned impact aligns with ADB's Strategy 2030, as well as ASEAN's Sustainable Urbanization Strategy which aims to promote high quality of life, competitive economies, and sustainable environments. The expected outcome of the Fund will be that through the adaptation and adoption of digital solutions, across three core functional areas (planning systems, service delivery and financial management), systems and governance in participating ASEAN cities are improved, in particular by way of:

- Strengthening city planning processes by enhancing the collection, storage, analysis and utilization of data on geospatial platforms.
- Promoting the use of integrated and smart network management systems to strengthen operational systems and to improve quality and efficiency of service delivery.
- Introducing integrated financial management information systems to improve institutional credit worthiness and fiscal standing.

AASCTF acts as a mechanism for facilitating and channeling resources and financing for eligible projects, as well as activities agreed between DFAT and ADB for project preparation, implementation, and capacity development.

1.2 PROJECT RATIONALE

The occurrence of flooding and landslides, both regular phenomena in Baguio City, threaten Baguio's sustained and long-term economic development. Baguio City is considered the "summer capital of the Philippines", attracting 1.8 million tourists in 2018, with an annual growth rate of ca. 16%. In 2009, Baguio was significantly impacted by Typhoons Ondoy and Pepeng, resulting in more than 3,000 people being affected by flooding, and almost 2,500 people being affected by landslides. Japanese researchers from the International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO have concluded that the underlying causes behind the 2009 flooding were related to a limited drainage capacity due to obstructions caused by the accumulation of waste, and also by the presence of built-up structures (urban sprawl). In addition, the presence of informal settlers in flood prone areas worsens Baguio's exposure and vulnerability towards flood disasters.

By being exposed and having a high vulnerability to climate hazards, combined with the expansion of impervious paved areas within the city and its surroundings, Baguio is experiencing increasing runoff volumes and flood damages. All these impacts are expected to be compounded by climate change, which will very likely cause an increase in the frequency and intensity of rainfall events and further exacerbate flooding events and rain-induced landslides.

The ADB, through the AASCTF, supported Baguio City in implementing the Smart Flood Early Warning, Information and Mitigation System project. The project assisted the city with both the planning for flood mitigation and the delivery of the services of flood early warning and responses, using smart technologies. The project outcome has been improved flood early warning system, responses, and mitigation measures of Baguio City. It had three outputs: (i) smart flood early warning information system (FEWS) established and operational; (ii) real-time data capture system established in four river basins in Baguio City; and (iii) flood mitigation action plan prepared.

The FEWS has been developed with Baguio Local Government Unit (LGU) and other key stakeholders to improve community disaster preparedness, raise awareness, and ensure ownership. The FEWS is also set to become an integral element within the overall vision of Baguio City to become a truly resilient, dynamic, and smart city.

1.3 REPORT STRUCTURE

This report is the Final Report of the Baguio City Smart Flood Warning, Information, and Mitigation System, and is the 10th report produced in the project. The report summarizes the project achievements, findings and outputs and presents recommendations for further activities to enhance long-term sustainability.

The first chapter gives an overall introduction to AASCTF and the background of the project. The second chapter presents the project approach and timeline, as well as the various stakeholders and partners essential to the establishing and ensuring the sustainability of the FEWS and flood mitigation activities. Chapters 3 to 9 presents the key outcomes of the project, following the deliverables produced since the kick-off:

- Chapter 3 concerns the Baseline Assessment Report[1]
- Chapter 4 concerns the Hydraulic Modelling, Hazard and Risk Mapping Report[2]
- Chapter 5 concerns the Flood Mitigation Action Plan[3]
- Chapter 6 concerns the Targeted Capacity Building and Training Program reports[4,5,6,7]
- Chapter 7 concerns the Gender and Social Inclusion reports[8,9,10]
- Chapter 8 concerns the The FEWS Design Report[11]
- Chapter 9 concerns the Data Dissemination and Outreach Plan[12]

Chapter 10 provides a conclusion of the entire Baguio City Smart Flood Warning, Information and Mitigation System project, while chapter 11 presents recommendations for future activities and the need for a further consolidation phase of the project.

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1 Baseline Assessment Report Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, January 2021.
2 Hydraulic Modelling, Hazard and Risk Mapping Assessment Report Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, July 2021.
3 Flood Mitigation Action Plan Report Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, December 2021.
4 Scoping And Training Course Design Report. Targeted Capacity Building Program. Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, April 2022.
5 Module 1 Course Evaluation Report. Targeted Capacity Building Program. Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, June 2022.
6 Module 2 Course Evaluation Report. Targeted Capacity Building Program. Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, June 2022.
7 Module 3 Course Evaluation Report. Targeted Capacity Building Program. Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, December 2022.
8 Mixed Methods Gender and Inclusion Study Report. PHI: Gender Transformative Approach for Strengthened Development, Application, and Replication of the Baguio City Smart Flood Early Warning. AASCTF. August 2021.
9 Policy and Practice Recommendations: Towards a Gender Transformative Flood Early Warning System in Baguio City PHI: Gender Transformative Approach for Strengthened Development, Application, and Replication of the Baguio City Smart Flood Early Warning. AASCTF. September 2021
10 From Policy Recommendations to Practical Actions: Towards Gender Transformative Practices for Baguio City's Flood Early Warning System,AASCTF. 2021.
11 Flood Early Warning System Report Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, April 2022.
12 Data Dissemination and Outreach Plan, Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, December 2022.

2. OVERALL PROJECT APPROACH

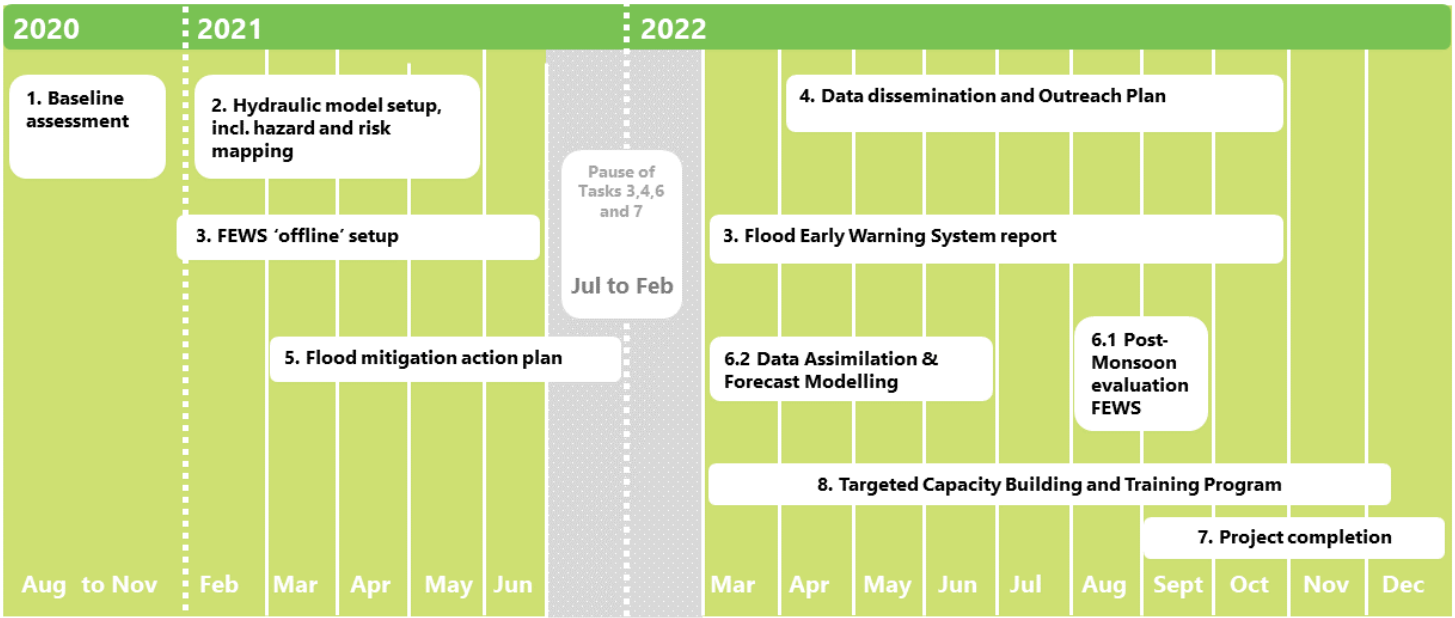
Source: Adobe Stock

2.1 PROJECT APPROACH

The overall approach followed in producing this project's three outputs (outlined in section 1.2) is to breakdown the project into working tasks, with each task containing key activities, and where inter-dependencies between tasks/activities are accounted for by defining milestones and keeping close contact with the project's working group. The overall project tasks and associated key activities and deliverables are shown in Table 1.

The project timeline is shown in Figure 1 below.

Figure 1: Project timeline



Source: Ramboll

Table 1: Activities and deliverables for Baguio City Smart Flood Warning, Information and Mitigation System.

Task	KEY ACTIVITIES AND DELIVERABLES
Task 1 – Baseline Assessment	• Setup working group, conduct scope consultations, revise workplan • Data and Information Collection • Establish baseline on climate change data and information • Plan the on-the-job (OTJ) training component • **D1: Baseline Assessment Report** (delivered January 2021)
Task 2 – Hydraulic model setup, including hazard and risk mapping	• Collect additional data, if needed, including river surveys • Confirm boundary conditions and target design levels for the hydraulic model and for inclusion of potential nature-based solutions (NbS) • Develop hydrologic model for all 4 rivers • Develop hydraulic model for the primary drainage system, incl. calibration • Hazard and Risk Assessment • OTJ training • **D2: Hydraulic Model and Hazard and Risk Mapping Assessment Report** (delivered August 2021)
Task 3 – Design of a Flood Early Warning System (FEWS)	• Planning the framework of the FEWS • Procuring and installing measurement devices in selected locations for pilot river (Balili) • Development of the pilot river real-time data acquisition system • Design the data storage and management system • Overall forecast system framework (database) • Setting up of FEWS at the LGU, and start of the real-time online simulations, before the monsoon • OTJ training • **D3.1: FEWS offline setup** (delivered September 2021) • **D3.2: Flood Early Warning System report** (delivered December 2022)
Task 4 – Data dissemination and outreach plan	• Design dissemination and outreach activities, including: Website/Dashboard, web applications – SMS alerts, mobile apps, e-mail chimps, etc. • Define dissemination roles and responsibilities among key stakeholders • Development and dissemination of FEWS O&M plan. Maintenance will be undertaken during the monsoon period (documented in D3.2) • OTJ training (documented in D3.2) • **D4: Data Dissemination and Outreach Plan** (delivered December 2022)
Task 5 – Flood Mitigation Action Plan	• Review and gap analysis of urban drainage data, including recommendations for actions. • Finalization of review of drainage data, documents, and guidelines for drainage infrastructure, initiated in task 2. • Development of multifunctional NbS typology toolbox, including key enabling criteria for implementation of typologies. • Demonstrate applicability and benefits of NbS typologies for 3 pilot-sites, including preliminary site-specific hydraulic calculations. • OTJ training • **D5: Flood Mitigation Action Plan** (delivered December 2021)
Task 6 – Replication of real-time data capture, and Monitoring & Evaluation[a]	• Procuring and installing measurement devices in the remaining three rivers • Evaluation of the FEWS (post-monsoon period) • Finalize data assimilation and forecast modelling • System Performance Assessment • OTJ training
Task 7 – Project completion	• Wrapping up everything • **D6: Final Report (this report)**

Task 8 – Targeted Capacity Building Programme to Enhance Delivery of a Sustainable FEWS	• Implementation of 3-module Targeted Capacity Building Programme led by DHI and supported by Ramboll
	• E-Learning Platform with course material and training videos
	  • **D2.5A: Scoping & Training Course Design Report** (delivered April 2022)
	  • **D2.5B: Module 1 and Module 2 Course Evaluation Reports** (delivered August 2022)
	  • **D2.5C: Module 3 Course Evaluation Report** (delivered December 2022)

[a] it was not possible to complete testing and operational acceptance in 2022 due to data quality issues, delays in obtaining data, construction and installation of real-time stations. Task 6 will be finalized in the planned consolidation phase (see Chapter 11: Recommendations).

2.3 WORKSHOPS

To ensure effective information flow between LGU and the project team, regular weekly check-in meetings were scheduled. Both sides could use the meetings to be informed on current work and get quick feedback or answers to pressing questions.

When feedback was needed from other stakeholders or for reporting on bigger project milestones, several workshops were scheduled. This way, ADB, LGU, and relevant local stakeholders were kept in the loop regularly and could provide invaluable input to the project team.

In addition to the workshops with LGU and ADB, a number of task-specific workshops were organised with relevant stakeholders to gather more in-depth feedback. These often involved group activities to facilitate discussions and transfer knowledge in an engaging manner. In-person workshops were preferred, as it was noted that engagement is much higher in face-to-face activities, while informal discussions during breaks help build rapport within the team. If fully in-person meetings were impossible due to travel restrictions, the workshops were organised in a hybrid manner (e.g. with local stakeholders meeting at the CDRRMO and others joining online).

Figure 2 shows an example of a hybrid workshop setup during the Final Workshop held in on 29 November 2022. Table 2 provides an overview of key workshops and their main objectives.

Figure 2: Picture taken during the Final Workshop, November 2022.
Source: Ramboll

Table 2: Overview of key workshop held during the project

Date	Title/main topic of the workshop
September 2020	**Kick-off meeting** • Introduce overall project objectives, expected outputs and project's approach • Present and discuss overall workplan • Present high-priority activities for the project initiation phase
December 2020	**Baseline Assessment Workshop** • Create a common understanding of this project's scope, objectives and main tasks • Obtain feedback from participants on the key highlights from the *Baseline Assessment Report* • Discuss the main gaps identified and commonly identify ways to address them • Align expectations as to the upcoming tasks and activities
June 2021	**Hydraulic Modelling and Risk Assessment Workshop** • Present the findings on Climate Change assessment, Hydraulic Modelling, Landslide Assessment, Risk Assessment • obtain feedback from the participants • Providing inspiration as to how state-of-the-art modelling tools and risk assessment methods can help increase resilience to climate risks through a holistic climate adaptation planning process • Discuss next steps, updated timeline and status update on ongoing activities
November 2021	**Flood Mitigation Action Plan Workshop** • Create an understanding of Nature-Based Solutions (NbS) and their benefits • Presentation and discussion of flood mitigation action plan work process • Gathering feedback on current findings, NbStoolbox development, and pilot sites
March 2022	**Capacity Building Workshop - Kick-off** • Kick-off the capacity building program • Meeting team members and participants • Overview of program workplan and activities
July 2022	**Capacity Building Workshop - Midway Evaluation** • Share experiences and impressions from Module 1 and Module 2 • Present the outcomes of the self-assessment survey and assess program effectiveness • Gather feedback on the format and content of the training modules to align expectations and shape the upcoming capacity building activities
November 2022	**Capacity Building Workshop - Final Evaluation** • Share experiences from participating in the Capacity Building Program • Present the Module 3 evaluation and feedback • Present the outcomes of the self-assessment survey and assess program effectiveness • Gather suggestions for additional capacity and training sessions needed
June 2022	**Data Dissemination and Outreach Workshop** • Present overview, current findings and outputs of the Baguio FEWS project • Validate findings and obtain feedback from participants on data dissemination and outreach approaches • Identify needs on FEWS data dissemination and outreach outputs, and identify ways to address them • Align expectations on upcoming tasks and activities
November 2022	**Final Workshop** • Present the overall Baguio FEWS project achievements, findings, and outputs • Obtain feedback from key project stakeholders on the relevance of the projects' key outputs • Align expectations to the Baguio FEWS

Source: Ramboll

2.5 COLLABORATION AND PARTNERS

Strong stakeholder partnerships are essential in ensuring success and sustainability of the FEWS. Collaboration, stakeholder engagement and partnerships have been a key priority throughout the project to ensure a strong foundation for local ownership and alignment to local governance and institutional structures. The FEWS project team has formed a relationship with the LGU based on mutual trust and understanding. The FEWS project team's visits to Baguio further strengthened the sense of team spirit and co-creation, and the team collaboration and motivation is high.

Through stakeholder partnerships with public and private organizations as well as academia, the LGU can gain knowledge, experience and innovation improving the overall impact and usefulness of the FEWS for the City of Baguio. These partnerships provide two-way benefits, where the partnering organizations gain access to the data and outputs from the FEWS. By collaborating with the LGU on the FEWS the partnering organizations can demonstrate their support and commitment to protecting the citizens of Baguio by ensuring timely and inclusive flood warnings.

Figure 3: Logos of partner organisations.
From top left: Baguio City LGU, ADB, DFAT, DOST, Dost-PAGASA, DOST-ASTI, Tuba LGU, La Trinidad LGU, NEDA, Department of Public Works and Highways (Baguio City District Engineering Office), Saint Louis University, University of the Cordilleras, OCD Region-CAR, Baguio City DILG, Philippine Air Force, Philippine Navy, Philippine Army, University of Baguio, University of the Philippines, Philippine Red Cross, PLTD, DHI, Rasa Surveying Company, Ifubeng, Alexan, Practical Action Consulting, REECS.

3. BASELINE ASSESSMENT

Source: Nathaniel Sison, Unsplash

3.1 OBJECTIVES AND APPROACH

The *Baseline Assessment Report*[13] was the first report to be produced in this project and documented the initial work in the first 3 months the project kick-off meeting in Baguio. The intended audience covered all key stakeholders forming the project working group. The report aimed at answering the following questions:

- What is the current situation in Baguio with regard to the main project components, i.e. climate change assessment, hazard mapping, FEWS, etc.?
- Which data and information are available to support the implementation of the project tasks and activities?
- Is the quality of that data sufficient to support this project?
- What are the data and information gaps that could impact the overall project results, and which actions can or will be taken to fill those gaps?

The report described the key project initiation tasks since project kick-off, including the Baseline Assessment Workshop, and presented the data and information collection process, including a review of key local reports and plans. It provided an overview of the climate change baseline assessment and associated main gaps. The project area and overall framework of the FEWS were introduced, followed by a hazard and risk mapping framework and the main gaps identified. Thus, the report mapped the baseline for the project and presented the recommended approach to close data gaps and the project framework for the outlined activities.

13 Footnote 1

A number of different local reports, studies and datasets have been collected and reviewed with the purpose of gaining a deep understanding of the local knowledge, constraints and possibilities in key specific areas related to the purposes of this project. This process has followed a tailored methodology (briefly explained below), focusing on the collection and assessment of technical and non-technical data and information.

3.1 METHODOLOGY FOR DATA COLLECTION AND REVIEW

This project applies a data management strategy that enables stakeholders/project members to work in a cohesive and streamlined way. While the majority of the data collected is GIS-data, i.e. data with a spatial (and sometimes temporal) dimension, some other non-spatial data has also been collected. For this reason, the process has from the outset followed an iterative approach whereby identification of knowledge/ information gaps can be done through a technique called Front Loading. This involved:

1. Identifying the data/information needed to reach the project objectives;
2. Collecting the data/information from official sources and categorizing it through primary and secondary filters. For this, a data and information registry has been created and is continuously been updated as more data is collected;
3. Assessing the data by corresponding technical international and national experts;
4. Creating a GIS inventory for all GIS-data, which is effectively a spatial database supporting production of maps. More details are given in section 3.2.;
5. Identifying data and information gaps; and
6. Defining the actions to fill the gap

The data and information registry allows proper data tracing and is updated regularly as the knowledge base of this project is expanded and fine-tuned with time. This registry could become an important tool for the LGU, as it is linked to many urban disciplines and important planning mechanisms within Baguio City.

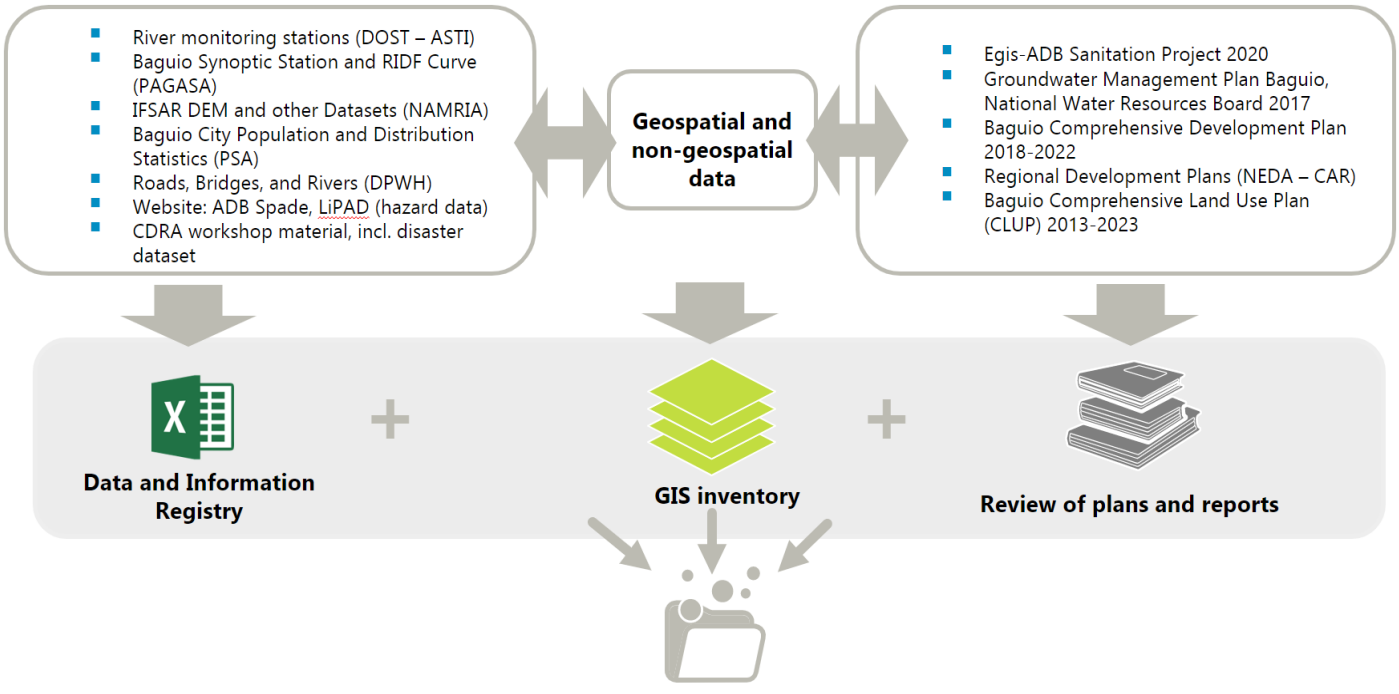


Figure 4: Collection of data (non-exhaustive list)
Source: Ramboll

3.2 DATA COLLECTION AND GIS INVENTORY

The bulk of data collected comes from the following sources:

- PHL: Baguio City Sanitation Improvement Project, Egis-ADB 2020
- Local Government Unit (LGU) of Baguio
- Websites: ADB Spade, LiPAD (hazard data)
- DOST – ASTI Philsensors (Water Level and Rainfall)
- PAGASA – Baguio Synoptic Station and RIDF Curve
- NAMRIA – IFSAR DEM and other Datasets
- PSA – Baguio City Population and Distribution Statistics
- DPWH – Roads, Bridges, and Rivers
- NEDA – CAR Regional Development Plans

The GIS inventory contains information on types of data (shape/raster, or any other format), as well as key descriptions and source information (and metadata, if relevant). The inventory also applies a naming convention for all the data and maps produced, so that local stakeholders can always trace back the maps and corresponding data upon completion of the project.

Table 3: Excerpt from the GIS inventory. The full table can be found Appendix B of the Baseline Assessment Report

Theme-File/Layer Name	Format	Description	Status	Collected From
BAG_FldHazAringayBauangRB_LiPAD	Shapefile	Hazard map downloaded from LiPAD website for 5 years, 25 years and 100 years to download	Original	DOST-UP Phil-LiDAR 1 and 2 programs
PH_BAG_HYDRO_RiverSystem_v1	Shapefile	River network: Basa Creek, Galiano river, Timber Creek, Ambalanga River, Bued River, Balili River, Elew River	Original	Collected From EGIS
BAG_HYDRO_Watercourse_v2	Shapefile	Water way data from OSM	Original	Collected From EGIS Sources: OSM

Source: Ramboll

Additionally, several local plans and reports have been reviewed with the purpose to properly understand the knowledge baseline in Baguio. Each report or plan was reviewed in terms of the type of information and the contextual support it could provide for the purposes of this project. This includes an assessment of GIS information and datasets; socio-economics; hydrology & hydraulics; hazard and risk assessments; climate change; and disaster risk reduction (DRR). The full list of reports reviewed can be found in Appendix F of the *Baseline Assessment Report*[14].

14 Baseline Assessment Report Appendix Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, January 2021.

3.3 GAPS IDENTIFIED

Through an assessment of the available data and information on drainage infrastructure in Baguio, documented in the technical note *Urban Drainage Modelling Assessment in Baguio, dated 10 September 2021*[15], significant gaps in available data were confirmed. These gaps include, among others, unknown dimensions and invert levels for drainage infrastructure, disconnected infrastructure detached from the main drainage network, unknown size and shapes of inlets, and unknown structural conditions of the drainage network. To close the gaps, extensive field surveys will be required, which were hampered during the project by the Covid-19 pandemic, and would also take much longer time than what was possible to accommodate in this project.

Six main gaps have been identified through this assessment: i) lack of river bathymetry data; ii) lack of additional water level station at Mamat-ing Bridge in La-Union; iii) lack of gauging stations on the River Ambalanga; iv) lack of discharge station data within the project area; v) absence of data on urban drainage system; vi) lack of data or information regarding existing hydrological or/and hydraulic models.
A summary of all data and information gaps can be found in the *Baseline Assessment Report*, as well as in the *Hydraulic Modelling, Hazard and Risk Mapping Report*[16].

Table 4: Main gaps identified in the baseline assessment and corresponding mitigating actions undertaken in this task

Topic	Gap	Action
Data (GIS and non-GIS)	• Key data missing to be collected, or pending further clarification (e.g., critical/social infrastructure; public transportation; land use, etc.)	• The project team has collected and analyzed available data from OSM and consulted with the LGU in regard to validity and quality. Data is reported in detail in the following sections.
Climate Change	• Climate factors (or design safety factors) • Analysis of uncertainty bounds • Unclear trend analysis	• The project team has discussed extensively with PAGASA regarding IDF information, climate factors and other key climate-related issues.
Hydrology/ Hydraulics	• Location of river inlets and outlets • No available river cross-sections (bathymetry data) • Data request for an additional station, Mamat-ing Bridge in La-Union • Discharge data within the FEWS project area is missing. • No gauging stations have been identified on the River Ambalanga • Urban drainage data not collected yet	• The project team has undertaken a river survey in the pre-monsoon period of 2021, covering more than 60 locations, incl. six river gauging stations and all four rivers in Baguio. • The project team has also developed a scope of works for the installation of several extra water-level monitoring stations • Data from the Mamat-ing Bridge has now been collected and assessed. • The project team is leading a process, in close consultation with the LGU, regarding the mapping of the primary drainage infrastructure in Baguio.

Source: Ramboll

15 *Urban Drainage Modelling Assessment in Baguio. Technical Note.* Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, *10 September 2021*

16 *Footnote 2*

3.4 DATA ASSESSMENTS

Based on the geospatial and non-geospatial data collected, a number of data assessments have been performed in order to create an overview of the local setting, including topography and land use; transport network and infrastructure; demographics (population density, poverty, informal settlements); areas susceptible to flooding, landslides, and sinkholes. These were combined to assess the vulnerability of barangays, and were used in furthers steps of the project to form the flood hazard assessment.

Full versions and descriptions of the map thumbnails presented in Figure 5 can be found in the *Baseline Assessment Report*. The flood hazard maps can be seen in section 4.2.3 of this report as well as in the *Hydraulic Modelling, Hazard and Risk Mapping Report*.

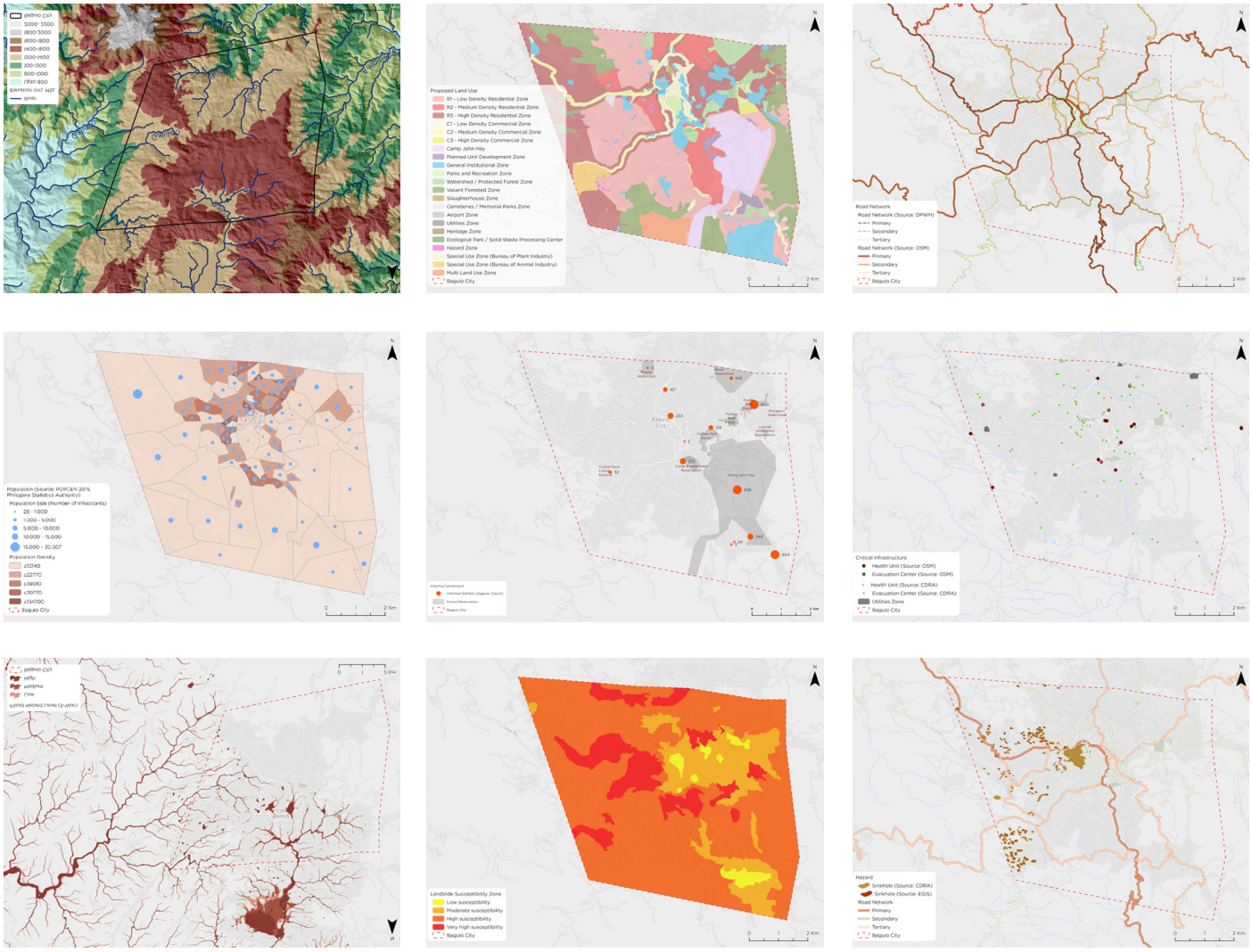


Figure 5: Thumbnails of selected maps presented in the Baseline Assessment Report: Local Settings. From top left: topography, land use, existing road network, population density, location of informal settlements, critical infrastructure include utilities, health units and evacuation centres, 5-year flood hazard map, landslide susceptibility zones, location of sinkholes in Baguio City.

Source: Ramboll

3.5 CLIMATE CHANGE BASELINE

To provide recommendations on climate change adaptation measures it is important to understand both the present climate in the city of Baguio and the main climate hazards that the city is facing today. The overall assessment of climate change is initiated by an evaluation of current indications of a changing climate. This evaluation focuses on precipitation and temperature using available long-term records and is followed by a description of the projected future changed.

In the development of a flood mitigation action plan this project outlined different climate change adaptation measures, and illustrated their effect using hydraulic simulations. These types of simulations require a high-resolution rainfall input generated from observed rainfall statistics. The uncertainty of the future climate and/or large natural variability have been accounted for in the conceptual design by including safety factors. The method for generating synthetic design storm is outlined in Appendix C of the *Baseline Assessment Report*, together with suggested steps for determining appropriate safety factors.

A wide number of different sources have been revised to properly assess the climate change baseline in Baguio. Appendix C of the *Baseline Assessment Report* contains an exhaustive list of sources.

Through a statistical analysis of observed extreme rainfall values and an estimation of extreme rainfall events for future conditions, the study recommends applying a 'safety' factor to rainfall design intensities of 25% to estimate future rainfall. The safety factor considers the present and future uncertainty of design rainfall events, independent of return periods, and has been used in the hydraulic modelling undertaken in this report when simulating future climate change scenarios.

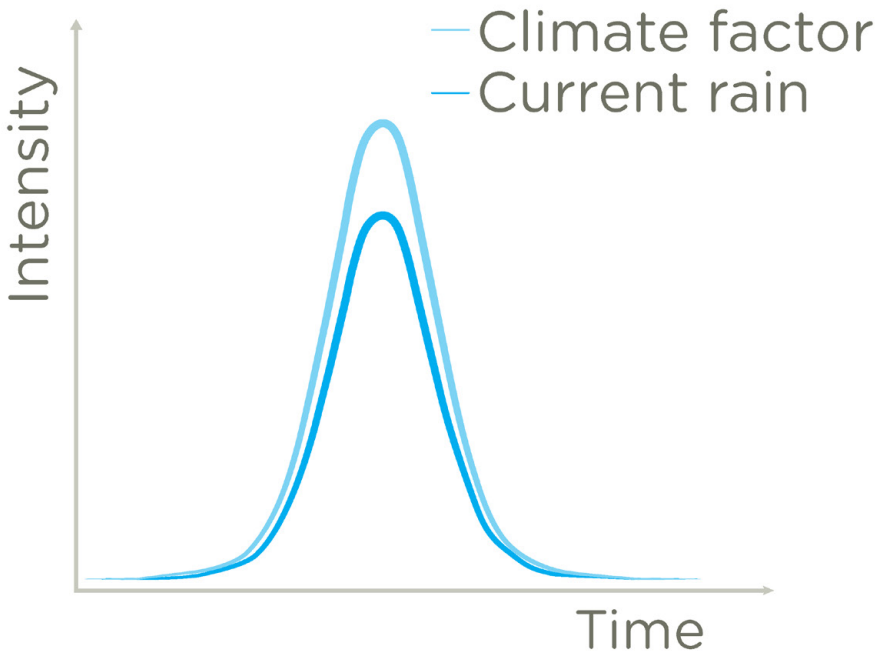


Figure 6: Conceptual visualization of the impact a climate factor on rainfall.
A climate factor of 1.0 indicates no change in future rainfall and a climate factor of 1.25 indicates 25 % increase in future rainfall, and a climate factor of 1.5 indicates 50% increase in future rainfall.
Source: Ramboll

Source: Adobe Stock

4. HYDRAULIC MODELLING, HAZARD AND RISK MAPPING

Source: Asian Development Bank

4.1 OBJECTIVES AND APPROACH

Mapping hazards and risks is an essential step in building business cases for informed decision-making when creating a resilient and smart city. By mapping hazards and risks from flooding and landslides in Baguio City, pilot areas for mitigation actions can be identified and information of priority areas can improve the effects of the FEWS.

One of the primary outcomes of Task 2, *Hydraulic Model and Hazard and Risk Mapping Assessment Report*[17] was an evaluation of historical flooding and a flood risk assessment. Comprehensive hydrodynamic flood modelling for Baguio was undertaken, resulting in several flood hazard and risk maps for eight modelling scenarios including four different return periods (3, 10, 20 and 50 years). The results were validated by local stakeholders and historical knowledge confirming that areas identified as particularly exposed to floods are indeed experiencing flooding on a regular basis.

Key findings from this assessment were:

- Damaging floods occur regularly with significant impacts
- Over a longer period of time, frequent but less intense rain events will lead to more damage compared to rare and more intense rain events
- The flood risk is found to be highest in the Balili catchment, the main drainage catchment in Baguio, flowing north-west. Flood hazard maps show that many houses, alleys, and roads are exposed to flooding.
- At Barangay level, Barangays with high percentage of flooded area (above 10 cm flood depth) for a 3-year present rainfall event were identified.

While the Baseline Assessment Report focused on mapping the baseline in Baguio in regards to climate hazards, data and information gaps and FEWS outline, the *Hydraulic Model and Hazard and Risk Mapping Assessment* goes deeper into very technical themes necessary to address in depth to be able to support the development of the two main technical components in the project: the FEWS and the *Flood Mitigation Action Plan*.

17 Footnote 2.

4.2 HYDROLOGICAL AND HYDRODYNAMIC MODELLING

4.2.1 MODELLING FRAMEWORK AND SCENARIOS

The modelling approach is primarily based on capturing surface flows, as represented in the Digital Elevation Model (DEM), which was documented in the *Baseline Assessment Report*. While this approach disregards existing underground drainage infrastructure, it is sufficient to map areas that are particularly exposed to flooding, assuming that the drainage infrastructure is blocked. The key drainage path for the more densely built up areas of Baguio is identified as Balili river, hence this is modelled separately in a one-dimensional river flow model based on surveyed cross-sections.

To capture the flooding scenarios in Baguio City, a combination of dynamic 1D and 2D models are prepared with different levels of detail and spatial extents, both to simulate scenarios for the flood risk assessment, and as the foundation for further development in the following stages of the project.

Modelling scenarios were selected to provide sufficient statistical inputs in the risk assessment and consider both smaller frequent events as well as larger and more rare rain events. While the potential damage from smaller rain events may be more limited, the higher frequency will often make these the main contributor to flood damages over a longer period of time. The return periods selected for the risk assessment are 3, 10, 20 and 50 years for both existing climate conditions and future climate projections, resulting in a total of 8 modelling scenarios in four river basins, yielding a total of 32 simulations. An overview of the scenarios assessed can be seen in *Hydraulic Model and Hazard and Risk Mapping Assessment Report.*

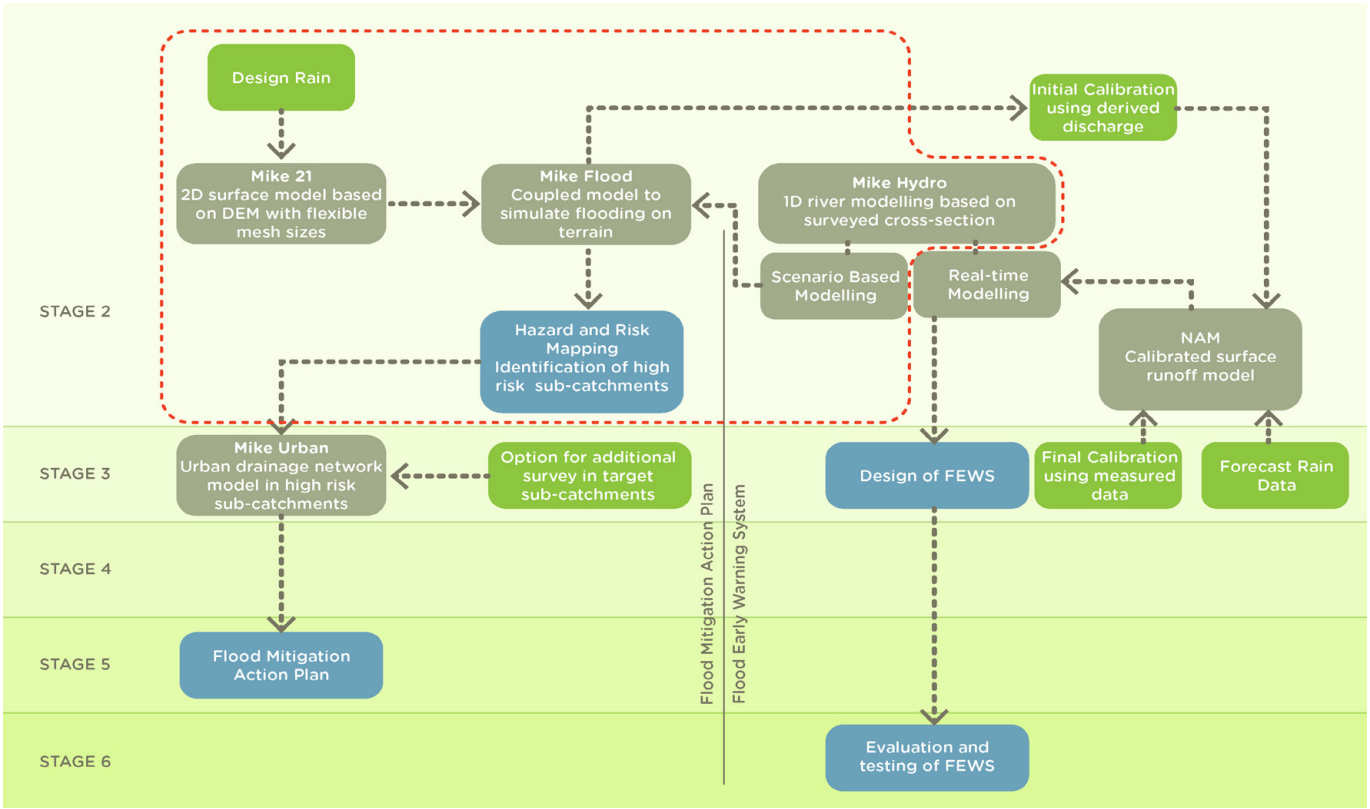


Figure 7: Modelling framework for the entire project. The Hydraulic Model and Hazard and Risk Mapping Assessment Report focuses on Stage 2, and more specifically on the scenario-based flood modelling, highlighted by the dashed red line.

Source; Ramboll

4.2.2 HYDROLOGICAL REGIME IN BAGUIO

Baguio City is drained by 4 major rivers, Balili flowing northwards, Bued flowing southwards, Galiano to the west and Ambalanga to the east. Out of the four rivers, Balili, Bued and Galiano drain most of the city, while Ambalanga drains very sparsely populated areas near the eastern boundary of the city. The four river catchments of Baguio City are characterized as mountainous with steep slopes leading runoff to the major rivers. Figure 8 presents an overview of the hydrology of Baguio City.

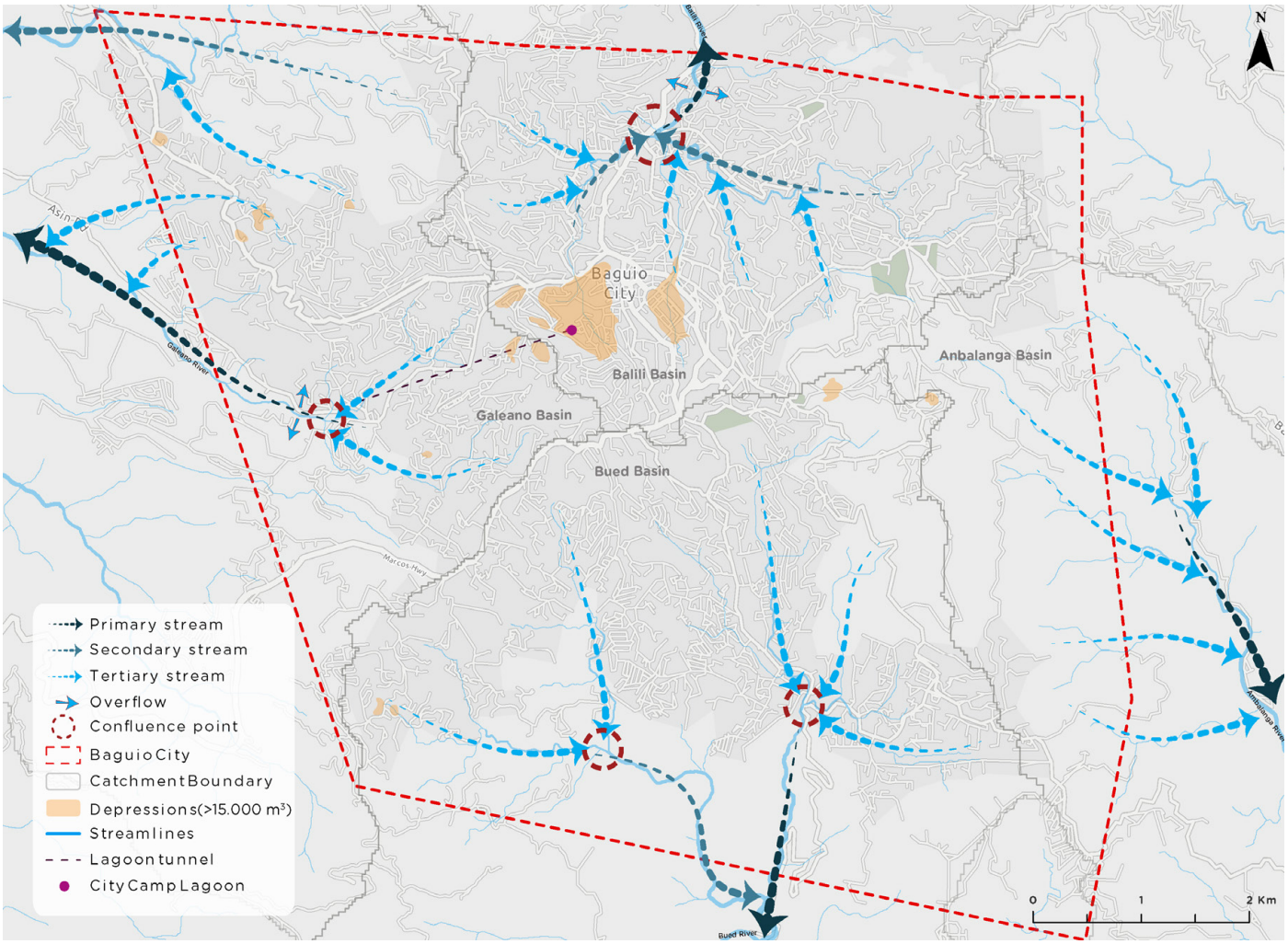


Figure 8: Overall hydrological regime within Baguio City.
Source; Ramboll

4.2.3 RESULTS: FLOOD HAZARD MAPS

The primary modelling output considered in the assessment is the maximum flooding extent and depth, both of which have been used in the risk assessment. Key observation from flooding caused by smaller rain events (3-year return period) are the inundation of natural depressions, in particular in the Balili catchment and scattered more localized flooding in densely built up areas which is likely caused by the lack of drainage and the blocking of natural overland flow paths by structures.

Comparison of flooding extent for present and future flooding for a specified return period indicate increase in flooding extent with climate impact due to increase in rainfall. Thus, the areas that are exposed to flood hazards will increase in the future. Similarly, areas that are flood prone today are likely to experience even greater impact (e.g. more flood related damages) in the future. Figure 9 indicates the flooding extent for extreme rain events (50-year return period in projected climate conditions). The entire range of flood maps can be seen in the *Hydraulic Model and Hazard and Risk Mapping Assessment Report Appendix*[18].

Based on the screening of flooding, 10 flood prone Barangays as well as 2 flood prone localized areas were identified. Many of the flood prone barangays and areas are located within the Balili river basin, as expected. "Rock Quarry, Lower" and "City Camp Central" located near the City Camp Lagoon are seen to have the greatest percentage of flooded area. Besides the ten flood prone Barangays, flood prone areas are identified at Teachers Camp Compound and near Wright Park. The screening approach and full list of flood prone Barangays and localized areas, as well as the process of validation of model results by local experts and historical disaster data comparison can be found in the *Hydraulic Model and Hazard and Risk Mapping Assessment Report.*

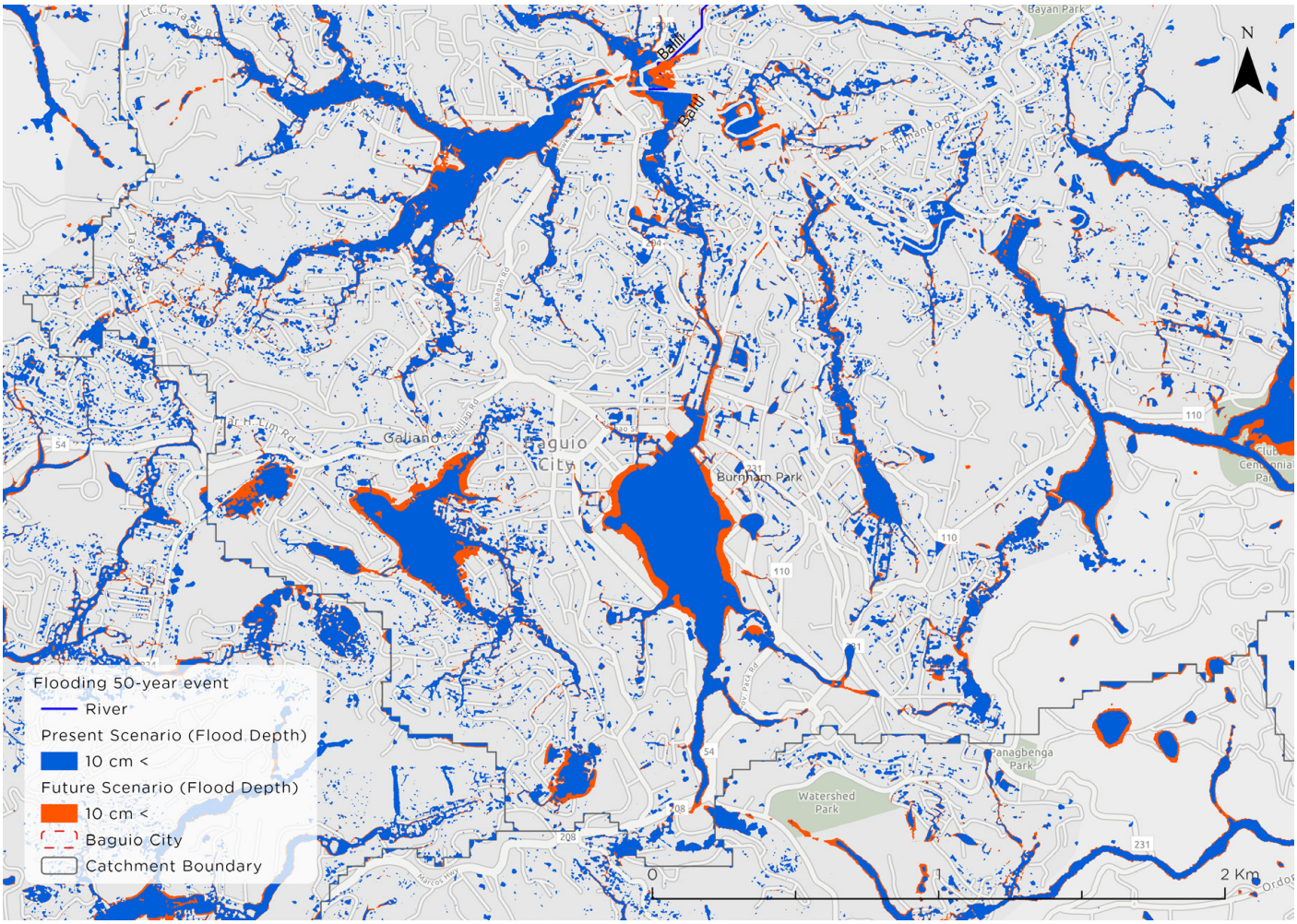


Figure 9: Extent of flooding (greater than 10 cm flood depth) for a 50-year event under future climate scenario.
Source; Ramboll

18 Hydraulic Modelling, Hazard and Risk Mapping Assessment Report Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, July 2021.

4.3 LANDSLIDE ASSESSMENT

Landslides are initiated in sloped areas due to rainfall and subsequent water saturation and destabilization of topsoils. Other causes include earthquakes. The effect of earthquakes on landslides is increased if topsoils are water saturated. The landslide susceptibility can furthermore be increased by human factors such as extra load from buildings, roads, heavy duty traffic, etc. The hazard assessment was based on the factors influencing soil destabilization including topography, rainfall, geology, hydrogeology, and earthquakes as well as latest research and data on landslide susceptibility, both regional and locally in Baguio.

The highly landslide susceptible areas are located in the sloping areas between the two plateaus and at the rim of the city to the west, south and east. The low to moderate landslide susceptible areas consist of approx. 20% of the city area. The remaining area of the city has either high or critically high landslide susceptibility (Figure 10).

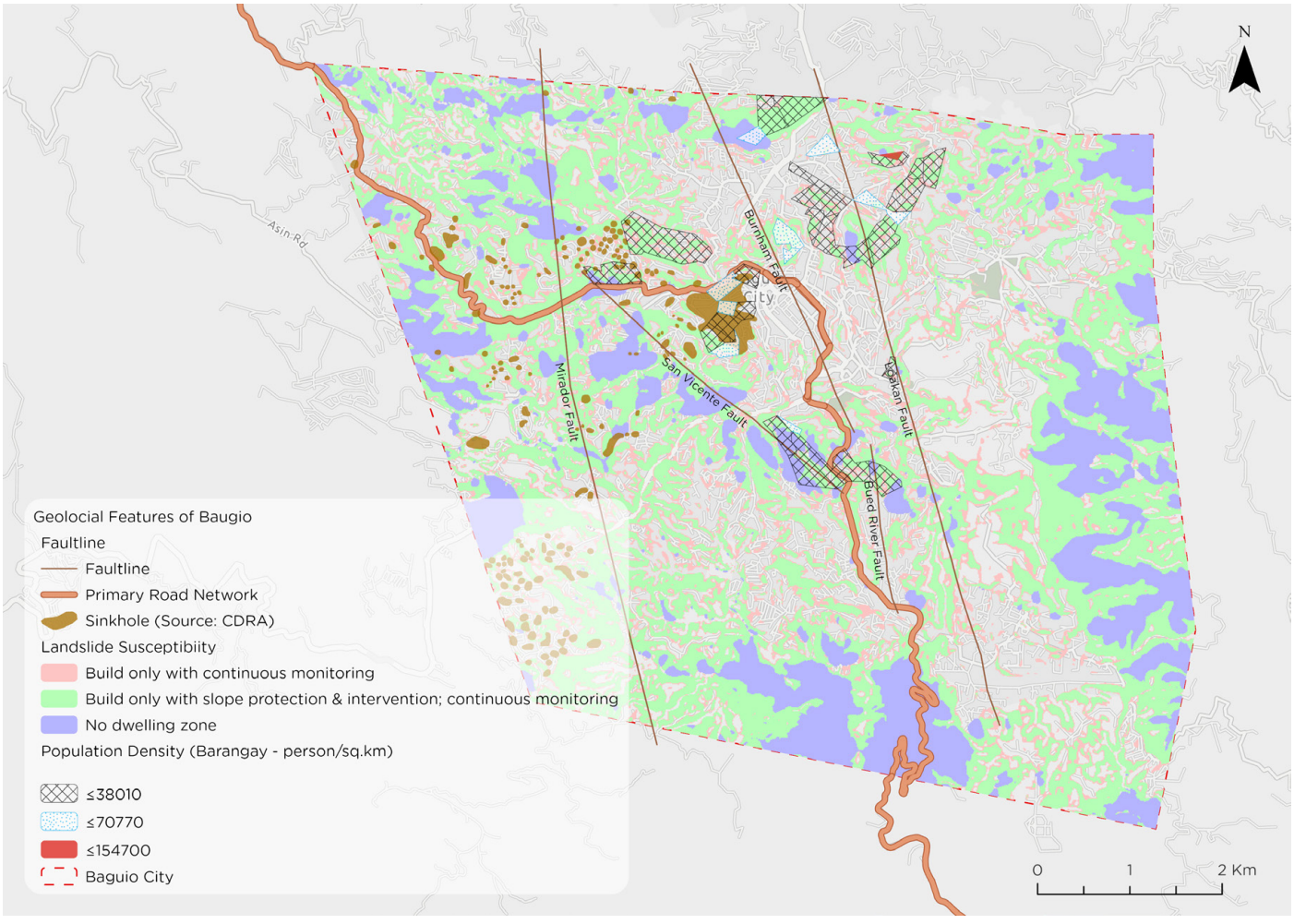


Figure 10: Landslide susceptibility in Baguio City
Source; Ramboll

4.4 FLOOD RISK ASSESSMENT

4.4.1 RISK ASSESSMENT FRAMEWORK (APPROACH AND METHODOLOGY)

As defined by the Fifth Assessment Report (AR5) of IPCC Working Group II (WGII), risk is the probability of adverse events multiplied by the consequences[19]. The consequences are defined by the sensitivity of the people and the physical assets exposed, and the adaptive capacity of the people (Figure 11).

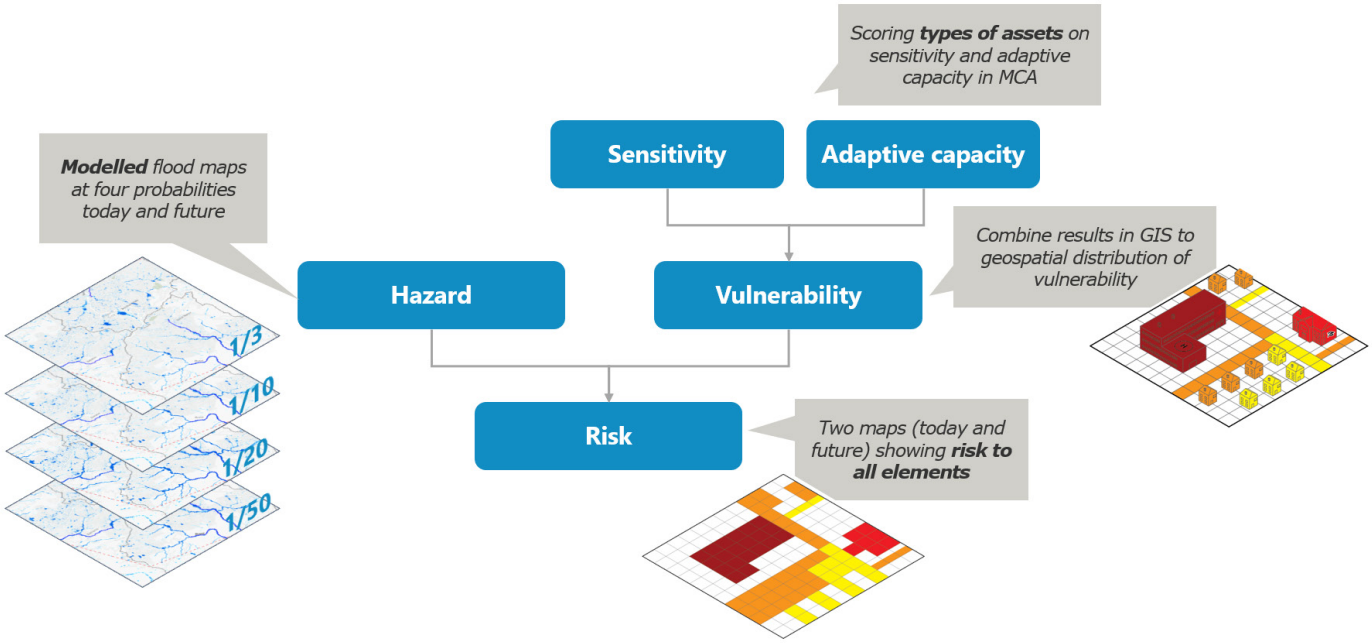


Figure 11: Framework for flood risk assessment
Source; Ramboll

A detailed, GIS-based process for flood risk assessment has been implemented in close consultation with the LGU and taking as point of departure the work carried out through the Climate and Disaster Risk Assessment (CDRA). The LGU's CDRA followed national guidelines provided by the Department of Human Settlements and Urban Development (DHSUD). The national guidelines are founded on the UN Framework Convention on Climate Change.

The FEWS project team performed hydrodynamic simulations and identified flood prone areas in relation to several rainfall return periods. This hazard information on exposure and probability of occurrence has been incorporated into the Risk Assessment and replaced the scoring of likelihood of occurrence, i.e. instead of scoring each exposed asset 1 to 6 by reviewing historic data, exposure is assessed through modelled probabilities.

Not only does the hydrodynamic modelling make the hazard piece in the risk assessment statistically and technically sounder, but it also yields a city-wide exposure and probability assessment now, and in the future, instead of only assessing historically exposed assets. The consequences of climate related hazards have been assessed as the vulnerability of assets as a product of adaptive capacity and sensitivity.

19 IPCC, "Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014.

Flood risk has been assessed for the current baseline scenario in 2020 and in a future baseline scenario (further described in the *Hydraulic Model and Hazard and Risk Mapping Assessment Report*).

For two points in time (present and future) four flood layers are available for the baseline scenario, i.e. status conditions: 3-year event, 10-year event, 20-year event, and 50-year event. In a risk assessment it is important to consider events with high probabilities, because even though damage costs of a singular 5-year event will be lower than less probable events, the accumulated costs of twenty 5-year events over 100 years, typically far outweigh the damage costs of one 100-year event in 100 years (Figure 12).

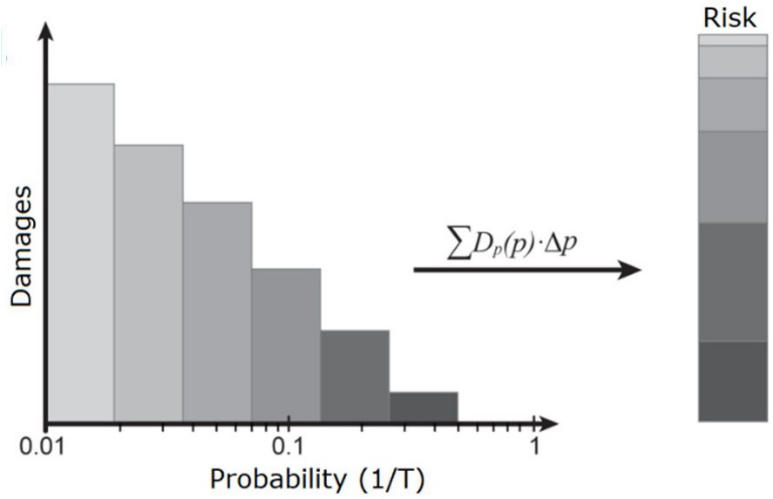


Figure 12: Illustration of summing return periods over probability.
Though damages are largest at the largest event, it's not the largest event that contributes the most to the annual damages (risk).[20]
Source: Ramboll

To assess adaptive capacity, the FEWS project team incorporated the scoring scheme of adaptive capacity as presented in the CDRA, which is a three-step scale from low to high adaptive capacity. The sensitivity of assets was calculated and scored on a three-step scale from low to high sensitivity based on information from the CDRA. A more detailed scale description and scoring of all asset types can be found in the *Hydraulic Model and Hazard and Risk Mapping Assessment Report*.

Table 5: Excerpt from 'Vulnerability scoring of types of assets in the Flood Risk Assessment'. The full table can be found in the Hydraulic Model and Hazard and Risk Mapping Assessment Report.

Theme	Asset	Adaptive capacity score	Sensitivity score	Vulnerability score	Vulnerability
Urban use areas	Commercial areas	2	2	4	Moderate
	Slaughterhouse	3	3	9	High
	Planned unit development	1	1	1	Low
	Airport	3	3	9	High
	Informal settlement	3	3	9	High

Source: Ramboll

20 A. S. Olsen, G. G. Dalgaard, B. Paludan, O. Mark, A. Laustsen, J. J. Linde, C. Jakobsen, K. Friis, M. Hundahl, D. Rosbjerg, P. S. Mikkelsen and K. Arnbjerg-Nielsen, 2017. Metoder til bestemmelse af serviceniveau for regnvand på terræn, Spildevandskomiteen, Skrift nr. 31, IDA Spildevandskomiteen 2017, Copenhagen.

4.4.2 RESULTS: FLOOD RISK MAPPING

Present risk is shown in Figure 13, and future risk is shown in Figure 14. It's important to note that damages do not increase with inundation, and more inundated areas do therefore not carry more weight for that reason.

The risk labelling follows the same risk scoring as in national guidelines, where three levels of risk were classified: Low (score 1-4), medium (score 5-10), and high (score 11-24). To identify most at-risk areas in this assessment the class "high" has here been split into two classes, and the maps therefore have four classes: Low (1-4), moderate (>4-10), high (>10-15), and very high (>15-24). As maximum cell values in some cases were greater than 24, all cell values are normalised based on maximum value in current conditions to a maximum value of 24.

Generally, most risks in both current and future conditions are found around the city centre, and the northern and eastern parts of the city, as this is more densely populated and therefore have more critical assets, roads, schools, etc.

More than 60 % of the city is at risk of flooding (based on areas covered by low to very high risk). As expected from the flood layers where more areas become exposed in the future, the total area size of areas at-risk increases in the future, albeit not very much, from 61 % to 62 %. The Balili catchment is identified as the catchment with the highest flood risk. As evident in the flood layers, the extent of flooding doesn't increase much in the future, and as noted earlier, the risk model is independent of inundation depths (as long as the inundation threshold is crossed). Therefore, as the exposure to flooding increases only slightly, so does the risk.

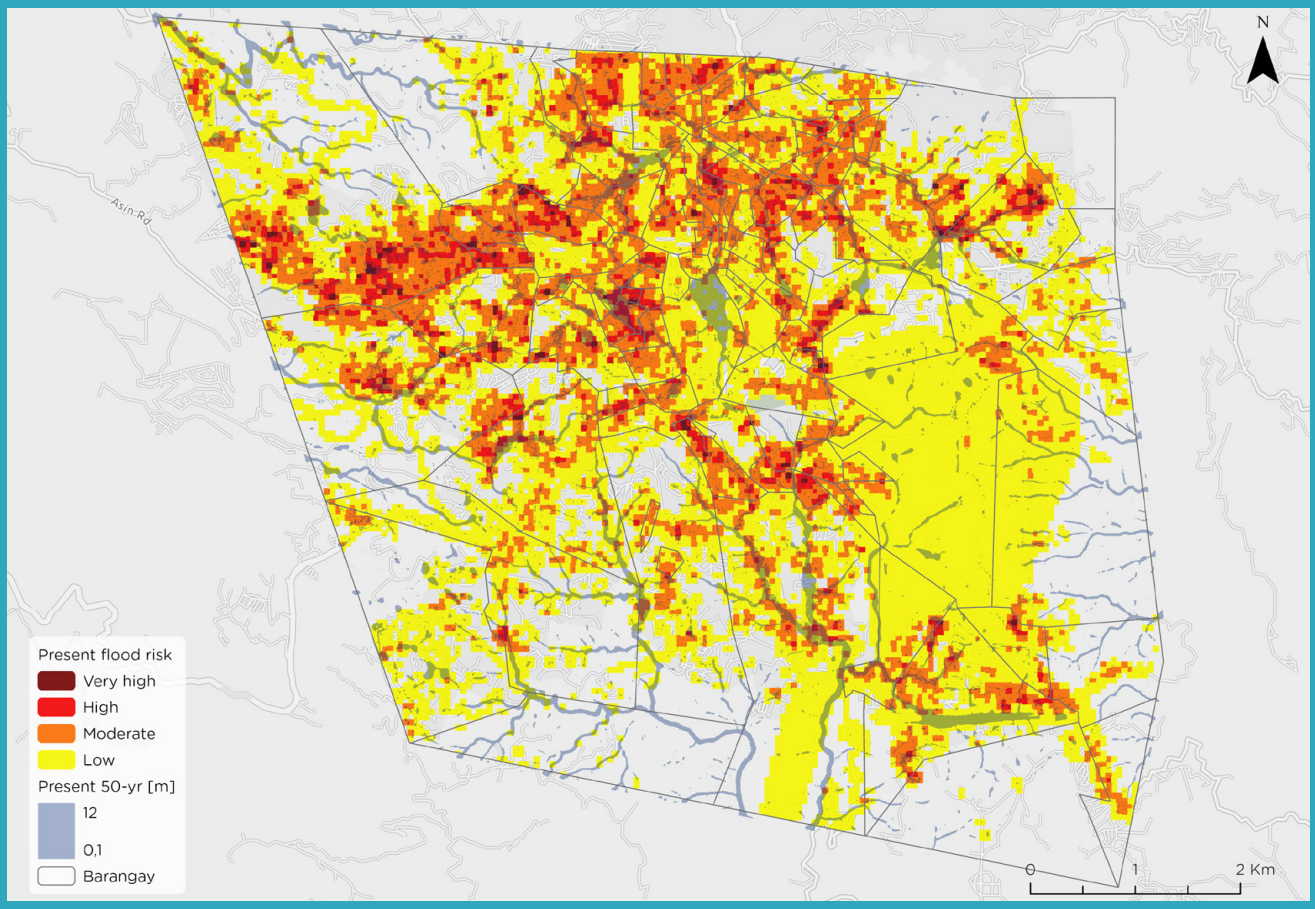


Figure 13: Map of present flood risk based on asset vulnerability and modelled flood hazard.
Source; Ramboll

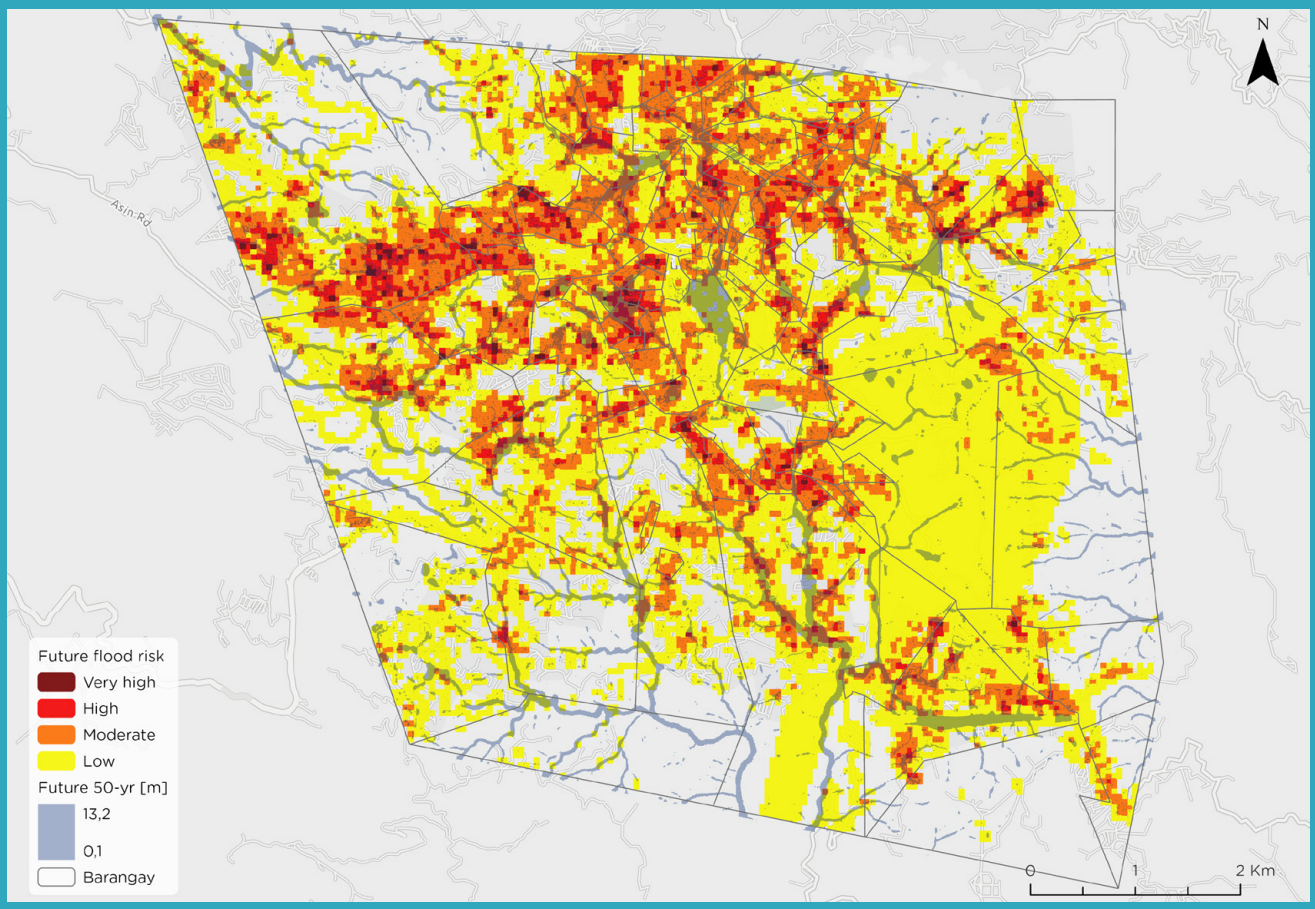


Figure 14: Map of future flood risk based on asset vulnerability and modelled flood hazard.
Source; Ramboll

5. FLOOD MITIGATION ACTION PLAN

"The implementation of the flood mitigation action plan, which includes a toolbox of replicable and scalable nature based solutions, will provide multiple benefits in addition to flood risk reduction, including enhanced local biodiversity, recreational values and social inclusion."

Antonette Anaban, Officer In Charge, CDRRMO, Baguio LGU

Source: Adobe Stock

5.1 OBJECTIVES AND APPROACH

To reduce the impacts of recurrent flooding, the *Flood Mitigation Action Plan*[21] report introduced a citywide assessment for the conceptual design and implementation of nature-based solutions (NbS) as a new paradigm for climate adaptation, where both flood mitigation benefits, and other co-benefits are analyzed through a structured approach and in close consultation with the LGU and ADB. The report contributed to the knowledge base supporting the current paradigm shift in urban planning practices taking place in Baguio, guided by an overall vision to make the city more liveable, more resilient, and more sustainable.

This report aimed at answering the following questions:

- To which extent are NbS a feasible option for flood mitigation in Baguio, and which types of NbS are most feasible?
- What are the key design considerations for NbS in Baguio?
- What are the co-benefits of implementing NbS in Baguio?
- How may NbS be planned and implemented in Baguio?
- How may NbS be replicated and scaled city-wide?

The approach followed in preparing this conceptual high-level flood mitigation action plan for the city of Baguio was composed of three overarching elements: i) defining the vision for nature-based flood mitigation, driven by a set of climate adaptation principles and adaptation typologies; ii) aligning the action plan with both existing development plans in Baguio and international best practices; and iii) integrating technical and non-technical assessments through holistic development of typologies and conceptual demonstration at pilot-site level. This overall approach was based on a close communication with the LGU, to ensure local anchoring and validation of assumptions and outputs.

The flood mitigation action plan prepared for Baguio had three key outputs:

1. Development of a multifunctional NbS typology toolbox, including key enabling criteria for implementation of typologies
2. Demonstration of the applicability and benefits of the NbS toolbox for three pilot-sites through conceptual design, including preliminary site-specific hydraulic calculations
3. Preparation of a roadmap for implementation of flood mitigation measures to serve as a guide for implemention of NbS in Baguio throughout all phases from project development to monitoring and evaluation post-implementation.

21 Footnote 3

5.2 VISION FOR FLOOD MITIGATION IN BAGUIO

The vision for nature-based flood mitigation in Baguio is viewed through a lens of inherent sustainability, where terrain- and nature-based solutions are connected throughout the city to mimic a natural system. The key characteristics of the vision for flood mitigation are the reliance on natural solutions to manage stormwater flows and improve ecological conditions by incorporating technologies proven to yield direct risk-reducing benefits. The vision also intends to achieve a high level of water circularity, through rainwater harvesting and reuse, and to provide resilient planning and infrastructure that reduces the risk of flooding both in current and future climate conditions. Based on this vision, the Flood Mitigation Action Plan aimed at presenting innovative solutions that are appropriate to the territorial and socio-economic complexity of Baguio City, to promote benefits beyond climate adaptation and resilience and to ensure inclusive and green urban spaces that promote health and quality of life for all citizens.

At the backbone of the Flood Mitigation Action Plan there is a set of high-level climate adaptation principles which guide the overall vision and objectives (Figure 15). These principles follow good adaptation practices and enable the development of typologies that show the benefits of adaptation solutions:

- Tangible benefits: development of typologies incorporating best-practice technologies proven to yield direct risk-reducing benefits, for instance water-related benefits (improved quality through e.g. filtration; and improved quantity control through e.g. detention) or slope stabilization benefits (reduced erosion through e.g. vegetation management)
- Co-benefits: This principle embraces the environmental, social, and economic impact of climate adaptation solutions contained in the typologies, e.g. improved air quality, health, mobility, etc.
- Resilient infrastructure: flexibility and reliability across a range of environmental and future conditions, as well as continuous provision of co-benefits to enhance people's lives, secure development gains and drive positive change.
- Sustainable land management: Utilization of the existing topography and inclusion terrain-based principles, to the greatest extent possible, and a broad focus on green land management approaches, including land uses on slopes and rehabilitation considerations.
- Multifunctional uses: incorporating multiple purposes by diversifying urban components, connecting urban planning, landscape design, water management and urban ecology in typologies that help visualize a possible future and communicate the need to adopt a multidisciplinary approach to realize that future.
- Replicable and scalable: Ensuring replicability and scalability of solutions at various locations and scales across Baguio City.

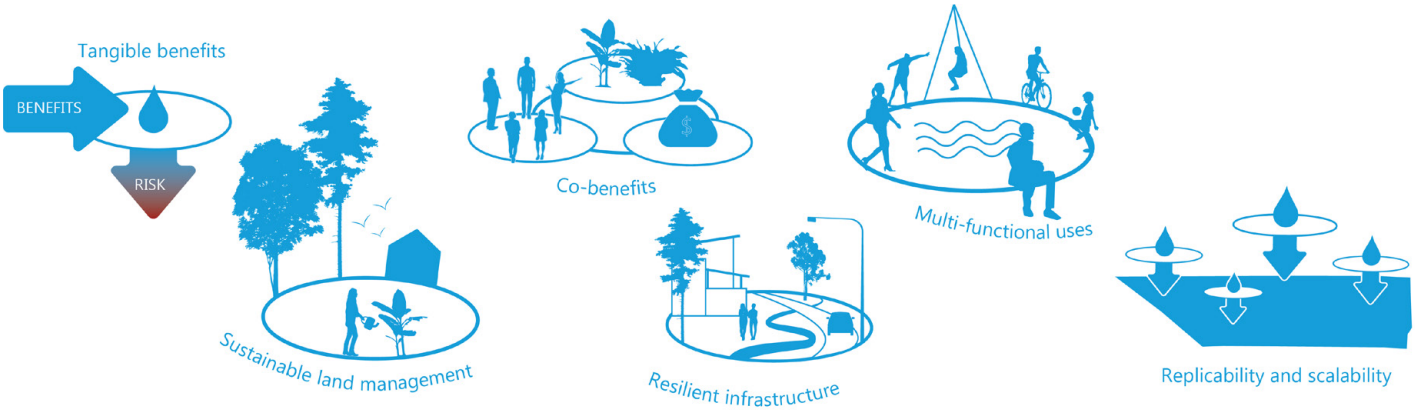


Figure 15: Vision for NbS as a tool for flood mitigation in Baguio
Source: Ramboll

5.3 NBS TYPOLOGY TOOLBOX

Each city has its unique features in terms of geography, topography, nature, functionality, history. When applying NbS, it's important to understand and design for the unique spatial context of the city to maximize benefits beyond flood adaptation. As Baguio is characterized by high building densities and limited open spaces, a decentralized approach to flood mitigation is recommended to match the characteristics of the Barangays. This is expressed as a connected system of smaller interventions that utilizes the available spaces optimally and when combined creates a flood mitigation system that meets the demands of the city.

The project's approach relies on NbS with hydraulic functions embedded for managing stormwater quantity and improving stormwater runoff quality reaching recipient water bodies. These solutions will be supported by traditional grey infrastructure where there are significant constraints on surface-based infrastructure, or where existing infrastructure is already in place and should be utilized so it does not become a redundant investment. The system of solutions should be developed as a strong green fabric or network which binds Baguio together.

The steps for the development of the NbS typology toolbox are outlined in Figure 16.

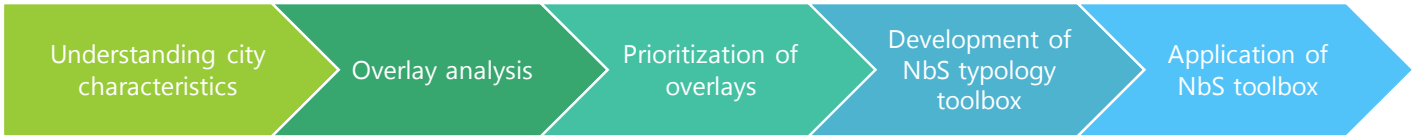


Figure 16: Development of the NbS typology toolbox
Source: Ramboll

Step 1: Understanding city characteristics.
To develop holistic flood mitigation solutions tailored to the unique context of Baguio maximizing benefits beyond flood risk reduction, it is necessary to understand the spatial and socio-economic layers comprising Baguio. Understanding the existing and future challenges and opportunities that may emerge in Baguio is key to ensuring robust design of mitigation measures. An assessment of challenges and opportunities for Baguio was completed extending beyond flood risk related themes to include social, economic, structural, and institutional themes. Following the assessment of challenges and opportunities, an assessment of catchment hydrology characteristics was completed to delineate sub-catchments for Baguio. When planning the connected system of solutions, division into sub-catchments assists in breaking the complex challenge of flood mitigation into smaller parts, making it easier to tackle. Thus, subcatchments allow for localized assessments of hydrologic and hydraulic conditions and design of smaller scale connected flood mitigation networks that meet the required sub-catchment storage capacity. Finally, an assessment of the public realm characteristics was completed to understand the emerging spatial similarities in the urban landscape of Baguio.

Step 2: Overlay analysis.
The overlay analysis enables a deeper understanding of the unique spatial context of the city. The overlay analysis is data-driven and should be completed utilizing GIS-based spatial data. A GIS-based overlay analysis utilizing the existing spatial data that is available for Baguio, as well as the results from the flood risk assessment in Task 2, was undertaken to identify 'zones' with similar characteristics where nature-based solutions can be applied. Thus, the outcome of the overlay analysis is a combination (or overlay) of spatial characteristics that define a place in the city. In this way, the overlay analysis allows for identification of 'zones' with similar characteristics ensuring replicability of adaptation solutions at various locations city-wide. In the overlay analysis for Baguio, four types of spatial data on hazard and risk, topography, land type, and infrastructure were included.

Step 3: Prioritization of overlays.
A prioritization exercise of 'zones' was undertaken to develop typologies based on cohesion with vision for the Flood Mitigation Action Plan as well as ongoing initiatives, guidelines and plans for Baguio, identification of dominating overlays, expert knowledge and international best-practice guidelines.

Step 4: Development of NbS typology toolbox.
A NbS toolbox of solutions was developed consisting of 8 typologies suitable for the prioritized spatial zones in the city (Figures 17 and 18). The toolbox can have many uses and provides a user-friendly and easy-to-understand narrative to communicate NbS to a broad audience, including experts and the general public. While the implementation of the mitigation measures recommended at the scale of individual pilot sites will have direct and immediate benefits when implemented, the toolbox typologies should be applied similarly across Baguio at city-wide scale to gain the full effect of the nature-based approach with interconnected systems that fulfil different hydrological and hydraulic purposes such as conveyance, treatment, storage, and infiltration.

Step 5: Application of NbS toolbox.
Finally, the application of the NbS toolbox was demonstrated for three pilot sites as described in Section 5.4.

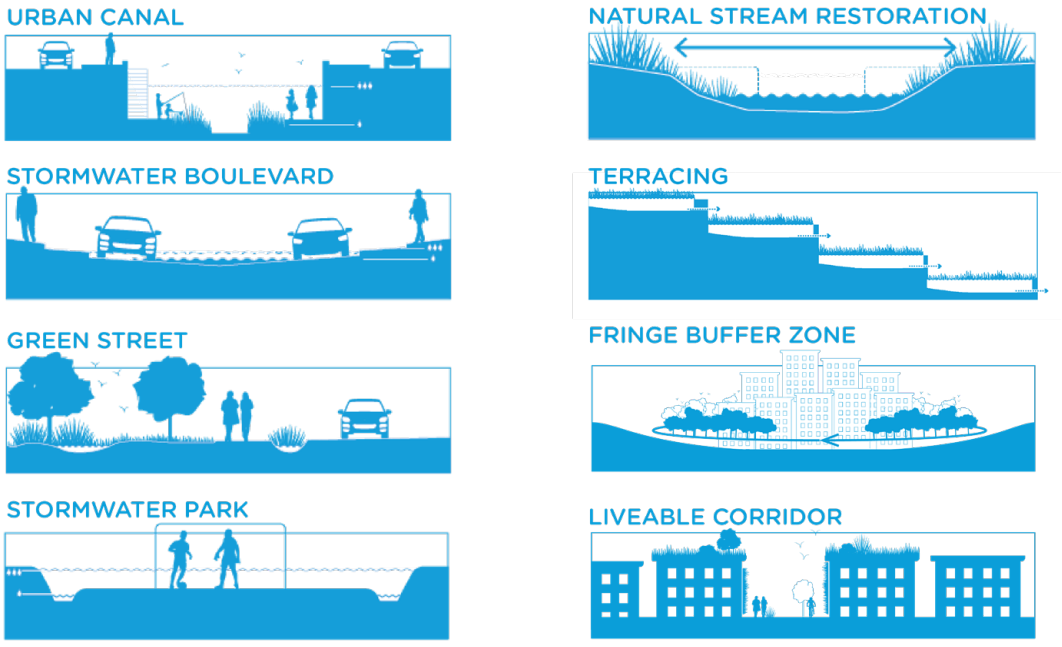


Figure 17: NbS typology toolbox consisting of 8 typologies
Source: Ramboll

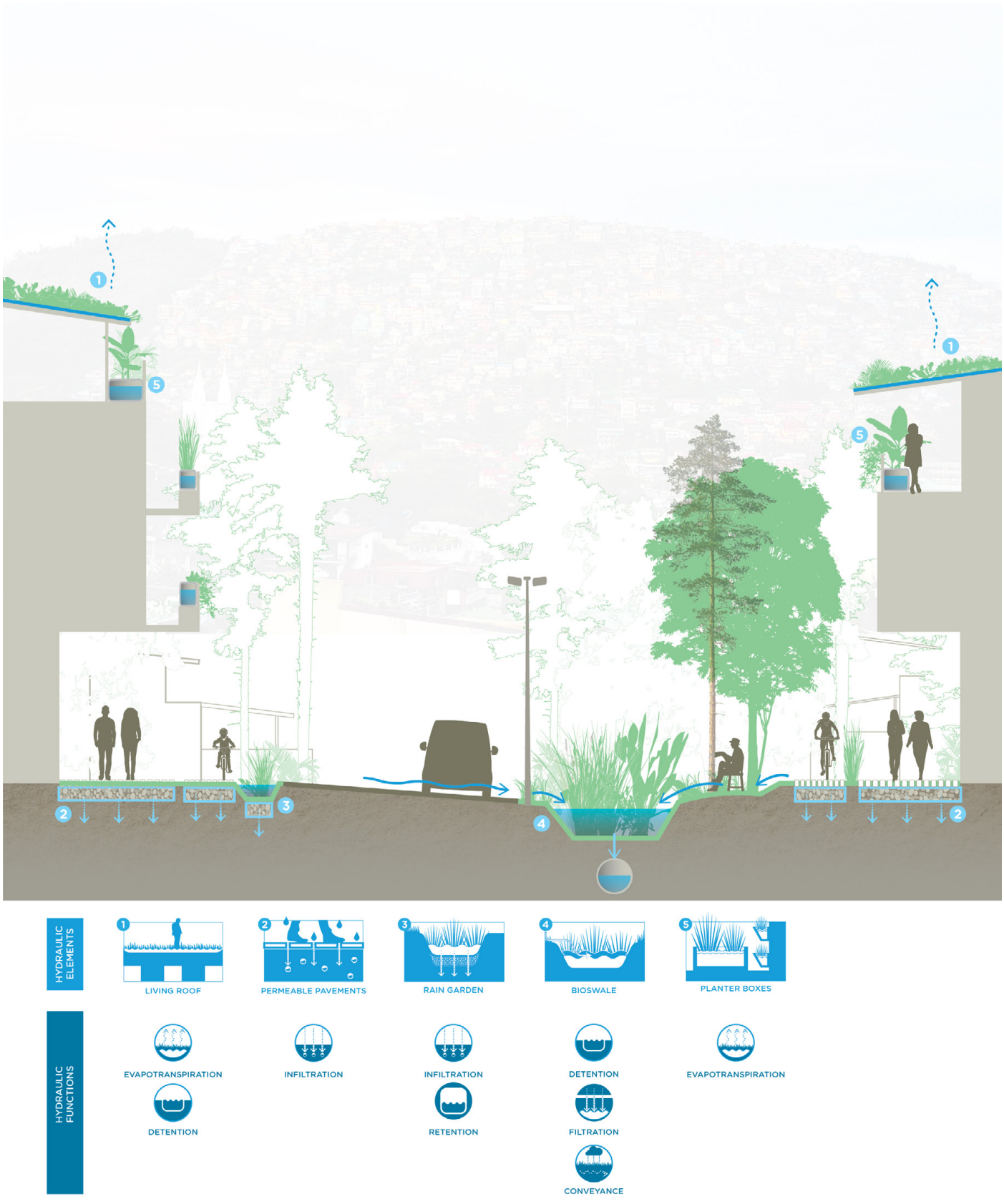


Figure 18: Conceptual cross-section of the 'Green Street' typology
Source: Ramboll

5.3.1 CITY-WIDE REPLICABILITY

The typologies in the toolbox have been designed to be applied city-wide at various scales to create a network of connected nature-based solutions.

The replicability map (Figure 19) highlights the various zones identified across Baguio where the developed typologies are particularly suitable. The zones have been identified based combinations of high risk to flooding or landslides, urban or non-urban context, and slope characteristics. Three types of space have been identified within each zone: open areas, roads/right-of-way, and canal/stream/river. Typologies are available for prioritized combinations of zones and space. The main considerations for prioritization were

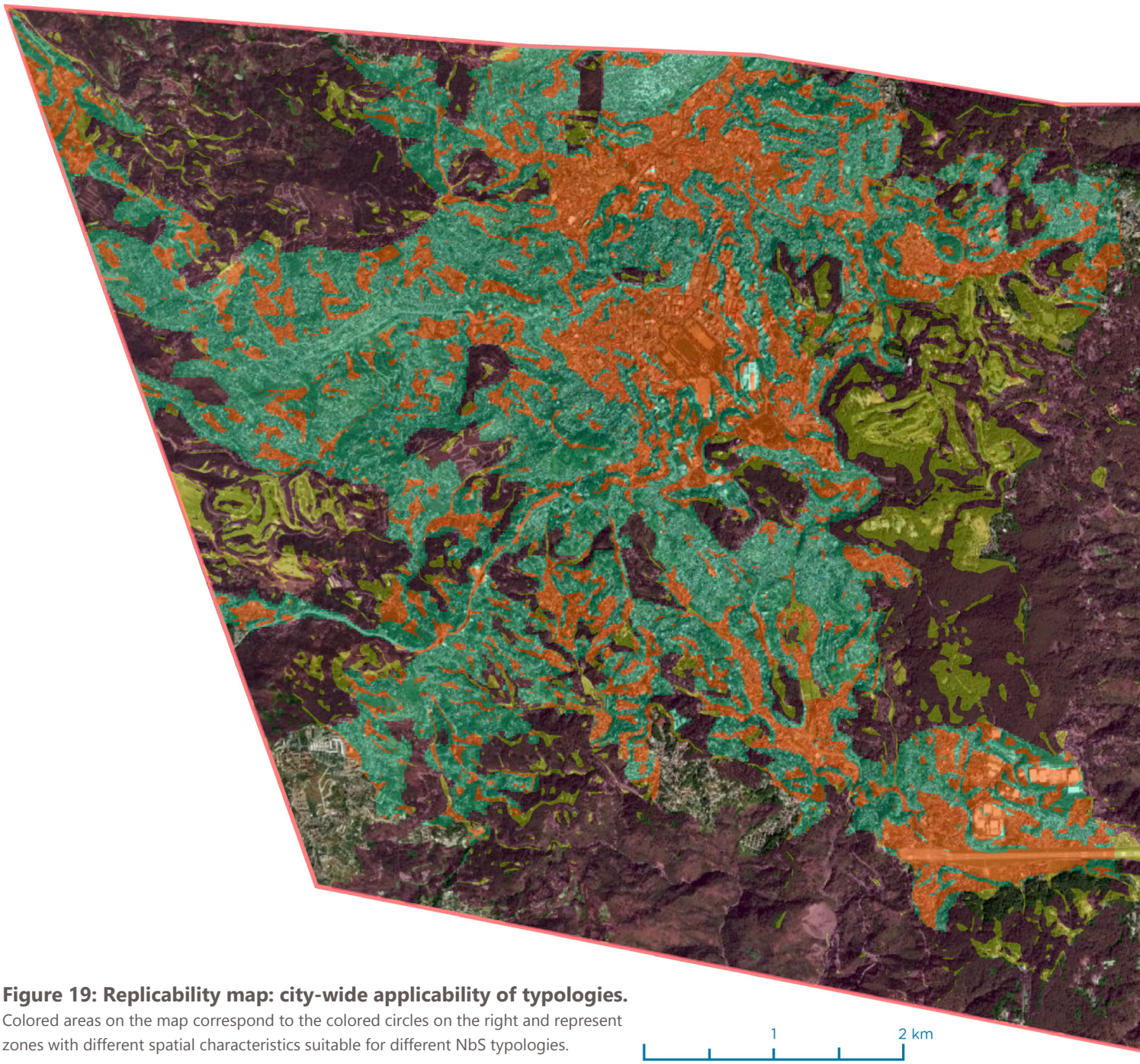
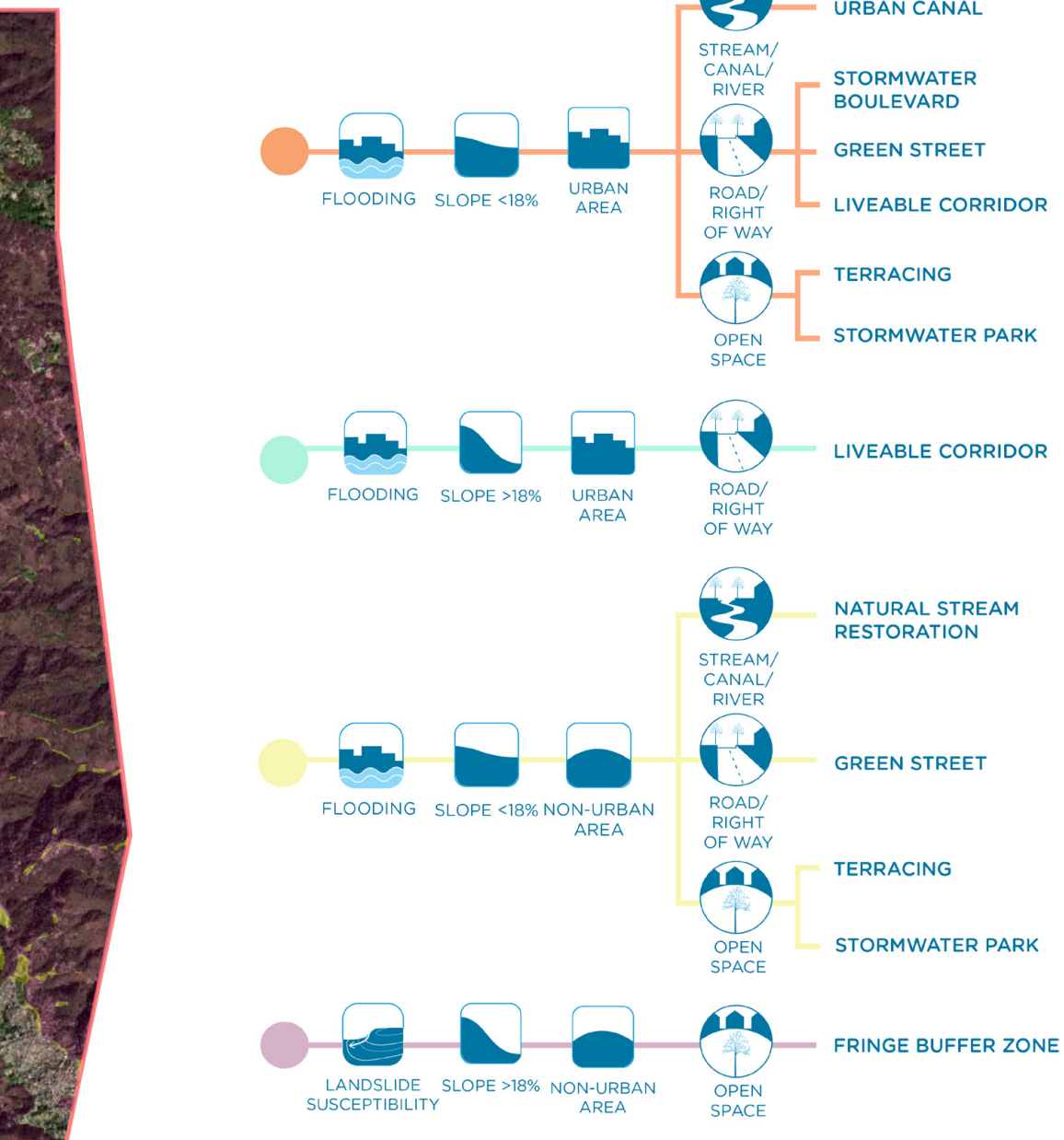


Figure 19: Replicability map: city-wide applicability of typologies.
Colored areas on the map correspond to the colored circles on the right and represent zones with different spatial characteristics suitable for different NbS typologies.
Source: Ramboll

cohesion with vision for the *Flood Mitigation Action Plan* as well as ongoing initiatives and plans for Baguio, determination of dominating overlays, expert knowledge of NbS applicability, and a diverse representation of space.

The replicability map can be used to identify a typology for specified site. The various zones (a combination of risk/hazard, spatial context, and slope characteristics) are represented by different colors on the map. Next to the map, colored circles correspond to each of the zones. Following the line from a colored circle, the spatial characteristics of the zone are visualized. To identify an applicable typology for a site, first identify a location on the map, then find the circle corresponding to the color of the zone and follow the line to the type of site (i.e. stream, road, open space).



5.4 PILOT DESIGNS

To demonstrate the applicability of the NbS toolbox, the toolbox has been applied at three pilot sites. The pilot sites were selected in close collaboration with the LGU to ensure the sites are aligned with city plans and initiatives. It was agreed with the LGU that the pilot sites should be located within the Balili catchment, following the common approach of prioritizing high-risk areas for improvements as the benefits are higher. It is recommended to apply a holistic approach to flood mitigation and design a connected network of mitigation measures for one sub-catchment at a time. However, this process was not possible to undertake within the timeframe of this project due to the complex nature of land ownerships in Baguio. Full descriptions of the process and the pilot designs can be found in the *Flood Mitigation Action Plan*.

The following three pilot sites were selected in close collaboration with LGU:

1. **Urban Canal near Manual Roxas (137-138) (Figures 21 and 22)**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Canal
2. **Green Street at Carino Street (Figures 23 and 24)**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Road
3. **Stormwater Park at Emilio Aguinaldo Park (Figures 25 and 26)**
   Site characteristics: Flood risk / Urban area / Slope < 18 % / Open area

The locations of the three pilot sites are seen in Figure 20. The selected pilot sites serve to demonstrate the wide range of concepts in the NbS toolbox and show how nature-based solutions are applicable for various types of spaces and infrastructure in the public realm in Baguio.

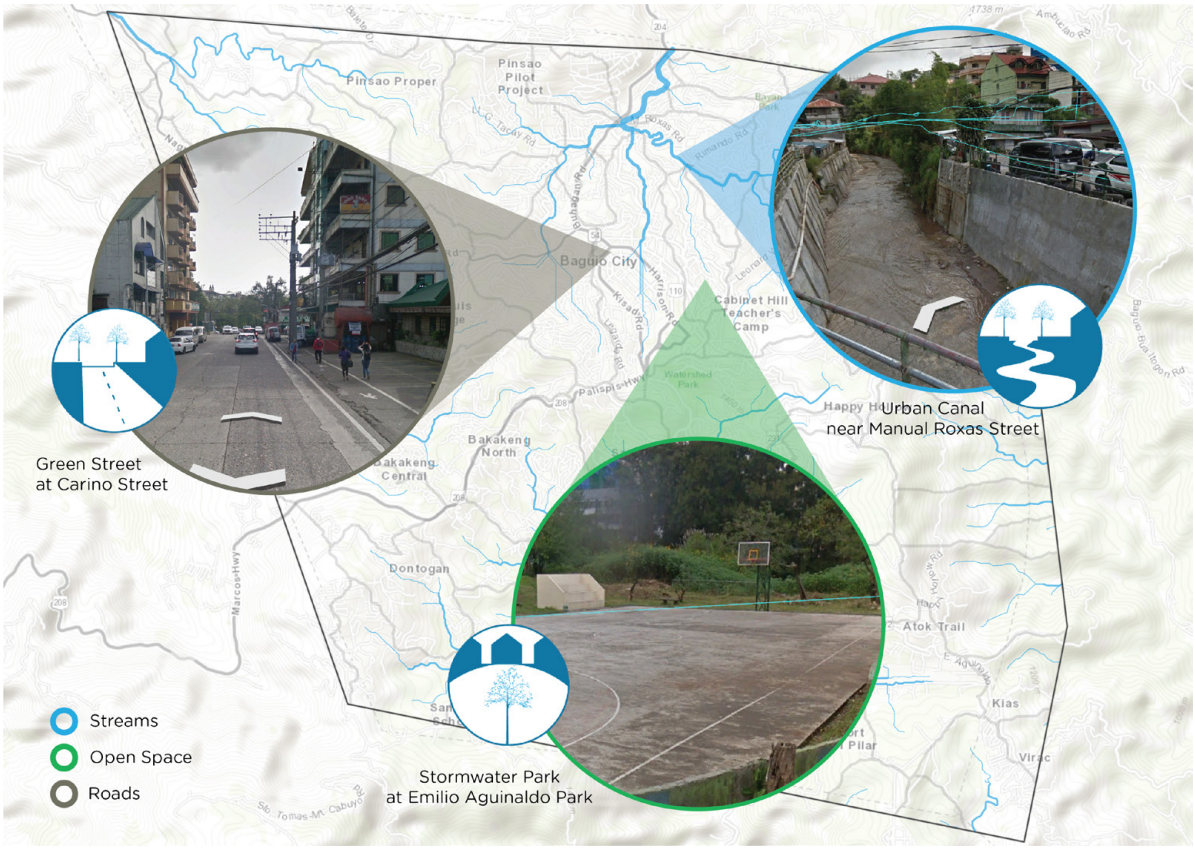


Figure 20: Plan view of Stormwater Park conceptual Design at Emilio Aguinaldo Park
Source: Ramboll

Figure 21: Plan view of Urban Canal conceptual design

Source: Ramboll

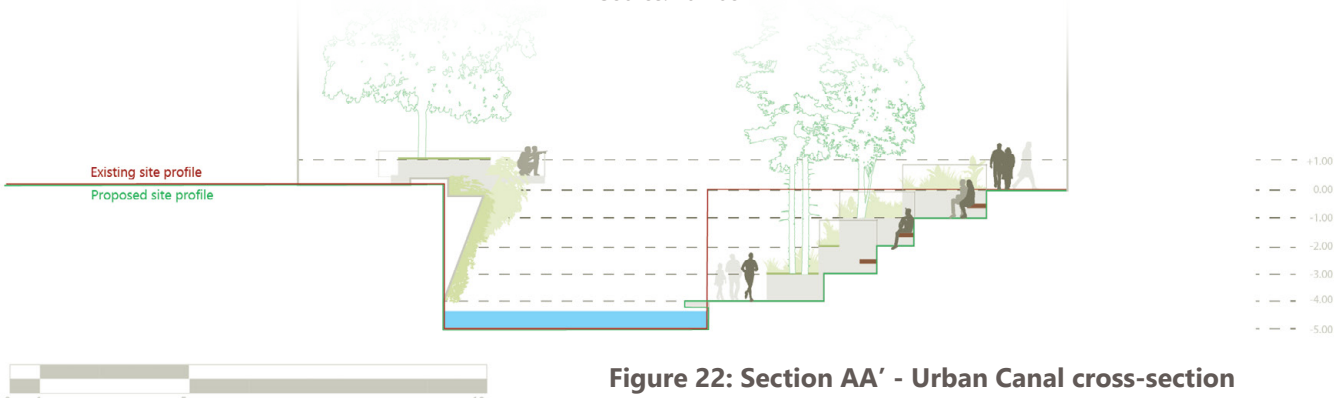


Figure 22: Section AA' - Urban Canal cross-section

Source: Ramboll

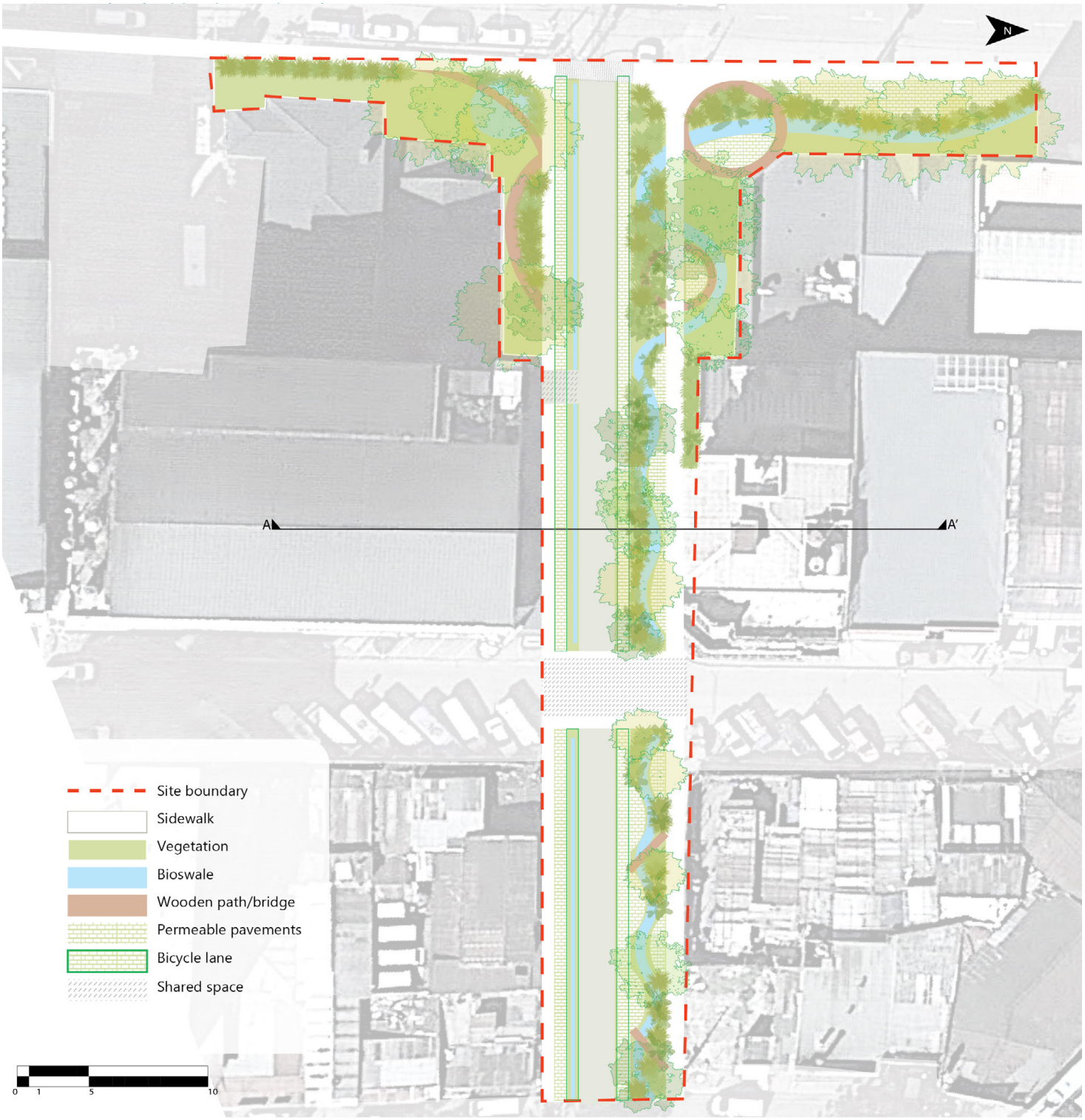


Figure 23: Plan View of Green Street Conceptual Design at Carino St.

Source: Ramboll

Figure 24: Section AA' - Green Street Conceptual Design at Carino St.

Source: Ramboll

Figure 25: Plan view of Stormwater Park conceptual Design at Emilio Aguinaldo Park

Source: Ramboll

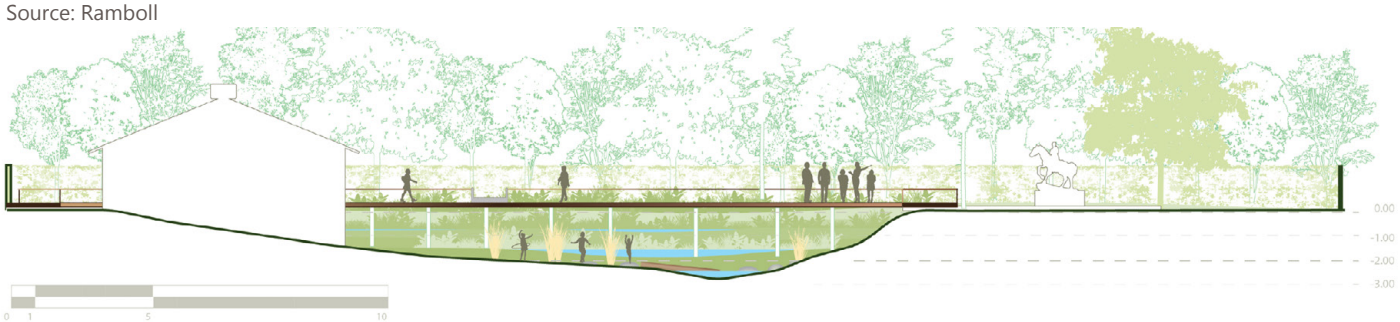
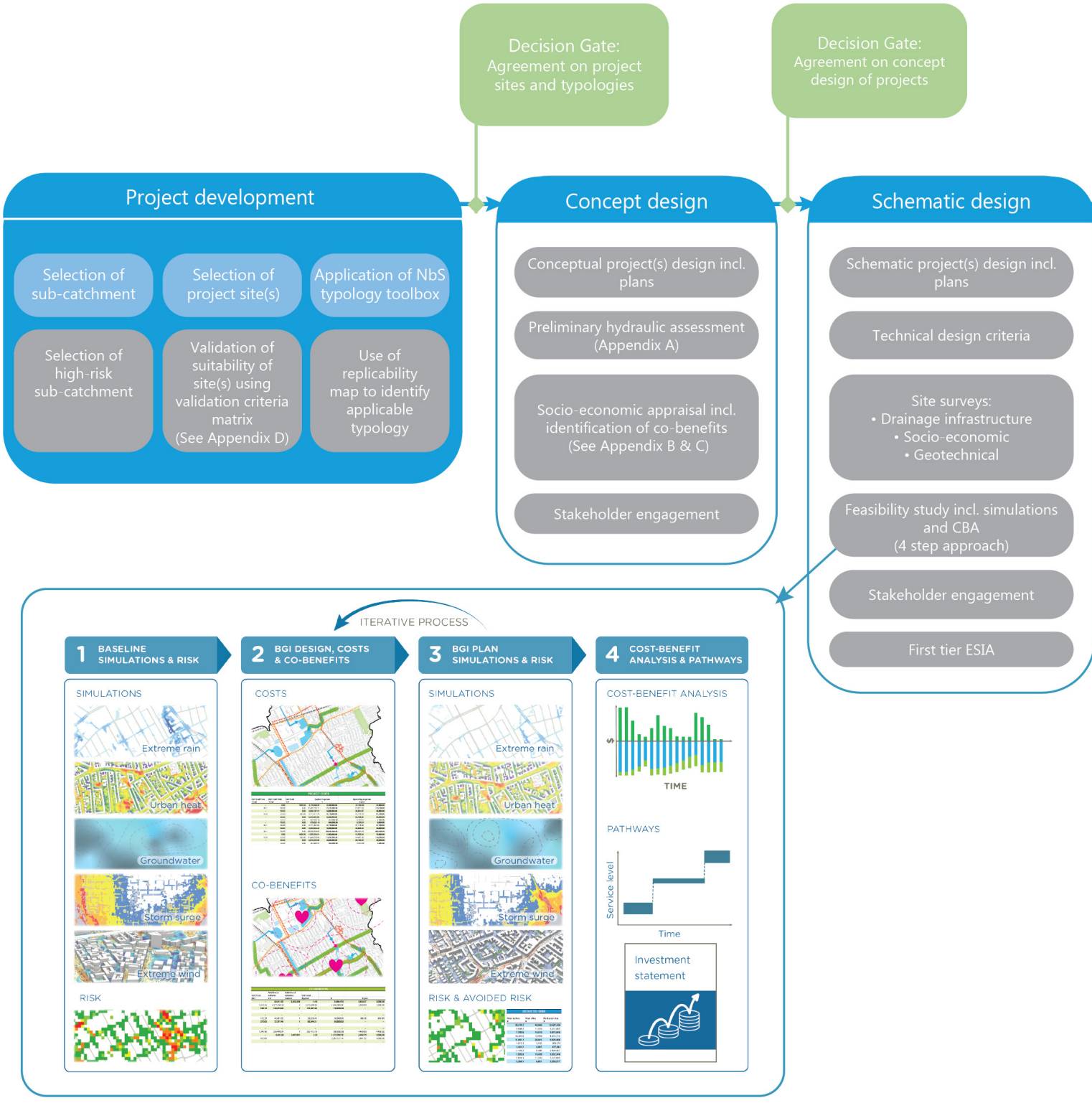


Figure 26: Section AA' - Stormwater Park conceptual Design at Emilio Aguinaldo Park

Source: Ramboll

5.5 ROADMAP FOR IMPLEMENTATION OF FLOOD MITIGATION MEASURES

Figure 27 presents a road map for implementation of flood mitigation measures in Baguio. The road map is to be used as a simple step-by-step guide from project development to implementation of flood mitigation in Baguio. The road map has been prepared with the intention of visualizing the processes for implementation of the NbS typology toolbox and is to be used by a multi-disciplinary project team comprising professionals from various offices at the LGU.



The road map aims at presenting a standardized approach for NbS projects, albeit well knowing that a standardized approach may not suit all projects. The end of a project phase is marked by a decision gate, where the project team comes to agreement and decides on the continuation of the project.

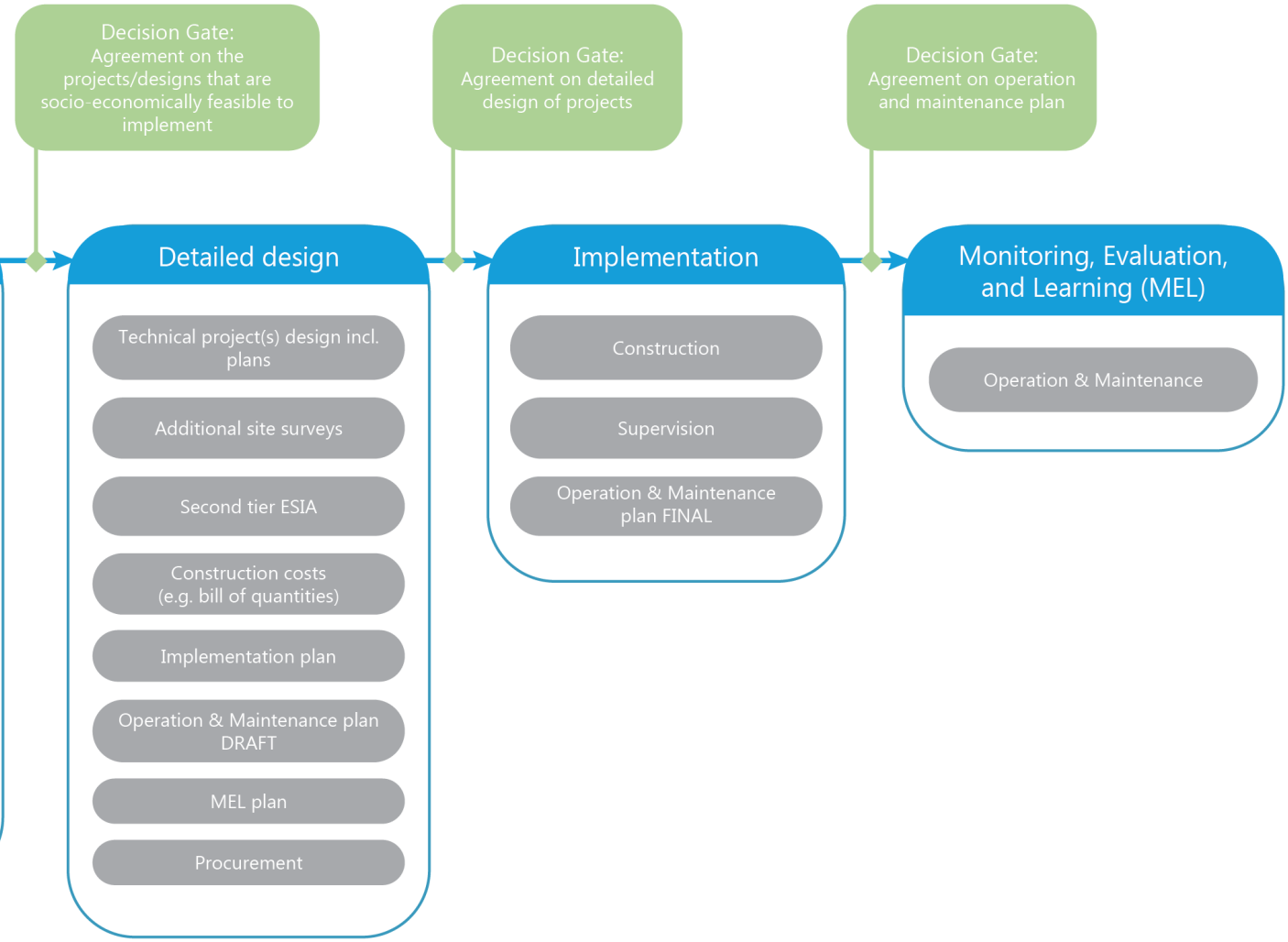
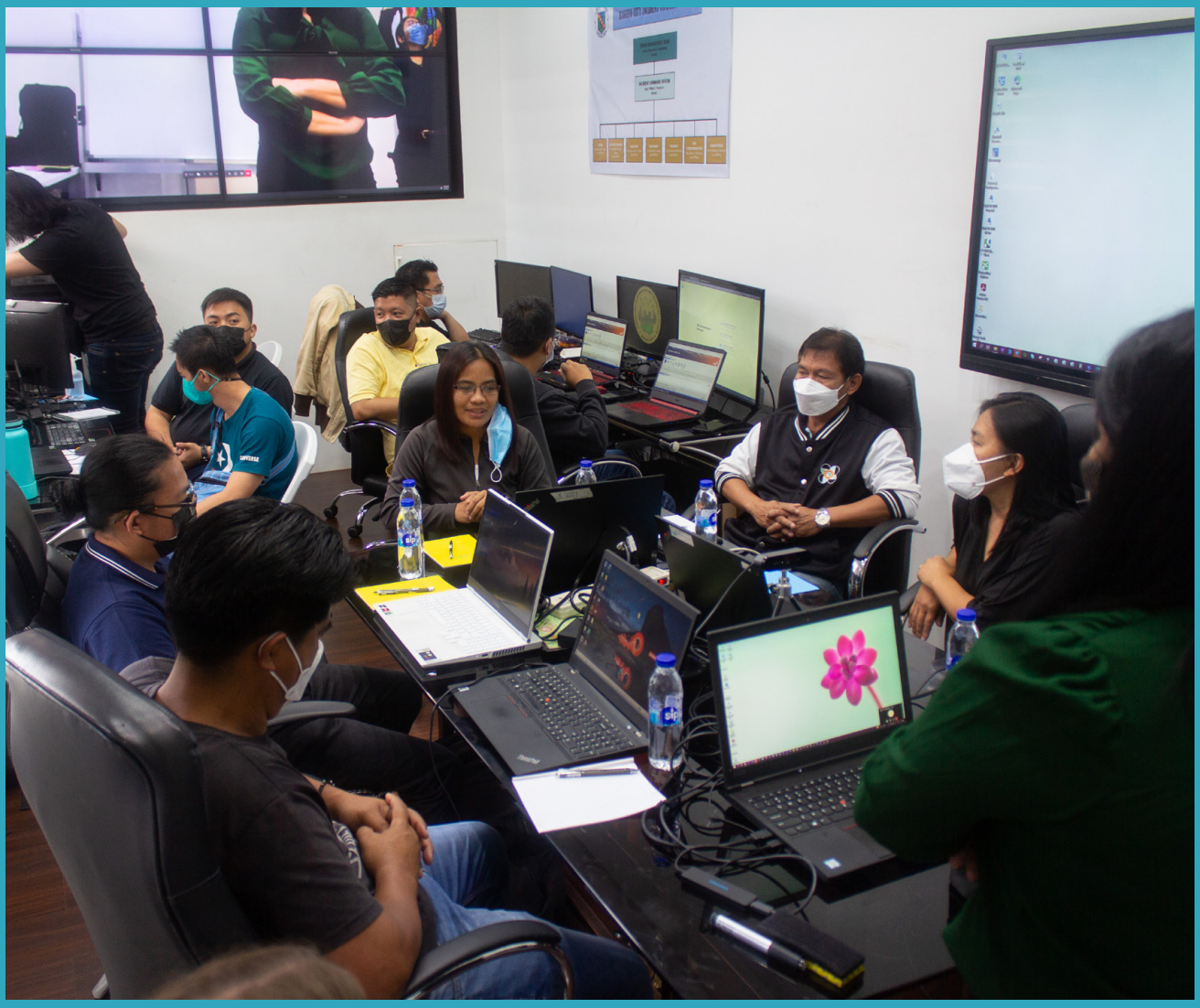


Figure 27: Road map for implementation of NbS in Baguio City.

Source: Ramboll

6. TARGETED CAPACITY BUILDING AND TRAINING PROGRAM



"...by just attending the flood early warning system on the job training sessions and just thinking of all the opportunities that my role in this project, moving forward gives me the sense of excitement, because I know that there are so many things ahead of me and I can be so much more after this."

Chester Comicho, Engineer, Baguio LGU

Source: Ramboll

6.1 OBJECTIVES AND APPROACH

In an effort to solidify and enhance program effectiveness and sustainability beyond the completion of the pilot project in December 2022, a year-long "Targeted Capacity Building Program to Enhance Delivery of a Sustainable FEWS" was implemented from end-December 2021.

The main objective of the targeted capacity building program was to ensure long-term sustainability for the established FEWS by securing the required local capacity for operating and utilising the FEWS as an active risk mitigation instrument beyond the timeframe of the pilot project.

The targeted training and capacity building program consisted of the following key elements:

1. **3-module training program:** This has been carried out by DHI and supported by Ramboll. It focused on giving the participants in the training program a general understanding of Flood Early Warning Systems and training in the different types of DHI software used in the FEWS system to be implemented in the "Baguio City Smart Flood Warning, Information and Mitigation System" pilot project. The training program was carried out as online (self-paced, instructor-led, and expert advice) courses based on the ACADEMY by DHI eLearning platform.
2. **On-the-job (OTJ) training:** This was carried out by Ramboll and included all the specific training and support related to the Baguio models and the FEWS system developed by Ramboll in collaboration with the Baguio LGU.

A total of eleven professionals have been selected to participate in the training and capacity building program following nomination from the LGU. Five staff members from LGU have been selected for participation in the program, and they constitute the "core group", who will have the main responsibility for operation and maintenance of the FEWS. A "peer group" consisting of six persons outside of the LGU has also been selected for the program. The peer group participants come from local public institutions (universities, other public intuitions etc.), and their main role is to support the core group.

6.2 PARTICIPANTS AND CRITERIA FOR SELECTION

When the Baguio pilot project commenced in August 2020, the original scope included a track for On-the-Job (OTJ) training to be provided to those few staff members of the LGU who would be responsible for the long-term sustainability (i.e., operation and maintenance) of the FEWS. Ramboll made an effort during project start-up to communicate clearly to the LGU regarding the ideal and appropriate qualifications and experience levels of preferred candidates for the OTJ training (and hence long-term operation and maintenance). The baseline assessment of selected participants' capacity is presented in the *Scoping and Training Course Design Report*[22].

None of the candidates nominated by the LGU satisfied the requested preferred qualifications/experience; all otherwise being tangentially involved in an area of disaster risk management, drainage infrastructure management or IT infrastructure management. Furthermore, as confirmed by the LGU, **candidates with more relevant experience (i.e., an educational background in hydrology, hydraulics/hydrodynamic modelling, FEWS, programming or similar) did not exist in the staff pool.** Despite lackings in qualifications, all nominated LGU candidates possessed a high level of interest and motivation both in terms of being upskilled in their FEWS knowledge and capabilities, as well as in being involved in the long-term operation and maintenance of the system.

Discussions between Ramboll and ADB commenced already in the first half of 2021 regarding the inability for the Task Team to, without significant additional effort and targeted capacity building, ensure an effective OTJ training and knowledge transfer under the originally scoped pilot intervention. Thus, the additional targeted Capacity Building Program was greenlighted by ADB, under a joint collaboration between Ramboll and DHI (the developer of the MIKE suite software).

Ramboll/DHI together with ADB agreed to expand the participant group for the trageted training from the original five "core group" LGU members to include an additional six "peer group" non-LGU members. The nominated members of the peer group were identified in January 2022 with the assistance of the LGU. The peer group participants were selected on the basis of (i) having relevant educational background and experience, and (ii) motivation/committment to support in the long-term sustainability of the FEWS. The peer group participants were nominated from- and represented different local public institutions including: 3 participants from 2 universities, 1 from PAGASA, 1 from DOST-CAR, 1 from the District Engineering Office (BCDEO).

22 Footnote 4

6.3 OVERVIEW OF THE CAPACITY BUILDING PROGRAM

The capacity building program consists of three modules, which are sub-divided into a total number of 10 sub-modules (Figure 28) delivered over the course of a year (Figure 29). The structure and content of the 3-module training program is described in detail in the *Scoping and Training Course Design Report*.

The program was based on the ACADEMY by DHI virtual eLearning platform tailored to the specific needs and requirements of the trainees and containing a number of self-paced and instructor-led courses. The program facilitated progressive learning ensuring that each trainee successfully passes one level before progressing to the next level. Each session contained an evaluation module for the trainee to pass before obtaining a certificate for the specific learning track.

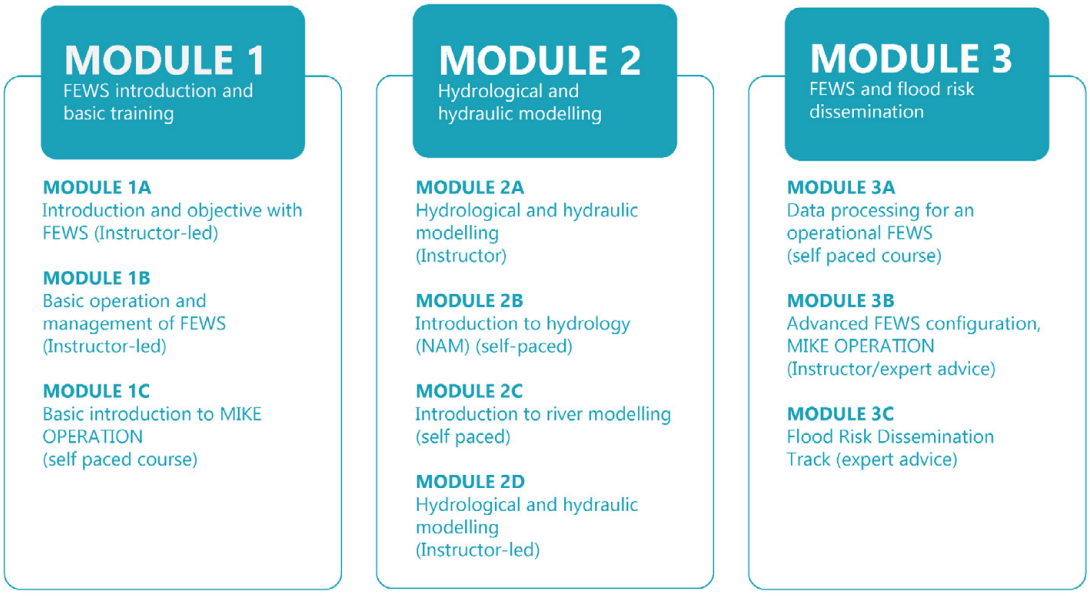


Figure 28: Illustration of the structure of the training program with 3 training modules and the underlying 10 sub-modules.

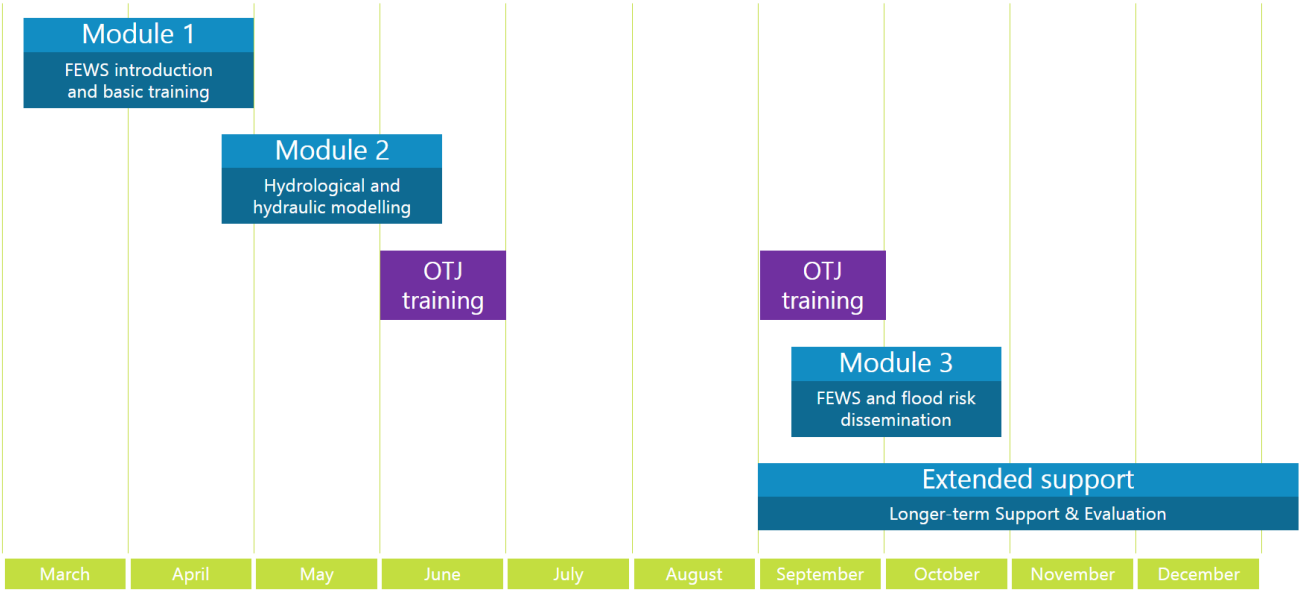


Figure 29: Training program timeline in 2022

6.4 PROGRAM EVALUATION

To ensure that the content, the technical level, and the format of the training are suitable for the participants, the lead trainers of DHI and Ramboll have been engaged in continuous dialogue with the participants to ensure that the training program meets expectations and is adapted to the wishes and suggestions from the participants. Accordingly, participant feedback has been actively encouraged and addressed constructively in all training and knowledge exchange sessions through open dialogue and discussion.

For Module 1 evaluation surveys and quizzes were also included in each sub-modules and was available to the participants through the eLearning Platform. Through continuous feedback dialogue with participants, it was observed that the number of evaluation surveys and quizzes were overwhelming for participants. Thus, for Module 2 it was decided to adapt the sub-module evaluation to dialogue-based feedback, having a quiz for each of the self-paced courses and then an evaluation survey covering the whole of Module 2.

Furthermore, a Workshop (W3) was facilitated following Module 2 as part of the Midway Program Effectiveness Assessment.

After the completion of Module 3, the participants were asked to complete a quiz and an evaluation survey covering Module 3. Furthermore, a Workshop (W4) was facilitated following Module 3 as part of the Final Program Effectiveness Assessment. The evaluations for the three modules can be found in their respective Course Evaluation Reports[23,24,25].

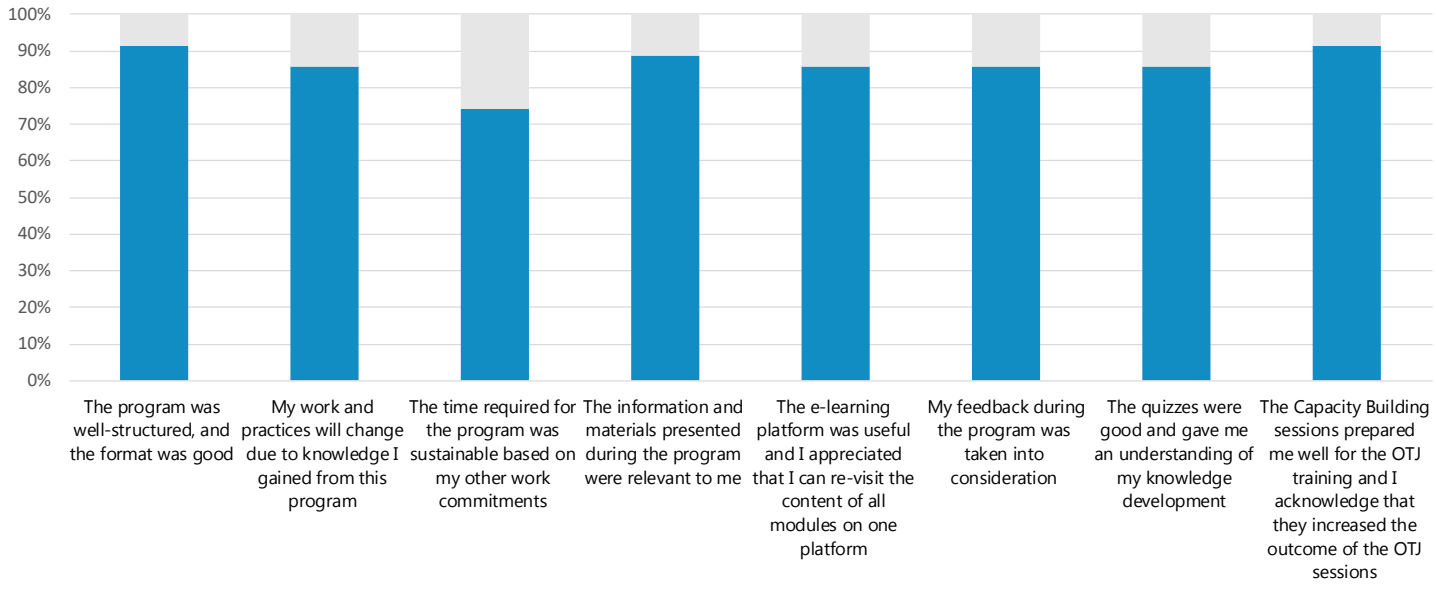


Figure 30: The participants response to statements presented to them prior to the final evaluation workshop.

23 Footnote 5
24 Footnote 6
25 Footnote 7

6.5 ASSESSMENT OF PROGRAM EFFECTIVENESS

The key objective of the 3-module online training programme was to provide the participants with fundamental knowledge and understanding of topics and tools to be used to setup, operate and maintain the FEWS for Baguio, thereby complementing and making the OTJ training more efficient.

To monitor the Program Effectiveness, a Baseline Knowledge Assessment was carried out prior to the start of the training program to garner a proper understanding of the participants existing knowledge and skills related to the planned topics of the training modules. This assessment was based on their self-assessment. To monitor their skill development and confidence in the relevant topics a Midway Knowledge Assessment was carried out after the completion of Module 2 and a Final Knowledge Assessment was carried out in relation to the Final Evaluation Survey after the completion of Module 3. Thus, by comparing the three knowledge assessment surveys, it is possible to assess how the trainees have gained knowledge and experience during the training course and thereby measure the Program Effectiveness.

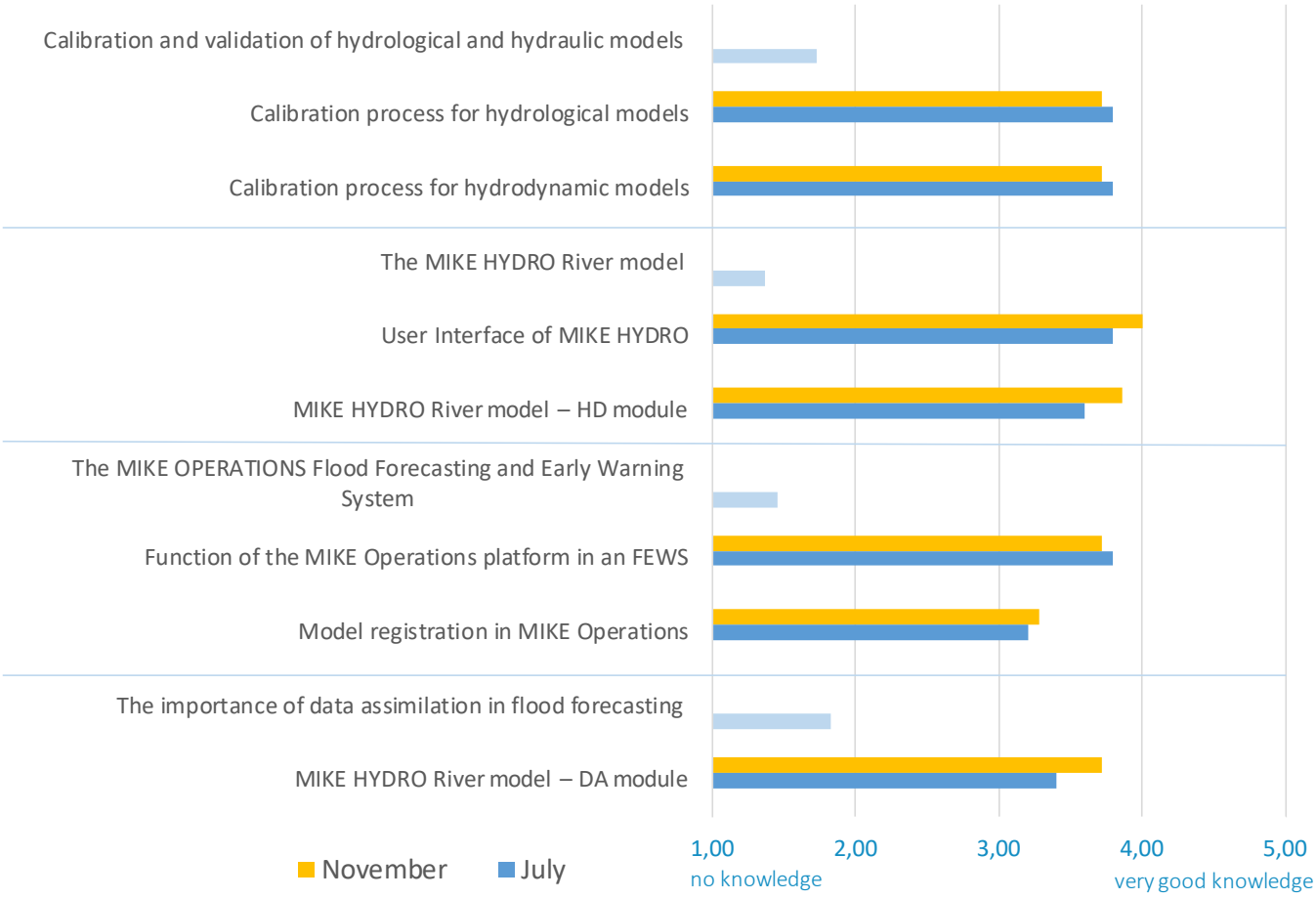


Figure 31: Example of Knowledge Assessment for Module 3. Comparison of Baseline (light blue), Midway (dark blue) and Final (yellow)

6.6 OTJ TRAINING

The OTJ training aimed at preparing the O&M team with skills and knowledge for setting up, operating, and maintaining the FEWS. The in-person training sessions provided in-depth hands-on experience to the trainees which will build the confidence in a more efficient manner than traditional classroom trainings or online e-learning training modules. Effective OTJ training was made possible by the Capacity Building Program, which provided the trainees with a general understanding of hydrology, hydraulics, flood modelling and early warnings systems as well an understanding of the DHI software used for the FEWS.

Thus, the OTJ training focused on four core elements:

- Understanding of the hydrological and hydraulic characteristics specific to Baguio
- Understanding the historical and real-time data available for Baguio
- Capability of managing annual post-monsoon management, calibration and evaluations and applying changes to the system
- Capability of troubleshooting and operating the system in real-time during monsoon

The OTJ training program was divided in two phases; a 6-day pre-monsoon training program, facilitated in June 2022, and a 5-day post-monsoon training program facilitated in September 2022. A breakdown of the content of the training sessions can be found in the *Flood Early Warning System Report*[26].

Figure 32: Participants during a OTJ training session.
Source: Ramboll

28 Footnote 11

In the feedback sessions concluding each of the phases, the trainees acknowledged that the outcome of the OTJ training was strengthened due to the online Capacity Building Program activities; a sentiment that was echoed by the project team leading the OTJ training.

The OTJ training has been key to building a sense of team spirit among the staff who will form the FEWS Operation and Maintenance (O&M) Team. Gathering the participants in-person at the same location for OTJ training allowed for enhanced interaction and collaboration between participants, and allowed the project team to get a better understanding of their skills and potential roles in the operation and maintenance of the FEWS.

To assess the improvement in understanding and confidence in the training topics, an evaluation survey was conducted before and after each of the two training sessions (see example in Figure 33). The survey results and direct feedback from participants indicate that the training program has successfully improved capacity within hydrology, hydraulics and modelling as all participants state that their knowledge and experience within all topics covered by the program has increased.

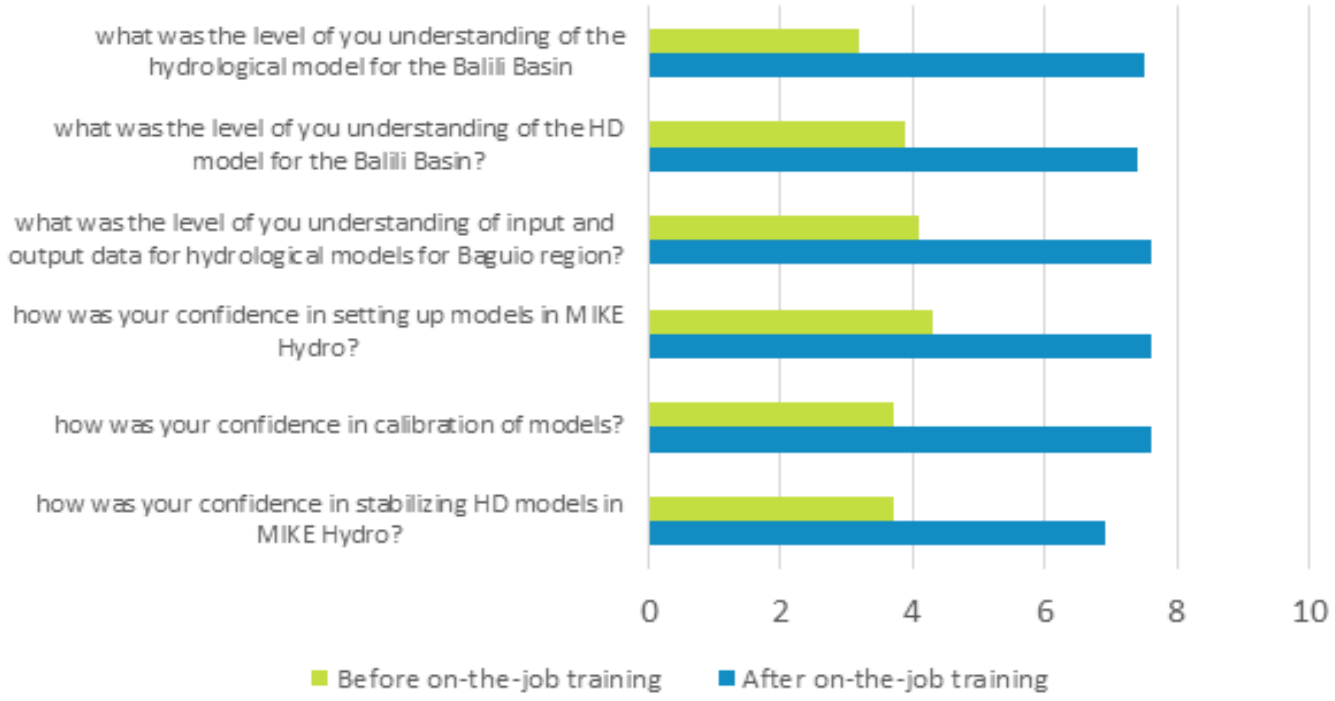


Figure 33: Self-reported level of confidence in training topics before and after OTJ training phase 2 in September 2022.
Source: Ramboll

However, given the starting point of the participants, it has not possible to bring them to the necessary professional level through completion of training to enable them to be fully responsible for the operation and maintenance of the FEWS system. This further enhances the need for Baguio City to continue receiving technical support and expert advice on the operation and maintenance of the FEWS to ensure the long-term sustainability of the system (see Chapter 11: Recommendations).

7. GENDER AND SOCIAL INCLUSION

Source: Asian Development Bank

7.1 OBJECTIVES AND APPROACH

This project involved a strategic collaboration with Practical Action Consulting (PAC), based on their innovative approach and experience implementing gender transformative FEWS.

Gender is a critical consideration in ensuring an effective FEWS leaves no one behind. Gender inequality and social marginalisation increases vulnerability to disasters, affects access to early warning, impacts preferences and capacities for preparation and response, and excludes women and marginalised groups from decision-making processes. Proactive efforts are needed to incorporate the needs, priorities, and capabilities of marginalised gender groups, and magnify their voices at every stage of the FEWS.

Broadly, the objectives of the report were to:

- Improve the understanding of decision-makers about drivers of gendered vulnerability and how these affect FEWS needs within and between communities;
- Link the needs of vulnerable and marginalised groups to considered and meaningful planning of preparedness and response actions; and
- Improve representation and inclusion of marginalised groups in the FEWS.

The gender and social inclusion component of the project included conducting the Mixed Methods Gender and Inclusion Study[29], compose a set of recommendations into the FEWS design and dissemination[30], as well as turning these recommendations to actions with an implementation plan[31].

The study refered throughout to marginalised gender groups, which includes (but is not limited to) cisgender women, transgender women, transgender men, and non-binary or third gender people. The research has predominantly interviewed cisgender men and women; however, the study consciously adopts an inclusive and intersectional approach and aims to acknowledge and reflect the diversity of identities and experiences that are integral to all discussions relating to gender. At the same time, this project is addressing the need and interest of the city of Baguio to implement gender transformative approaches to FEWS to ensure all its citizens can benefit from the FEWS development and implementation currently underway as part of the associated project.

29 Footnote 8
30 Footnote 9
31 Footnote 10

7.2 MIXED METHODS GESI STUDY

The study brings together a suite of analysis and data collection techniques to deliver a holistic and well-rounded understanding of the connections between flood risk, and gender, marginalisation and inequality within Baguio. The study draws on secondary sources of data through a global and national literature review on areas of inequality and on the influence of gender and inequality on disaster risk. This secondary data is complemented by three types of quantitative and qualitative primary data, including a community survey, key informant interviews, and Missing Voices interviews (Figure 34).

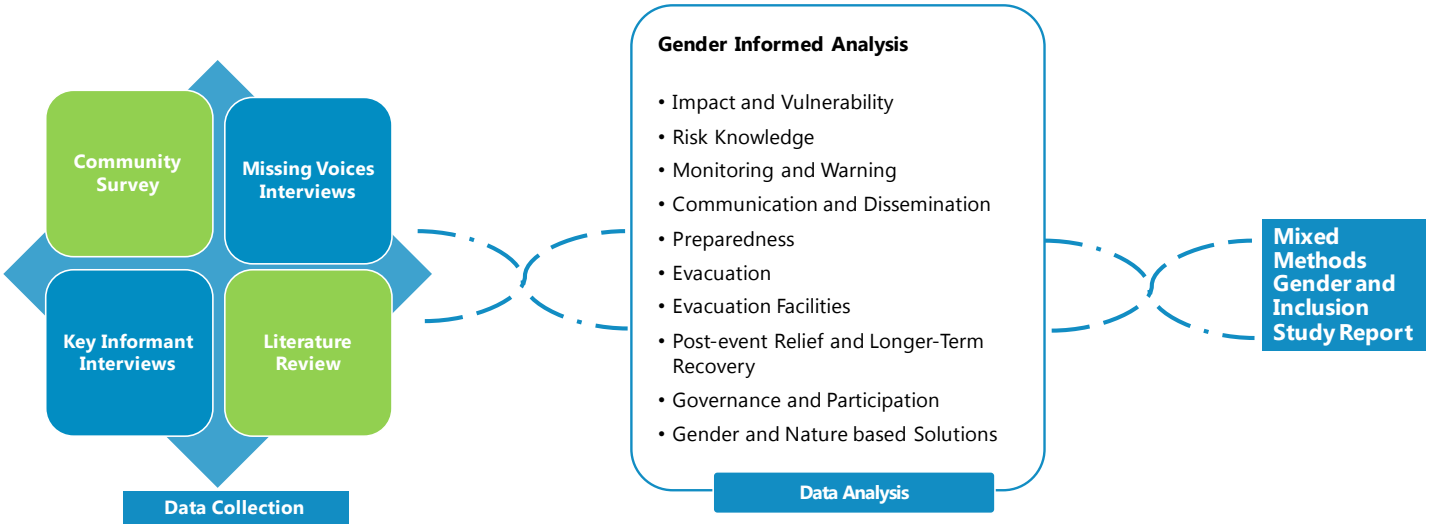


Figure 34: Elements of the mixed methods study approach
Source: Practical Action and Ramboll

The methodology recognises the importance of intersectionality in our approach and analysis, acknowledging the ways in which multiple axes of identity influence experiences of vulnerability and capacity to respond.

The "Missing Voices" methodology is an approach that starts with identification of the groups and individuals likely to experience marginalisation or increased vulnerability in a specific context. It involves talking to community-based organisations, informal support groups and other intermediaries who are themselves members of, work with, know, and are trusted by marginalised communities. These organisations and groups are often able to provide insight into the issues facing specific groups and enable the introduce the research team to start a process of snowball sampling to find, build trust with and listen to individuals who are people they know that would be willing to speak to the research team, face multiple axes of marginalisation and are likely to be left out of traditional dataset and mainstream narratives. Interviews are conducted over the phone, rather than visiting people's homes, providing greater privacy and anonymity, and drawing unwanted attention to individuals who may want or need to avoid attention.

In this way, the research team is able to hear candid and detailed accounts, often about subjects which, due to their sensitivity, are not heard about in wider community group discussions. This "Missing Voices" approach provides a much more nuanced understanding of how different individuals and gender groups experience floods and FEWS, an understanding that is critical forthe development of actions and procedures to enable for gender transformative FEWS

7.2.2 GENDER-INFORMED ANALYSIS

Effective FEWS comprise 4 core components as shown in Figure 35. Risk Knowledge is vital, ensuring effective understanding of flood risk both in those managing the FEWS and in those living in flood affected areas, enabling risk informed action. Monitoring and Warning ensures that appropriate observations and thresholds enable appropriate forecasting and triggering of early warning. Response Capability ensures that effective plans, resources and preparedness is in place to take effective action in response to a warning. Dissemination and Communication ensures that understandable, actionable information is communicated to all who need it, enabling timely risk-informed early action. Effective FEWS also require consideration of 4 cross-cutting components:

- Involvement of Local Community;
- Effective Governance and Institutional Arrangements;
- A Multi-Hazard Approach; and
- Consideration of Gender and Cultural Diversity.

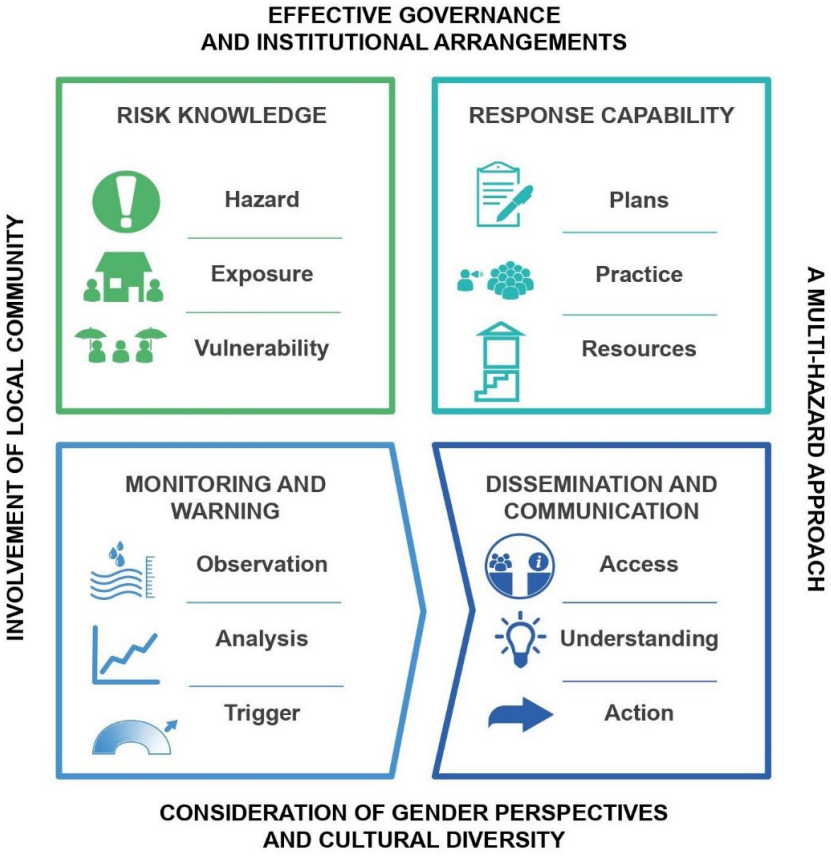


Figure 35: Elements of an effective early warning system
Source: Practical Action, 2020, adapted from World Meteorological Organisation, 2017.

7.3 RECOMMENDATIONS FOR A GENDER TRANSFORMATIVE FEWS

The findings of the study highlight a number of ways in which stakeholders involved in the design and implementation of the flood early warning system in Baguio City can take action to ensure that the EWS is effective for everyone who needs it, leaves no one behind, and supports equitable and inclusive. The full findings can be found in the *Mixed Methods Gender and Inclusion Study report*.

The findings provided the basis for a set of targeted recommendations and guidelines for the FEWS design and dissemination (Figure 36). The recommnedations and guidance policy brief is recommended reading for stakeholders engaged in implementing different components of the Baguio Flood Early Warning System.

Figure 36: Overview of the categories for recommendations for a gender transformative FEWS

7.4 FROM RECOMMENDATIONS TO ACTIONS

The policy recommendations have been shared with stakeholders in the Baguio FEWS, including government and civil society actors. The project team facilitated a series of bilateral discussions with these stakeholders, discussing the relevance of the above recommendations for each person's organization, remit and responsibilities. Within these bilateral conversations, the Project team sought to co-develop priorities for how these recommendations can be effectively put into action as part of the Smart Flood Early Warning, Information and Mitigation System under development. This process of co-development, discussion and refinement of agreed actions, laid a foundation for ongoing enhancement and adaptation of the FEWS, a system that is inherently adaptive and evolving. The process followed in this project is outlined in Figure 37 and further detailed in the *From Policy Recommendations to Practical Actions*[32] document.

32 Footnote 10

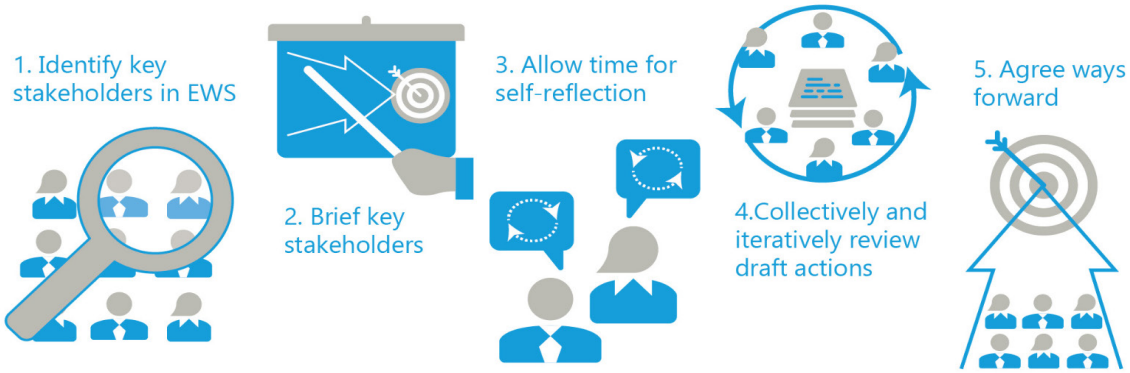


Figure 37 Steps for moving from recommendations to actions to support a gender transformative FEWS

In addition to the list of recommendations and specific actions and responsiblities of each stakeholder, the process allowed stakeholders involved in this process to gain important benefits including improved awareness, ownership, and empowerment. The process of having to take the time to review findings and recommendations aims to improve each stakeholder's knowledge and awareness of the issues, barriers, challenges, and needs of vulnerable groups in their context. By spending time developing their own actions and considering actions of their partners, the EWS stakeholders develop a greater sense of ownership in the actions they develop (compared to if someone had developed a list for them) and are empowered them to take a clear strategic direction forward.

The actions should be treated as a starting point and revised later as the FEWS evolves and the needs of the context evolve. They should also be integrated into plans, procedures, and policies for DRRM and FEWS stakeholders, in order for gender and social inclusion to be considered and addressed across all areas of the FEWS, rather than as a separate list of gender-specific "add-ons".

Table 6: Excerpt from table of recommendations and their respective actions. The full table can be found in the Implementation Plan[33]

Recommendation	Immediate actions	Later actions
In-person, community leader-led dissemination may be suited for distributing simple uniform instructions (i.e. evacuate now). It may be less suited to sharing more complex information or earlier alerts – consider which dissemination channels are best suited for which type of communication, with multiple dissemination channels aligned to different communications enabling the development and evolution of a sophisticated, people-centred early warning system that leaves no-one behind.	CDRRMO will: • Establish a set of standards for disseminating a range of early warning instructions with tailored and/or multiple types of content for various users. [LGU PIO and other media partners, BDRRMC] AASCTF Pilot Project will: • Provide a clear distinction in Data Dissemination and Outreach Plan on which type of communication channel is recommended for various messages / warnings and specific user groups, including who is responsible in carrying these out. [CDRRMO, OPCEN, BDRRMO, Baguio PIO]	• Conduct post-disaster assessments of effectiveness of the set of standards for the dissemination of early warnings. • Develop clear SOPs for early warning dissemination and communication strategy that contains instructions on which type of communication channel is to be used for various messages/warnings and specific user groups, including who is responsible in carrying these out.

33 Implementation Plan. Actions and Responsibilities for a Gender Transformative FEWS in Baguio City, s.l.: ASEAN Australia Smart Cities Trust Fund. November 2021.

8. THE FEWS DESIGN

"I think it's important for the Baguio LGU to be able to independently operate the flood early warning system... as we are in the frontline when it comes to the implementation of Disaster Risk Reduction and Management... the FEWS can greatly help officials and decision makers during disaster and in dealing with flooding incidents in the city."

Stephanie Trinidad, DRRM Officer, Baguio LGU

Source: Ramboll

8.1 OBJECTIVES AND APPROACH

The design of an inclusive people-centric FEWS aims at reducing the climate change-enhanced risk of flooding by providing appropriate and applicable early warning to Baguio's residents. The FEWS is developed with Baguio Local Government Unit (LGU) and other key stakeholders to improve community disaster preparedness, raise awareness, and ensure ownership. This section, describing the *Flood Early Warning System Report*[34], presents the overall design approach for the FEWS and outlines the main components of the technical and institutional setup, including efforts to further solidify and enhance long-term sustainability through capacity buildings and partnerships.

The report aimed at answering the following questions:

- What are the main benefits and the overall design approach of the FEWS?
- What are the supporting IT infrastructure requirements?
- What are the supporting institutional requirements?
- How is the FEWS to be operated and maintained to ensure long-term sustainability?
- What efforts are required in testing and validating the FEWS?

34 Footnote 11

8.2 FEWS – OVERALL DESIGN FRAMEWORK

The end-goal of the Flood Early Warning System (FEWS) development for Baguio City is to improve the city's resilience to flooding and facilitate early preparedness. The value added by the FEWS is an increase in reaction lead time by way of forecasting future water levels in the main rivers, with linked risk of flooding in Baguio. At the core of its design, the FEWS is an IT system, composed of a back-end and front-end development. The FEWS essentially hosts calibrated hydrological and hydraulic models based upon historical data and measurements which take in real-time and forecasted inputs to predict time series of flows and water levels in a river system.

The data outputs from the system are translated into flood warnings which can be disseminated to various stakeholder groups through different channels.

The FEWS framework including its main components are show in Figure 38 below.

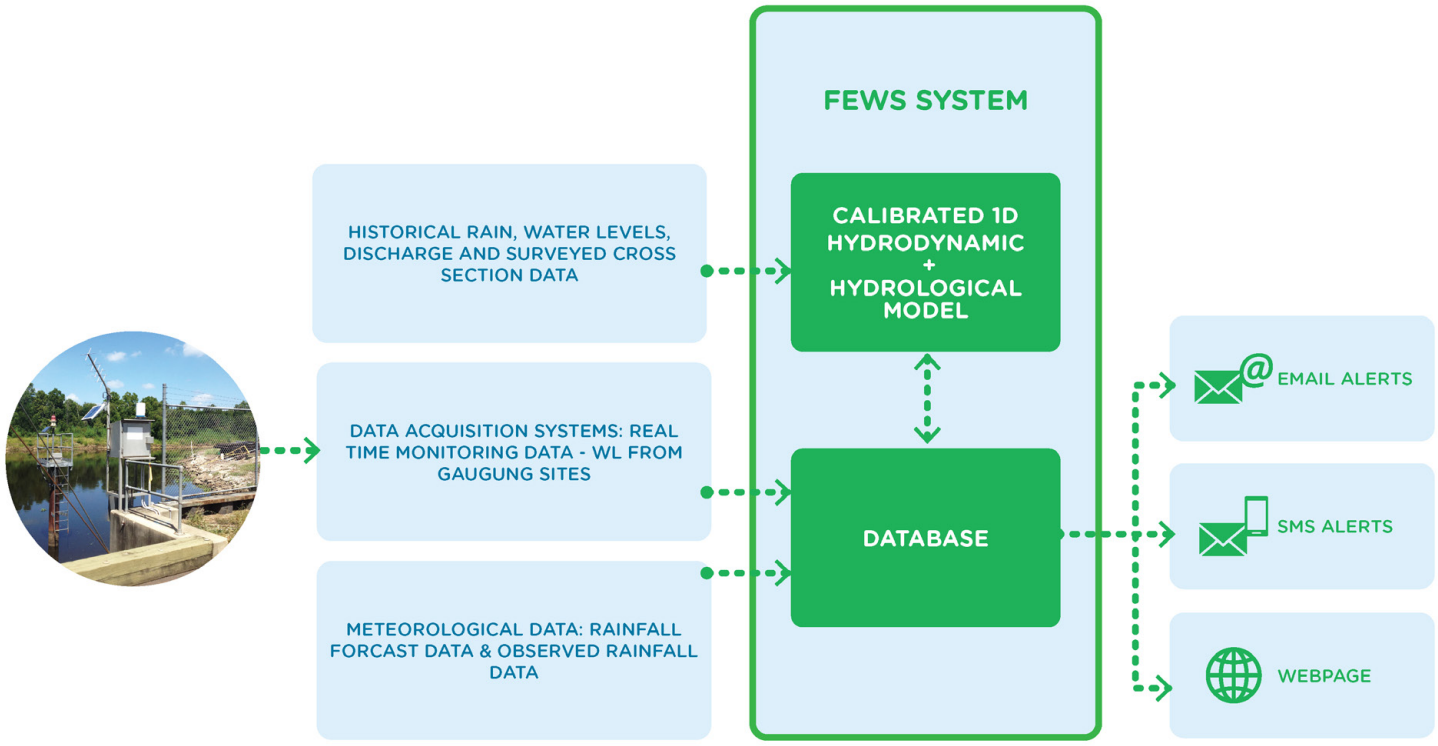


Figure 38: The framework for FEWS.
Source: Ramboll

The hydraulic and hydrological models are calibrated in parallel with respect to recorded water level data and discharge data to allow for the replication of expected routing in the rivers and the hydrological response of the catchments to rainfall events. The rainfall forecast is the main input for the calibrated coupled Hydrodynamic-Rainfall Runoff (HD-RR) model along with real-time rain data and water level from telemetric stations for data assimilation. The models are setup using the MIKE HYDRO River software, a state-of-the art modelling tool by DHI.

The FEWS IT system is designed and built using the MIKE OPERATIONS product by DHI. The real-time flood forecasting domain within MIKE OPERATIONS is configured for LGU specific forecasting and warning requirements.

The FEWS is configured to run automated jobs to acquire all the required real-time data and information from external data sources, perform data checking for timeseries analysis and visualization, run forecast models and issue automated alerts. All the processes such as downloading the real-time data, forecast rain data, updating model inputs, triggering model runs and updating model results are automated.

The main components of the FEWS are:

Calibrated backend models in MIKE HYDRO:

- 1-Dimensional (1D) Hydrodynamic module (HD): The 1D hydrodynamic model takes the runoff inputs from the RR model and routes it through the defined river network.
- Hydrological Rainfall-Runoff module (RR): The hydrological model simulates the catchment reactions and essentially routes rainwater to the rivers and drains.
- Data assimilation module (DA): The data assimilation uses the available real-time measurements of water level on the river to calculate error patterns and then applies the same to the water level forecasts. Real time data assimilation is an essential prerequisite for an accurate flow forecasting system.

MIKE OPERATIONS setup:

- MIKE Workbench: Interface to input data into the database and apply data analysis, process tools interactively, configure automated workflows, write scripts for automation and configure custom-made data reports.
- MIKE OPERATIONS Desktop: Interface to interact with PostgreSQL database for configuring dashboards and establishing publishing rules.
- MIKE OPERATIONS WEB: Interface that allows for visualization of the dashboards that are setup through MIKE OPERATIONS Desktop.

As evident from the above, the FEWS is heavily data dependent; hence, reliability and quality are key to ensuring the success of the project. A highly technical, smart, and resilient IT framework to house the systems, see Section 3, as well as an active participation from relevant agencies is important to ensure the sustainability of the project. The operation and maintenance activities for the FEWS are outlined in Standard Operating Procedures (SOPs), which contribute to achieving efficiency, quality output and uniformity of system performance, while reducing miscommunication and failure to comply with standards.

8.2.1 REAL-TIME DATA

Countrywide Weather Research and Forecasting (WRF) models are run at PAGASA for Philippines. For the FEWS, the rainfall forecast from PAGASA is key as this data input is essentially a primary driver for the flood forecast.

Real-time data from monitoring stations, rainfall and water level, is used in the real-time operation of the system to run the models. In addition to the five existing stations, five new stations, one tandem station (i.e. monitoring rainfall and water level) and four water level stations, that have been procured and installed as part of the project to be used for the FEWS setup (Figures 40 and 41). The new stations are owned by the LGU and ensure greater spatial real-time data coverage of the river basins in Baguio. The stations are linked to the PhilSensors website, where real-time data from the existing stations is being published, and API access is provided by DOST-ASTI. An overview of the real-time monitoring stations in Baguio City and surroundings is seen in Figure 39.

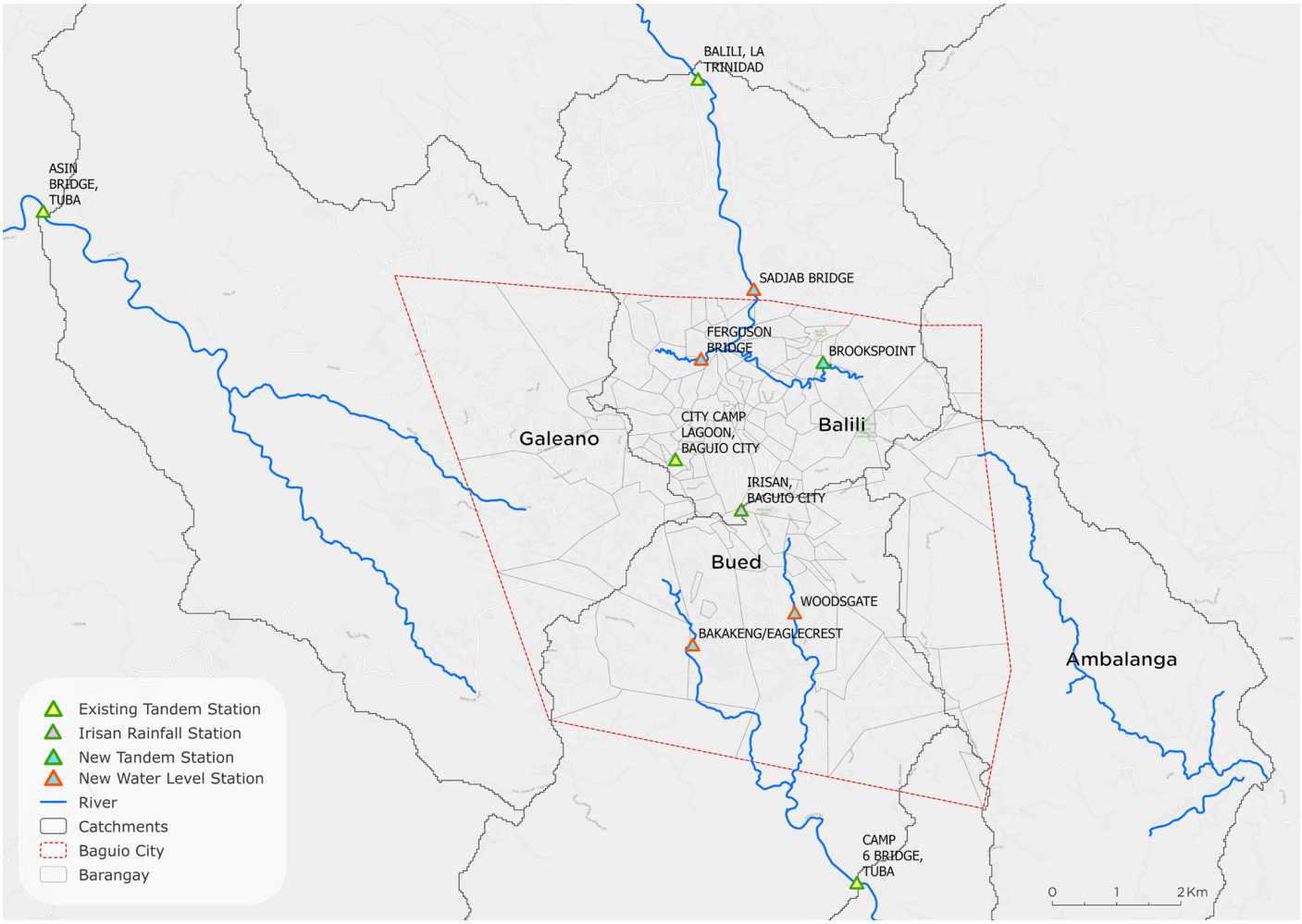


Figure 39: Overview of existing and new gauging stations within Baguio City and surroundings (excl. Mamating Bridge station).
Source: Ramboll

Figure 40: Monitoring station at Fergusson Bridge. The station was constructed as part of the project in 2022.
Source: Ramboll

Figure 41: Monitoring station at Sadjat. The station was constructed as part of the project in 2022.
Source: Ramboll

8.2.2 THE FEWS DASHBOARD

A dashboard has been setup for the FEWS. The dashboards can be viewed and shared through the MIKE OPERATIONS Web platform. This would allow for dissemination of warnings to stakeholders. The finalization of the dashboard is dependent on the validation of on the dissemination plan and finalization of FEWS dissemination SOPs.

The setup of the web dashboard is shown in Figure 42.

Numbers (in red) are inserted on this figure representing the following:

1. Baguio City LGU Logo
2. Gallery to check map objects on or off

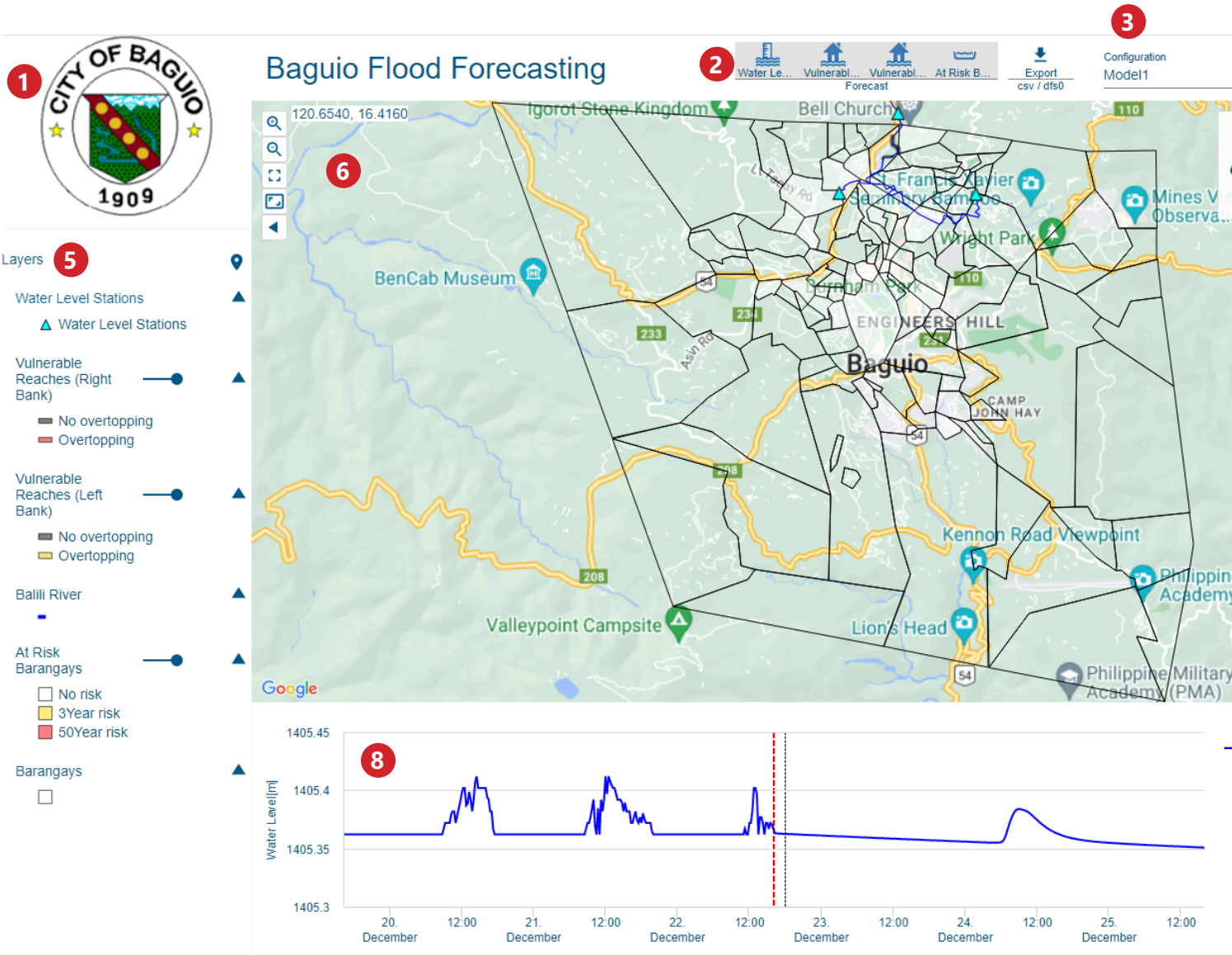
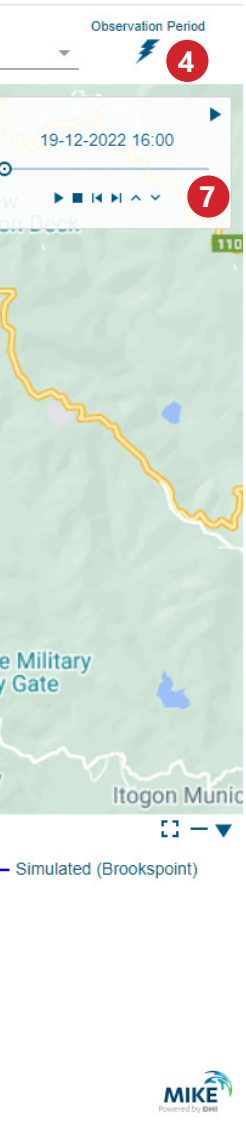


Figure 42: Baguio Flood forecasting webpage - currently available on internal systems.
Source: Ramboll

3. Drop down menu to access which of the models (pilot river basin or secondary river basins) should be displayed
4. Drop down menu to select the simulation based on which the values in the charts should be displayed
5. Legend of items in the map view. This pane in the dashboard can be switched to visualize the menu from where individual objects for chosen layers can be selected
6. Map view
7. Animation slider bar to navigate the timeline for the period when data is available in the chosen simulation
8. Chart/timeseries plot – the data in this view gets updated based upon which object is selected in the map view or the menu. The vertical red line indicates the time of forecast in the selected simulation. The horizontal dashed lines represent the defined thresholds.



The dashboard displays two types of warnings:

- **Riverbank overtopping**
  Color-coding is used in the dashboard to illustrate the riverbanks where overtopping is forecasted; No overtopping, no color. Overtopping is defined as the water level exceeding the identified critical water level threshold. The stretches along the river where right bank overtopping is forecasted will be indicated in 'red' and the stretches along the river where there is a risk of left bank overtopping will be indicated in 'yellow'.

- **Warnings for at-risk Barangays**
  Color-coding is used in the dashboard to illustrate Barangays at-risk of flooding; No color indicates low risk of flooding, 'yellow' indicates flood risk corresponding to a 3-year rainfall, and 'orange' indicates flood risk corresponding to a 50-year rainfall. Based on the flood maps produced during the Flood Hazard and Risk Assessment (Task 2), Barangays at-risk of flooding have been identified for different intensities of rain corresponding to 3- and 50-year return periods. In the current configuration, Barangays at-risk are being identified and displayed appropriately on the dashboard by correlating rainfall forecasts for 72 hours with these rain intensities in real time.
  The Barangays at risk with respect to the rain intensity for a 3-year return period are being indicated in yellow and the Barangays at risk with respect to the rain intensity for a 50-year return period are being indicated in red. It should be noted, that this is a preliminary setup. Ideally, the WRF data, bias-corrected against station rainfall data, will be compared to rain intensities for various return periods (as per existing IDF curves developed by PAGASA) and based on this comparison, flood warnings will be triggered by the FEWS for the various at-risk barangays.

8.3 INSTITUTIONAL FRAMEWORK SUPPORTING THE FEWS

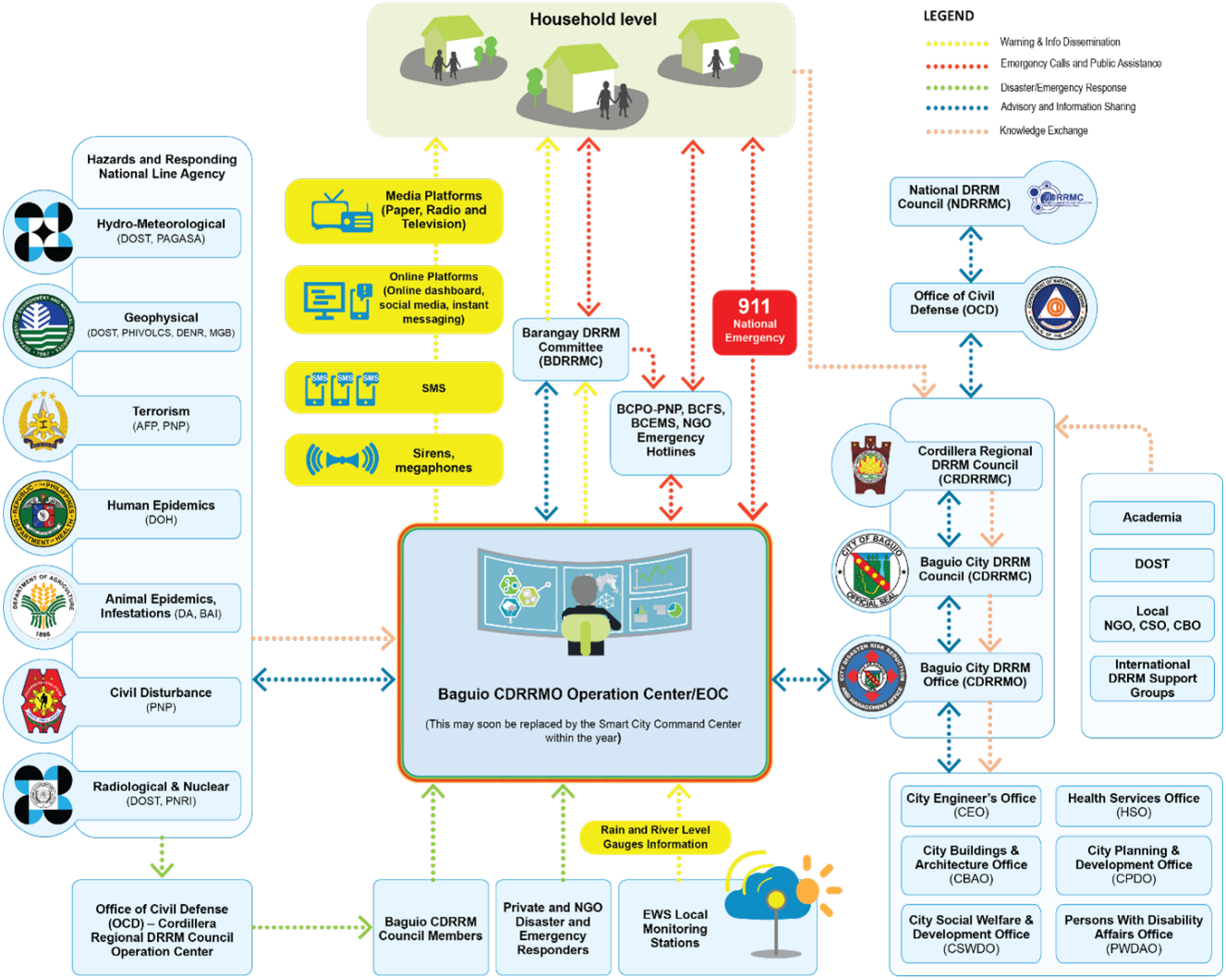


Figure 43: Baguio City CDRRMO OPCEN operational flowchart including local stakeholders
Source: Ramboll

Strong stakeholder partnerships are essential in ensuring success and sustainability of the FEWS. Through stakeholder partnerships with public and private organizations as well as academia, the LGU can gain knowledge, experience and innovation improving the overall impact and usefulness of the FEWS for the City of Baguio. The *Flood Early Warning System Report* provides an overview of stakeholders relevant in operating the FEWS, while the *Data Dissemination and Outreach Plan*[35] describes stahekolders involved in warning and information dissemination/outreach activities, as well as the chain of communications before, during and after a hazard event.

The ownership of the FEWS lies with the Baguio City LGU. Within LGU, the system is anchored between three bodies: City Disaster Risk Reduction and Management Office (CDRRMO) and its Operations Center (OPCEN), Management Information Technology Division (MITD), and Baguio Smart City Command Center (SCCC). It was essential to place the FEWS into the already established organisational structure to leverage the connections between LGU staff and peer organisations, to facilitate knowledge exchange, and ensure long-term effectiveness beyond the completion of the pilot project.

34 Footnote 12

8.4 OPERATION AND MAINTENANCE FRAMEWORK

To enable effective operation and maintenance of the FEWS for Baguio, an FEWS Operation and Maintenance (O&M) Team has been formed consisting of the trainees that participated in the capacity building program. The ownership of the FEWS is anchored at the Local Government Unit (LGU) and thus, the O&M core team consists of LGU staff with support from a peer team of representatives from academia and selected relevant agencies (i.e. PAGASA, DOST-CAR, BCDEO). To ensure long-term sustainability of the FEWS, the LGU should continuously ensure that the O&M team members are available to perform the required tasks. It is crucial that O&M team is institutionalized and well-trained, and that team members have the mandate to prioritize the required tasks.

To secure effective operation of the FEWS, Standard Operating Procedures (SOPs) have been prepared to guide the FEWS O&M team. The purpose of a SOP is to carry out operations correctly and always in the same manner. The SOPs contribute to enhancing sustainability by outlining specific activities and tasks to be undertaken by the O&M team and serving as a guide for the team throughout the different operation and maintenance phases.

The proposed organizational structure of the O&M team can be seen in Figure 44. Overall supervision of the FEWS O&M team will be with the head of CDRRMO who has the mandate to coordinate directly with high-ranking government officials and guide in decision-making. The full description of O&M team composition and detailed descriptions of roles can be found in the *Flood Early Warning System Report*.

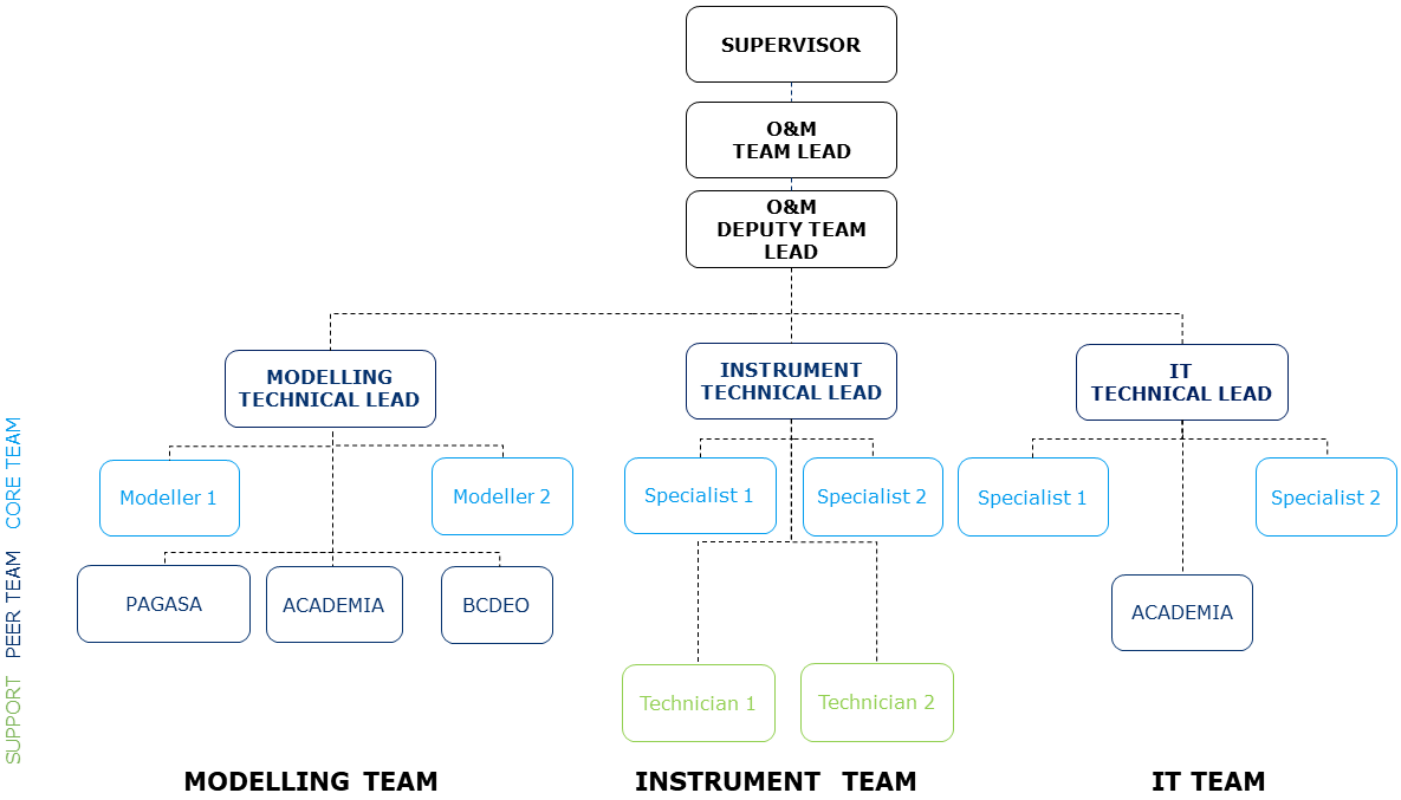


Figure 44: The structure of the FEWS Operation and Maintenance (O&M) team.
Source: Ramboll

9. DISSEMINATION AND OUTREACH

Source: Ramboll

9.1 OBJECTIVES AND APPROACH

The terms **Dissemination** and **Outreach** refer to the process of distributing information to relevant recipients (dissemination) and the expansion of the information dissemination to marginalized and vulnerable groups in Baguio (outreach). Thus, the objective of the *Data Dissemination and Outreach Plan*[35] was to define **who** is communicating **what messages** to **whom** and **when**, before, during and after a natural hazard event in Baguio city.

The report followed the recommendations of the *Baguio City Gender and Inclusion Study*[36], aiming to base the system on the understanding of needs of those most vulnerable and laying the ground for a further development of the FEWS in a collaborative manner with local stakeholders.

As Baguio is classified as a highly urbanized city, a common assumption is that large portions of the population are known to have access to various Information and Communications Technology (ICT) equipment, such as televisions, radios, computers (PCs/laptops), mobile phones, and smart devices (such as phones and tablets). While this to a degree is true, this does not consider those who have limited or no access to this equipment due to their economic or social standing, or due to a physical disability. Adopting a varied and redundant, multi-channel communication approach to disseminate disaster preparedness messages and warnings is crucial to establishing an inclusive FEWS. This is to ensure that urgent warning messages are disseminated as wide as possible and reach their intended recipients, regardless of the communication channel they prefer or have access to. The report provided an overview of the different channels and tools, along with the advantages and disadvantages of each channel.

The intended audience of the plan are the key stakeholders at a local level:

- The City Disaster Risk Reduction and Management Council (CDRRMC)
- The City Disaster Risk Reduction and Management Office (CDRRMO) and its Emergency Operations Centre (OPCEN)
- The Barangay DRRM Committees in every Barangay
- Private and NGO emergency responders

35 Footnote 12
36 Footnote 8

9.3 RECIPIENTS OF WARNING MESSAGES

According to the *Baguio City Gender and Inclusion Study*, an effective, people-centric FEWS implies appropriate and timely early warning reaching the last mile, including the most vulnerable. The *Data Dissemination and Outreach Plan* divides the recipients into 10 groups depending on their concerns and needs when confronted with a hazard event. The primary target groups of the FEWS are Group 1: Communities directly affected by the emergency and Group 2: Vulnerable groups directly affected by the emergency. However, these groups being the prime target groups for the FEWS does not imply that they should be "guinea pigs" in the testing and validation of the system. To avoid misunderstandings and misbehaviors, e.g. unnecessary relocation of vulnerable groups, the FEWS dissemination and outreach mechanisms need to be tested on selected City staff (the FEWS O&M team) and officials first, and then gradually expanded to include more groups.

Understanding the key stakeholders and their concerns makes it easier to tailor messages and select means of communication explicitly. It is important to acknowledge that different recipients have different concerns and needs, and tailoring messages becomes crucial when wanting to get the messages across in a clear and swift manner before and during emergency situations. A "one size fits all" approach is not applicable to early warning messages, as the diverging needs, abilities, preferences, and access to communication channels might mean that the warning doesn't reach the last mile and puts the vulnerable community members at a disproportionate risk.

Table 7: Excerpt from the overview of concerns of target recipients during emergencies. The full table can be found in the Data Dissemination and Outreach Plan

Target recipients	Concerns
Group 1: Communities directly affected by the emergency	• Personal safety • Family safety • Access to essential goods/services during emergencies (e.g. food/water/shelter/medical assistance, etc.) • Property security/damage • Loss of livelihood • Disruption to normal activities
Group 2: Vulnerable groups directly affected by the emergency, including: • People with disabilities (PWDs) and their families • Older persons with mobility and/or medical issues and their families • Indigenous People • Single mothers/women-headed households and their families • Women in especially difficult circumstances (WEDC) • (...)	• Personal safety (especially for WEDCs and CEDCs) • Family safety • Access to essential goods/services during emergencies (e.g. food/water/shelter, etc.) • Access to feminine hygiene products or private breastfeeding stations • Access to adequate WASH facilities in evacuation centers • (...)
NOTE: Full descriptions of all ten groups can be found in the Data Dissemination and Outreach Plan	

Source: Ramboll

9.4 RECOMMENDED CHANNELS AND MESSAGE GUIDE

To ensure that urgent warning messages are disseminated as widely as possible and reach their intended recipients regardless of the communication channel they prefer/have access to, a multi-channel approach is essential and follows the recommendation in the *Policy and Practice Recommendations: Towards a Gender Transformative Flood Early Warning System in Baguio City*[37].

Table 8: Excerpt from the characteristics of communication channels overview. The full table can be found in the Data Dissemination and Outreach Plan.

Channel	Direction of ommunica-tion	Broadcast coverage	Audience	Currently in place?	Indepen-dence from power supply	Active maintenance required	Speed	Agency responsible	Best used for
Online Dashboard	→	)))	👥	–	⚡	✓	●●●	OPCEN	⚠ ⚠ ⚠

Additional advantages	Additional disadvantages	Limitations (not suitable for)
• One-stop reference for all disaster-related information that will allow residents access to information/data which could help them decide for themselves actions that they can take to prepare for, during and/or after a flood event/disaster. • Helps establish integrity of data sources • Shows residents that the local government is on top of the situation by having the relevant data that facilitates both government and personal action.	• Would need to be updated frequently via various data sources. • Would need rapid information verification to ensure that information is timely and accurate before making it publicly available. • Budget implications in terms of dashboard development and maintenance (e.g., webhosting, domain, cloud/server storage, data security, etc.).	• Persons who are blind or with vision impairments (unless dashboard has provision for screen readers/text-to-speech apps). • Those without access to ICT equipment or the internet.

It is important to design an effective disaster preparedness strategy/campaign before a hazard event arises, as well as establish clear warning messaging strategy for deployment during hazard events. The *Data Dissemination and Outreach Plan* provides an overview of key and supporting sample messages before, during, and after these events. These sample key messages can then serve as a basis for developing more specific messages after testing their form and contents (text, audio, visuals) with focus groups, including people with barriers to understanding majority-targeted content such as language, education, literacy and disabilities.

Table 9: Example of the FEWS message guide: Sample mockup of SMS flood warnings. The full message guide-can be found in the Data Dissemination and Outreach Plan.

Alert classification	Sample mock-up	Sample text
Yellow flood warning		*YELLOW FLOOD WARNING in [Brgy Name]. Flooding is likely in low-lying areas. Early evacuation for households with special needs recommended. Call 911 for emergency assistance. More info: bit.ly/XXXXXX.*

Source: Ramboll

37 Footnote 10

9.5 TESTING AND VALIDATION

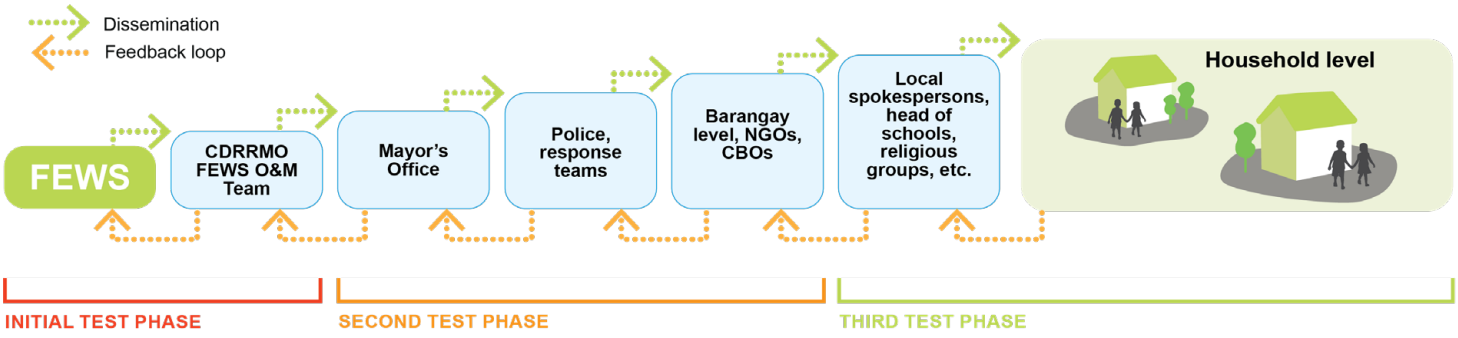
To avoid sending flawed warnings to the wrong recipients at a wrong time, the FEWS in Baguio needs to be tested and the quality of the messages need to be validated in several steps, before sending messages to the end-recipients, the affected residents of Baguio.

Launching a FEWS without proper testing and troubleshooting time can have serious consequences on the credibility of the LGU and ultimately on the confidence in the system itself. The need for testing is not limited to one single monsoon season, as any FEWS requires proper validation before it's publicly launched. A test and validation phase will last several years, depending on the number of flood events, their severity and the feedback loops established to review the messages and channels.

Feedback loops are crucial when testing the system. In practice, this means that whenever a warning has been issued via one of the channels, the Officers-In-Charge and/or supporting staff, will move physically to the affected area to check, whether the forecasted events are taking place, and whether the risk level was appropriate. The feedback loop is essential to check the validity of the forecasts, and to gradually upgrade the system to become more precise in the forecasting of specific events.

During the initial test phase, the FEWS will only be tested by the FEWS Operation and Maintenance team anchored at the CDRRMO, and the Mayor's office will be informed about the test results on a frequent basis (Figure 45). The subsequent test phases will gradually involve more levels and eventually include the end-users of the information. It will be a political decision when to include the different levels of recipients, as there will always be a risk involved in either disseminating too little or too late information or too broadly and too much information.

Figure 45: Organisational set-up during the test phases



Source: Ramboll

Source: Adobe Stock

10. CONCLUSION

Source: Ramboll

The Baguio City Smart Flood Early Warning, Information, and Mitigation System project assists the city with planning for flood mitigation and delivery of the services of flood early warning and responses, using smart technologies. The project outcome is improved flood early warning system, responses, and mitigation measures of Baguio City. The project has three key outputs:

1. Smart flood early warning information system (FEWS) established and operational;
2. Real-time data capture system established in four river basins in Baguio City;
3. Flood Mitigation Action Plan prepared.

The outputs and achievements are further detailed for each project task below.

Baseline Assessment

The Baseline Assessment (Task 1) focused on mapping the baseline in Baguio in relation to the main project components, the data availability and the gaps as well as required actions to fill the data gaps. Key outputs comprise a detailed analysis of the Digital Elevation Model (DEM) to be used moving forward; identification of key social and critical infrastructure to shape the risk assessment; climate change trend analysis of historical temperature and rainfall records to understand past and future climate change developments together with an analysis of climate scenarios; definition of the FEWS framework to guide all hydraulic and hydrodynamic modelling activities; delineation of the FEWS project area based on the DEM and the monitoring stations available in the catchment; selection of the Balili river to pilot the FEWS on the basis of flood predominance and available data; definition of the methods driving the risk assessment; and a preliminary on-the-job (OTJ) training plan. Key data and information gaps related to all project components, the most critical identified as the lack of bathymetry data, i.e. river cross-sections. This data gap was closed with the completion of river cross-section surveys. Datasets and information were collected and reviewed, leading to the development of a GIS inventory. The outputs of the baseline assessment provided the foundation for the following project tasks.

Hydraulic modelling, hazard and risk mapping

The Hydraulic Model and Hazard and Risk Mapping Assessment (Task 2) focused on the overall understanding of the flooding dynamics, climate change impacts and climate risks in Baguio. Through a statistical analysis of observed extreme rainfall values and an estimation of extreme rainfall events for future conditions, the study recommends applying a 'safety' factor to rainfall design intensities of 25% to estimate future rainfall. The safety factor considers the present and future uncertainty of design rainfall events, independent of return periods, and has been used in the hydraulic modelling undertaken in this report when simulating future climate change scenarios. The 1D/2D hydrodynamic modelling, supported by the measurement of more than 60 river cross-sections, shows that the Balili catchment is the most flood prone area in Baguio, with 10 Barangays identified as experiencing recurrent flooding, incl. Rock Quarry, Lower.

Despite uncertainties in the modelling, the results were largely qualitatively validated by the LGU and by comparison to historical disaster data from the City Disaster Risk Reduction and Management Office (CDRRMO). The landslide assessment confirmed the findings of previous landslide susceptibility mapping projects, highlighting that the flood modelling carried out in this study supports the current knowledge in Baguio whereby landslides are initiated in sloped areas due to rainfall and subsequent water saturation and destabilization of top-soils. The results of the assessment are used to inform the Flood Mitigation Action Plan and can be used by the LGU to inform land use and stormwater infrastructure planning, among other topics.

Flood Mitigation Action Plan

The Flood Mitigation Action Plan (Task 5) presents a holistic approach to address flooding and urban challenges through the application of integrated solutions. The plan argues and demonstrates that NbS could provide a cohesive resiliency planning path, allowing for prioritization of multifunctional solutions that specifically address key urban challenges. The NbS typology toolbox developed presents conceptual NbS deemed feasible for the socio-economic and spatial context of Baguio. The typologies comprise a wide range of nature-based hydraulic functions including conveyance, retention, detention, and treatment. A city-wide replicability assessment allows for identification of areas for implementation of the typologies at various scales to create a network of connected nature-based solutions.

To demonstrate the applicability of the NbS toolbox, three pilot projects were developed at a conceptual level: an Urban Canal near Manual Roxas, a Green Street at Carino Street and a Stormwater Park at Emilio Aguinaldo Park. The pilot projects serve to demonstrate the wide range of concepts in the NbS toolbox and show how nature-based solutions are applicable for various types of spaces and infrastructure in the public realm in Baguio. The Flood Mitigation Action Plan presents a roadmap of implementation, a step-by-step guide from project development to implementation of flood mitigation in Baguio, together with a set of recommendations pointing at how to go from conceptual design, to schematic and detail design, as well as implementation, monitoring, evaluation and learning. The report demonstrates how a multifunctional, and highly adaptive network of terrain-based solutions in combination with traditional stormwater infrastructure can mitigate flooding, while improving overall liveability in Baguio.

Targeted Capacity Building and Training Program

The 'Targeted Capacity Building Programme to Enhance Delivery of a Sustainable FEWS' (Task 8) was added, effective from December 2021 and implemented in 2022, in an effort to further solidify and enhance program effectiveness and sustainability. A total of eleven (11) trainees from the LGU and local/ regional public institutions completed the program and form the FEWS O&M team, who will be in charge of operating and maintaining the FEWS. The 3-module Capacity Building Program was led by DHI and supported by Ramboll, focusing on giving the trainees a general understanding of Flood Early Warning Systems and training in the different types of DHI software used in the FEWS for Baguio.

The capacity building activities successfully enhanced the outcome of the OTJ training based on participant feedback and observations by the project team. The hands-on in-person OTJ training program led by Ramboll was divided in two phases; a 6-day pre-monsoon training program, facilitated in June 2022, and a 5-day post-monsoon training program facilitated in September 2022. The training sessions were facilitated at the Mayor's IT Department (MITD) at Baguio City Hall. The assessment of Program Effectiveness concludes that the training has successfully enhanced the knowledge within all topics covered in the program: hydrological and hydraulic modelling; FEWS design and operation; O&M; IT infrastructure; and instrumentation. However, given the starting point of the trainees, it has not been possible to bring the O&M team to the necessary professional level to enable them to be fully responsible for the operation and maintenance of the FEWS system. More training and technical support is required to the LGU as the FEWS O&M team to ensure long-term sustainability.

Gender and Social Inclusion

The Gender and Social Inclusion Study aimed at providing an understanding and an in-depth analysis of gender and social inequalities that are present in the existing flood warning procedures and developing pathways to address those inequalities. To deliver a holistic understanding, a mixed methods methodology was used for the study of Baguio. It drew on secondary data and primary data which included surveys and interviews, specifically Missing Voices interviews. Missing voices interviews included identification and engagement with groups and individuals who are likely to experience marginalisation or increased vulnerability in a specific context. This approach provided a much more nuanced understanding of how different individuals and gender groups experience floods and FEWS, an understanding that is critical for the development of actions and procedures to enable for gender transformative FEWS.

Findings from the Gender and Inclusion Study, informed recommendations and further actions that can be taken forward with key FEWS stakeholders to design a gender transformative FEWS.

Flood Early Warning System

The Flood Early Warning System (Task 3) has been developed in collaboration with the Baguio Local Government Unit (LGU) and other key stakeholders to improve community disaster preparedness, raise awareness, and ensure ownership. At the core of its design, the FEWS is an IT system, composed of back-end and front-end components. A highly technical, smart, and resilient IT framework to house the system has been established using MIKE OPERATIONS by DHI, a state-of-the-art software product for model-based forecasting. The deployment of the MIKE OPERATIONS platform has been completed at the LGU premises and comprises three key servers: MIKE OPERATIONS Web Server Hardware Information, MIKE OPRERATIONS Platform Server Hardware Information, and Backup Server. The FEWS IT system has initially been installed at the servers located in the Management and Information Technology Division (MITD), at the Baguio City Hall. In time, it is expected that the system will be moved to the Smart City Command Center (SCCC), which is envisioned to be the anchor for all smart city solutions in Baguio. As part of the real-time data acquisition, a total of 5 new gauging stations (4 water-level stations and 1 tandem station) have been installed on the two main river basins within Baguio: the Balili and Bued basins.

The FEWS system has successfully been configured to run automated jobs to acquire the currently available real-time data and information from external data sources, perform data checking for timeseries analysis and visualization, and run forecast models. The front-end development of the system includes a dashboard that triggers warning messages based on pre-defined thresholds. The data outputs from the system are translated into flood warnings which can, following a system testing and validation phase, be disseminated to various stakeholder groups through different channels. Although the FEWS has been fully installed at the LGU servers, it was not possible to complete online testing and operational acceptance during the 2022 monsoon with the key reasons being delays in obtaining data from stakeholder organizations, data quality issues, unforeseen delays in construction, installation and commissioning of real-time stations. The finalized system with the calibrated models and WRF inputs was not running during the monsoon of 2022, and therefore a full-scale test of the system during real-time operation has not yet been completed. The FEWS could yield significant benefits in Baguio and serve as a tool to provide timely flood warnings to Baguio's residents.

Dissemination and Outreach

The Data Dissemination and Outreach Plan (DDOP) (Task 4) defines who is communicating what messages to whom and when, before, during and after a natural hazard event in Baguio City with specific reference to the FEWS. The DDOP follows the recommendations of the Gender and Inclusion Study, aiming to base the system on the understanding of needs of those most vulnerable and laying the ground for a further development of the FEWS in a collaborative manner with local stakeholders.

Adopting a varied and redundant, multi-channel communication approach to disseminate disaster preparedness messages and warnings are encouraged. This is to ensure that urgent warning messages are disseminated as wide as possible and reach their intended recipients, regardless of the communication channel they prefer or have access to. As a general principle, preparedness messages and warnings should (as much as resources allow) make provisions for accessibility. Recognizing the different concerns of the city's different target groups, a library of key messages centering on pre-disaster preparedness and post-disaster actions has been developed. Thus, the DDOP can serve as a guide for the LGU in the dissemination of warnings generated by the FEWS ensuring an inclusive warning approach centering on those who might otherwise be considered an afterthought or left behind altogether - and empowering them.

Source: Adobe Stock

11. RECOMMENDATIONS

Source: Adobe Stock

The following activities are recommended to finetune, validate, and test the FEWS and to further enhance the project outcomes ensuring that proposed plans, actions and lessons learned are implemented in Baguio City:

Consolidation phase
Following the completion of the pilot project, it is recommended to initiate a project consolidation phase to ensure long-term sustainability of the FEWS. The FEWS has been fully installed at the LGU servers but it was not possible to complete online testing and operational acceptance during the 2022 monsoon. The finalized system with the calibrated models and WRF inputs was not running during the monsoon of 2022, and therefore a full-scale test of the system during real-time operation has not yet been completed. Furthermore, given the starting point of the FEWS O&M team, it has not been possible to bring the team to the necessary professional level to enable them to be fully responsible for the operation and maintenance of the FEWS system.

In the proposed consolidation phase, the necessary finetuning, troubleshooting, testing and feedback loops will be executed and the capacities within the FEWS O&M team will continue to increase through on-the-job training and implementation of standard operating procedures. The need for testing is not limited to one single monsoon season, as any FEWS requires proper validation (several monsoons) before it's publicly launched. Launching a FEWS without proper testing and troubleshooting time can have serious consequences on the credibility of the LGU and ultimately on the confidence in the system itself. The overall purpose of the consolidation phase is for the FEWS O&M group to be fully ready to launch the system publicly and operate it independently utilizing the FEWS as an active risk mitigation instrument for Baguio City.

A preliminary consolidation phase roadmap has been prepared outlining the planned activities and deliverables (only at a very high level for 2024 & 2025), see Figure 46. A Final Consolidation Plan and Roadmap will be delivered in the early stage of the consolidation phase.

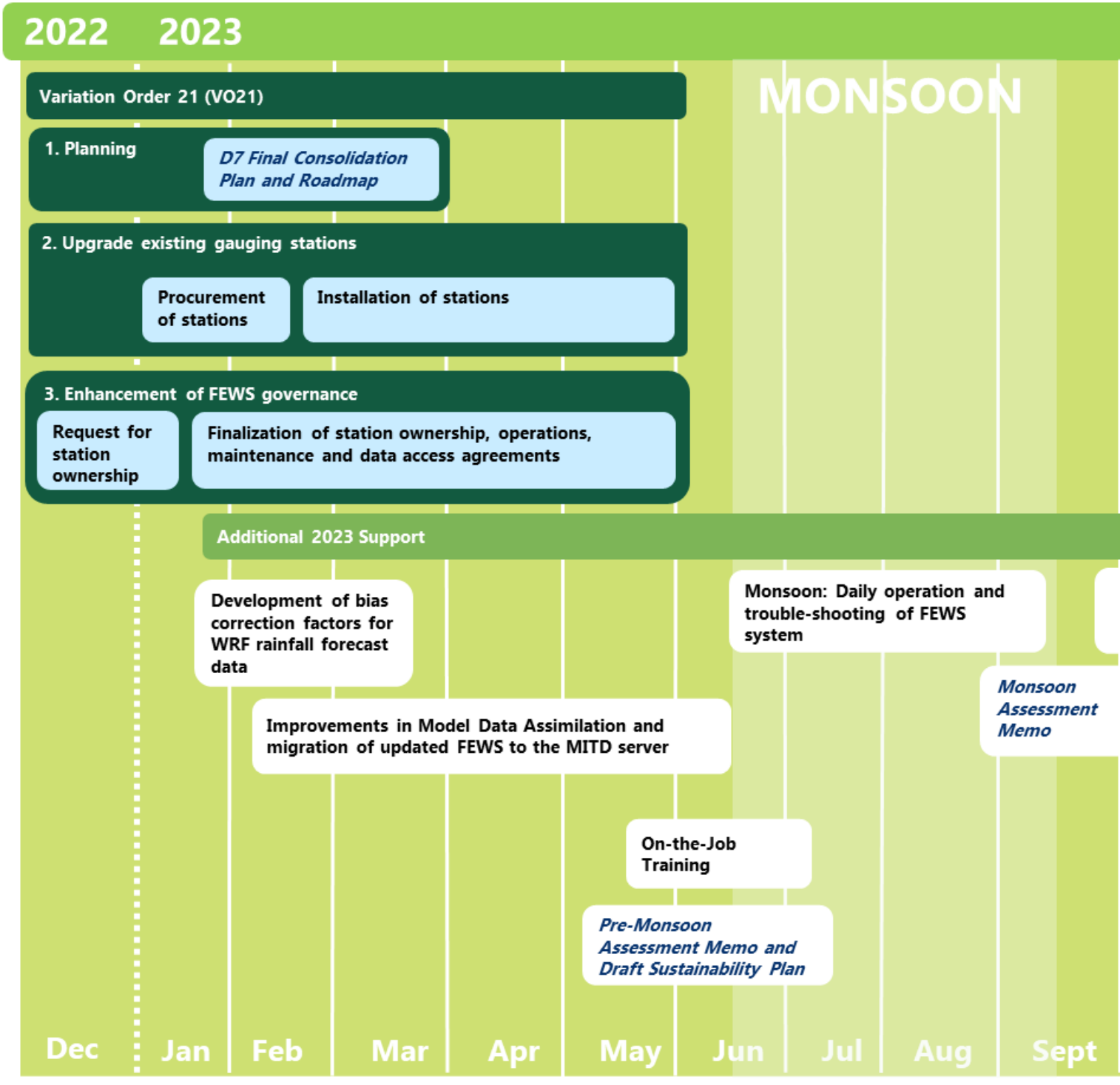
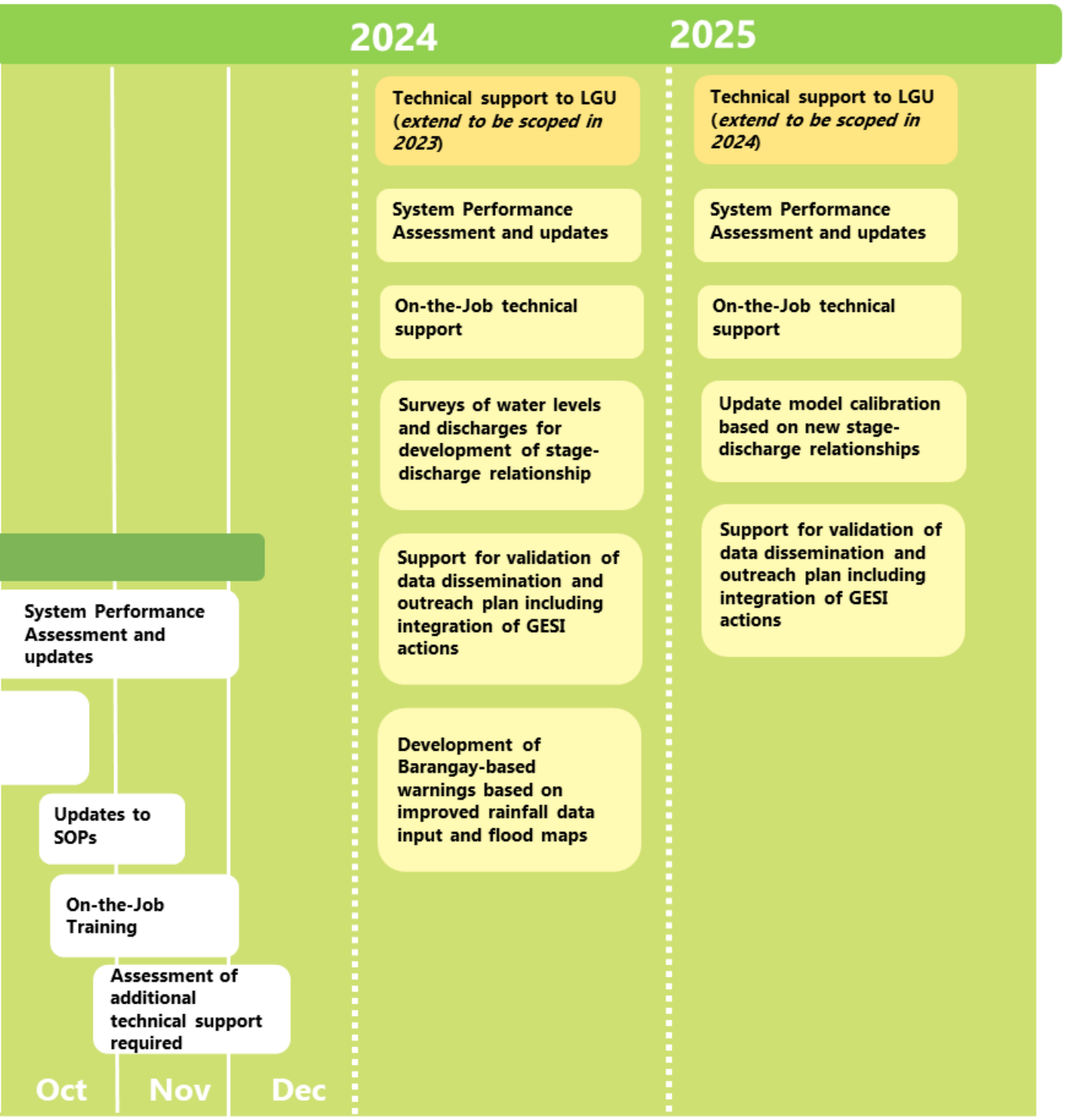


Figure 46: Preliminary Roadmap for the proposed Consolidation Phase
Source: Ramboll


2024
2025
Technical support to LGU (extend to be scoped in 2023)
Technical support to LGU (extend to be scoped in 2024)
System Performance Assessment and updates
System Performance Assessment and updates
On-the-Job technical support
On-the-Job technical support
Surveys of water levels and discharges for development of stage-discharge relationship
Update model calibration based on new stage-discharge relationships
Support for validation of data dissemination and outreach plan including integration of GESI actions
Support for validation of data dissemination and outreach plan including integration of GESI actions
Development of Barangay-based warnings based on improved rainfall data input and flood maps
System Performance Assessment and updates
Updates to SOPs
On-the-Job Training
Assessment of additional technical support required
Oct
Nov
Dec

FEWS Design

In the proposed consolidation phase, the FEWS will be tested and validated, and finally refined based on a system performance assessment. A pre-requisite to initiating the full-scale test of the system is an upgrade of five existing real-time monitoring water-level and rainfall stations utilized in the system. This is a fundamental task to complete, as the existing stations have not been working consistently throughout 2022. The historical data from these stations, prior to 2022, also contains significant inconsistencies and gaps, with a few exceptions covering limited periods of time. To solve the issues, the equipment at the existing stations would likely need replacement as identified by DOST-CAR. Additionally, improvements to the model are recommended, with some updates implemented pre-monsoon to be tested during the monsoon period and additional updates to be implemented post-monsoon following monsoon data capture and assessment of system performance. The recommendations for the activities related to the FEWS design are further described in the Flood Early Warning System report.

FEWS Capacity Building and Governance

The focus on building capacities at local level has been a fundamental driver throughout the pilot project. Through the Targeted Capacity Building Program and OTJ training, the local technical capacity was increased, however, more training and technical support is required for the FEWS O&M group to be operate the system independently. Capacity building efforts should be continued through facilitation of OTJ training and technical guidance in the implementation of SOPs. Furthermore, efforts to enhance the FEWS governance are recommended to ensure the foundation for effective operation and maintenance of the system. In addition to the two MOAs achieved in the pilot project, it is recommended to formalize partnerships with DOST-ASTI, SLU, and other relevant partners, to delineate expectations across organizations and set the foundation for long-term sustainability of the system, anchored at the LGU. Additionally, efforts to ensure financial sustainability and institutionalization of the FEWS O&M team are of key priority. Further recommendations for capacity building and enhancement of governance are outlined in the Flood Early Warning System Report.

Flood Mitigation Action Plan

The Flood Mitigation Action Plan included the development of high-level conceptual designs for three pilot sites identified for potential NbS implementation in Baguio. The perspectives of formulating an investment project as part of the city's overall urban sustainability projects (Green Walks and Blue Walks) are big and it is recommended to further assess the opportunity for advancing the pilot projects to a schematic design phase and eventually initiating construction. As outlined in the Flood Mitigation Action Plan, the adaptive capacity of the population, institutions and governmental bodies will play a key role in the continuous shift towards a resilient city in future climate conditions. Thus, in addition to implementation of physical flood mitigation measures, efforts to prepare individual households and build technical and institutional capacities across stakeholders in Baguio should be prioritized to enhance the adaptive capacity of the city and thereby improve resilience. The recommendations for flood mitigation actions are further outlined in the Flood Mitigation Action Plan.

Dissemination and outreach

During the process of developing the Data Dissemination and Outreach Plan, a series of actions to move forward were identified with the primary action being the testing and validation of the FEWS. It is proposed that the testing and validation phase includes three distinct phases gradually increasing the stakeholder groups involved, followed by the development of SOPs for the different stakeholders involved in getting messages across to the recipients/end-users. In the third testing phase, Awareness and Education activities should be developed, as well as media partnerships to ensure the effective delivery of messages. The testing and validation phase is expected to cover multiple monsoon seasons, depending on the frequency of events and resources available to develop the necessary communication tools and channels. An explicit vulnerability program and specific gender and social inclusion actions will also need to be included. The recommendations for Data Dissemination and Outreach are further described in the Data Dissemination and Outreach Plan.

Gender and Social Inclusion

The findings of the Gender and Social Inclusion study highlight a number of ways in which stakeholders involved in the design and implementation of the flood early warning system in Baguio City can take action to ensure that the FEWS is effective for everyone who needs it, leaves no one behind, and supports equitable and inclusive. The list of recommendations can be found in the Mixed Methods Gender and Inclusion Study report. The report is recommended reading for all stakeholders engaged in implementing different components of the FEWS.

ABOUT THE ASEAN AUSTRALIA SMART CITIES TRUST FUND

The ASEAN Australia Smart Cities Trust Fund (AASCTF) assists ASEAN cities in enhancing their planning systems, service delivery, and financial management by developing and testing appropriate digital urban solutions and systems. By working with cities, AASCTF facilitates their transformation to become more livable, resilient, and inclusive, while in the process identifying scalable best and next practices to be replicated across cities in Asia and the Pacific.

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