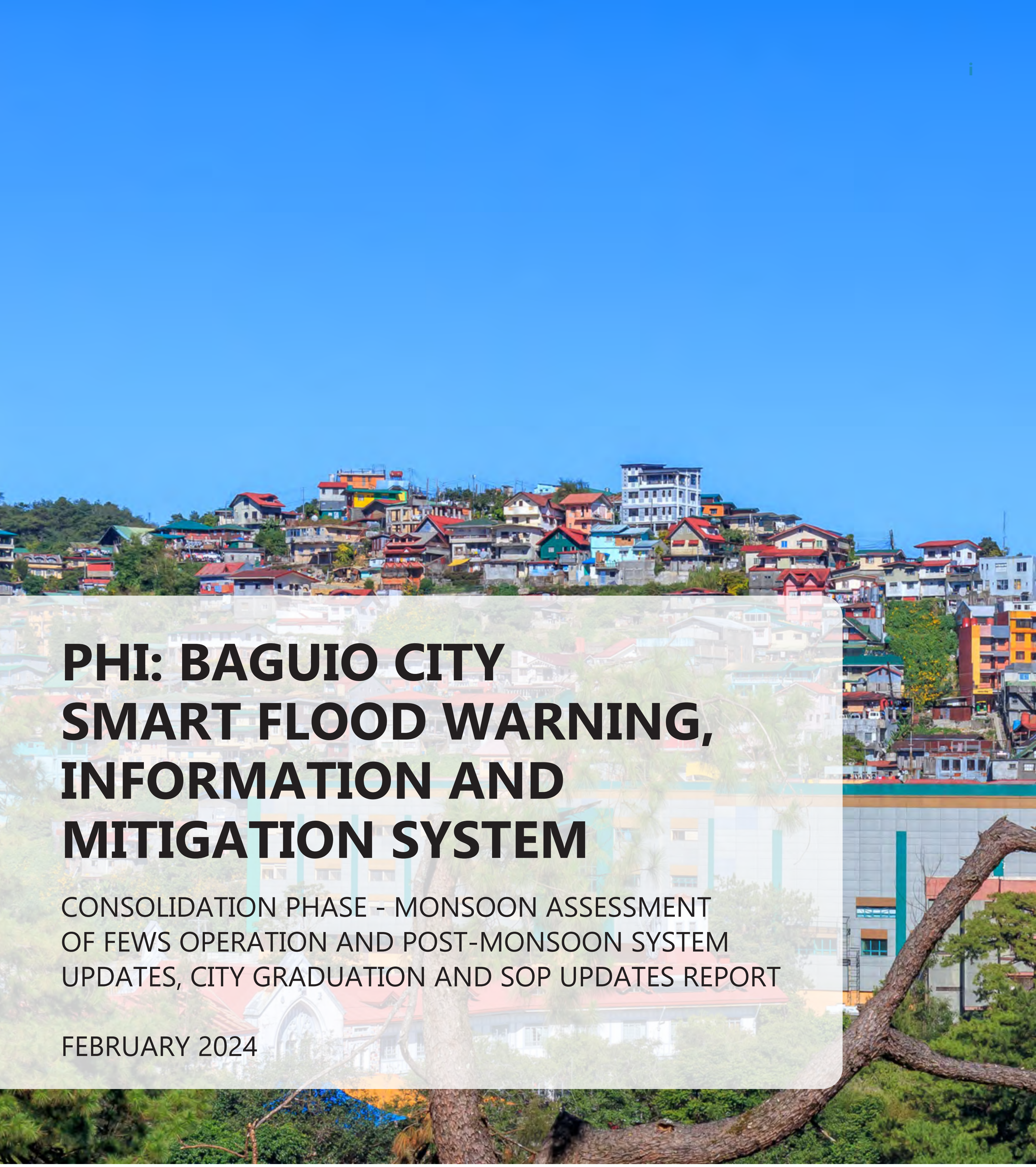

PHI: BAGUIO CITY SMART FLOOD WARNING, INFORMATION AND MITIGATION SYSTEM

CONSOLIDATION PHASE - MONSOON ASSESSMENT OF FEWS OPERATION AND POST-MONSOON SYSTEM UPDATES, CITY GRADUATION AND SOP UPDATES REPORT

FEBRUARY 2024

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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Approved by	Alvaro Fonseca
Cover image	Adobe Stock

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ABBREVIATIONS

AASCTF	ASEAN Australia Smart Cities Trust Fund
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
CDRRMO	City Disaster Risk Reduction and Management Office
CSWDO	City Social Welfare and Development Office
DA	Data assimilation
DFAT	Department of Foreign Affairs and Trade (Australia)
DOST	Department of Science and Technology (Philippines)
DOST-ASTI	DOST Advanced Science and Technology Institute
DOST-CAR	DOST Cordillera Administrative Region
DRRM	Disaster Risk Reduction and Management
DSWDO	
FEWS	Flood Early Warning System
GEDSI	Gender Equality, Disability, and Social Inclusion
ICT	Information and Communications Technology
LGU	Local Government Unit
MITD	Management Information Technology Division
MOA	Memorandum of Agreement
NAM	Nedbør-Afstrømnings-Model (Rainfall-Runoff model)
O&M	Operations and maintenance
OTJ	On-the-job (Training)
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PIO	Public Information Office
RR	Rainfall-Runoff
SCCC	Smart City Command Center
SOP	Standard Operating Procedure
WRF	Weather Research and Forecasting

EXECUTIVE SUMMARY

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, though 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.

Following the completion of the pilot project in April 2023, the Baguio Flood Early Warning System (FEWS) Consolidation Phase kicked off in May 2023. The activities of the consolidation phase build on what has been achieved and delivered under the pilot project. It covers activities supporting the Baguio LGU with continued technical assistance throughout the 2023 monsoon, which includes testing and troubleshooting throughout the monsoon, as well as finetuning the system during the post-monsoon phase. The 2023 monsoon test has been the first full-scale test of the Baguio FEWS during real-time operation.

This report provides an overview of the 2023 monsoon system performance, the subsequent system updates identified and implemented, the sustainment plan for the system as well as Baguio City's AASTCF City Graduation journey. The report concludes and summarizes the activities and achievements of the Baguio FEWS Consolidation Phase.

During the 2023 Monsoon, the operation and maintenance of the FEWS was performed by the established Operations and Maintenance (O&M) team in closed collaboration with the technical project team to further enhance team's confidence in following the SOPs and understanding their roles and responsibilities, and to ensure self-sufficiency of the O&M team in the long run.

The performance assessment of the 2023 real-time monsoon operation was successfully completed to identify strengths and weaknesses of the system to further improve the accuracy and dependability of the Baguio FEWS. The key components which were evaluated to assess the overall FEWS performance were: station performance, data quality, model performance, real-time setup, and operation and maintenance. The model and real-time set-up of the FEWS exhibited satisfactory performance during the entirety of the 2023 monsoon operations, with incidents of model and real-time job failure observed in less than 10% of cases throughout the monsoon operation. Following the performance assessment, post-monsoon updates were successfully made to the different components that make up the system: data, model, real-time set-up, and SOPs.

Significant progress has been made in implementing and operationalizing the FEWS Baguio City to set the stage for continuous improvement and long-term viability of the system. A detailed sustainment plan has been developed, focusing on four critical lenses: human resources, institutional, technical, and financial sustainment. Risk assessments across the four critical lenses of sustainment have been completed and the most critical risks and mitigating actions have been identified. A thorough risk assessment is vital for anticipating and addressing potential challenges, paving the way for the lasting success of the Baguio City FEWS.

The AASCTF City Graduation readiness assessment shows, that Baguio fully meets the criteria for graduation from Bronze to Silver City and scores 95/100 on the City Report Card. Following the prospective graduation to Silver Tier, the readiness for Gold City graduation was assessed throughout the consolidation phase as efforts on system testing/validation and sustainment advanced. The team has confidence in Baguio fulfilling the graduation criteria (once this is more officially communicated/requested of them to do so), therefore the city is deemed ready to graduate to Gold Tier with a score of 85/100 (readiness for graduation above 80 points).

There is a need for the Baguio City Government to receive technical support finetuning, testing, and operating the system in the coming years, as the team does not yet have the experience to independently operate and maintain the FEWS. The extent of the technical support is expected to gradually decrease in the coming years as the experience of the team advances. 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.

1 INTRODUCTION

Source: Adobe Stock

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 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.

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

1.2 CONSOLIDATION PHASE

Following the completion of the pilot project in April 2023, the Baguio FEWS Consolidation Phase kicked off in May 2023.

The activities of the consolidation phase build on what has been achieved and delivered under the pilot project. It covers activities supporting the Baguio LGU with continued technical assistance throughout the 2023 monsoon, which includes testing, running, troubleshooting throughout the monsoon, as well as fine-tuning the system during the post-monsoon phase. The 2023 monsoon is the first full-scale test of the Baguio FEWS during real-time operation.

Furthermore, the technical capacities within the Local Government Unit (LGU) are increased through on-the-job (OTJ) training and implementation and testing of the prepared FEWS standard operating procedures (SOPs). Enhancement of system governance and support for partnership agreement further strengthen the foundation for effective and sustained operation and maintenance of the system. The activities enhance the LGU's capacity to utilize the FEWS as an active risk-mitigation tool serving as an integral element within the overall vision of Baguio City to become a truly resilient, dynamic, and smart city.

The main activities are divided in three phases following the operational phases of the FEWS: pre-monsoon, monsoon, and post-monsoon. The main activities and deliverables of the Consolidation Phase are outlined in Table 1-1. The roadmap for the consolidation phase is seen in Figure 1-1.

Table 1-1 Activities and deliverables for Baguio FEWS Consolidation Phase

Delivareble	Activities	Timeline
D1 Pre-Monsoon Assessment and Report	• Development of bias correction factors for weather and rainfall (WRF) forecast data and update FEWS • Improvement of model data assimilation and error calculation in real-time operation • Online capacity building sessions in SOPs • In-person OTJ training for SOPs to prepare the FEWS O&M team for real-time operation	September 2023
D2 Monsoon Assessment of FEWS operation and post-monsoon system updates, city graduation and SOP updates report (this report)	• Daily operation, maintenance, and troubleshooting of FEWS, and training in real-time monsoon SOPs • Conduct system performance assessment based on real-time operation and complete system updates including data adjustments of rainfall-runoff (NAM) parameters and other required system updates • Complete updates to SOPs and operation and maintenance framework based on learnings from real-time operation • In-person OTJ training in SOPs for assessment of system performance and completion of post-monsoon system updates • Post-monsoon operation coordination including gold city graduation and scale-ups as necessary • Assessment of additional technical support required	February 2024
D3 Training Report for real-time operation of the FEWS	• Documentation of training activities • Assessment of team performance and program effectiveness • Assessment of local ability to operate the system beyond 2023	November 2023

Source: Ramboll

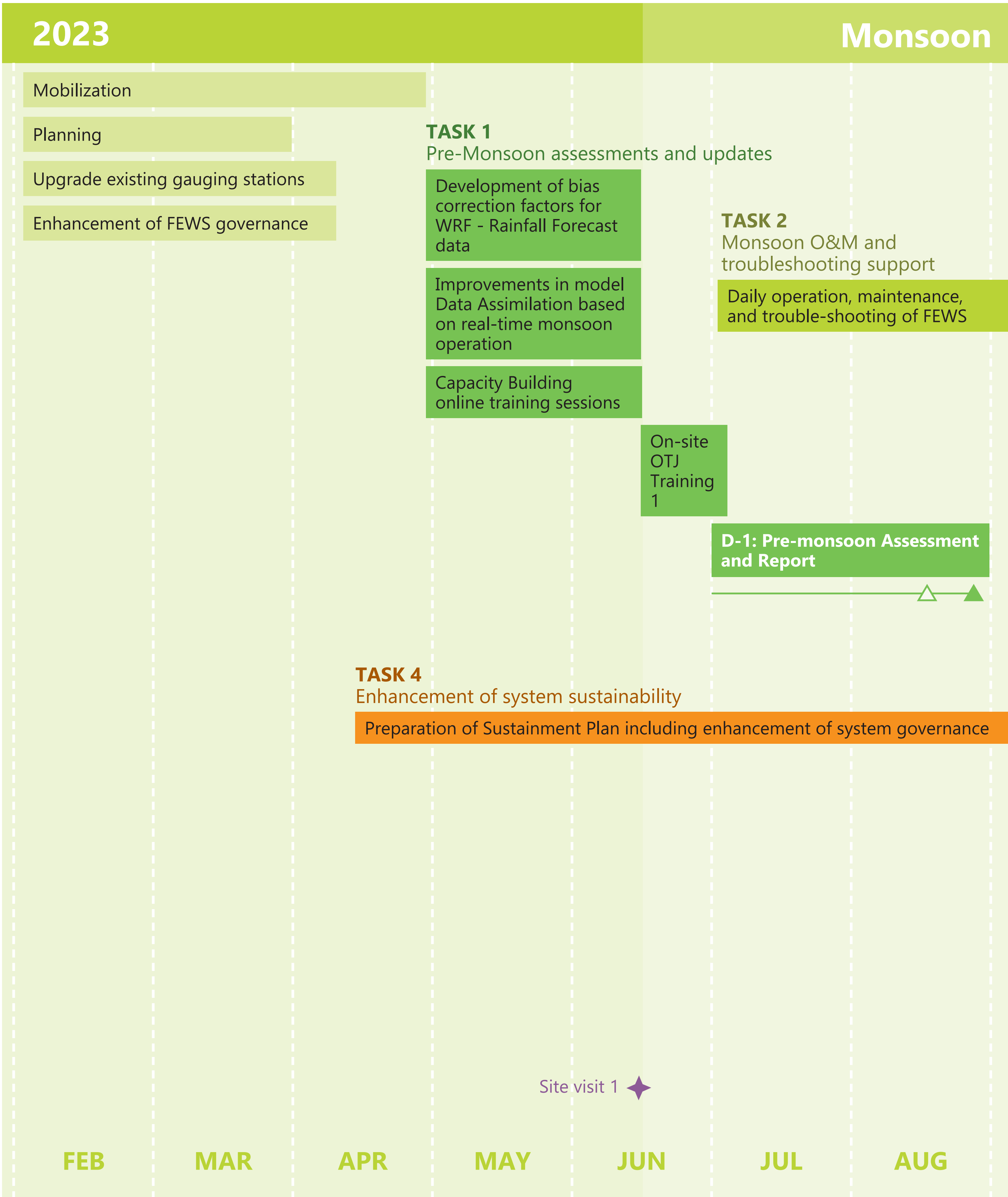


Figure 1-1 The roadmap for the Consolidation Phase
Source: Ramboll

2024

Technical support to LGU (extent to be scoped in 2023)

- System Performance Assessment and updates
- On-the-Job technical support
- Surveys of water levels and discharges for development of stage-discharge relationship
- Support for validation of data dissemination and outreach plan including integration of GEDSI actions
- Development of Barangay-based warnings based on improved rainfall data input and flood maps

2025

Technical support to LGU (extent to be scoped in 2024)

- System Performance Assessment and updates
- On-the-Job technical support
- Update model calibration based on new stage-discharge relationships
- Support for validation of data dissemination and outreach plan including integration of GEDSI actions

TASK 3
Post-monsoon system performance assessment and system updates

- System performance assessment and system updates
- Updates to SOPs and O&M framework
- On-site OTJ Training 2
- Assessment of additional technical support required

D-2: Monsoon Assessment of FEWS Operation and Post-monsoon System Updates, City Graduation and SOP Updates Report

D-3: Training Report for Real-time Operation of the FEWS

Site visit 2

SEPT OCT NOV DEC

△ Submission of draft deliverable ▲ Submission of final deliverable ✦ Site visit

1.3 REPORT STRUCTURE

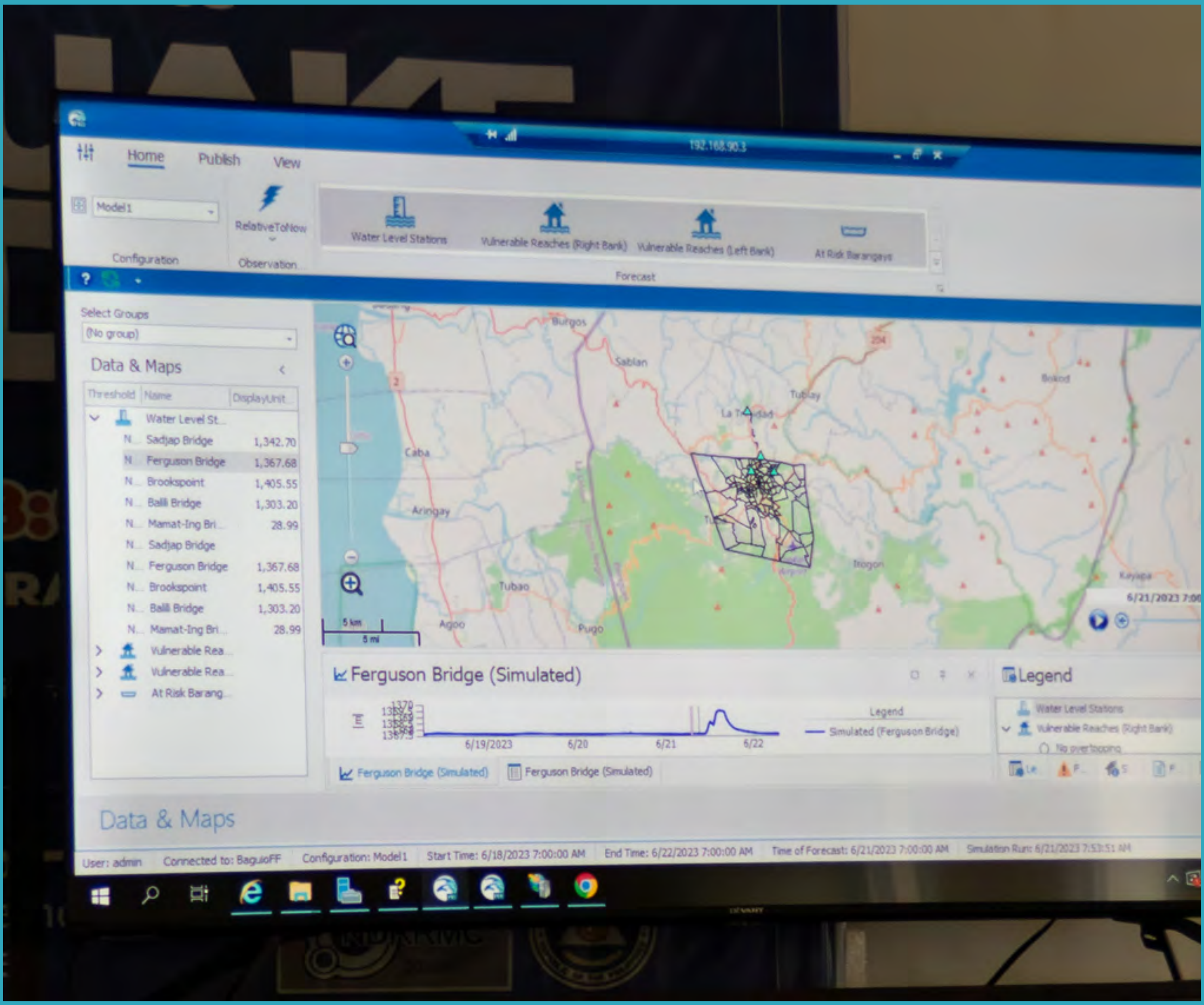
This *Monsoon Assessment of FEWS operation and post-monsoon system updates, city graduation and SOP updates report* is the third report out of three reports to be produced in the Baguio FEWS Consolidation Phase. The report builds on the achievements documented in the twelve reports produced in the Baguio City Smart Flood Early Warning, Information and Mitigation System pilot project and the two additional reports produced under the Baguio FEWS Consolidation Phase. The primary intended audience comprises technical personnel from the LGU and ADB. Other intended audiences comprise policymakers, city planning officials and the broad general audience with knowledge and/or interest in smart flood early warning systems, real-time monitoring systems, city resilience, data storage and management.

The aim of this report is to provide an overview of the 2023 monsoon system performance, the subsequent system updates identified and implemented, the sustainment plan for the system as well as Baguio City's AASTCF City Graduation journey.

- Section 1 introduces the AASCTF programme and the overall consolidation phase activities.
- Section 2 presents the overall FEWS framework and introduces the components to be operated and maintained during the monsoon of 2023.
- Section 3 details the 2023 system performance, the post-monsoon assessment, and evaluates the 2023 operation and maintenance FEWS components.
- Section 4 presents the system updates identified and implemented based on the post-monsoon assessment.
- Section 5 presents the main components of the Sustainment Plan prepared.
- Section 6 presents Baguio's City Graduation Journey under the AASCTF program umbrella.
- Section 7 outlines the main recommendations for further technical support, future FEWS updates, and linkages/synergies to other projects.
- Section 8 summarizes the main conclusions.

Source: Adobe Stock

2 FEWS FRAMEWORK



Source: Ramboll

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 response 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 FEWS is a dynamic system to be continuously improved as more data is collected and as further needs are identified. The FEWS is developed, operated, and maintained in close collaboration with the LGU and other key stakeholders to ensure ownership, which will eventually allow for independent operation and maintenance of the system by the LGU.

The FEWS framework including its main components are presented in Figure 2-1.

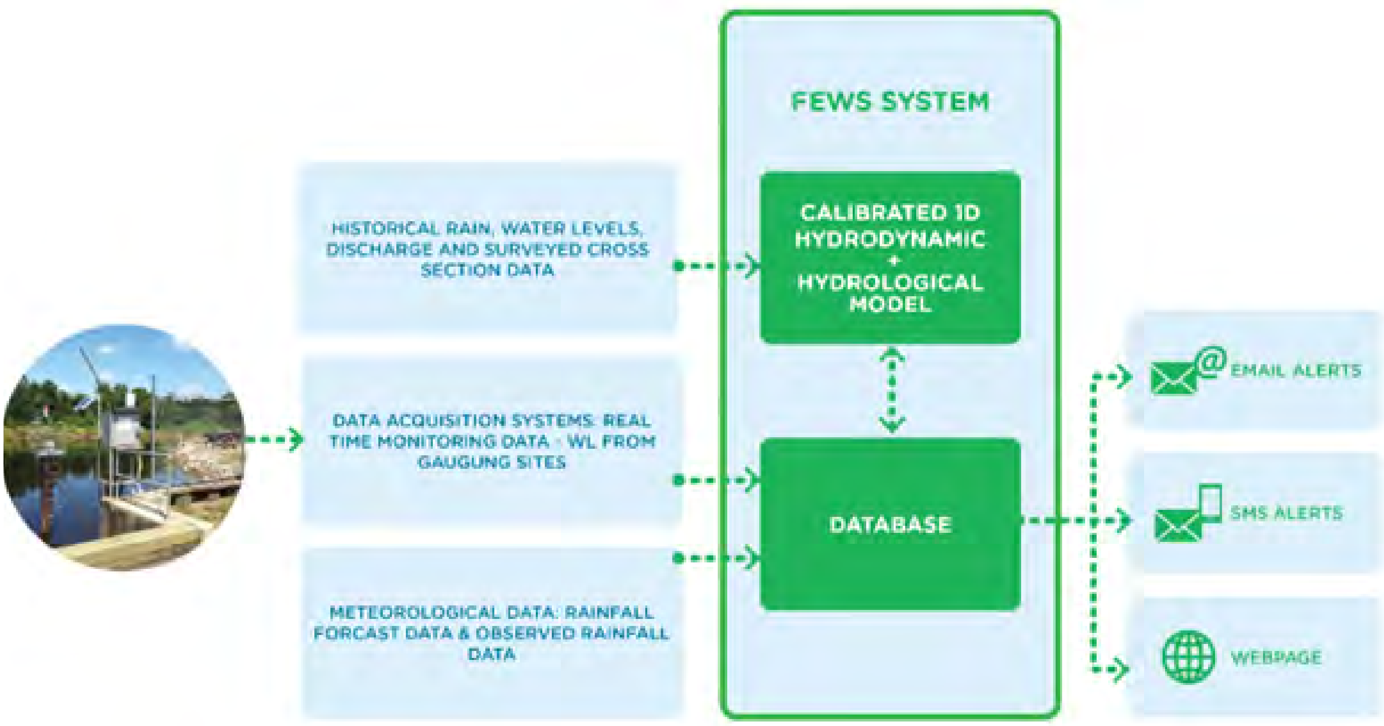


Figure 2-1 The framework for the FEWS
Source: Ramboll

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's specific forecasting and warning requirements. The Baguio FEWS dashboard as well as the daily system logs allows the LGU to easily monitor observed and forecasted water levels ensuring efficient operation and timely response.

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 processes such as downloading real-time and forecast data, updating model inputs, triggering model runs, and updating model results are automated.

In 2022, the first version of the FEWS system with calibrated models was established and run. Towards the end of the year recommendations for improvements to the system and updates for long-term sustainable operation were planned, which formulated the basis for the Baguio FEWS Consolidation Phase as described in Section 1.2.

This chapter summarises the FEWS framework at the beginning of the consolidation phase in 2023. A detailed description of the FEWS framework, the technical design and system governance are provided in the *Flood Early Warning System Report*[1] published under the pilot project.

2.1 REAL-TIME DATA FROM STATIONS

There are ten hydrometeorological stations included in the system, as listed in Table 2-1 and Table 2-2, which monitor and record data at 10-minute intervals. These monitoring stations are now owned by Baguio City, Tuba and La Trinidad, respectively, depending on the station location, and linked to the PhilSensor website (Philsensors[2]), wherein the data gets published in real-time and is currently being accessed by the FEWS through an API provided by DOST-ASTI.

There was a need for recalibration of the existing stations in 2022 for the water-level gauges. This issue was resolved following completion of datum surveys and the stations were re-calibrated in the system.
Five out of these ten gauging stations (4 water-level stations and 1 tandem station[3]) were installed in 2022 on the two main river basins within Baguio: Balili and Bued basins. The stations have been operational since mid-July 2022 but with several non-operational periods due to issues with the SIM-cards and data transmission. This issue with the data transmission was resolved towards the end of the monsoon period in 2022.

1 Flood Early Warning System Report Phi: Baguio City Smart Flood Warning, Information And Mitigation System, AASCTF, April 2022
2 https://philsensors.asti.dost.gov.ph/
3 A tandem station is a combined water-level and rainfall monitoring station

The task of upgrading the remaining five was initiated in early 2023 to ensure completion ahead of the monsoon. As part of the upgrade, the station equipment and construction works were procured, civil works repairs completed, platforms constructed, and the new station equipment were installed. The five upgraded stations have been operational since May 2023.

Apart from these ten stations, there is an existing station Irisan PSHS, which was used in setting up the FEWS system. The station is currently inactive and has been inactive throughout 2023. The location of the un-operational station is only approximately 600 m from the newly installed "Irisan Fire Station". The data from this new station replaced the data from the un-operational station in the FEWS setup for the monsoon of 2023.

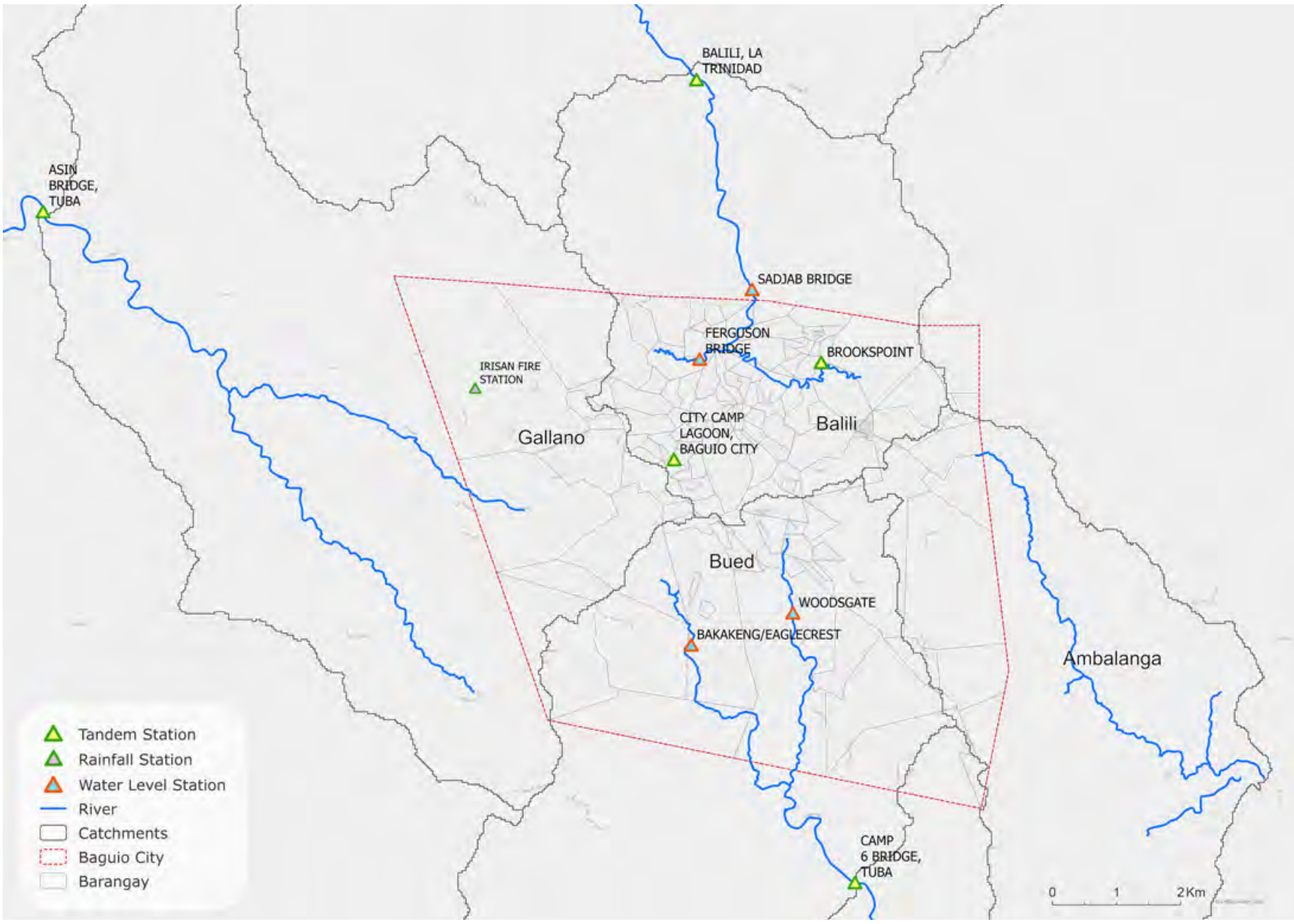


Figure 2-2 The network of real-time monitoring stations for Baguio FEWS
Source: Ramboll

Table 2-1 Real-time water level monitoring stations used in Baguio FEWS

S. No.	Station ID	Station Name	Type	Year	City/location
1	892	Camp 6 Bridge	Tandem	2023	Tuba
2	460	City Camp Lagoon	Tandem	2023	Baguio City
3	463	Asin Bridge	Tandem	2023	Tuba
4	2894	Brookspoint	Tandem	2022	Baguio City
5	1390	Balili Bridge	Tandem	2023	La Trinidad
6	2893	Sadjap Bridge	Water Level	2022	La Trinidad
7	2896	Camp 7	Water Level	2022	Baguio City
8	2892	Ferguson Bridge	Water Level	2022	Baguio City
9	2895	Eagle Crest	Water Level	2022	Baguio City

Source: Ramboll

Table 2-2 Real-time rainfall monitoring stations used in Baguio FEWS

S. No.	Station ID	Station Name	Type	Year	City/location
1	892	Camp 6 Bridge	Tandem	2023	Tuba
2	460	City Camp Lagoon	Tandem	2023	Baguio City
3	463	Asin Bridge	Tandem	2023	Tuba
4	2894	Brookspoint	Tandem	2022	Baguio City
5	1390	Balili Bridge	Tandem	2023	La Trinidad
6	3028	Irisan Fire Station	Rainfall	2023	Baguio City

Source: Ramboll

2.2 WRF DATA

Countrywide Weather Research and Forecasting (WRF) models are run at PAGASA for Philippines. Initialization and information of boundary conditions of the WRF model is set using Global Forecast System (GFS) data. These models are not yet initialized with the data from the radar stations in the country. This is mainly due to current unavailability of adequate infrastructure for storage and processing of the data in real time from the stations at PAGASA. The outputs for the WRF models are produced every 3 hours and the different resolutions for the available gridded meteorological output is the following:

- Hourly data at a 3 km x 3 km grid and at 12 km x 12 km grid
- 3-hourly data at a 3 km x 3 km grid and at 12 km x 12 km grid
- 6-hourly data at a 3 km x 3 km grid and at 12 km x 12 km grid

The 3 km x 3 km hourly data is used in the FEWS for 0 to 48-hour forecasts.

Currently in the FEWS, gridded data is converted to a single timeseries per sub-catchment by direct area weighted formula. Bias correction is performed to these timeseries to correct the rainfall forecast data based on statistical correlation with historical rainfall for a period of 12 hours prior to the time of forecast for each model simulation.

2.3 MODEL SETUP

Based on data availability, basin coverage, flood risk and vulnerability assessment, the Balili river basin was prioritized as the pilot basin for the FEWS. The lessons learned from the Balili model performance, operation and maintenance has been used to develop the standard operating procedures (SOPs) for operation and maintenance (O&M) of the system, including guidance for troubleshooting, the institutional collaboration requirements, and the setup of an O&M team to enhance long-term sustainability of the system.

Hydraulic and hydrological models calibrated with respect to recorded water level data and discharge data provides the foundation for the FEWS which has been operated in Monsoon 2023 to replicate expected flows in the rivers and the hydrological response of the catchments to rainfall events. The rainfall forecast (Bias corrected WRF data) is the main input for the calibrated coupled Hydrodynamic-Rainfall Runoff (HD-RR) model along with real-time rainfall and water level data for data assimilation.

The FEWS is utilizing the MIKE HYDRO River software. The key components of this system include:

1. Hydrodynamic (HD) Module: This component is responsible for simulating the movement and behavior of water in the river system, using physical parameters and hydrodynamic equations.
2. Rainfall-Runoff (RR - NAM) Module: This module employs the NAM (Nedbør-Afstrømnings-Model) conceptual model for predicting the runoff generated in a catchment as a response to rainfall and potential evapotranspiration. It translates rainfall data into flow predictions, contributing to the understanding of how much water will reach the river system.
3. Data Assimilation (DA) Module: This integrates real-time data, such as water levels and flow rates from gauging stations, into the model. By doing so, it enhances the accuracy of the predictions by aligning model simulations with observed data.

The system's operation involves:

- Calibration against historical data to fine-tune the models for accuracy.
- Automated collection of real-time monitoring stations data and forecasted meteorological data, crucial for initializing the models.
- Triggering model simulations with forecasted rainfall to predict water levels and potential flood risks
- The real-time data from gauging stations is used as the initial conditions in the models.

Overall, two Rainfall-Runoff and Hydrodynamic models have been developed to setup FEWS framework for Baguio city, which are:

1. Model for Balili river basin – "Model 1: Balili"
2. Model for secondary river basins – A single model "Model 3: Bued, Ambalanga and Galiano" has been prepared for the three rivers, Bued, Galiano and Ambalanga.

An additional model "Model 2: Balili" was developed for Balili river basin in 2022. The model is discontinued in the consolidation phase as it was meant to be a fail-safe model to ensure that the remaining FEWS system continues to function in the absence of any station data.

A coefficient of determination of 0.75 (R^2) has been achieved between the simulated discharge and the calculated historical discharge in the stand-alone NAM Model for the Balili river, which is the pilot river where the work is focused on (see Figure2-3 and Table 2-3).

The coupled model for Balili has been calibrated by re-adjusting the NAM model parameters and assigning appropriate roughness coefficients in the model to achieve coefficient of determination of close to 0.8 in the monsoon period at Balili Bridge station for both water level and discharge. The calibration result has been achieved using historical data from real-time station rainfall inputs for the 2017-2019 monsoon seasons, and the water-level data available for the same period.

Coefficient of determination of 0.84 has been achieved between the simulated discharge and the historical discharge at the Asin Bridge station in the stand-alone NAM model for Galiano river (see Figure 2-4 and Table 2-4). The calibration result has been achieved using historical data from real-time station rainfall inputs for the 2017-2018 monsoon seasons, and the water-level data available for the same period. The calibration results are further elaborated the *Flood Early Warning System Report*[4] published under the pilot project.

The coupled model for Galiano river has been calibrated by re-adjusting the NAM model parameters and assigning appropriate roughness coefficients in the model to achieve an average coefficient of determination close to 0.85 at Asin Bridge station for both water level and discharge.

Given the data constraints and the many data gaps in the datasets, this result is considered highly satisfactory, and defines a strong starting point for the calibration and fine tuning during the consolidation phase.

Table 2-3 Correlation coefficient at Balili Bridge station

Simulation Period	Correlation (R^2) – simulated vs. observed discharge at Balili Bridge station	Correlation (R^2) – simulated vs. observed water level at Balili Bridge station
06/25/2017 – 12/15/2017	0.825	0.876
06/15/2018 – 12/15/2018	0.785	0.879
06/15/2019 – 08/10/2019	0.733	0.812

Source: Ramboll

4 Footnote 1

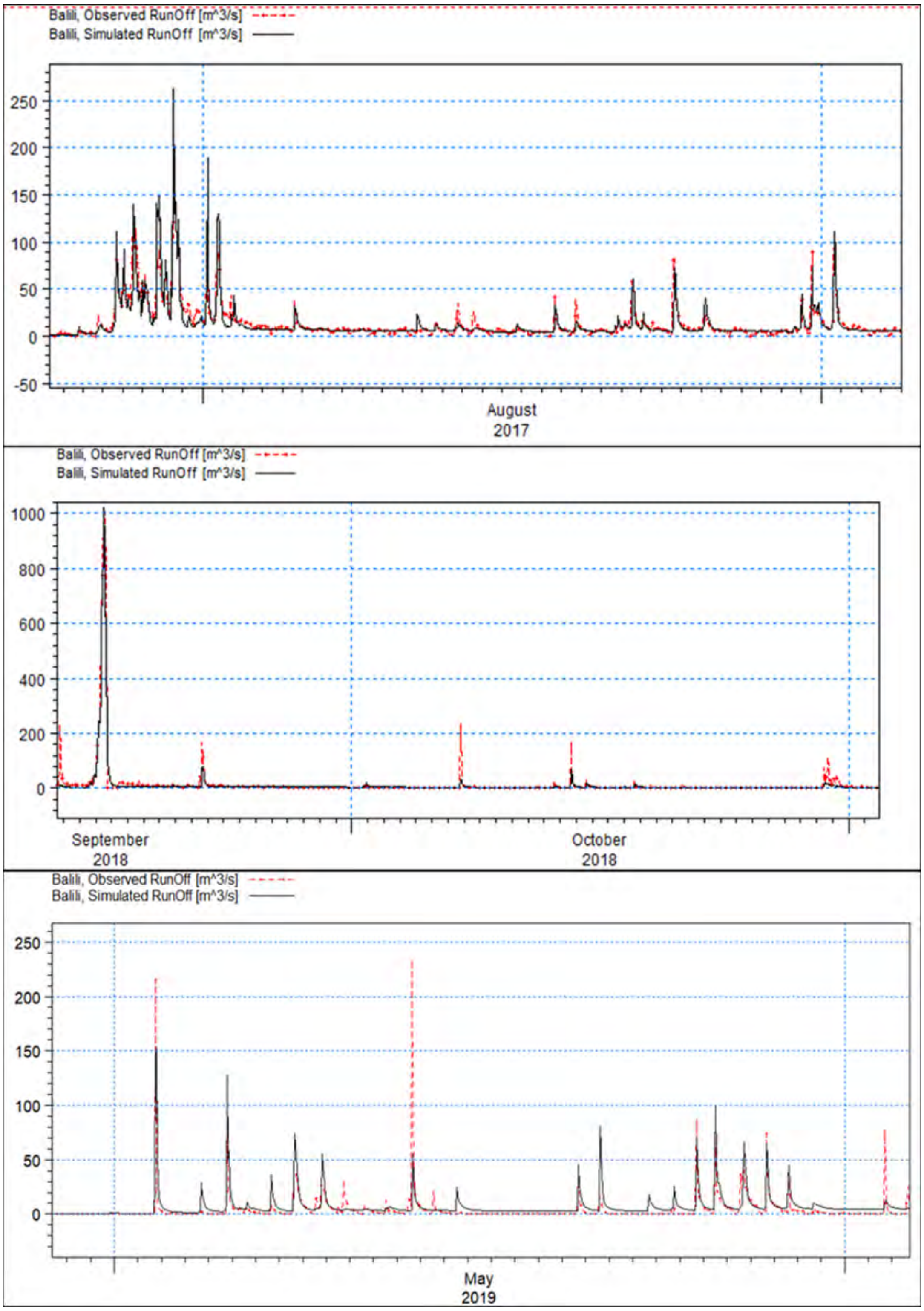


Figure 2-3 Calibration results showing a 75% correlation (R^2) between simulated discharge and calculated discharge from observed water levels at Balili Bridge for the 2017-2019 monsoon season

Source: Ramboll

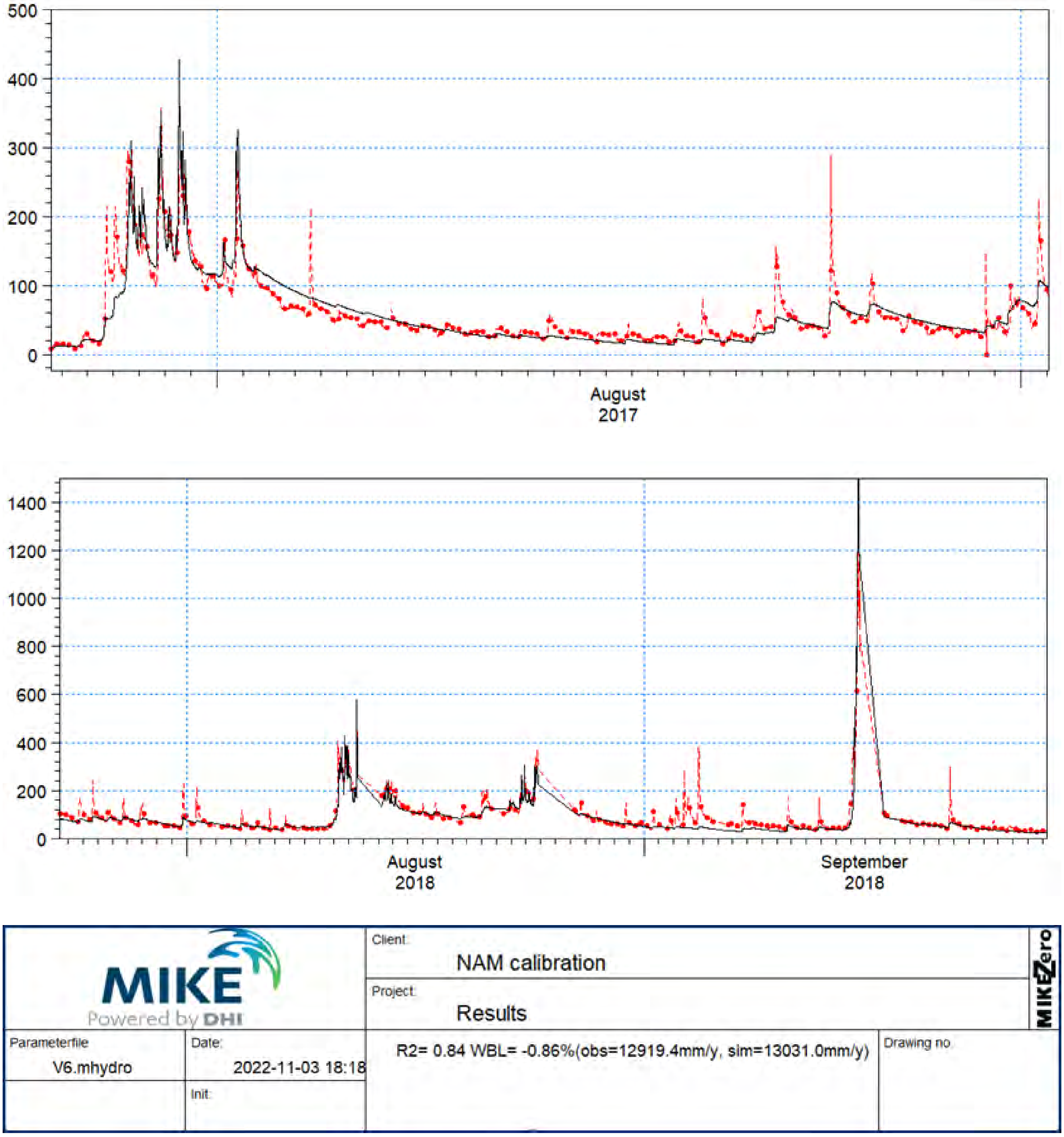


Figure 2-4 Calibration results showing an 84% correlation (R^2) between simulated discharge and calculated discharge from observed water levels at Asin Bridge for the 2017-2018 monsoon season

Source: Ramboll

Table 2-4 Correlation Coefficient at Asin Bridge station

Simulation Period	Correlation (R^2) – simulated vs. observed discharge at Asin Bridge station	Correlation(R^2) – simulated vs. observed water level at Asin Bridge station
06/25/2017 – 11/15/2017	0.873	0.847
06/15/2018 – 11/15/2018	0.79	0.88

Source: Ramboll

2.4 OPERATION AND MAINTENANCE FRAMEWORK

To enable effective operation and maintenance of the FEWS for Baguio, the FEWS Operations and Maintenance (O&M) Team has been formed. The ownership of the FEWS is anchored at the 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). Establishing the O&M Team is a strategic move towards ensuring the long-term sustainability and effectiveness of the Flood Early Warning System.

To further support this initiative, the following measures have been addressed:
1. Institutionalization of the O&M Team:
    - **Formal Structure** Establish a formal structure for the O&M team, defining roles, responsibilities, and hierarchy. This structure has been recognized and endorsed by all stakeholders, including the LGU and partner agencies.
    - **Official Mandate** Seek formal recognition and mandate from local authorities. This officially acknowledges the team's responsibilities and authority.
2. Continuous Training and Capacity Building:
    - **Regular Training Programs** Organize ongoing training sessions to keep the team updated with the latest technology, practices, and knowledge in flood management and early warning systems.
    - **Skill Development Workshops** Conduct workshops focusing on specific skills such as data analysis, system maintenance, and emergency response.
3. Stakeholder Engagement:
    - **Regular Meetings and Collaboration** Hold regular meetings with all stakeholders, including academia, PAGASA, DOST-CAR, and community representatives, to discuss updates, challenges, and strategies.
4. Monitoring and Evaluation:
    - **Performance Metrics** Develop and implement metrics to evaluate the team's performance and the effectiveness of the FEWS.
    - **Regular Reporting** Establish a system for regular reporting on the status of the FEWS and the activities of the O&M team to the LGU and other stakeholders.
5. Sustainability Planning:
    - **Succession Planning** Implement a plan for the training and integration of new team members to ensure sustainability.
    - **Knowledge Management** Develop a knowledge management system to document processes, learnings, and best practices for future reference.

The developed operational plan for the FEWS is structured to follow a cyclic approach, ensuring the system is continuously improved and remains effective. It is required that the system is operated and tested in the coming monsoon seasons and maintained henceforth. It is also required that, as the network of real-time monitoring stations for the basins grow and develop, the system is updated accordingly to produce better forecasts and timely warnings.

2.4.1 FEWS O&M TEAM STRUCTURE

The organogram for the FEWS O&M team is seen in Figure 2-5. The well-defined team structure provides guidance to all team members by outlining the official reporting relationships that govern the workflow of the team and enhances the foundation for efficient operation and communication. The team consists of 12 people. Overall supervision of the FEWS O&M team is with the Head of Department (HoD) at the Climate Disaster Risk Reduction and Management Office (CDRRMO) who has the mandate to coordinate directly with high-ranking government officials and guide in decision-making. The O&M team is led by the Team Lead supported by the Deputy Team Lead. The team is sub-divided in three smaller teams: the modelling team, the instrument team, and the IT team. Each team has a team lead and two core team specialists from the LGU. Peer support by staff from partner organizations is defined for each team. The responsibility for a defined SOP will be assigned to one of the three teams.

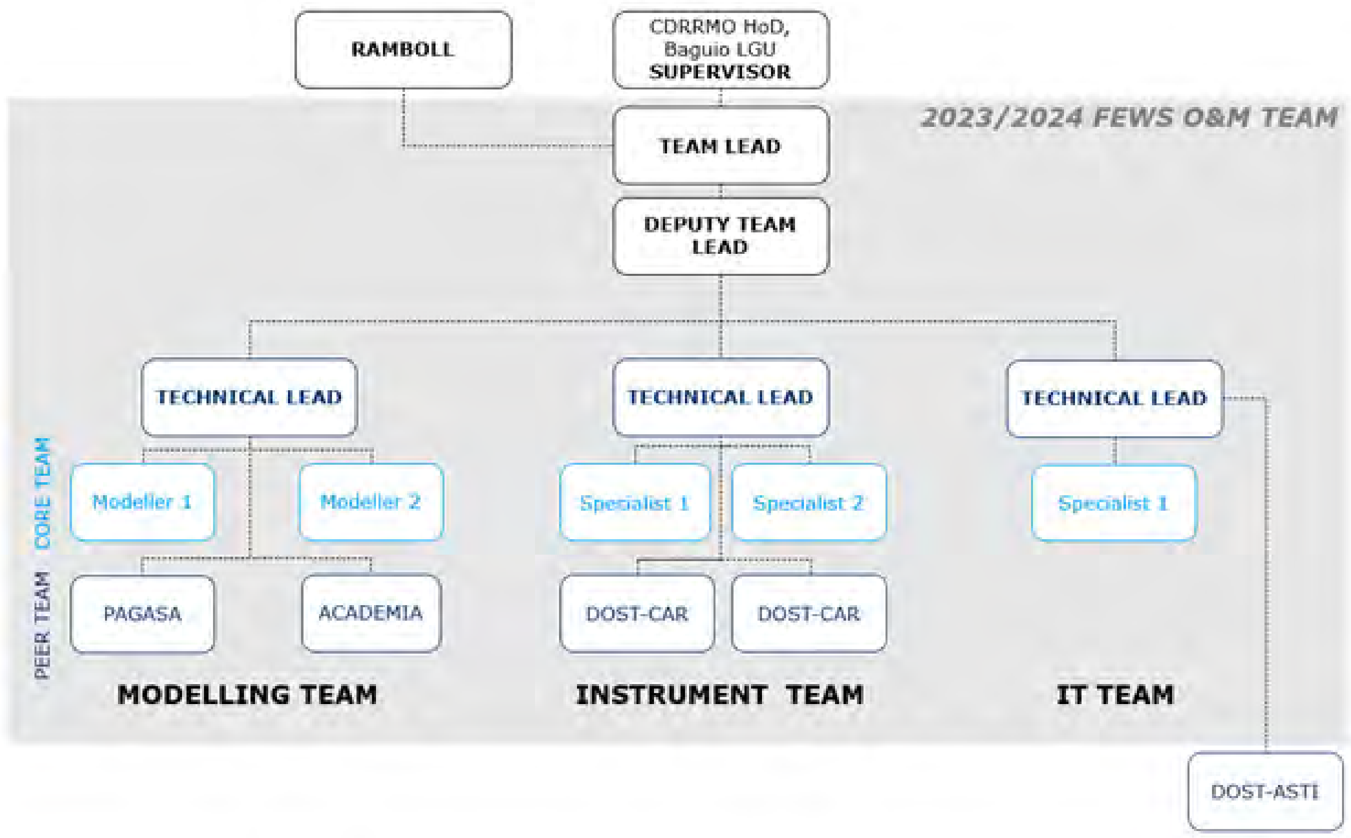


Figure 2-5 The 2023 FEWS O&M Team
Source: Ramboll

2.4.2 STANDARD OPERATING PROCEDURES

To ensure effective operation of FEWS, Standard Operating Procedures (SOPs) have been prepared to guide the FEWS Operation and Maintenance team (O&M team). The purpose of a SOP is to carry out operations correctly and always in the same manner. SOPs can be defined as a written document with step-by-step instructions on how to perform a designated activity to obtain a desired outcome. Clearly defined SOPs are crucial to ensuring consistent operation of the FEWS. The benefits of effective SOPs for the FEWS include:

- Consistency and Reliability: Ensures that operations are performed uniformly, leading to predictable and reliable outcomes.
- Accountability and Responsibility: Clearly assigns tasks, reducing confusion and enhancing accountability.
- Efficiency and Time Management: Streamlines processes, saving time and reducing operational costs.
- Safety: Promotes a safe working environment by providing clear instructions for handling emergencies and routine operations.
- Quality Control: Helps in maintaining high standards of operation and data integrity.
- Adaptability: Facilitates dynamic updates and improvements to the FEWS based on regular assessments and feedback.

Thus, the implementation of Standard Operating Procedures (SOPs) for the Flood Early Warning System (FEWS) in Baguio is a crucial step in ensuring its effectiveness and reliability. SOPs provide a standardized approach to operations, enhancing consistency and efficiency 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. An overview of the Standard Operating Procedures for the Baguio FEWS is shown in Figure 2-6. The full SOPs can be found in Appendix C.

The key elements covered in the SOPs are:

- System Monitoring and Maintenance: Procedures for regular monitoring and maintenance of the FEWS, including hardware, software, and data integrity checks.
- Data Collection and Analysis: Guidelines for collecting, storing, and analyzing data from gauging stations and other sources.
- Emergency Procedures: Detailed steps for responding to flood warnings and emergencies, including communication protocols and coordination with emergency services.
- Training and Capacity Building: SOPs for conducting regular training sessions and drills for the O&M team and other stakeholders.
- Community Engagement: Procedures for public communication and awareness programs.
- System Upgrades and Expansion: Guidelines for assessing system performance, implementing upgrades, and expanding the network of monitoring stations.
- Reporting and Documentation: Standards for documenting operations, incidents, and lessons learned, as well as regular reporting to stakeholders.

All SOPs are structured is the following manner:

- Phase: Identifies the specific phase of the FEWS operation (e.g., Preparation, Application, Assessment) during which the SOP is applicable.
- Frequency: Specifies how often the task should be performed (e.g., daily, weekly, monthly, annually, or during specific events).
- Responsible: Details the team or individual responsible for executing the SOP. This could be a specific role within the O&M team or a collaborative effort between multiple teams or departments.
- Section: Refers to the section number in the SOP document where the procedure is described in detail.
- SOP Title: Provides a concise and descriptive title of the SOP, reflecting the task or process it covers.

Phase	Frequency	Responsible	Section	Standard Operating Procedure
Monsoon	Daily	IT	4.1.1	Operate system, check IT system, connectivity and create backup
	Daily	TL DL M IT IN	4.1.2	Daily review of jobs
	Daily	IT IN	4.1.3	Daily review of data logs
	Daily	IT	4.1.4	Daily report on job and script performance
	Daily	M	4.1.5	Daily report on model performance
	As needed/as scheduled	IN	4.1.6	Real-time station maintenance and weekly report on station performance
	Weekly	M	4.1.7	Weekly report on quality of model input data
	As needed	M IN	4.1.8	Flood warning and flood occurence
Post-monsoon	Post-monsoon	IN	4.2.1	Station assessment
	Post-monsoon	M	4.2.2	Model input data assessment
	Post-monsoon	M	4.2.3	Catchment assessment
	Post-monsoon	M	4.2.4	NAM-model assessment
	Post-monsoon	M	4.2.5	Hydrodynamic (HD) model assessment
	Post-monsoon	M	4.2.6	Data assimilation (DA) assessment
	Post-monsoon	IT	4.2.7	Update Mike Operations (MO) back-end
	Post-monsoon	IT	4.2.8	Update MO front-end
	Post-monsoon	M IT	4.2.9	Update reports
	Post-monsoon	TL DL M IT IN	4.2.10	Update SOPs
Pre-monsoon	Pre-monsoon	TL	4.3.1	Ensure completion of post-monsoon SOPs
	Pre-monsoon	TL	4.3.2	Coordinate with stakeholder organizations
	Pre-monsoon	TL	4.3.3	Plan O&M activities
	Pre-monsoon	TL	4.3.4	Assemble O&M team
	Pre-monsoon	IN	4.3.5	Ensure real-time stations are operational

TL Team leader · DL Deputy team leader · M Modelling team · IT IT team · IN Instrument team

Figure 2-6 Standard Operating Procedures for the Baguio FEWS

Source: Ramboll

The activities related to operation and maintenance of the FEWS are divided into three phases, as seen in Figure 2-7:

- **Preparation phase: Pre-monsoon period (expected in April-May)**
  - System Review and Preparation: Based on the post-monsoon analysis from the previous season, check all components of the FEWS for functionality and efficiency. This includes software updates, hardware checks, and ensuring communication channels are functioning properly.
  - Data Analysis: Review the data collected in the previous monsoon season to refine predictive models.
  - Training and Simulation Drills: Conduct training sessions for staff and stakeholders. Simulation drills can be effective in preparing the team for various scenarios.

- **Application phase: Monsoon period (expected in May-October)**
  - This phase includes operation and maintenance of the FEWS during the monsoon.
  - Real-time Monitoring: Continuously monitor data from gauging stations and other sources for flood prediction.
  - System Maintenance: Ensure that the system, including hardware and software, is running smoothly without interruptions.
  - Data Management: Regularly update and back up the data collected.

- **Assessment phase: Post-monsoon period (November-March)**
  - Performance Evaluation: Assess the system's performance in terms of accuracy of predictions, timeliness of warnings, and effectiveness of communication.
  - Station Assessment: Evaluate the real-time monitoring stations' performance and data accuracy.
  - System Update: Based on the assessments, update the FEWS to improve its forecasting and warning capabilities.
  - Documentation: Document lessons learned, best practices, and areas for improvement.
  - Expansion Plans: Plan for the expansion of the network of real-time monitoring stations, as required.

Figure 2-7 Operation and maintenance phases of the FEWS
Source: Ramboll

The FEWS is a dynamic system that should be adapted as additional data and knowledge is gained and lessons learned are utilized in the system. This enhances the system's resiliency, sustainability and value for the citizens of the City of Baguio. The SOPs may need to be updated as new information becomes available and data, tasks and responsibilities for the operation and maintenance of the Baguio FEWS are validated. All procedures should be reviewed and, if necessary, adjusted or expanded to ensure lessons learned from the monsoon season are incorporated. Thus, the SOPs for the FEWS in Baguio is a living document, regularly reviewed and updated to reflect changes in technology, operations, and environmental conditions. Implementation of the SOPs is a responsibility shared by all members of the O&M team. To foster long-term sustainability of the FEWS, it is key to ensure continuous maintenance of the system as well as availability and capacity of resources.

3 SYSTEM PERFORMANCE ASSESSMENT FOR MONSOON 2023

Source: Ramboll

Assessing the performance of a flood forecasting system is crucial to ensure its reliability, effectiveness, and overall dependability. It is also essential to perform regular and comprehensive performance assessments for maintaining and improving the effectiveness of flood forecasting systems over time. Key reasons for continuous comprehensive system performance assessment include:

- Ensuring that the system can be trusted for timely, reliable, and accurate predictions.
- Identifying and addressing any weaknesses in the system, reducing the likelihood of false alarms or missed flood events.
- Improving the forecasts that are not only accurate but also actionable, supporting effective decision-making in emergency situations.
- Allowing for the optimization of resource allocation by focusing on areas where the risk of flooding is higher.

In summary, the performance assessment is needed to identify the strengths and weaknesses of the system to further improve the accuracy and dependability of FEWS. The key components which must be evaluated to assess the overall FEWS performance are:

- Station performance
- Data quality
- Model performance
- Real-time setup
- Operation and maintenance

Assessment of each of the above components are discussed in detail in following sections.

3.1 STATION PERFORMANCE ASSESSMENT

Station performance assessment involves evaluating the efficiency, reliability, and overall functionality of different types of stations (rainfall, water level, and tandem), ensuring they are achieving their intended purposes and contribute effectively to the FEWS.

The features described in the subsections below were evaluated while undertaking the station performance assessment.

3.1.1 NON-OPERATIONAL PERIOD

Non-operational period refers to the periods the station is not online, i.e., it is not recording and transmitting the data. The monsoon SOPs are planned such that there is high availability of stations during monsoon operations. From the pre-monsoon station assessment, it was observed that the major cause of station being offline is battery backup and sim card subscription. During 2023 monsoon operations, it was ensured that the battery change and extension of SIM subscriptions is performed at regular intervals.

A summary of operational period of the station is presented in Table 3 1. From the analysis of the station data, it was observed that:

- All stations exhibited operational periods exceeding 80%, with the exception of the City Camp Lagoon, Camp 7 and Eagle Crest stations.
- The stations were non-operational during the maintenance of the stations. This has been presented in section 3.1.3.
- City Camp Lagoon was giving erroneous data (negative water depth) and required recalibration and was not operational for initial months.
- Eagle Crest station required station recalibration and adjustments and therefore, was not operational in the month of June and July.

3.1.2 SEAMLESS DATA TRANSMISSION

It is imperative that the data observed is efficiently transmitted in real-time to FEWS. The station data are linked to the PhilSensors website and from the website, the data is accessed through an API provided by DOST-ASTI. The system was able to seamlessly fetch the data or more than 99% of the time. Only one data transmission incident was reported during the total 122 days of 2023 monsoon operation. The failure occurred due to incomplete data set. To avoid any such incident in future, another script was added to get the data for the entire day to complete the database. In summary, a seamless data transmission was observed throughout the 2023 real-time operation of FEWS.

Table 3-1 Summary of station operation

Station ID	Station Name	Type	Percentage time station is operational (%)	
892	Camp 6 Bridge	Tandem	Waterlevel - 88	Rainfall – 91.75
460	City Camp Lagoon	Tandem	Waterlevel - 76.25	Rainfall - 85
463	Asin Bridge	Tandem	Waterlevel - 90	Rainfall – 94.25
2894	Brookspoint	Tandem	Waterlevel – 92.75	Rainfall - 97
1390	Balili Bridge	Tandem	Waterlevel – 91.25	Rainfall - 100
2893	Sadjap Bridge	Water Level	80.75	
2896	Camp 7	Water Level	76.25	
2892	Ferguson Bridge	Water Level	92.75	
2895	Eagle Crest	Water Level	44.5	
3028	Irisan Fire Station	Rainfall	94.75	

Source: Ramboll

3.1.3 SENSOR CALIBRATION AND MAINTENANCE

The network of real-time monitoring stations needs to be operational at all times. To ensure this, The instrument team performed regular scheduled inspections, servicing, and repairs of all the monitoring stations. These inspections are performed with two objectives:

- To prevent equipment or system failures.
- To repair station in case of failure.

3.1.3.1 PREVENTIVE MAINTENANCE

Preventive maintenance is a crucial aspect of ensuring the continuous and reliable operation of monitoring stations. Regular maintenance helps identify and address potential issues before they lead to equipment failure. This proactive approach minimizes downtime, ensuring that monitoring stations can operate consistently. Some key reasons for preventive maintenance are:

- Early detection of issues
- Minimize equipment downtime
- Extend equipment lifespan
- Optimize performance
- Improve data accuracy

During the monsoon operation of 2023, preventive maintenance was conducted a total of 28 times across various monitoring stations. Figure 3-1 illustrates the distribution of preventive maintenance activities among the stations. The stations were inspected every month and routine maintenance activities, such as cleaning, lubricating, and inspecting components were performed. Through routine inspections, instrument team identified the issues before they escalate into major problems. Figure 3-2 outlines the common findings identified and addressed by the team during these routine inspections. Notably, negative water levels were a major concern observed at two specific stations, namely Balili Bridge and Camp 6 Bridge. Preventive maintenance allowed for timely re-calibration and adjustment of the monitoring instruments to ensure accurate readings.

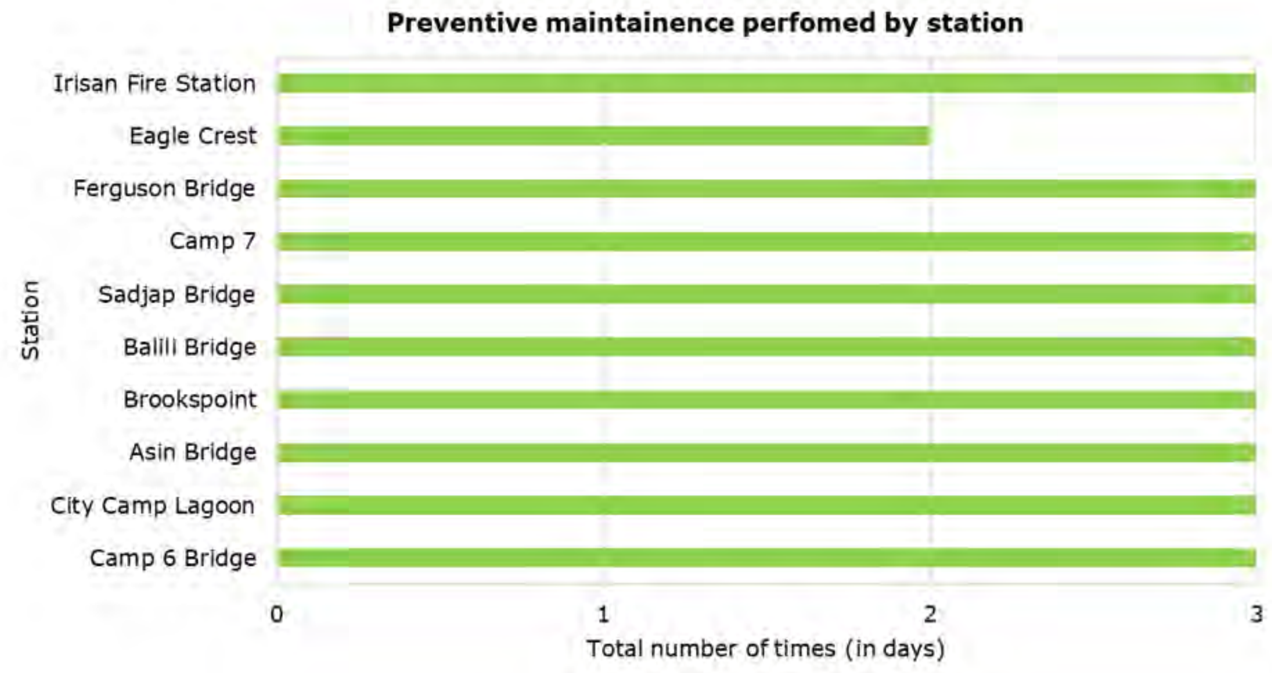


Figure 3-1 Station-wise preventive maintenance performed during 2023 monsoon
Source: Ramboll

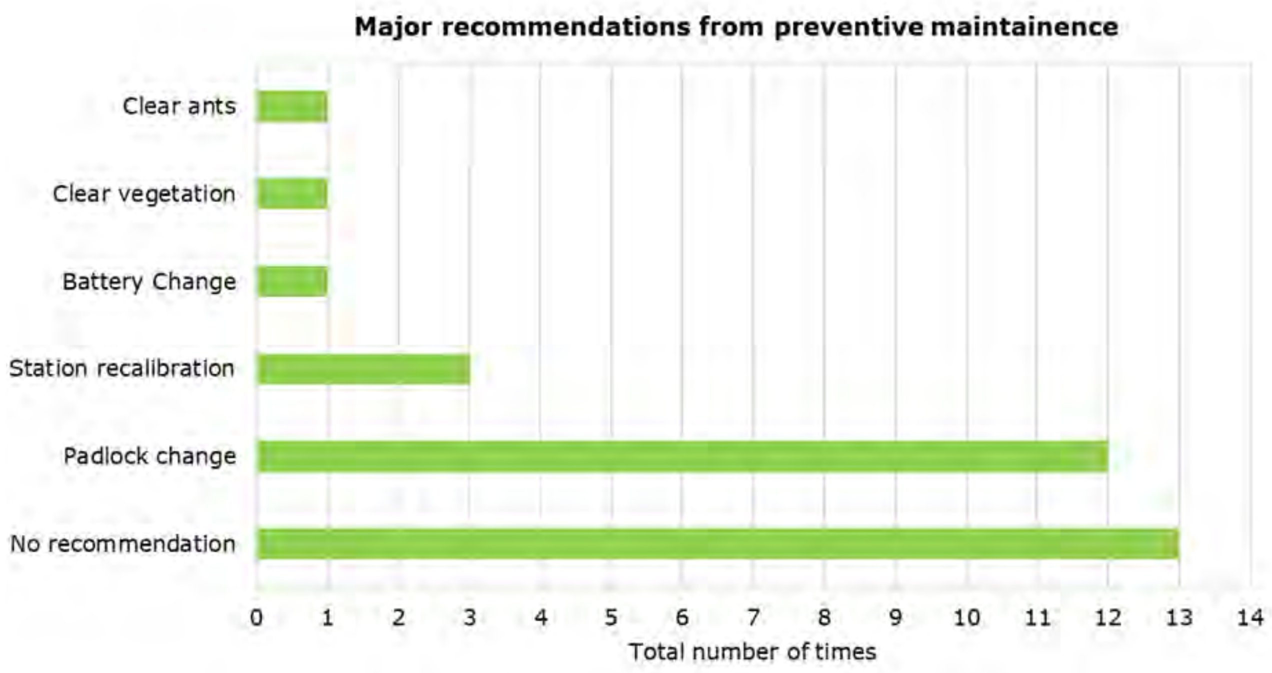


Figure 3-2 Major recommendations from preventive maintenance of stations
Source: Ramboll

3.1.3.2 CORRECTIVE MAINTENANCE

Corrective maintenance refers to the set of activities undertaken to address and resolve issues or faults that have occurred in a station after a failure has been identified. Unlike preventive maintenance, which is proactive and aims to prevent issues before they occur, corrective maintenance is reactive and focuses on restoring the station to its normal operational state after a malfunction or breakdown has taken place. Corrective maintenance typically includes fault Identification, procurement, and replacement of parts and execution of repairs.

During 2023 monsoon operation, the corrective maintenance was conducted a total of 37 times across various monitoring stations. Figure 3-3 illustrates the distribution of corrective maintenance activities among the stations and Figure 3-4 outlines the common reasons of corrective maintenance of the monitoring stations. Out of these, station repair and renovation were the major reasons for corrective maintenance. The Eagle Crest and City Camp Lagoon station needed more repairs than other stations to rectify the issue. Apart from this, the O&M team also conducted diagnostic assessments in an effort to operationalize the Irisan PSHS station, however, this objective could not be achieved.

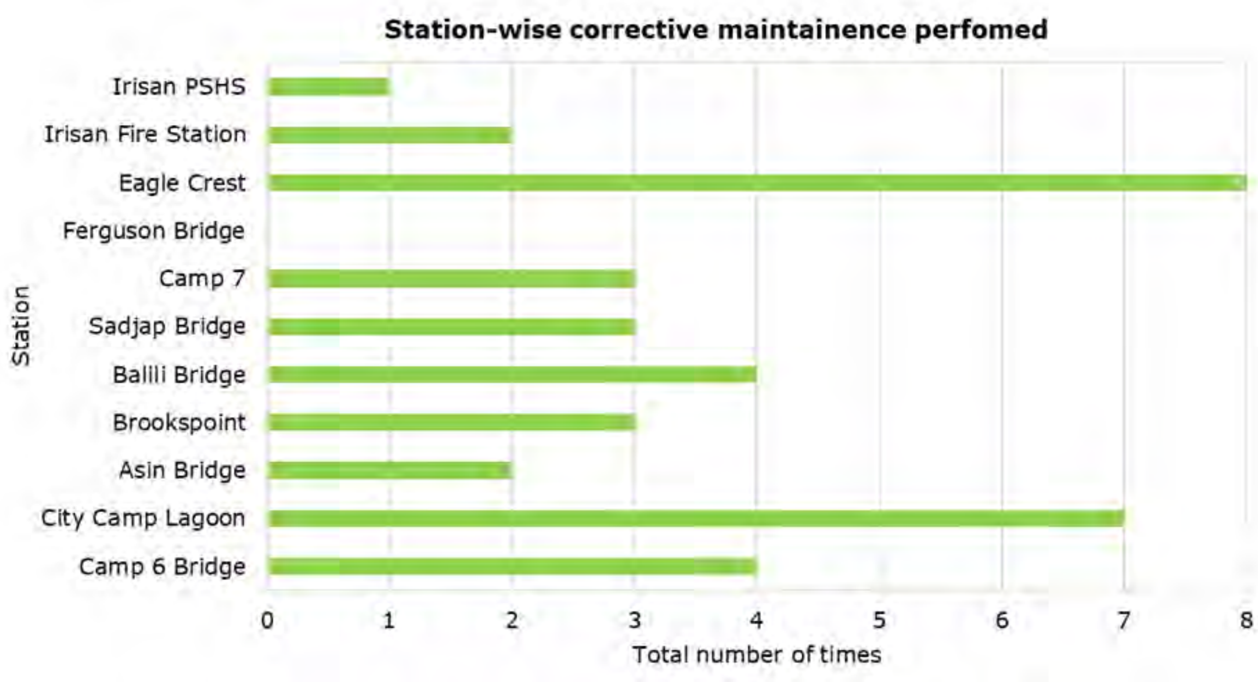


Figure 3-3 Station-wise corrective maintenance performed during 2023 monsoon
Source: Ramboll

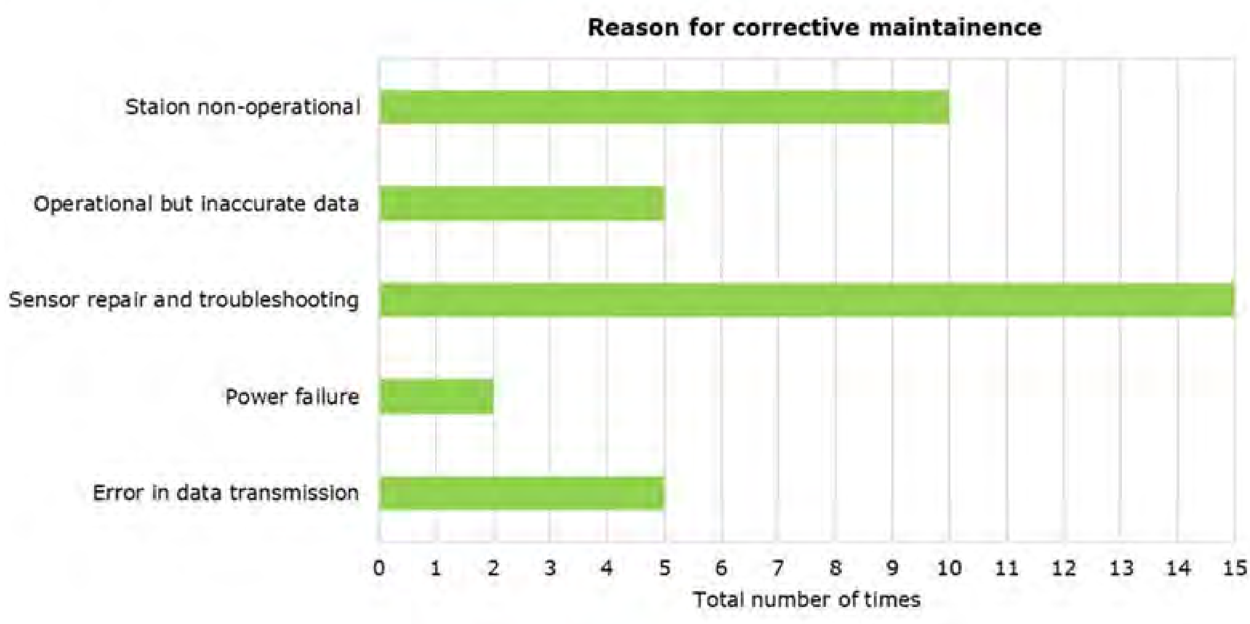


Figure 3-4 Major reasons for corrective maintenance
Source: Ramboll

3.2 DATA QUALITY ASSESSMENT

In data quality assessment, the accuracy, reliability, completeness, and overall quality of data transmitted by monitoring stations and PAGASA were evaluated. There are three types of data which are consistently used in real-time operation – real-time water level and rainfall data and WRF rainfall forecast data. The flood forecasting model accuracy and reliability largely depends on the quality of these input data. In the following sections, the quality of each of the input data is comprehensively assessed.

3.2.1 REAL-TIME WATER LEVEL DATA ASSESSMENT

During the assessment of real-time water level data, sudden jumps or shifts in y-direction i.e., datum were observed. This shift is majorly observed in the month of May. The details of these shifts/jumps are listed below:

- Balili bridge station shows two datum shifts in the recorded water levels, shown in Figure 3-5.

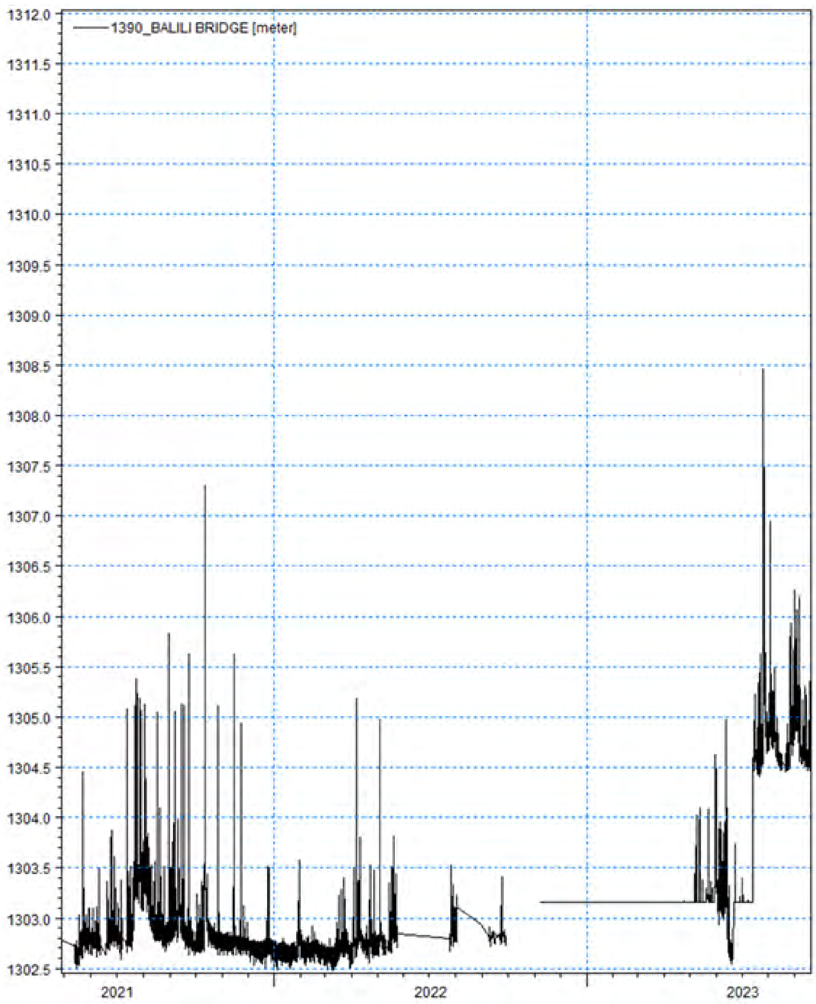


Figure 3-5 Datum shifts observed in water level data at Balili Station
Source: Ramboll

- The first datum shift at Balili station was observed between 2022 and 2023. This shift was observed due to diversion of a part of the flow from upstream of the location of the station directly to further downstream using an alternative pipe. This is indicated in Figure 3-6.

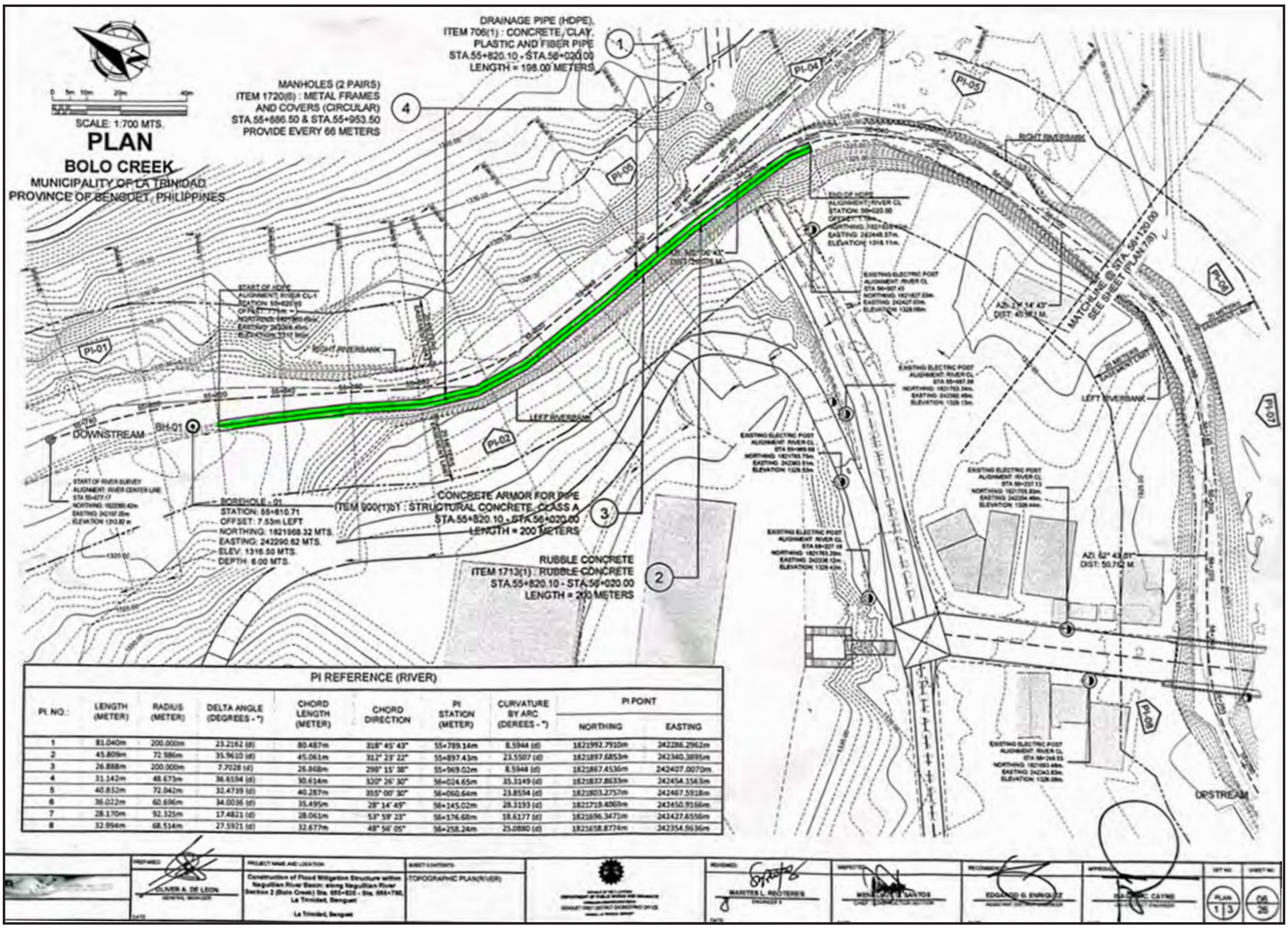


Figure 3-6 Plan of flow diversion from upstream of Balili Station using concrete pipe (indicated in green)
Source: Baguio City LGU

- The second datum shift at Balili station was due to sensor adjustments. The sensor's position at this location was changed during routine maintenance and the corresponding changes in the backend calculations was not made accurately.

- Similar to Balili station, the issue with the datum shift due to sensor adjustments was also observed at City Camp Lagoon, Camp 6 bridge, and Eagle Crest station. These stations are listed in **bold** in Table 3-2.

Table 3-2 Reference and datum levels of real-time water level monitoring stations
Stations marked with shift in the datum levels are shown in **bold**.

Station Details		Measurements from Survey			Measurements used by Philsensors		
ID	Name	Riverbed Elevation (m)	Sensor Elevation (m)	Sensor Reference Height (m)	Riverbed Elevation (m)	Sensor Elevation (m)	Sensor Reference Height (m)
460	**City Camp Lagoon**	**1410.989**	**1421.253**	**10.264**	**1413.24**	**1421.253**	**8.01**
463	Asin Bridge	213.205	225.509	12.304	213.205	225.509	12.304
1390	**Balili Bridge**	**1303.151**	**1315.182**	**12.031**	**1301.73**	**1315.182**	**13.45**
892	**Camp 6 Bridge**	**770.619**	**782.074**	**11.455**	**770.09**	**782.074**	**11.985**
2893	Sadjap Bridge	1342.355	1352.387	10.032	1342.355	1352.387	10.032
2892	Ferguson Bridge	1366.701	1372.673	5.972	1366.701	1372.673	5.972
2894	Brookspoint	1405.362	1412.056	6.694	1405.362	1412.056	6.694
2896	Camp 7	1236.103	1242.226	6.123	1236.11	1242.226	6.123
2895	**Eagle Crest**	**1306.896**	**1313.458**	**6.562**	**1302.59**	**1313.458**	**10.87**

Source: Ramboll

Based on the lessons learnt from the assessment of water level station data, the instrument team has been advised to avoid adjustments of sensor heights and carefully coordinate with the modelling team as well as DOST-ASTI prior to any sensor adjustments to ensure that datum shifts are minimized.

3.2.2 REAL-TIME RAINFALL DATA ASSESSMENT

In the assessment of real-time rainfall data, a few isolated rainfall peaks in the data in were observed, majorly in months of June and September. These peaks or data recorded during those periods does not correlate with the recorded water levels. It was found that the peaks occurred when the rainfall monitoring stations were under routine maintenance and testing. The periods of maintenance of rainfall stations are listed in Table 3-3.

Table 3-3 Period of maintenance of real-time rainfall monitoring stations

Station ID	Station Name
Camp 6 Bridge	20-Jun-23, 9-Jul-23 to 10-Jul-23, 14-Aug-23, 19-Sep-23, 26-Sep-23
City Camp Lagoon	9-Jun-23, 13-Jun-23, 20-Jun-23, 9-Jul-23, 11-Jul-23 to 13-Jul-23, 20-Jul-23 to 21-Jul-23, 25-Jul-23, 31-Jul-23, 2-Aug-23 to 5-Aug-23, 9-Aug-23 to 10-Aug-23, 15-Aug-23 to 16-Aug-23, 9-Sep-23, 18-Sep-23, 27-Sep-23
Asin Bridge	5-Jun-23, 15-Jun-23, 20-Jun-23, 9-Jul-23 to 10-Jul-23
Brookspoint	14-Jun-23, 20-Jun-23, 15-Aug-23 to 16-Aug-23, 30-Aug-23, 6-Sep-23, 9-Sep-23, 11-Sep-23, 18-Sep-23
Balili Bridge	5-Jun-23, 20-Jun-23, 9-Jul-23 to 11-Jul-23, 15-Aug-23, 6-Sep-23 to 7-Sep-23
Irisan Fire Station	14-Jun-23, 20-Jun-23, 9-Jul-23, 14-Aug-23, 7-Sep-23

Source: Ramboll

Based on the lessons learnt from the assessment of rainfall station data, the instrument team has been advised to report the dates of maintenance to the modelling and IT team to avoid the spurious inputs to the bias correction script and model. The IT team will remove the data records for the selected period to avoid erroneous response of these maintenance.

Based on the data collected for the Irisan fire station, a comparison has been carried out against data from the old Irisan PSHS station data which indicated that although the two station are 600 m apart, they do not receive similar rainfall and the data of the new station could not replace the data in the model for the old Irisan rainfall data. Hence, the data from Irisan PSHS is no longer used in the system.

3.2.3 WRF DATA ASSESSMENT

The accuracy of meteorological inputs significantly impacts the performance of flood forecasting models. During the monsoon of 2023, it has been observed that the WRF data is much higher than the observed rainfall data. Figure 3-7, Table 3-4 and Table 3-5 illustrates the variability in the second level rainfall forecast and rainfall observed at the monitoring stations. It must be noted that WRF data being assessed and indicated here is non-bias corrected.

The bias correction implemented in the model satisfactorily reduces this large rainfall observed in the WRF data. However, there have been overprediction observed the model during the real-time operations. Based on the model performance assessment it was found that this overprediction is not attributed to the failure of bias correction model to rectify larger WRF values. The forecast spikes result from outliers in the observed water level data and DA. This has been further explained in Section 3.3.2.1.

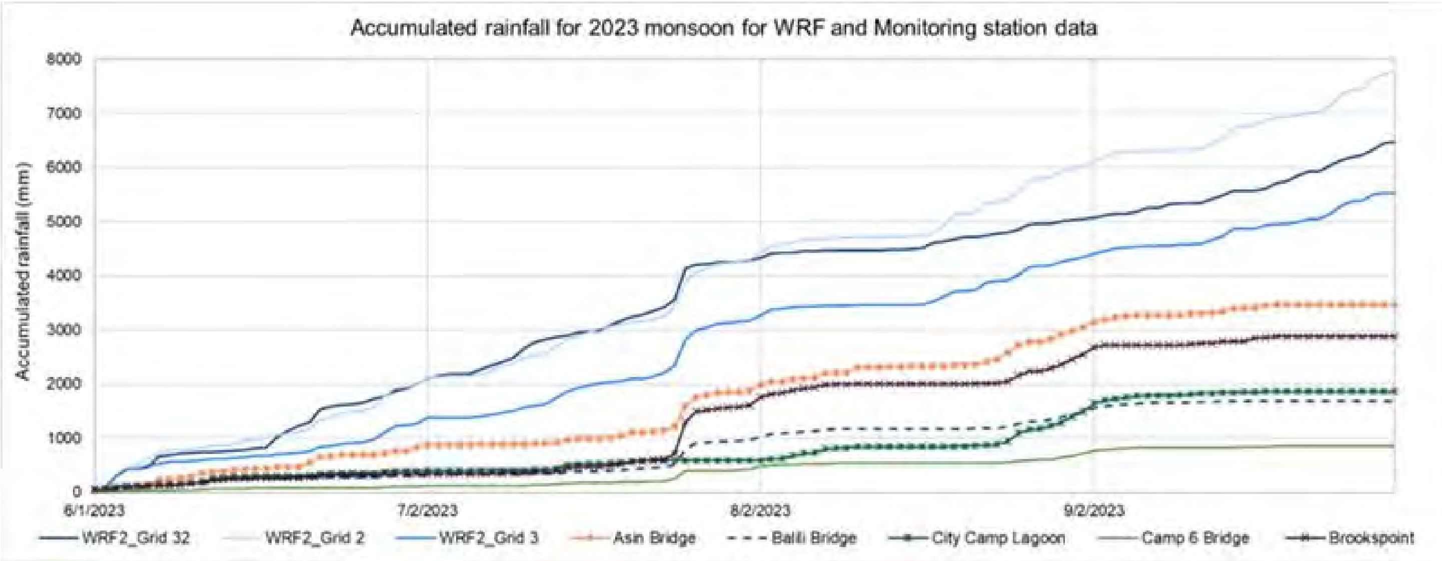


Figure 3-7 Accumulated precipitation in forecasted and observed rainfall data
Source: Ramboll

Table 3-4 Summary of monthly total precipitation in WRF second level and rainfall station data

Month	Monthly total precipitation (in mm)					
	WRF2_Grid 32	WRF2_Grid 2	WRF2_Grid 3	Brookspoint	Balili Bridge	City Camp Lagoon
June	1919.48	1951.54	1242.89	343.00	310.39	397.50
July	2341.28	2321.85	1915.78	1233.50	637.54	192.00
August	767.00	1706.22	1142.64	888.50	502.67	816.50
September	1443.40	1778.62	1230.73	415.50	228.60	463.00

Source: Ramboll

Table 3-5 Summary of daily maximum in month precipitation in WRF second level and rainfall station data

Month	Daily maximum in month precipitation (in mm)				
	Date of occurrence	WRF2_Grid 32	Brookspoint	Balili Bridge	City Camp Lagoon
June	03-Jun-2023	251.80	19.5	8.38	16
July	26-Jul-2023	575.22	586.50	298.70	Non-operational
August	27-Aug-2023	102.44	79	36.07	64.5
September	29-Sep-2023	127.81	Non-Operational	Non-Operational	Non-operational

Source: Ramboll

3.3 MODEL PERFORMANCE ASSESSMENT

The assessment of model performance is a critical phase in the development and deployment of flood forecasting models. It involves evaluating how well a model performs with new, unseen data and how reliable and consistent its predictions are in various situations. Therefore, the assessment of the model performance centres around two key aspects – model stability and model accuracy.

3.3.1 MODEL STABILITY

The stability of the model measures the consistency and robustness of the model throughout its operational time. A stable model maintains its effectiveness across different datasets, varying conditions, and over time. A robust model should demonstrate reliability and the ability to operate consistently under dynamic and evolving meteorological conditions.

During the 2023 monsoon operations, the model stability was evaluated using the model failure logs maintained by IT team. On evaluation of the IT system logs, it was observed that:

1. Model 1 (for Balili River) and Model 3 (for Bued, Galiano and Ambalanga Rivers) failed 79 and 88 times (out of 1048 runs) respectively due to various reasons such as input data failure, data pre-processing failure and model simulation failure.
2. However, out of these failures, the model failed due to model simulation issues only at three incidences - Model 1 on 11th July and 15th July and Model 3 on 11th July.
   - Simulation failure occurred due to limited Q-h boundary defined in the model. The model has been strengthened by incorporating extended Q-h tables. This ensures model stability, particularly during periods of higher observed flows.
   - The model also failed due to high precipitation observed this year for which the model was not previously tested. The model was calibrated in 2022 using the available historical data.

To overcome the stability issues, the model is fine-tuned and recalibrated in the post-monsoon phase with 2023 observed data to become resilient to variation in input data.

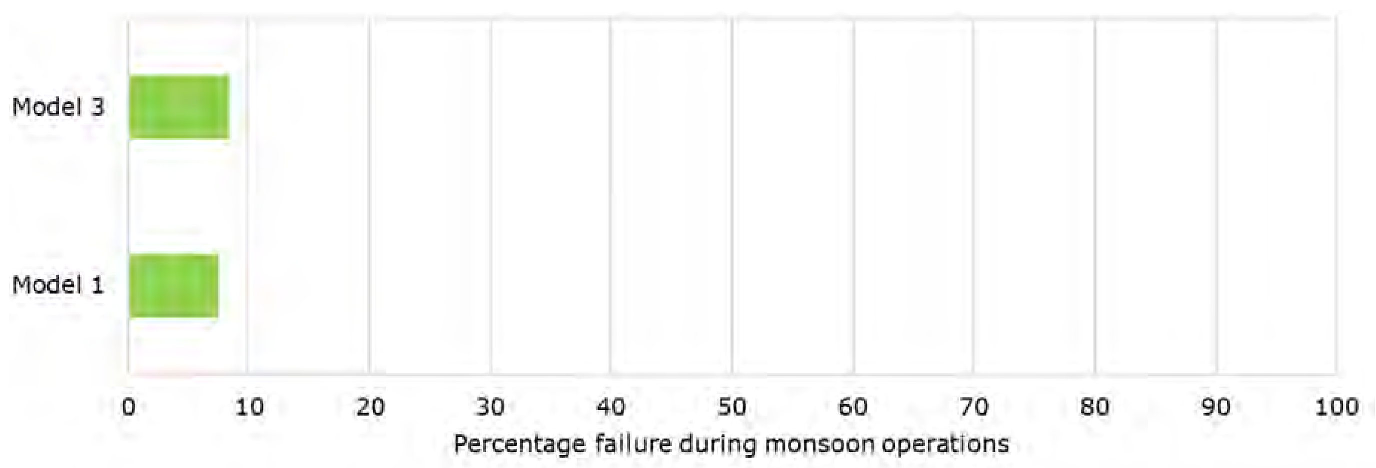


Figure 3-8 Model failures observed during 2023 monsoon operation
Source: Ramboll

3.3.2 MODEL ACCURACY

Model accuracy examines how closely the model's predictions or results align with reality or observed outcomes. It is a fundamental aspect of model evaluation, indicating the degree to which the model's predictions are correct. The accuracy of the model is evaluated through the following elements:

1. Precision in alerts
2. Accuracy in results

3.3.2.1 PRECISION

Precision assesses how effectively the model predicts the occurrence of a specific outcome, such as a flood. A higher precision value indicates fewer false alarms. To estimate the precision of the model predictions, true positives, true negatives, false positives, and false negatives predictions are identified, where:

- True positives are instances where the model correctly predicts a positive outcome i.e., the FEWS forecasts flood and the flood occur.
- True negatives are correct negative predictions, i.e., FEWS doesn't forecast flood and flood doesn't occur.
- False positives are incorrect positive predictions i.e., FEWS forecasts flood but the flood doesn't occur.
- False negatives are incorrect negative predictions i.e., FEWS doesn't forecast flood, but the flood occurs.

During the pre-monsoon phase, a set of procedures for flood occurrence and flood warning were introduced (see Appendix C). In this, it is described that the O&M team should gather and record the on-ground field information, in case of flood warnings and/or occurrence. However, during the 2023 monsoon the O&M team only surveyed on field in one case of flood warning by the system. No field surveys were completed in the remaining flood warning cases.

Based on the assessment of flood warning and occurrence logs, it was found that at Balili Station:

- Total number of flood warnings reported by FEWS: 8
- Total number of flood warnings surveyed by O&M: 1
- Total number of flood occurrences surveyed or recorded: 0

This implies that there were no floods due to overtopping of banks in Bailli river although the system generated overtopping warnings. There could have been floods elsewhere in the city e.g., driven by lack of proper road-side drainage capacity. However, no flooding due to overtopping of Balili river has been observed.

The following observations were made:

- It was observed that these warnings occurred near the time of forecast (shown in Figure 3-9) and were few isolated events i.e., flood or high water level event was not observed in the previous simulations of the event. Through process of elimination, it was deduced that these events occurred due to missing or erroneous observed water level data affecting the model's DA component.

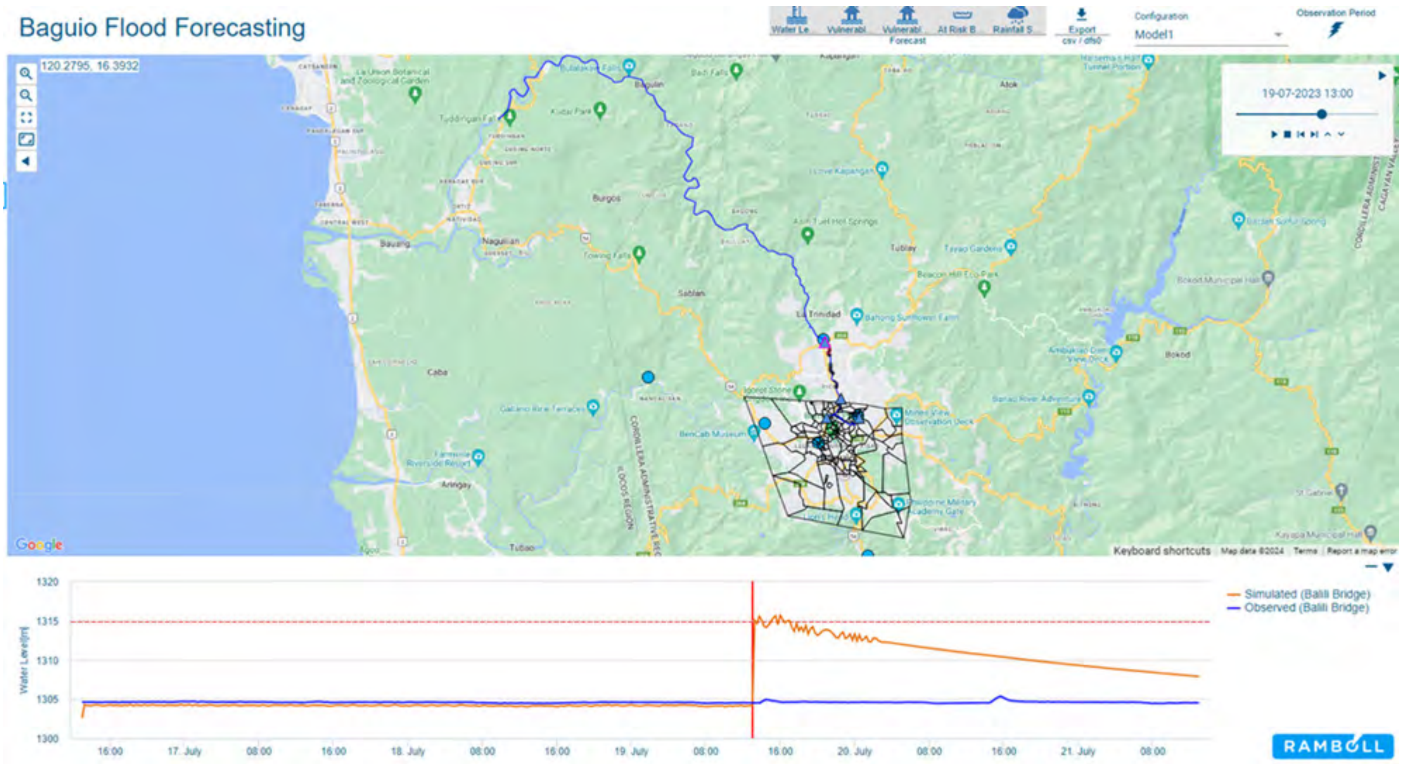


Figure 3-9 Snapshot of flood warning in FEWS
Source: Ramboll

- When the model was run again with the corrected observed data the thresholds did not exceed (shown in Figure 3-10) hinting towards the error in the observed water levels close to the TOF. DA initializes the water levels in the model against the observed WL data. When there is a sudden outlier (spike) in observed data, the model is initialized incorrectly causing overprediction just after the time of forecast. This can be verified by the fact that the overprediction is absent in the forecasts simulated before and after. The system is designed such that it updates the database with the complete dataset at regular intervals to fill up the missing data which may not have been available or be erroneous at the time of forecast thus eliminating the error in the overprediction in subsequent simulations. This will need to be further verified and tested in the real time operation during 2024 monsoon.

- As the false warnings from the system is due to errors in the observed data, the precision of the FEWS is acceptable as long as the checks and relevant corrections for erroneous observed data is carried out in a timely manner as is describe in the updated monsoon SOPs.

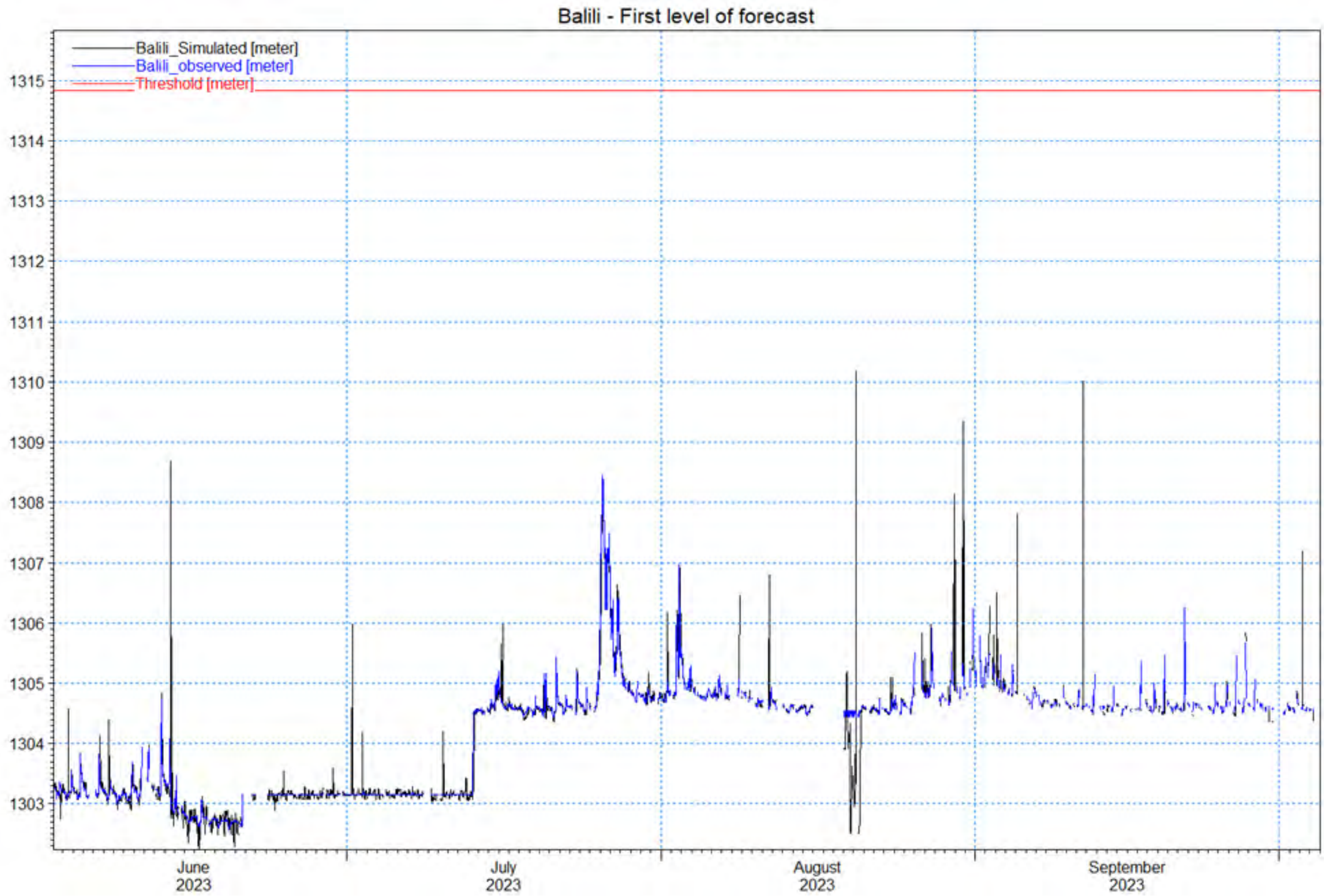


Figure 3-10 Simulated vs observed water levels at Balili Station during 2023 monsoon
Source: Ramboll

- The observed water levels or the water level plots at the time of event were also not recorded during the monsoon operations to support the argument. There was understanding gaps for the FEWS O&M team on the procedures defined for Flood warning and Flood occurrence as also outlined in the Sustainment Plan (Appendix D) under 'identified training and technical support needs'. Therefore, there is a need to further elaborate and train the O&M team on these SOPs. This has been addressed in the revised SOPs presented in Appendix C.
- It must be noted that the flood warnings were given based on the proposed water level thresholds estimated from riverbank levels. However, these thresholds need to be estimated using the previous flood reports to generate the reliable flood warnings, this is further described in Section 7 under recommendations for future FEWS updates.

3.3.2.2 ACCURACY

Accuracy measures how closely (numerically) the model can predict the outcome, in this case, the water levels. A higher accuracy signifies better management and planning, reflecting the proximity of the model's predictions to the actual data points. It is represented by a single numerical value that encapsulates the overall performance of the model. There are various metrics to define model accuracy such as Root Mean Square Error (RMSE), Mean Absolute Error (MAE), R-squared (coefficient of determination), amongst others.

RMSE measures the average differences between the predicted values and the actual (observed) values, while penalizing larger errors more heavily. Smaller RMSE values indicate that the model's predictions are, on average, closer to the actual values. RMSE is also in the same units (m) as the variable (here water levels) thus, making it easier to interpret the accuracy of the model. On the other hand, R-squared is a statistical measure that represents the proportion of the variance in the predicted value that is explained by observed value. The R-squared value ranges from 0 to 1, where 0 indicates that the model does not explain the observed system and 1 indicates that the model accurately explains the variability in observed values.

The model performance metrics for the various level of forecasts at Balili station are presented in Table 3-6. The RMSE and R-squared (R^2) for the first 12-hours of forecasts gives an acceptable correlation with the observed water levels. As expected, the reliability of the forecasts reduces as the forecasting time increases. The full model performance assessment, including the assessment for the remaining stations, is presented in detail in Appendix A.

Table 3-6 Baguio FEWS model performance in real-time during 2023 monsoon at Balili Station

Level of Forecast	Time of forecast	RMSE	R^2
First	0-2 hours	0.357	0.86
Second	3-5 hours	0.640	0.67
Third	6-8 hours	0.689	0.62
Fourth	9-11 hours	0.65	0.63

Source: Ramboll

3.4 ASSESSMENT OF REAL-TIME SETUP IN FEWS

The real-time monsoon operation of 2023 began in June 2023 and concluded in October 2023. During this period, the system executed 1048 job runs. This assessment of real-time operation was conducted primarily for the Operational Process Job, which is vital for the system's functioning. Other jobs were unsuccessful due to issues such as license failures and internet disruptions. Based on the tasks that failed during the job run, an analysis undertaken focused on identifying which tasks were crucial and how often they failed during the monsoon. This analysis informed the improvement of these tasks in future runs. A summary of Operational Process job failures is shown in Figure 3-11.

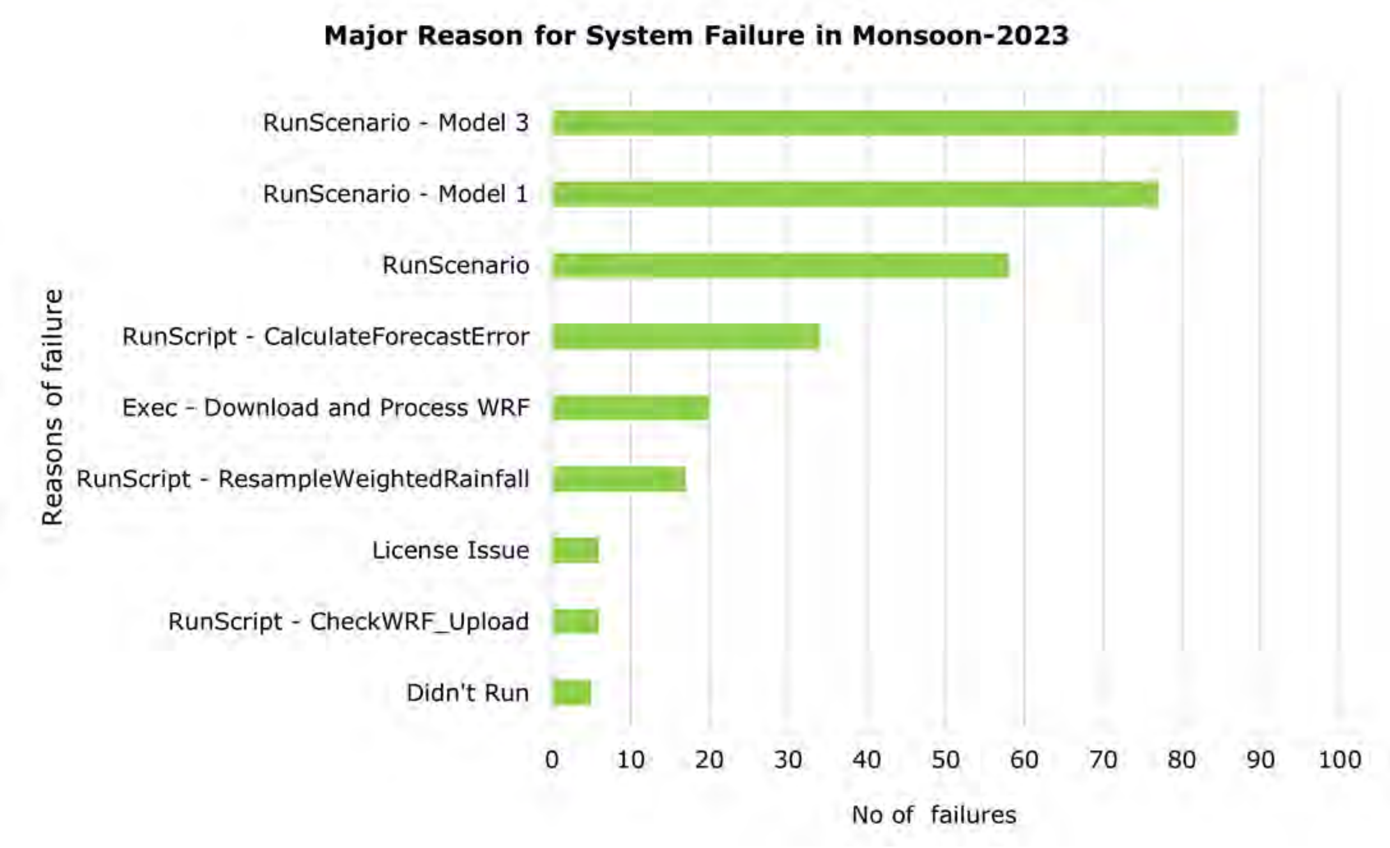


Figure 3-11 Summary of system failure based on task
Source: Ramboll

Further, the failures have ben categorized according to the reason of failures and it was found that all the failures can be divided into four major categories (Table 3-6):

1. Internet License Error
2. Failure of Mean Area Weighted (Catchment Rainfall) File Update
3. WRF Data Upload Failure
4. Model Failure.

Table 3-7 Categorization of the failures

Sr. No	Reasons of Failure	Category
1	Didn't Run	License Error
2	License Issue	
3	RunScript - ResampleWeightedRainfall	Failure of MAW File Update
4	RunScript - CheckWRF_Upload	WRF Data upload Failure
5	Exec - Download and Process WRF	
6	RunScript - CalculateForecastError	
7	RunScenario	Model Failure
8	RunScenario - Model 1	
9	RunScenario - Model 3	

Source: Ramboll

Failure due to license

Dealing with this issue was a major challenge. The core problem wasn't with the DHI License Service failing, but rather the license manager on the application server giving trouble. Initially this was resolved by restarting the application server on a fix interval. Additionally, another solution was explored – using a physical dongle instead of relying on an internet license for the application server. However, the application server didn't have a slot to plug in the USB license dongle. The final solution became to create a separate machine equipped with a USB slot, which could then serve as a network license server. This alternative approach ensures a reliable fix to the problem.

Failure of MAW File Update

In the system's day-to-day functioning, correcting biases in rainfall predictions is crucial. This correction relies on using a file from the previous model run. However, if the model fails and cannot update this file, the next step, which involves rearranging rainfall data, lacks enough information. This shortage of data can seriously affect the system's accuracy. To tackle this issue, when the model faces problems, it's necessary to run the models before fixing the biases. This ensures that the system has the right information it needs to work effectively and make reliable predictions. In simpler terms, it's like making sure the system has all the puzzle pieces it needs before trying to put them together correctly.

Failure due to non-availability of WRF data

System failures often happen because the WRF data doesn't get uploaded to the server properly. To fix this, a possible solution is to manually kick off the Operational Process job occasionally. This way, any upload problems can be caught early, making the system more reliable and less prone to disruptions.

Failure due to Model Runs

The system runs models eight times a day. When a particular model consistently faces issues and fails, it becomes essential to tackle and fix these problems in collaboration with the modeling team. Addressing and resolving issues promptly ensures the smooth functioning of the models, maintaining the reliability and effectiveness of the overall system. Model failures in 2023 monsoon operation are described in section 3.3.1.

3.5 ASSESSMENT OF MONSOON OPERATION AND MAINTENANCE

The assessment of operation and maintenance of the FEWS during monsoon involves evaluating how well the system functions and ensuring that it is properly maintained to provide accurate and reliable data during the monsoon season, for which the FEWS is intended for. For effective and smooth operation of FEWS, the FEWS O&M team has been setup and trained to carry out the operation and maintenance of FEWS following the designed SOPs, as discussed in Section 2.4. Therefore, assessment of monsoon operation and maintenance includes:

- Performance assessment of FEWS O&M team
- Assessment of Monsoon SOPs

3.5.1 PERFORMANCE ASSESSMENT OF FEWS O&M TEAM

The FEWS O&M team consists of three sub-teams: the modelling team, the instrument team, and the IT team. During the 2023 Monsoon, the operation and maintenance of the FEWS was performed by O&M team in closed collaboration with the technical project team to further enhance team's confidence in following the SOPs and understanding their roles and responsibilities, and to ensure self-sufficiency of the O&M team in the long run.

The performance of the O&M team was evaluated based on the following indicators:

- Knowledge and skill levels
- Team dynamics and performance
- Individual time availability

An improvement in knowledge and confidence levels across all teams was observed during the pre monsoon OTJ training as outlined in D3 Training Report for the Real-time Operation of the FEWS. Confidence levels especially increased regarding confidence in understanding SOPs and their specific roles and tasks. This was demonstrated by the O&M team by operating and maintaining the FEWS throughout the monsoon season in close coordination with project team. All the three teams maintained the daily logs assigned to them and took necessary troubleshooting measures, wherever required with the support from project team. In the training sessions throughout the consolidation phase, and particularly in the post-monsoon OTJ training, the project team observed a good team collaboration and a sense of trust and honest communication between team members. However, the following gaps were observed:

- The team was able to follow the daily SOPs but they lacked in following up on event-based and weekly SOPs.
- There was a training deficiency identified within the instrument team, particularly concerning instruments, sensor adjustments, and their impact on model performance. This issue was subsequently addressed during the Post-Monsoon OTJ training and updated SOPs.
- Due to this gap in understanding, there was an observed lack in coordination and reporting between the teams. This led to led to delay in identification of reasons for discrepancies in model results.
- The time commitment from everyone in the team varied due to their primary roles and commitments. However, it must be noted that the real-time monitoring of FEWS during monsoon is of utmost importance for generating accurate and reliable forecasts. Therefore, it was observed that there is an imperative need of aligning the O&M team especially during the real-time operation.

3.5.2 ASSESSMENT OF MONSOON SOPS

During the 2023 monsoon operation, a continuous assessment of the monsoon SOPs was performed in coordination with O&M team. The monsoon SOPs were evaluated on the following measures:

1. Clarity and understanding
2. Comprehensiveness
3. Applicability
4. Adherence
5. Training and responsibility assignment

The assessment can be found in Table 3-8.

In summary, the evaluation of the 2023 monsoon operations revealed the following findings:

- The O&M team has acquired the knowledge and skills necessary to execute FEWS operations and maintenance effectively with the support from the project team. However, for few procedures the team requires more training to gain the understanding and confidence to operate with minimal support as outlined in the Sustainment Plan (Appendix D) under 'identified training and technical support needs'. These include training in:
  - Instrument maintenance
  - Flood warning and flood occurrence
  - Advanced troubleshooting
- Additional time availability of the team during the monsoons is deemed necessary for the successful operation of the FEWS by the team.
- The Standard Operating Procedures (SOPs) thoroughly document procedures, tasks, and troubleshooting methods, enabling the team to operate the system with minimal external support. However, gaps were observed by the team in application and documentation of Real-time station maintenance and weekly report on station performance SOP, Weekly report on quality of model input data SOP, and Flood warning and flood occurrence SOP.

Table 3-8 Assessment of monsoon SOPs

S. No.	Measure	Assessment
1.	Clarity and understanding	The SOPs were followed by the O&M team during the 2023 operation. The team was able to maintain the requisite daily system logs and perform troubleshooting during the real-time operation of FEWS highlighting the clarity of the procedures. However, a gap was seen in following, logging, and reporting the weekly and event-based tasks such as station maintenance, input data and flood warning and flood occurrence. This may be attributed to the lack of clarity of the respective SOPs.
2.	Comprehensiveness	During the real-time operation, feedback from the O&M team was taken on weekly basis to gather insights and ensure a thorough understanding of the tasks outlined in the SOPs. This iterative feedback loop aimed to enhance clarity and precision in the SOPs, facilitating better adherence to established protocols during the ongoing operational activities. Based on the feedback, the weekly (station maintenance and model input data) and event-based (flood warning and flood occurrence) procedures were further elaborated in the SOPs document (refer to section 4.4.1 and Appendix C).
3.	Applicability	Based on the feedback from the O&M team, the daily SOPs were determined to be pertinent and suitable for the current monsoon operation. The documented procedures are in alignment with the objectives for monsoon monitoring, ensuring that the system remains operational throughout the monsoon operations. However, a gap was observed in application of event-based and weekly SOPs. These activities of the SOPs were elaborated for checks, logs, frequency, and reporting (refer section 4.4.1 and Appendix C).
4.	Adherence	During the monsoon operation, the team was able adhere to the documented procedures for daily SOPs. However, there were observed gaps in consistency and efficiency in adhering to the documentation due to: • Availability of the team members • Time constraints • Lack of experience in and/or understanding of some procedures • Requirement of more detailed procedures
5.	Training and responsibility assignment	The 2023 monsoon operation indicated that the O&M team has increased level of confidence in following the SOPs. All the team members were able to perform their jobs as specified in the SOPs indicating successful training on the SOPs. There are a few procedures and advanced troubleshooting process for which the team requires training: • IT team – troubleshooting the advanced errors in scripts • Instrument team – reporting the sensor adjustments, maintenance, and flood survey. • Modelling team - model input data assessment and flood warning and occurrence events.

Source: Ramboll

4 POST-MONSOON UPDATES

Source: Adobe Stock

Based upon the assessment of the performance in the monsoon period, post-monsoon updates have been made to the different components that make up the system: data, model, real-time set-up, and SOPs. These updates are described in the following sections.

4.1 DATA UPDATES

4.1.1 REAL-TIME WATER LEVEL DATA UPDATES

Bailli WL data updates

As described in Section 3.2.1, two datum shifts were seen in the water level data for the Bailli bridge station. It has been found that the first datum shift is justified, and no correction has been applied. Between 2022 and 2023, an alternative pipe has been installed to bypass a part of the flow converging to the river just upstream of the location of the stations to further downstream.

It was found that the second jump in the datum was due to manual error. The sensor's position at this location was changed during routine maintenance and the corresponding changes in the backend calculations was not made accurately. This has been corrected post-monsoon based upon the new position of the sensor.

All other updates to WL data

For all the other stations, the issue with the datum shift was caused by manual error. Similar to the sensor at Bailli bridge, the sensors position at other station locations was changed during routine maintenance and the corresponding changes in the backend calculations was not made accurately. This too has been corrected post-monsoon based upon the new position of the sensors.

4.1.2 REAL-TIME RAINFALL DATA UPDATES

During investigation it was found that few large peak events were recorded as described 3.2.2. It was determined that these were caused due to cleaning and testing of instruments during the routine maintenance.

To rectify these erroneous peaks, the data recorded during the periods of maintenance of rainfall stations has been removed from the recorded data during post monsoon model updates.

Based on the data collected for the Irisan fire station, a comparison has been carried out against data form the old Irisan station data which indicated that although the 2 station are 600 m apart, they do not receive similar rainfall and the data of the new station could not simply replace the data in the model for the old Irisan rainfall data. As the old Irisan station in not operational anymore, it has been removed from the updated model in the post monsoon period and the model has been re-calibrated against inputs from the Irisan Fire station rainfall data.

4.1.3 WRF DATA UPDATES

To improve the rainfall forecast the process of converting the gridded rainfall to a single timeseries input for each of the sub-catchments has been updated.

49 grids of the WRF data are tested for the first three levels (i.e. up to 9th hour of forecast) to attain the best possible permutation of weightages against each grid in order to obtain the closest correlation with the observed rainfall data for each sub-catchment.

The process has been limited to 3 levels of the forecast rain data out of the total 16 levels as the process for the first 3 levels required over 1000 simulations and their assessments. This would imply that in the updated system, the performance will be improved up to 9 hours after the time of forecast and from the 10th hour and beyond, the forecasts will not show any improvements. To increase the accuracy of predictions with greater lead time, the corrections to the WRF data beyond level 3 should be carried out in the next pre- and post-monsoon periods.

4.2 MODEL UPDATES

Model 1 which is setup in 2023 for Balili river has been operated and run in 2023 monsoon in real time in the FEWS setup. Data for the new water level and rainfall stations has been collected for 2023. Using this addition data, the model has been recalibrated in the post monsoon phase.

During the post monsoon assessment of the model performance, it has been seen that the system generated false overtopping warnings based on forecasted water levels. As the model had been calibrated against station data and the WRF forecasted rain data is significantly larger than the observed rainfall data, it was a preliminary deduction that that the bias correction was unable to correct the WRF data to the extent required, thus causing the over predictions.

Upon deeper assessment, it was seen that the spikes in water level data triggering the false overtopping warnings almost always occurred immediately after the time of forecast and the spikes was not predicted for the same time in the prior simulations and that the system corrected itself in the next simulation. This redirected the deduction that the false warnings were being generated due to the bias correction process not working as intended to the conclusion that the DA process has been introducing the false initial condition of water level. This also indicated that have been instances of sudden jumps in the observed water levels (outliers) that were not filtered by the FEWS setup. The outliers get overwritten by the scripts for the download and processing of real time data and the data corrects itself for the next simulations. SOPs have been updated to check for such outliers during the real time operation and maintenance.

Although the WRF data is seen to be giving satisfactory forecasts with the help of bias correction process and DA, the forecasts can be further improved by applying correction to WRF data prior to the same.

During the recalibration of the model in the post monsoon period, data from the new stations as well as the corrected WRF data for level 2 to 4 have been used as input rain is separate scenarios such that the model parameters remain the same while giving the best possible correlations between the modelled and simulated water-levels in all cases.

The recalibrated model performs very well with the observed rain as input and also the corrected forecasted rainfall as input indicating that the forecasted water levels can be expected to be further improved for 3 levels of forecast (up to 9 hours after time of forecast). The performance of the recalibrated model is further described in the subsections below. In addition to R^2, index of agreement is also calculated. The index of agreement represents the ratio of the mean square error and the potential error. The agreement value of 1 indicates a perfect match, and 0 indicates no agreement at all. The index of agreement can detect additive and proportional differences in the observed and simulated means and variances. It should be noted that it is overly sensitive to extreme values due to the squared differences which makes it more suitable while focusing on floods.

To compare performance of the model calibrations, process of bias correction and DA are assessed separately.

4.2.1 FERGUSON STATION

The Ferguson Station is at chainage zero of the tributary defined in the Balili river model setup.

Figure 4-1 shows the calibration plot when the model is run with only observed rainfall data. Figure 4-2 and Figure 4-3 show how the correlation between the observed water level data and simulated water level data improves when corrected level 2 forecast rainfall is used in place of the uncorrected level 2 forecast rainfall.

Table 4-1 Ferguson station: comparison of correlation between water levels for various rainfall inputs

Rainfall input	[m]	[-]	[-]
	Root Mean Square Error	Coefficient of Determination (R^2)	Index of Agreement
Stations observed rain	0.09	0.73	0.92
Level 2 forecasted rain	0.15	0.33	0.58
Corrected level 2 forecasted rain	0.14	0.33	0.73
Level 3 forecasted rain	0.15	0.36	0.61
Corrected level 3 forecasted rain	0.14	0.39	0.77
Level 4 forecasted rain	0.15	0.28	0.62
Corrected level 4 forecasted rain	0.15	0.37	0.75

Source: Ramboll

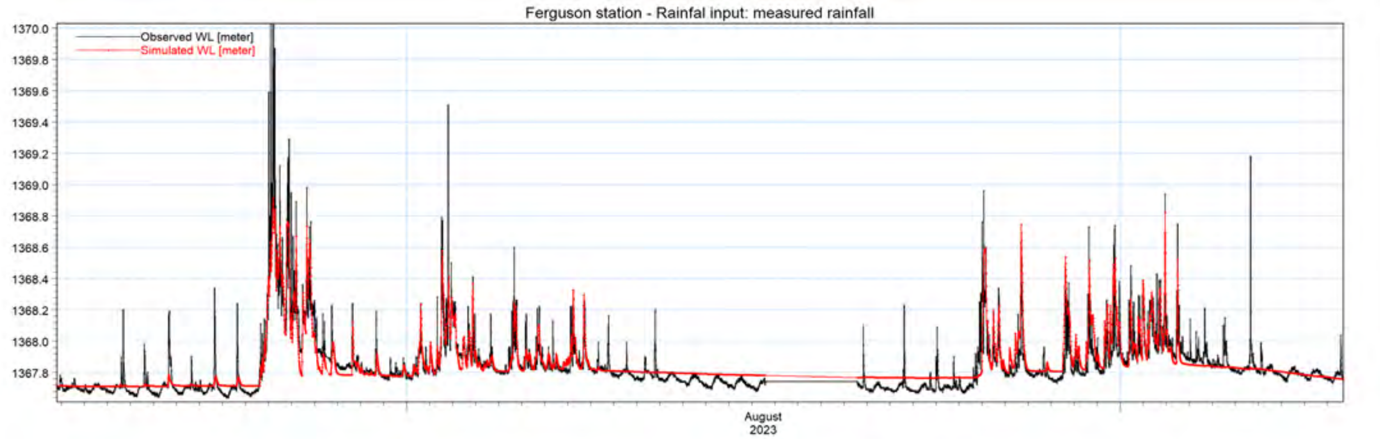


Figure 4-1 Ferguson station (observed vs. simulated water levels): measured rainfall as input
Source: Ramboll

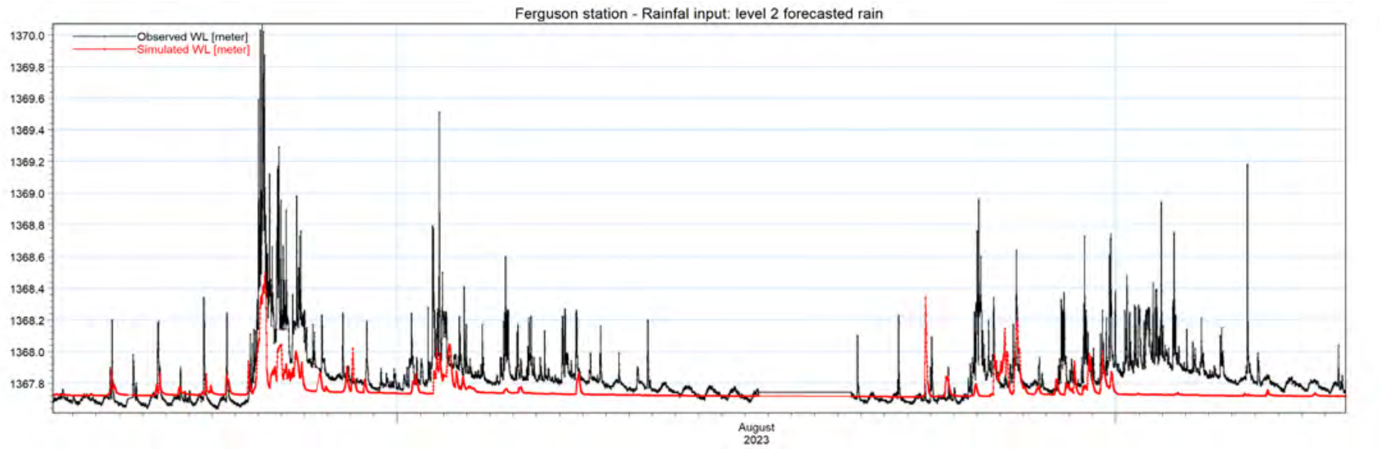


Figure 4-2 Ferguson station (observed vs. simulated water levels): level 2 forecasted rainfall as input
Source: Ramboll

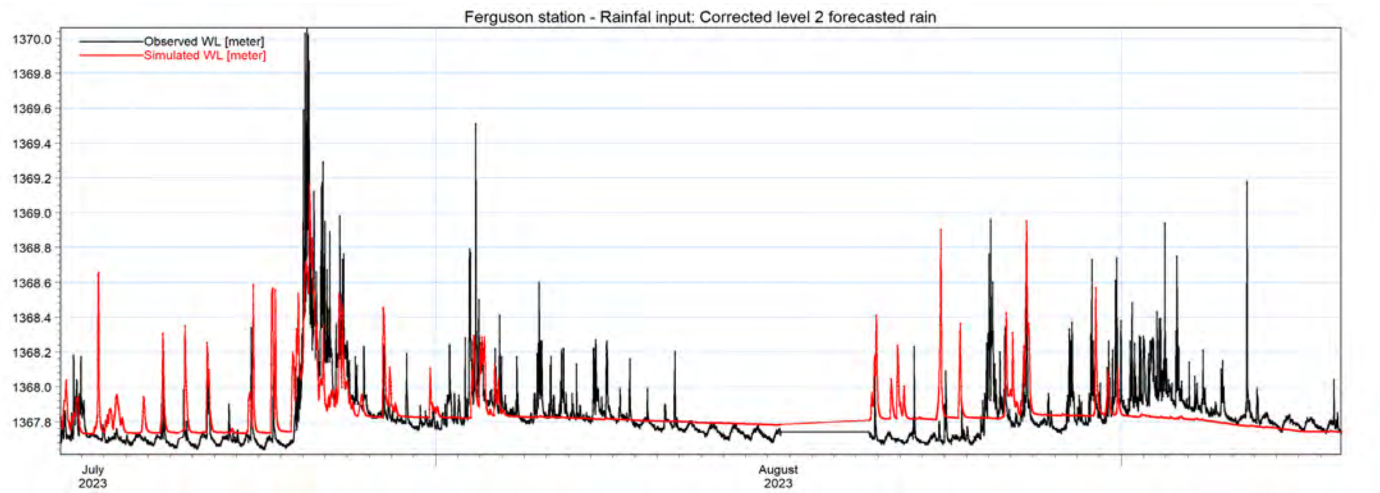


Figure 4-3 Ferguson station (observed vs. simulated water levels): level 2 corrected forecasted rainfall as input
Source: Ramboll

4.2.2 BROOKSPOINT STATION

The Brookspoint station is at chainage zero of the main Balili river in the model setup.

The Figure 4-4 is the calibration plot when the model is run with only observed rainfall data.
Figure 4-5 and Figure 4-6 show how the correlation between the observed water level data and simulated water level data improves when corrected level 2 forecast rainfall is used in place of the uncorrected level 2 forecast rainfall.

Table 4-2 Brookspoint station: comparison of correlation between water levels for various rainfall inputs

Rainfall input	[m]	[-]	[-]
	Root Mean Square Error	Coefficient of Determination (R^2)	Index of Agreement
Stations observed rain	0.08	0.76	0.93
Level 2 forecasted rain	0.17	0.23	0.67
Corrected level 2 forecasted rain	0.14	0.40	0.77
Level 3 forecasted rain	0.14	0.43	0.80
Corrected level 3 forecasted rain	0.12	0.53	0.84
Level 4 forecasted rain	0.18	0.34	0.73
Corrected level 4 forecasted rain	0.14	0.43	0.79

Source: Ramboll

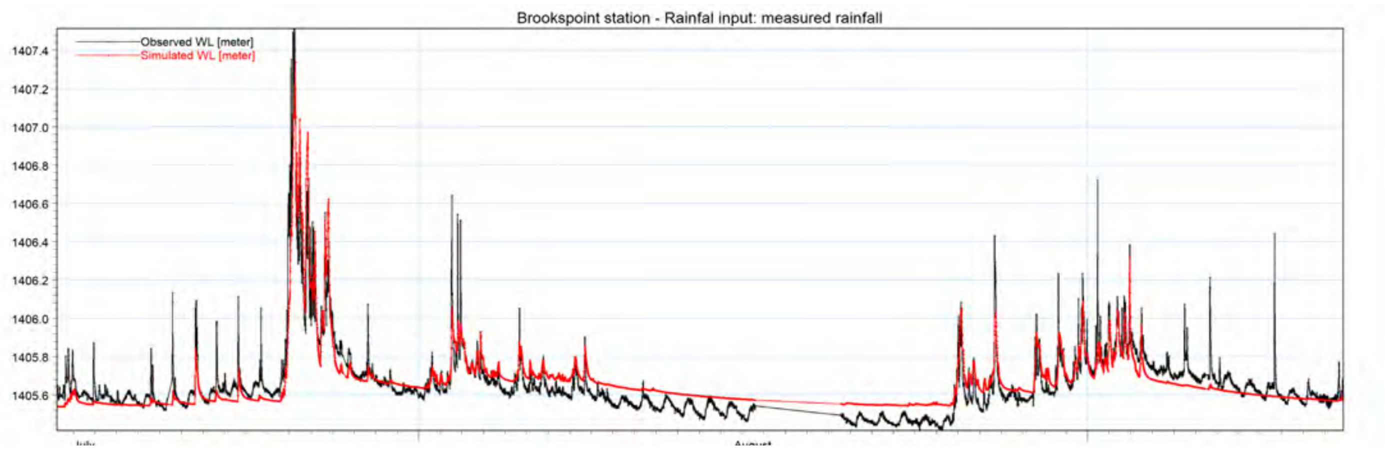


Figure 4-4 Brookspoint station (observed vs. simulated water levels): measured rainfall as input
Source: Ramboll

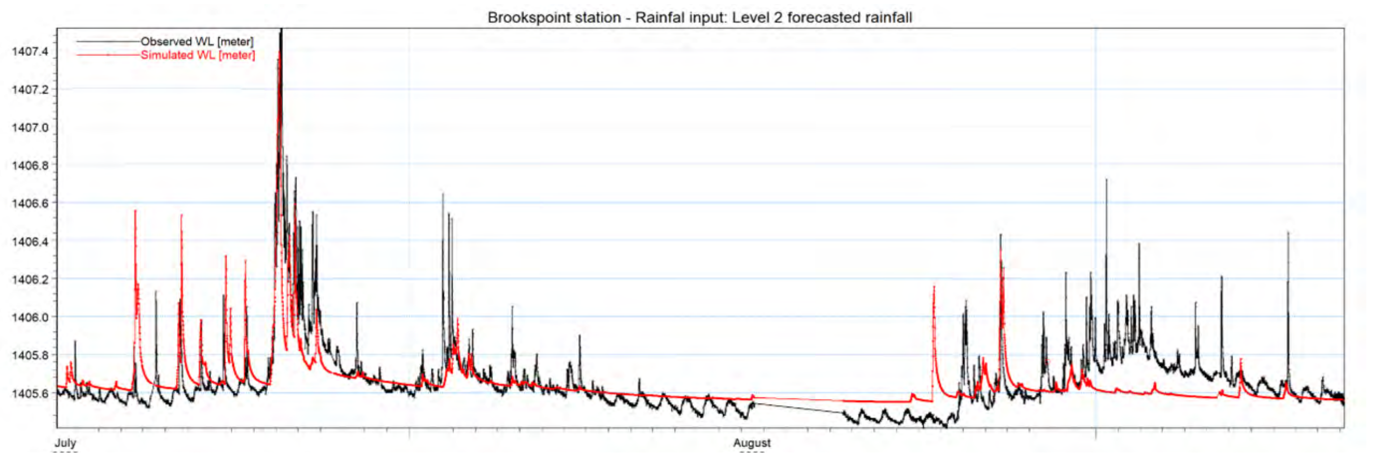


Figure 4-5 Brookspoint station (observed vs. simulated water levels): level 2 forecasted rainfall as input
Source: Ramboll

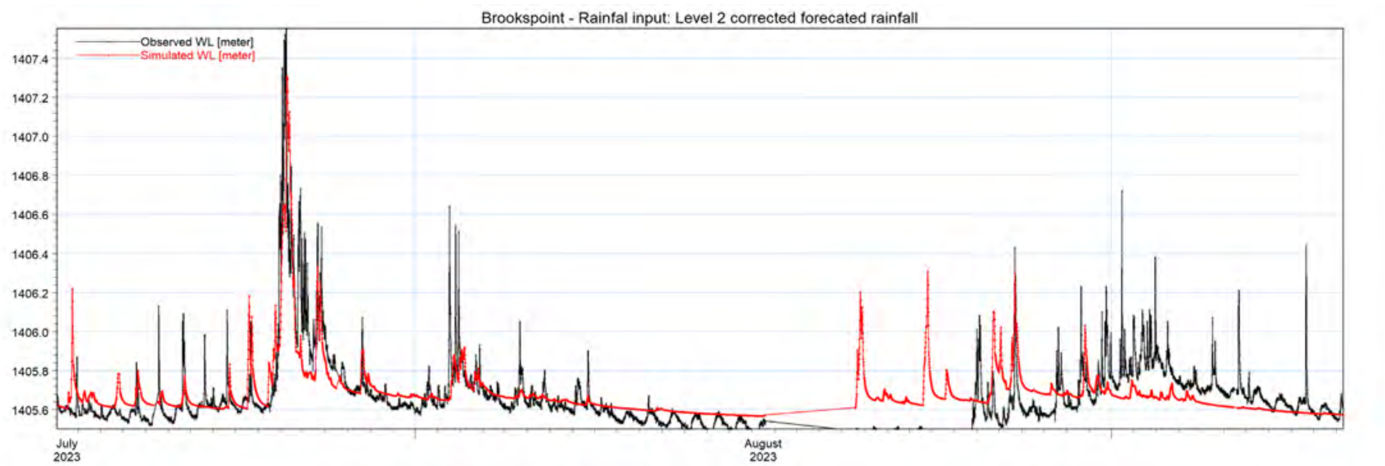


Figure 4-6 Brookspoint station (observed vs. simulated water levels): level 2 corrected forecasted rainfall as input
Source: Ramboll

4.2.3 SADJAP STATION

Sadjap station is located a little downstream of the confluence point of the main Balili river.

The Figure 4-7 is the calibration plot when the model is run with only observed rainfall data.
Figure 4-8 and Figure 4-9 show how the correlation between the observed water level data and simulated water level data improves when corrected level 2 forecast rainfall is used in place of the uncorrected level 2 forecast rainfall.

Table 4-3 Sadjap station: comparison of correlation between water levels for various rainfall inputs

Rainfall input	[m]	[-]	[-]
	Root Mean Square Error	Coefficient of Determination (R^2)	Index of Agreement
Stations observed rain	0.15	0.83	0.93
Level 2 forecasted rain	0.28	0.23	0.66
Corrected level 2 forecasted rain	0.24	0.45	0.80
Level 3 forecasted rain	0.22	0.50	0.82
Corrected level 3 forecasted rain	0.20	0.58	0.86
Level 4 forecasted rain	0.25	0.43	0.79
Corrected level 4 forecasted rain	0.22	0.55	0.85

Source: Ramboll

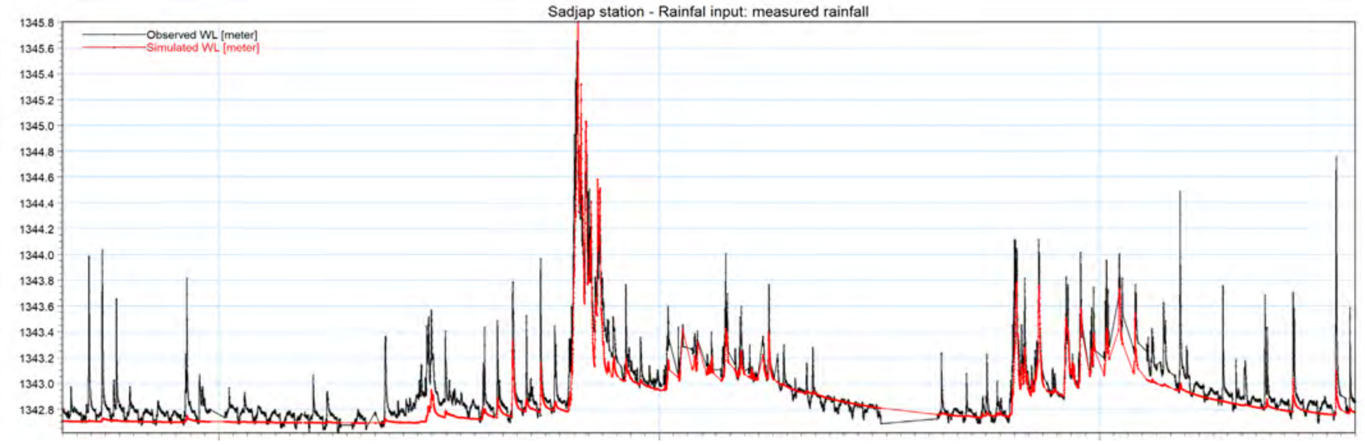


Figure 4-7 Sadjap station (observed vs. simulated water levels): measured rainfall as input
Source: Ramboll

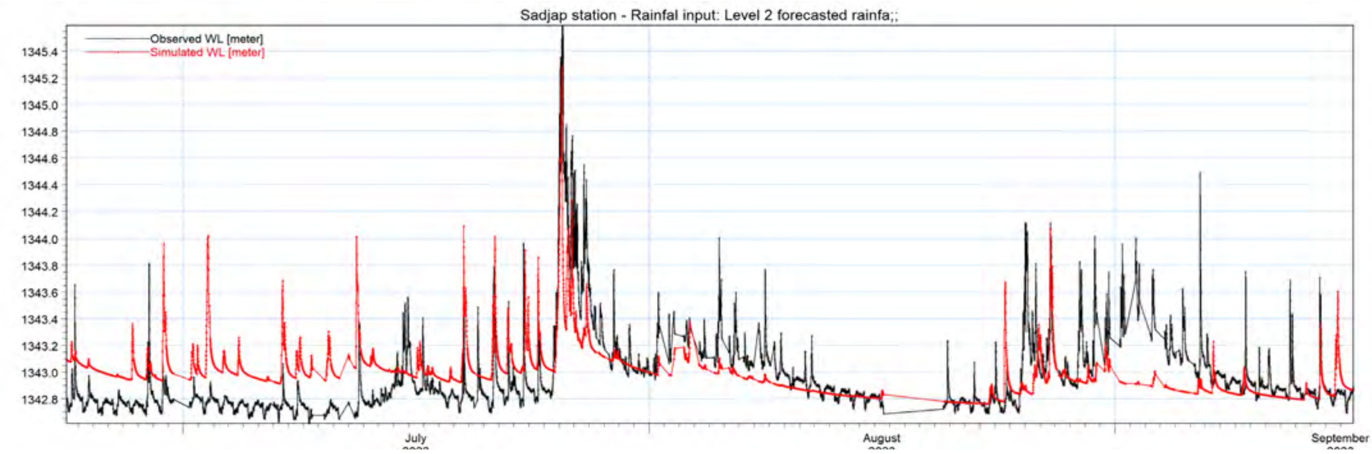


Figure 4-8 Sadjap station (observed vs. simulated water levels): level 2 forecasted rainfall as input
Source: Ramboll

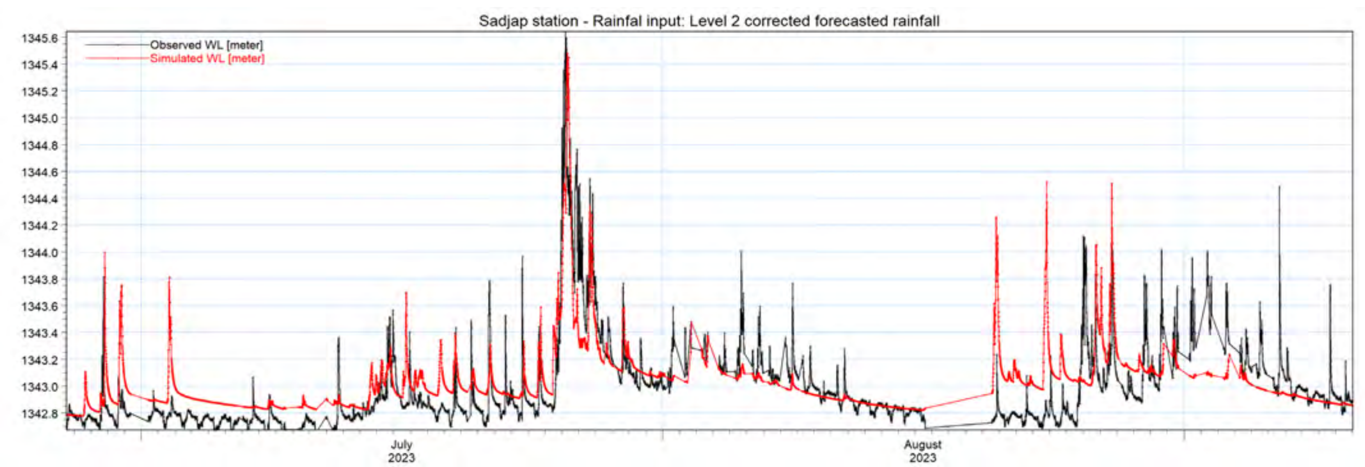


Figure 4-9 Sadjap station (observed vs. simulated water levels): level 2 corrected forecasted rainfall as input
Source: Ramboll

4.2.4 BALILI BRIDGE STATION

Balili Bridge Station is located in La Trinidad, a little after of the main Balili river exits Baguio City.

The Figure 4-10 is the calibration plot when the model is run with only observed rainfall data.
Figure 4-11 and Figure 4-12 show how the correlation between the observed water level data and simulated water level data improves when corrected level 2 forecast rainfall is used in place of the uncorrected level 2 forecast rainfall.

Table 4-4 Balili Bridge station: comparison of correlation between water levels for various rainfall inputs

Rainfall input	[m]	[-]	[-]
	Root Mean Square Error	Coefficient of Determination (R^2)	Index of Agreement
Stations observed rain	0.17	0.81	0.95
Level 2 forecasted rain	0.34	0.22	0.66
Corrected level 2 forecasted rain	0.28	0.46	0.81
Level 3 forecasted rain	0.28	0.50	0.83
Corrected level 3 forecasted rain	0.28	0.55	0.85
Level 4 forecasted rain	0.34	0.42	0.77
Corrected level 4 forecasted rain	0.30	0.48	0.82

Source: Ramboll

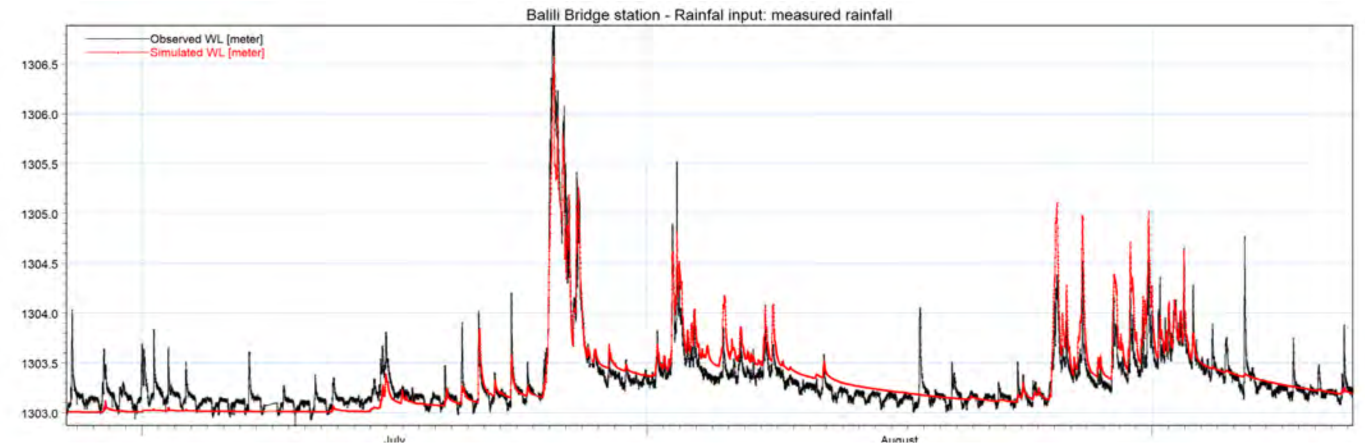


Figure 4-10 Balili Bridge station (observed vs. simulated water levels): measured rainfall as input
Source: Ramboll

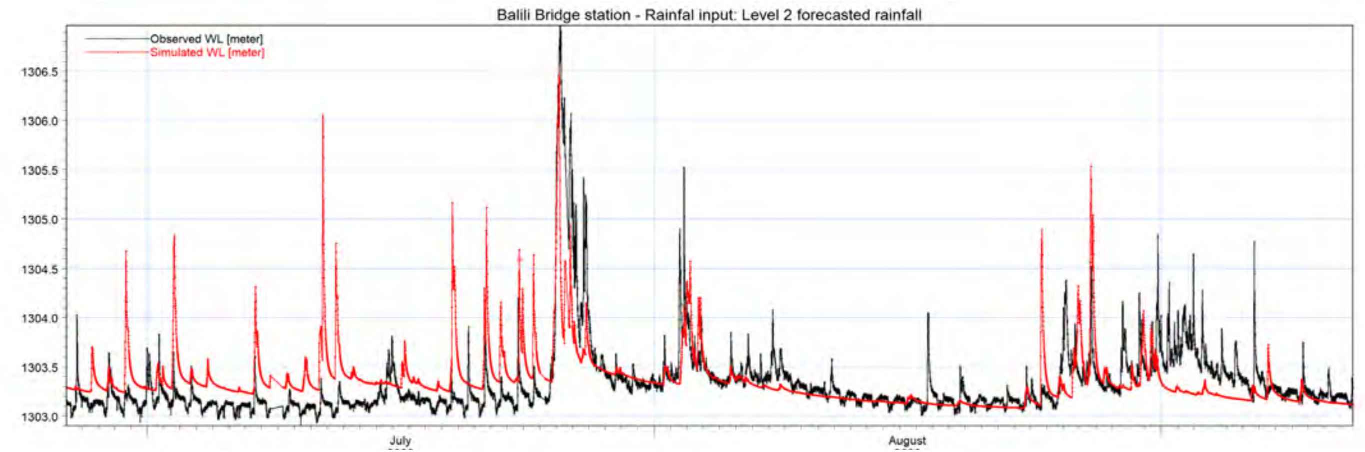


Figure 4-11 Balili Bridge station (observed vs. simulated water levels): level 2 forecasted rainfall as input
Source: Ramboll

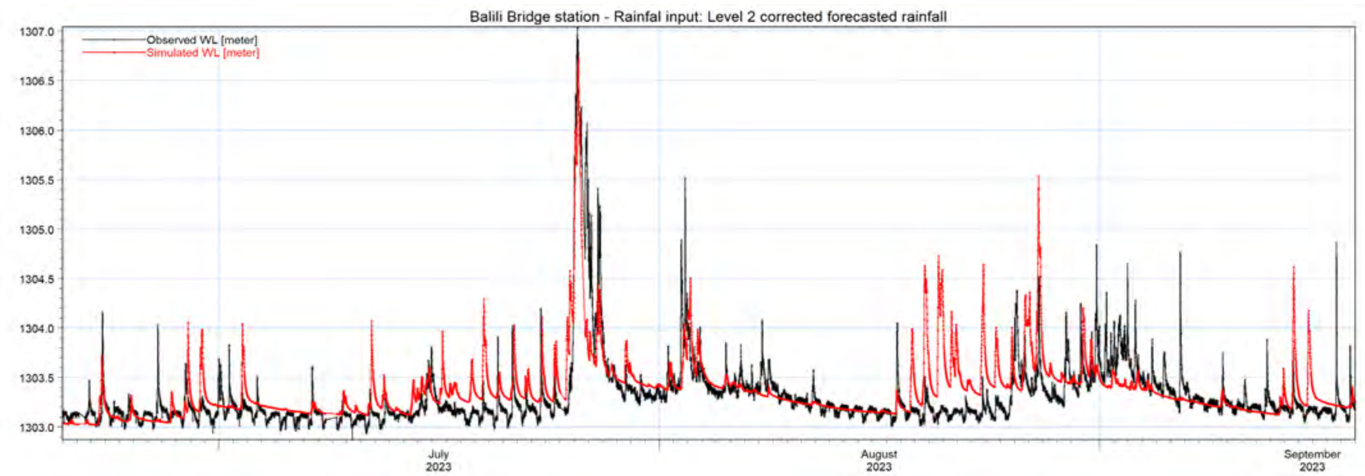


Figure 4-12 Balili Bridge station (observed vs. simulated water levels): level 2 corrected forecasted rainfall as input
Source: Ramboll

4.2.5 EXPECTED IMPACT DUE TO DA AND BIAS CORRECTION IN REAL TIME OPERATION.

The DA and bias correction will improve the correlations during real-time operation as can be seen for level two of forecast of the 2023 monsoon in Figure 4-13 and Table 4-5.

It can also be seen in Figure 4-13 how the incorrect datum jumps and erroneous data of observed rainfall and water level data can negatively impact the results from the system as these will be taken by the model as true values. SOPs have been updated to identify and correct such issues in real time instead of while carrying out the post monsoon assessments. It can be seen that once the data is corrected, the threshold (1314.83 m) is not exceeded at Balili station (refer to Section 3.3.2).

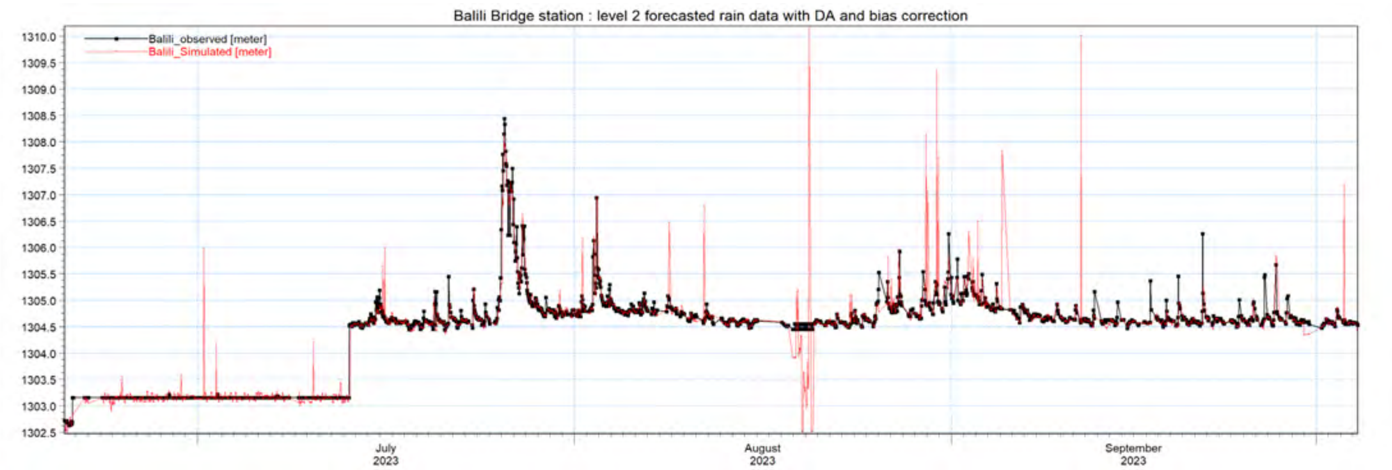


Figure 4-13 Balili bridge station (observed vs. simulated water levels): level 2 forecasted rainfall as input with DA and bias correction
Source: Ramboll

Table 4-5 Impact of DA and bias correction on correlation between water levels for monsoon 2023 (Balili Bridge Station)

Level of Forecast	Time of forecast	With DA and bias correction		Without DA and bias correction	
		RMSE	R^2	RMSE	R^2
First	0-2 hours	0.36	0.86	0.34	0.23
Second	3-5 hours	0.64	0.67	0.28	0.50
Third	6-8 hours	0.69	0.62	0.34	0.42
Fourth	9-11 hours	0.65	0.63	0.30	0.48

Source: Ramboll

The remaining correlation plots are included in Appendix B.

4.3 UPDATES TO REAL-TIME SETUP IN FEWS

After the assessment of the system during monsoon, the below mentioned updates have been done in the system to mitigate issues faced during monsoon 2023. Apart from the fixing the issues faced during monsoon, the system has also been updated based on the LGUs requirements while maintaining the system during monsoon 2023.

Implementation of physical dongle

To address the internet license problem, a physical dongle has been utilized to operate the MIKE software with a stable license. The dongle acquired from DHI was intended for installation at the FEWS server at the MITD at the City Hall. However, since the server lacks a USB port for the dongle, an alternative has been proposed; connecting the dongle to the network and using the license service from there. The technical team then set up a dedicated machine and linked it to the server. Currently, the MIKE software is operating seamlessly on the server, utilizing the network license as shown in Figure 4-14, and there have not been any issues since the switch to the network license.

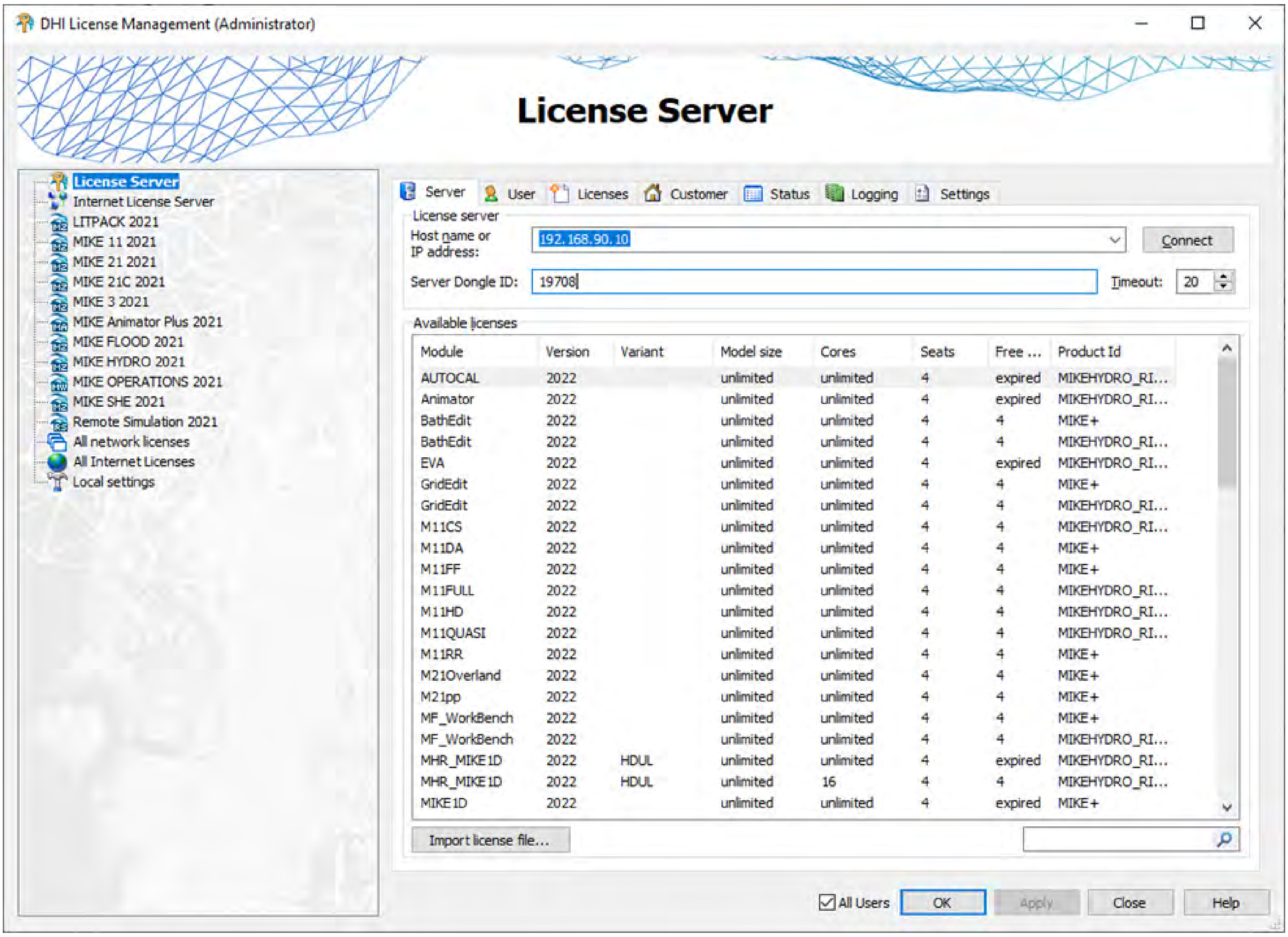


Figure 4-14 DHI License Administrator for Application Server

Source: Ramboll

Setup email and message notifications

Email and message alerts from the system have been updated and additional alerts have been set up. Throughout the 2023 monsoon, the system had been sending all the alerts to all the team members for testing. Post-monsoon these alerts have been segregated and specific alerts are sent to specific team. The FEWS O&M sub-teams receive separate alerts suited for their responsibilities.

Table 4-6 Overview of email and message alerts

Alert	Description	Team
Daily Status: Jobs and Model Simulation	This is a routine email that includes the status updates for the most recent three job instances and the last four instances of model simulations.	IT Team - The FEWS system server can only be accessed by the IT team.
Rainfall Station Log	Enclosed in this email are the working hours for the station in the past 24 hours, along with the accumulated rainfall data over the same period.	Instrument Team and IT Team – The Instrument Team is responsible for managing sensors, while the IT Team oversees the storage of data in the database.
Water Level Station Log	Enclosed in this email are the working hours for the station in the past 24 hours.	Instrument Team and IT Team – The Instrument Team is responsible for managing sensors, while the IT Team oversees the storage of data in the database.
Model Performance Log	Attached to this email is a zip file containing Excel documents that include station-specific sheets for comparing simulated forecast data with observed data from simulations conducted two days ago. The provided data encompasses all simulations conducted on the specified day.	Modelling Team – The Modelling Team is dedicated to evaluating and assessing the performance of the model.
WRF Forecast Upload Failure	If PAGASA fails to timely upload WRF data, it results in disruptions to system operations. In the event of upload failure, FEWS promptly sends an email notification to report the lack of accurate forecast data received at the expected time.	IT Team, Modelling Team and PAGASA – The IT and Modelling teams must be informed that system functionality relies on timely WRF data uploads by PAGASA. If data upload fails, PAGASA should promptly address and rectify the issue to prevent disruptions in system operations.

Source: Ramboll

Setup result analysis for modelling team

During the monsoon season, the modelling team is tasked with daily result analysis for simulations conducted by the system. The system receives real-time data for comparison at water level stations. For instance, if analysis is planned for August 15, 20XX, simulations with end dates of August 14, 20XX are selected since real-time data is available on August 15, 20XX.

Due to limited access to MIKE Workbench for the modelling team, they traditionally depended on data delivered to their inbox. Post-receiving the data, the team faced the challenge of aligning simulated and station data in the same time step for effective comparison. This process consumed significant time during the monsoon season.

To address this, a script has been developed to automate the arrangement of simulated and station data into a desired format for all stations, creating an Excel spreadsheet. This spreadsheet includes the simulated, observed and their difference for all the simulations for each station, in a structured manner, as illustrated in Figure 4-15.

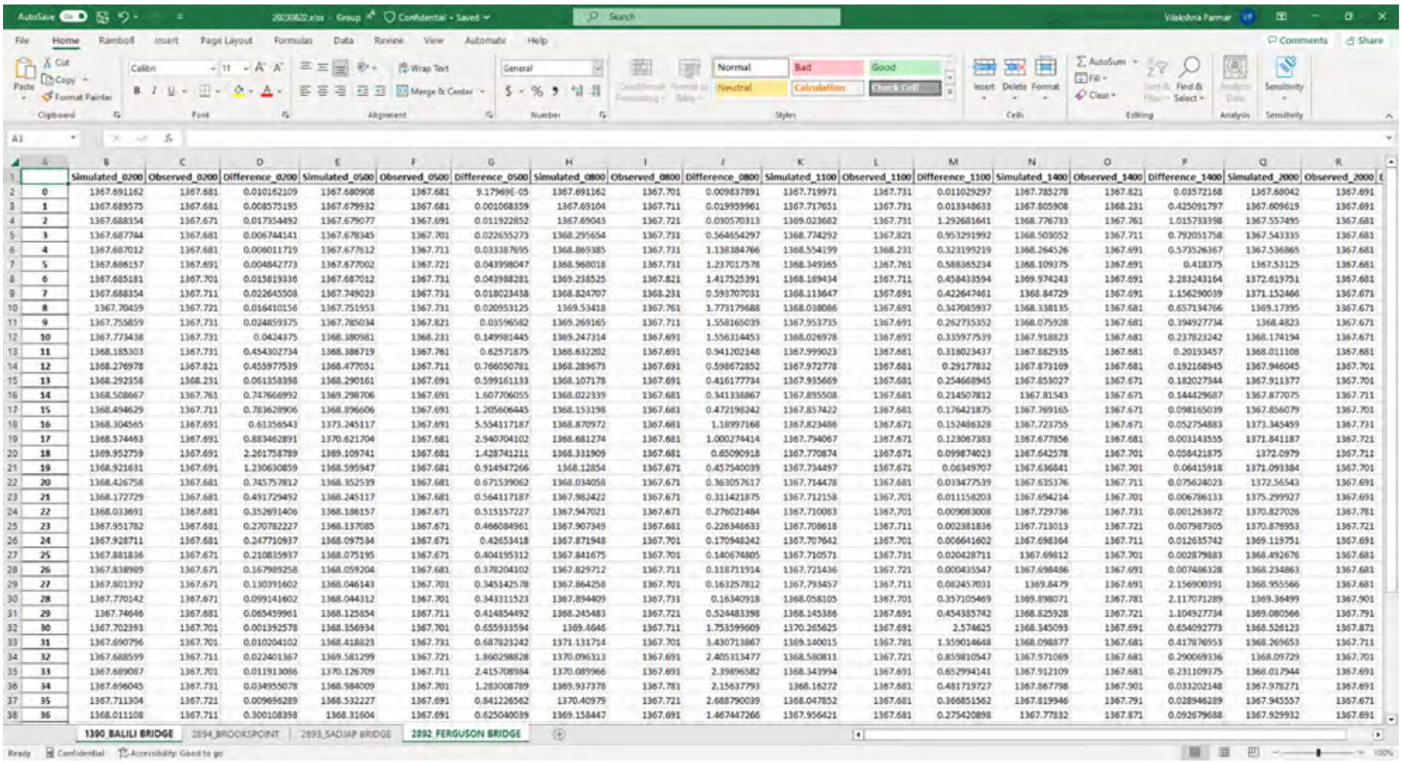


Figure 4-15 Spreadsheet for result analysis generated by FEWS

Source: Ramboll

Updated MIKE OPERATIONS for flood warning alert

In addition to various messages and notifications, flood warning alerts for team members were updated. To configure these alerts, the names of vulnerable reaches on the left and right banks were revised in close collaboration with the O&M team to ensure the location names made sense in a local context. This provides clarity to team members about the specific city areas under flood warning. Furthermore, the threshold values for flood warnings at station locations not included in the 2022 FEWS version (i.e. newly constructed stations) were added.

In the event of a flood, MIKE OPERATIONS autonomously generates emails corresponding to selected warning levels, disseminating them to all members listed in the contact roster, as depicted in Figure 4 16. This ensures timely communication and response to potential flood situations.

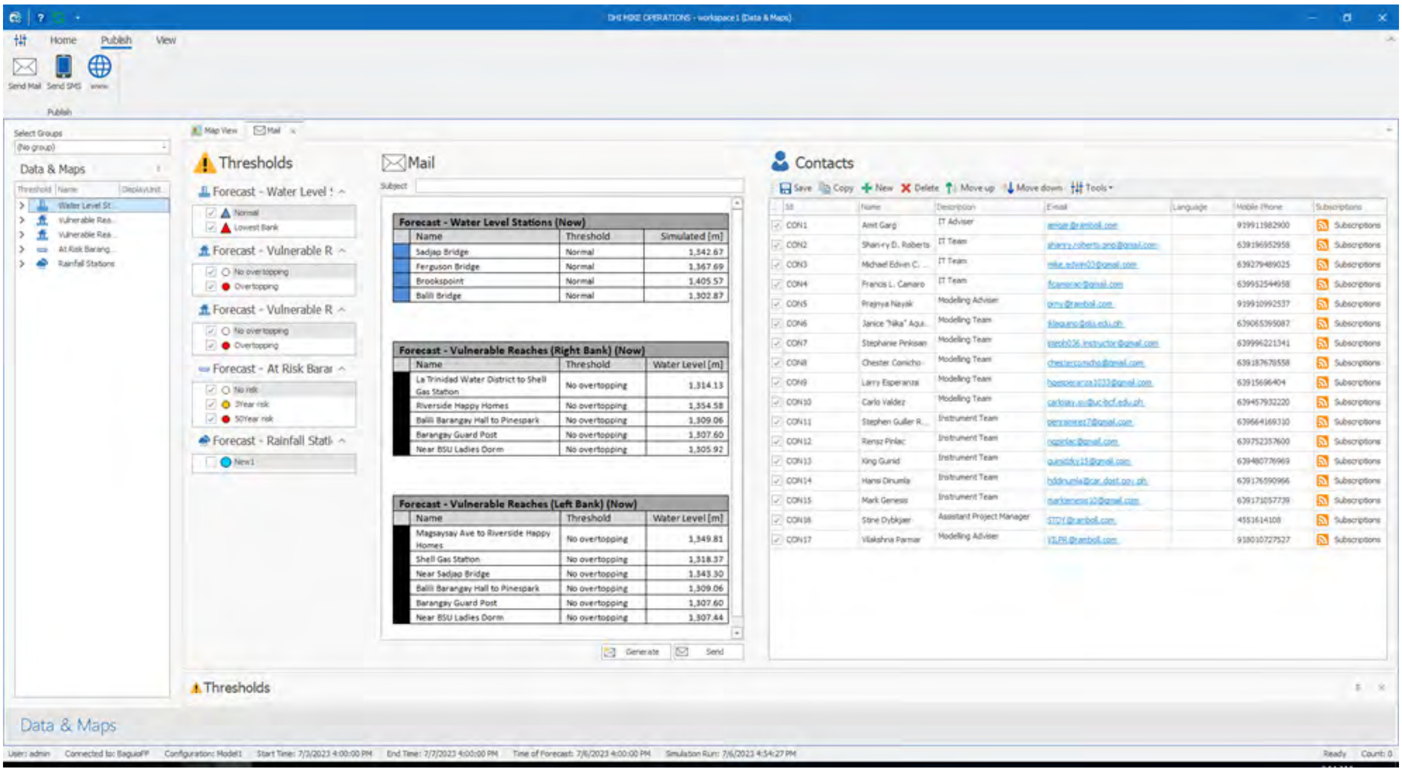


Figure 4-16 MIKE OPERATION interface for sending flood warning alerts
Source: Ramboll

Updated FEWS dashboard

Small updates have been done in FEWS dashboard. Station thresholds added in the chart for all the stations with horizontal dotted red line and reduced the size of the City of Baguio logo as suggested by the FEWS O&M team.

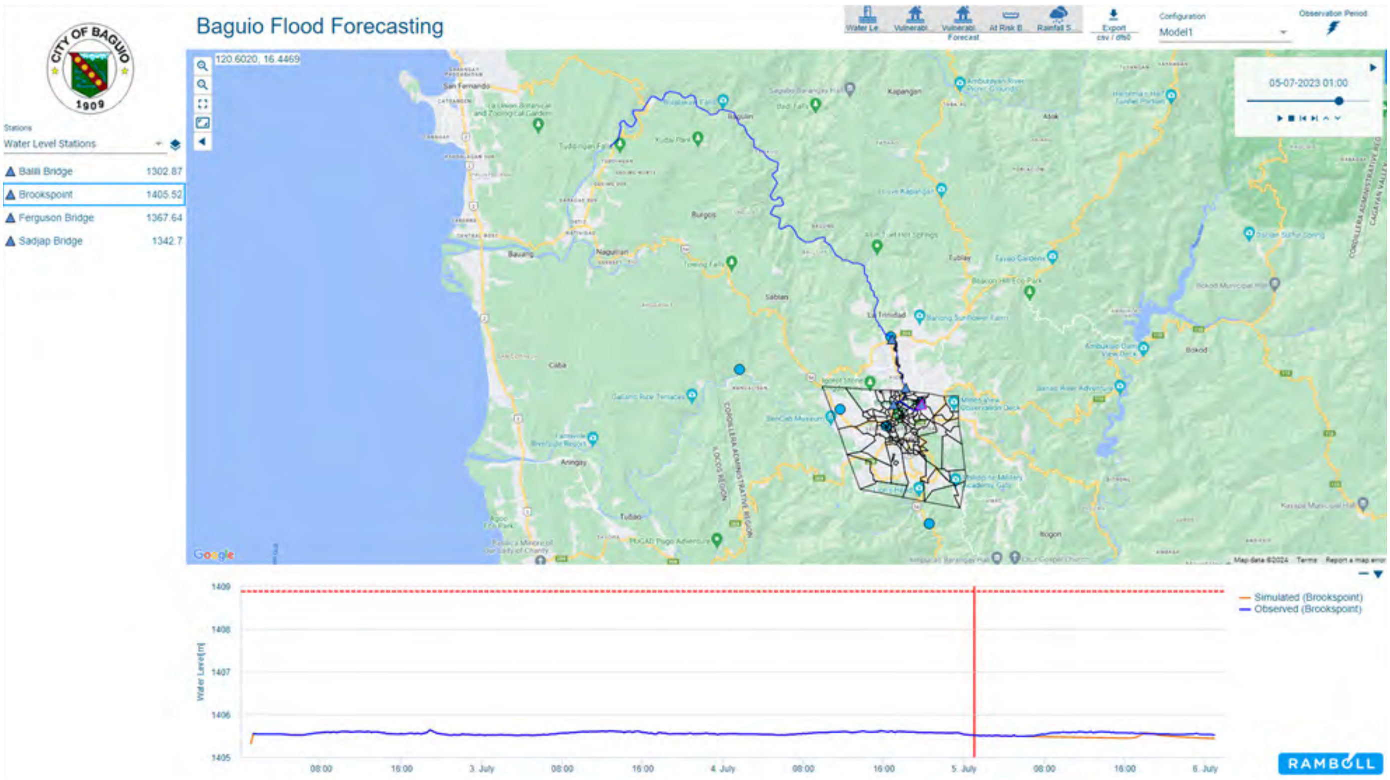


Figure 4-17 FEWS dashboard

Source: Ramboll

Updated logic for real-time correction of WRF data

Research on code for solvers has been carried out to apply the WRF correction described in 4.1.3 in real time. The code still needs to be implemented, tested and finetuned in the upcoming monsoon.

4.4 UPDATE OF OPERATION AND MAINTENANCE FRAMEWORK

During the 2023 monsoon operation and maintenance, following observations were made:

- The O&M team requires further training on some of the SOPs (see Appendix D) to carry out system operation with minimal support.
- Availability of the team is needed to routinely carry out the tasks during the monsoons for the successful operation of the FEWS.
- The SOPs needs to be more elaborative to enable the team to operate the system with minimal external support.

Based on the lessons learnt, the following updates were made for more effective operation and maintenance:

1. Daily alerts for the team have been setup as illustrated in Section 4.3 to support the team in reviewing the system performance in a more efficient manner.
2. Automated results analysis has been setup for the modelling team. This will allow more time to the team to review the model performance and input data. This has been elaborated in Section 4.3.
3. Updates in the SOPs were made to allow team to follow the procedures and allow more coordination between the teams and other stakeholder. These updates are presented in detail below.

4.4.1 UPDATES TO SOPS

SOPs function as a comprehensive guide for the team during various operation and maintenance phases. These establish a uniform method for conducting operations, promoting consistency and efficiency by delineating precise activities and tasks assigned to the team. Hence, drawing from the insights gained during the real-time operations of 2023, detailed modifications were implemented on the following SOPs.

- Daily report on model performance SOP
- Real-time station maintenance and weekly report on station performance SOP
- Weekly report on quality of model input data SOP
- Flood warning and flood occurrence SOP.

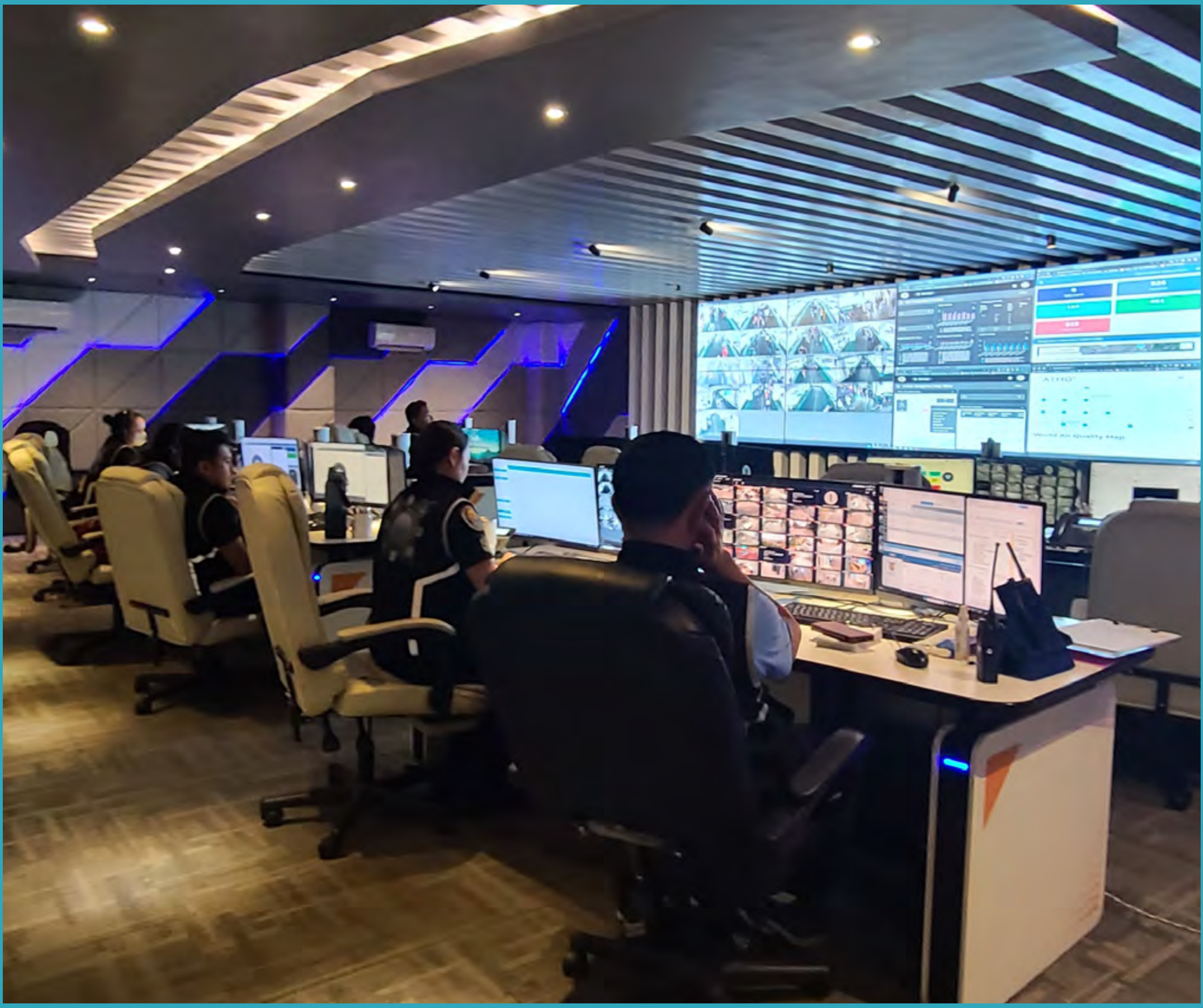
The revisions to the SOPs are outlined in Table 4-7.

Table 4-7 Revisions of SOPs

Alert	Description	Team
Daily report on model performance	• Limited access to the server for modelling team • Reviewing of model performance after preparing results.	A step-by-step instruction after reviewing the model daily report, this includes: • Reviewing the model performance • Identifying any outlier in model input or output • Reviewing the dashboard and identifying any inconsistency.
Real-time station maintenance and weekly report on station performance SOP	• Logging of the station maintenance was not detailed. • Adjustments made to the sensors or stations were not reported to the O&M team	The SOPs for each type of maintenance is added, which includes: • Procedures for maintenance • Frequency of maintenance • Revised logs • Reporting
Weekly report on quality of model input data	• Confidence of the team in conducting data checks	• Delineation of precise activities to be performed. • Links to the reference material of the training for the ready support.
Flood warning and flood occurrence SOP	• Limited access to the server for modelling team • Understanding of flood occurrence and flood warning • Conducting of survey • Time availability of the team	The steps to follow during a warning and occurrence event have been elaborated, this includes: • Routine checks • Data logging • Documentation procedure • Survey procedure and documentation • Review of model performance The template for flood warning and occurrence log is also updated.

Source: Ramboll

5 SYSTEM SUSTAINMENT



Source: Ramboll

Significant strides were made in implementing and operationalizing the FEWS since the inception of the project. Several steps for enhancement of long-term sustainability have already been taken, including the establishment of the FEWS O&M team, implementation of targeted capacity building and training programs, preparation of standard operating procedures (SOPs), establishment of Memorandums of Agreement (MOAs) with partner organizations, and development of an implementation plan which outlines actions and responsibilities for a Gender Transformative FEWS in Baguio.

The sustainment plan (Appendix D) describes strategies to maintain the operational capabilities of the Baguio FEWS and to continue to develop the system and the technical capacity of the FEWS O&M team, building upon the successes and the lessons learned throughout the project. The sustainment plan addresses the ongoing needs for capacity building, governance, system enhancements and adaptation, and resource allocation. The goal is to ensure that the FEWS remains a viable and reliable system and that it continues to add value to the citizens of Baguio as an active risk mitigation instrument. In essence, this sustainment plan sets the stage for continuous improvement and long-term viability of the FEWS.

Building on these efforts, actions to further enhance the foundation for effective operation and maintenance were identified at the end of the pilot project, and support to the LGU towards achieving these actions has been prioritized in the Consolidation Phase in 2023. The sustainment plan combines the activities already in progress with recommendations for next steps from 2024 onwards.

5.1 SUSTAINMENT WORKSHOP

Co-developing the sustainment plan together with the O&M team was crucial to ensure that the team members take ownership of future sustainment activities, play an active role in planning them, and are well informed of all recommendations post-2023. Consequently, a workshop on system sustainment was held on October 25, 2023, with all members of the O&M team participating. The primary aim of the workshop was to agree on components that should be included in the sustainment plan, and collect inputs for the plan, and bring the team's attention to recommended activities, further strengthening the sense of local ownership of the FEWS.

Figure 5-1 The FEWS O&M team during the sustainment workshop
Source: Ramboll

The workshop consisted of four group exercises:

- Sustainment plan components and risks exercise, where participants were asked to come up with topics that should be covered in the sustainment plan under of the four main areas of sustainment (human resources, institutional, technical, and financial). Additionally, they were asked to identify potential risks or challenges and propose actions to mitigate them.
- Planning the FEWS year exercise, in which participants were divided into the three teams (IT, modelling, instrument). They were asked to plan out cyclical annual activities by month, which included both the teams' assigned activities according to the SOPs, but also external activities that can influence their timing, such as closing of the annual budget.
- SOP confidence exercise, which aimed to evaluate the teams' overall confidence levels associated with carrying out SOPs. Participants were asked to grade how confident they are as a team in implementing each SOP and provide a detailed description of activities they would require more support with.
- Budget preparation, aimed to create an estimated budget for O&M, including compensation, hardware and software costs, training costs and other.

The outcomes of the workshop highlight that the team demonstrates very good knowledge of the system and the efforts required to sustain it. The team was highly engaged during the workshop and were actively involved in shaping the contents of the sustainment plan.

5.2 SUSTAINMENT PLAN

The sustainment plan is structured around four key areas of sustainment (human resources, institutional, technical, and financial, as seen in Figure 5-2) to form a comprehensive roadmap of activities that ensure the LGU and FEWS O&M team can effectively operate, adapt, and evolve the FEWS in the long term.

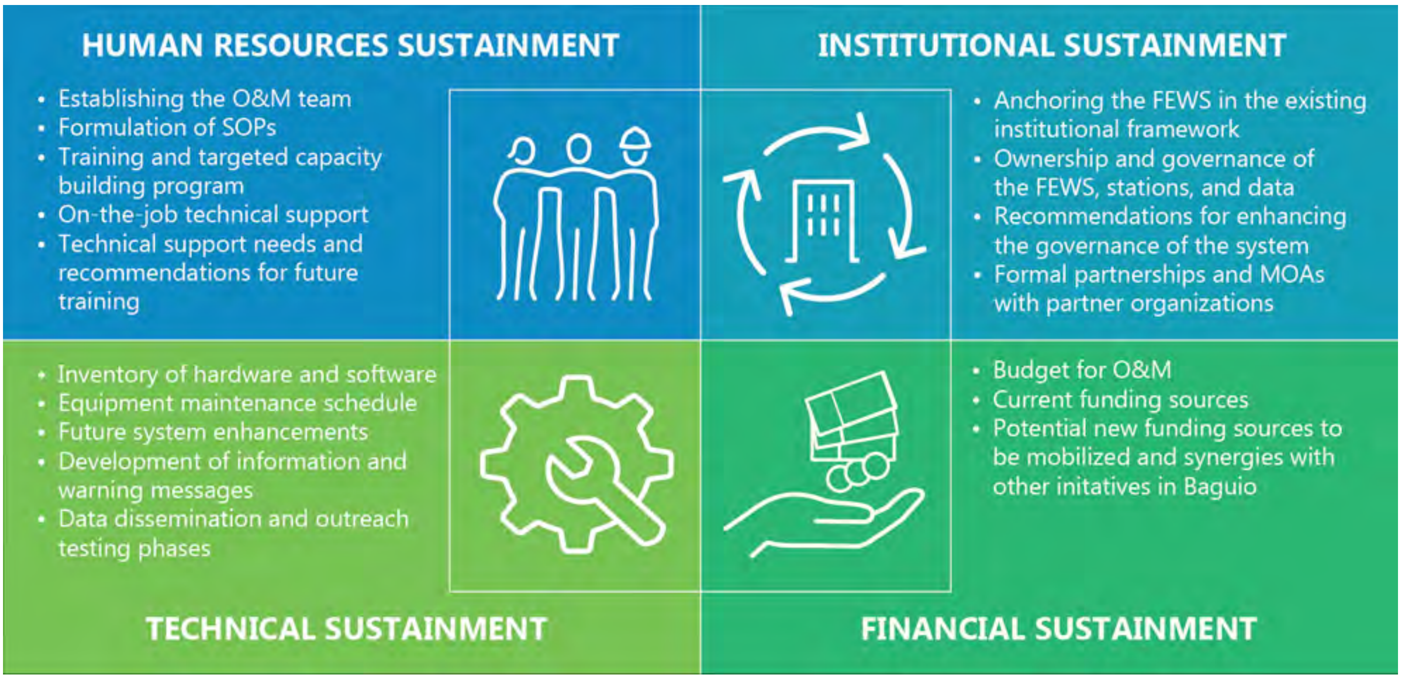


Figure 5-2 Overview of the four areas of the sustainment plan
Source: Ramboll

5.2.1 HUMAN RESOURCES SUSTAINMENT

The successful long-term operations and maintenance of the FEWS relies primarily on available and well-trained personnel. A significant effort in training, teambuilding, and guiding the designated local resources for the FEWS project was made, but there is a need for continuously developing the team's knowledge and skills, to ensure seamless functionality and continual system enhancements in the long run as the LGU is still dependent on expert advice.

The first part of the sustainment plan outlines the structure of the established O&M team, the roles, responsibilities, and estimated workloads for each team member. To ensure long-term operations of the FEWS, the LGU should continuously ensure that the O&M team members are available and have the mandate to prioritize and perform the required tasks. The CDRRMO is currently undergoing organizational changes as part of their formalization as a department within the LGU, with the possibility of assigning additional permanent staff to FEWS in the future being discussed. It is envisioned that the FEWS O&M will collaborate closely with the Operations and Warning Division, and that the team could potentially be anchored in this division.

To ensure effective operations of the FEWS, Standard Operating Procedures (SOPs) were formulated, designed to ensure that all procedures are performed consistently and efficiently across all team members and over time. The sustainment plan outlines the SOPs for each of the sub-teams of the O&M team (modelling team, instrument team and IT team). It also delves into the results from the SOP exercise conducted during the sustainment workshop, which showed the teams' confidence levels in carrying out their responsibilities. The SOPs should be reviewed and updated annually to reflect the changing conditions and enhancements to the system.

Recognizing the paramount importance of continued training in long-term sustainability of the system, the targeted capacity building program was implemented during the pilot project and continued throughout the consolidation phase to strengthen the team's ability to independently operate and maintain the FEWS. Despite significant progress and increased confidence among team members, they are not yet at a technical level for independent operation and have expressed concerns for operation without further external support and training. The sustainment plan outlines recommendations for the organisation of future training and highlights the importance of establishing partnerships with organizations outside of the LGU (such as Saint Luis University and University of the Cordilleras) for knowledge exchange, on-the-job expert support and the onboarding of additional trainees to assure team continuity. All materials used in the targeted capacity building program are stored, available for the team to access and download, and it is recommended that this practice is followed for all future trainings organised to build a continually updated and expanded training material repository.

5.2.2 INSTITUTIONAL SUSTAINMENT

The second part of the plan addresses anchoring of the FEWS within the existing institutional setup in Baguio, which is essential to ensure that the O&M team has the mandate to carry out and prioritize their tasks, and that roles and responsibilities between LGU departments and partner organizations are clear.

Ownership of the system, understood as the decision-making authority and responsibility for the system's operations, maintenance, and performance, is placed in the LGU, with responsibilities shared between the City Disaster Risk Reduction and Management Office (CDRRMO), Management Information Technology Division (MITD), and Baguio Smart City Command Center (SCCC). The sustainment plan outlines actions taken to legitimize that ownership and relationships between them through a Mayor's Executive Order signed in October 2023, and recommendations for next steps that would bring further clarity to the sharing of responsibilities.

To further support Baguio LGU's capacity to reliably maintain the system, the ownership of monitoring stations was formally transferred from PAGASA to Baguio City LGU and to neighbouring municipalities. Additionally, new stations owned by the Baguio LGU have been procured and installed to ensure greater spatial real-time data coverage of the river basins in Baguio.

Partnerships with organizations outside of the LGU are essential in ensuring the success and sustainability of the FEWS, as they enable the sharing of data, knowledge, and personnel to build a strong foundation for the system's long-term sustainability. The formalization of these relationship through MOAs supports the clear delineation of roles and responsibilities between organizations, sets expectations, and shows bilateral commitment to the success of the FEWS. Key MOAs have been signed with DOST-CAR, PAGASA, and the LGUs of La Trinidad and Tuba. The sustainment plan furthermore lists further MOAs that are already in development or are recommended to further enhance the system's long-term performance. The MOAs represent an important achievement as they ensure ownership, delineate expectations across organizations and set the foundation for long-term sustainability of the system.

Institutional sustainment has also been considered through the lens of building a gender transformative and people-centric FEWS, in relation to the Implementation Plan: Actions and responsibilities for a gender inclusive FEWS in Baguio City, which has been shared with the LGU. The plan was developed in consultation and collaboration with the CDRRMO, the City Social Welfare and Development Office (CSWDO), and the Public Information Office (PIO). LGU support has thus far played an important role in advancing the gender transformative actions, helping legitimize the actions beyond the CDRRMO to other institutional actors and agencies, and underscoring their importance. Closely linked to leadership are the broadly supportive institutional structures emerging in Baguio that prioritize gender equality, disability and social inclusion efforts in the context of DRRM.

5.2.3 TECHNICAL SUSTAINMENT

To ensure that the FEWS remains operational and up to date in the long term, the sustainment plan includes the actions undertaken to maintain, update, and enhance the technical components of the system, such as monitoring stations, ICT equipment, and software. The focus on future improvements to the system ensures that maintenance activities are not only reactive, but aim to perfect the system, adapt it to changing conditions, and incorporate new knowledge and lessons learned on a continual basis.

The plan provides an outline of the hardware and software inventory that make up the system, the maintenance schedules as indicated in the SOPs, and the potential for future enhancements. The hardware inventory comprises of nine water level monitoring systems, workstations, servers, and CCTV equipment. Software includes the overview of the IT infrastructure, software updates, as well as recommendations for the system’s cybersecurity. For future system enhancements, the sustainment plan provides recommendations for the improvement of stage-discharge relationships, expanding the network of stations, and incorporating additional features and functionalities.

Actions pertaining to the data dissemination and outreach are another key component of the technical sustainment of the FEWS. The system needs to be tested over multiple monsoon seasons and the quality of the messages need to be validated in several steps, to avoid sending flawed messages to wrong recipients at a wrong time. The sustainment plan outlines the testing phases. Dissemination is also a key area under which the gender transformative actions are being taken forward. The development of information and warning messages (written text, audio, visual, etc.) will involve thorough testing with vulnerable groups, multiple iterations, real-life application, and refining based on feedback.

5.2.4 FINANCIAL SUSTAINMENT

The fourth critical lens of the sustainment plan, financial sustainment, provides an overview of costs connected with O&M activities and current and future sources of funding that will Baguio LGU to effectively allocate resources, anticipate challenges, and plan for future enhancements of the system.

The plan outlines an operations and maintenance budget, including compensation for technical staff, the maintenance and replacement of hardware, software updates, expert technical support, training and workshops, and future system enhancements. This is presented alongside current sources of funding that CDRRMO is using, as well as recommendations for potential new sources of funding that could be mobilized in the future as the system develops, such as public-private partnerships or linkages between the FEWS and other projects in Baguio.

Specific attention is given to funding of the gender transformative actions, as they might not always fall directly under existing DRRM fund specifications. While funding is available and funnelled towards DRRM programming and meeting the needs of women, persons with disabilities, and vulnerable members of the community, there are still limitations in funding sufficiency, timeframes for budget expenditure, and specifications for use. The sustainment plan provides several recommendations on how actions identified in the Gender Transformative FEWS may be financially supported and taken forward.

5.2.5 RISKS

The implementation, operation and maintenance of the Baguio FEWS is invariably exposed to a certain level of risk. During the sustainment workshop in October 2023, the O&M team members asked to identify these potential risks under each of the four critical lenses and come up with proposed actions to mitigate these risks. The outcomes of their discussion have been used to develop the risk matrix (Table 5-1).

Developing a robust risk management plan is a crucial step in fostering long-term sustainability of the Baguio City FEWS, serving as a practical guide for the O&M team to navigate any challenges proactively. As part of the sustainment plan, each of the risks was assigned a likelihood score and an impact score to identify most pressing risks to address.

Table 5-1 Risk matrix

Risk Category	Individual Risk	Likelihood (1-5)	Impact (1-5)	Risk Score (Likelihood x Impact)	Mitigation
Human Resources Risks	Lack of available, trained, dedicated staff	4	5	20	Hire additional staff, create a permanent team dedicated to FEWS O&M, hire additional technical staff (hydrology, engineering background)
	Lack of training and experience	3	5	15	Continuous training and technical support, request external staff for training and technical support, creation of a teaching/ training module for new staff, explore research potential using FEWS outputs/ experience
	Top-down changes to the team	3	4	12	Formalize the commitment of dedicated FEWS staff through a council resolution to ensure they have the mandate to perform their tasks and to make the team more resilient to changes in leadership
	Change in O&M Team members (e.g., retirement, promotion of staff to other offices)	4	3	12	Ensure continuous training of staff, leverage students/trainees from partner organizations, and establish a plan for role-specific mentorship Cross-training of staff members to handle multiple roles can minimize knowledge loss when personnel change
Institutional Risks	Change of leadership in LGU / local executive offices	5	3	15	Formalize the FEWS governance through a council resolution to strengthen the Executive Order

Risk Category	Individual Risk	Likelihood (1-5)	Impact (1-5)	Risk Score (Likelihood x Impact)	Mitigation
Institutional Risks	Change of leadership in partner organizations	4	2	8	Continually build and nurture relationships with partner organizations to ensure continuity in communication in case of leadership changes and facilitate smooth knowledge transfer
	Amendment of E.O	4	4	16	Inform top-level decision-makers, share learnings and positive outcomes, inform in case of organizational changes
	Amendment of MOAs	2	4	8	Maintain relationships with partners, share learnings and positive outcomes, inform in case of organizational changes
Technical Risks	Power outage/ unstable power supply	5	3	15	Backup batteries/power source, signing a MOA with BENECO to prioritize the electricity supply to FEWS during monsoons
	Damage to the infrastructure or theft	4	4	16	Ensure redundancy, check if spare parts and equipment is always available, CCTV in the monitoring stations
	Outdated hardware	3	4	12	Regular maintenance and upgrades to equipment and stations as written in the SOPs, periodic evaluations of the ITC equipment, workstations and servers
	Data transmission failure	4	4	16	Regularly scheduled maintenance and monitoring of the data transmission equipment, redundancy
	Outdated software	5	2	10	Maintain the system, implement updates as needed
	Data breach/ unauthorized access to data	1	4	4	Data security training for all O&M staff, implementing a data backup and recovery plan to recover the data in case of a breach or loss, ensuring that the software is always updated and secured with firewalls and antivirus programs, regular vulnerability assessments and testing
	Cyber attack	1	5	5	Data security training for all O&M staff, implementing a data backup and recovery plan to recover the data in case of a breach or loss, ensuring that the software is always updated and secured with firewalls and antivirus programs, regular vulnerability assessments and testing

Risk Category	Individual Risk	Likelihood (1-5)	Impact (1-5)	Risk Score (Likelihood x Impact)	Mitigation
Technical Risks	Change to the input data format received from partner organisations	2	5	10	Establish agreements with partner organizations about data format consistency. Agree on coordination processes with partner organizations to receive advanced notice of any unavoidable changes to ensure enough time for the O&M team to prepare/train
Financial Risks	Lack of funding	3	5	15	Formalize the FEWS in LGU structures to ensure inclusion in yearly budget, diversification of funding sources. Regular Financial Reviews: Routine reviews of project expenditure against budget projections will be carried out to identify potential cost overruns early. Contingency Budget: A portion of the project budget will be set aside as a contingency fund to cover unexpected costs.
	FEWS not prioritized in LGU budget	3	5	15	Formalize the FEWS governance through a council resolution to ensure inclusion in the yearly LGU budget and stability of funding
	No available suppliers	2	3	6	Ensure multiple suppliers of equipment and parts, secure long-term contracts with reliable suppliers to guarantee availability of resources

Source: Ramboll

Based on the insights gained throughout the project and during the sustainment workshop, key considerations are: securing available, dedicated and well-trained staff to operate and maintain the system, further formalizing the FEWS governance within the LGU to ensure clear responsibilities and stability of funding, as well as clearly defining roles and relationships with partner organizations to build a stable network of support and knowledge exchange around the FEWS. Furthermore, proactive mitigation of technical risks and evaluation of system performance are essential to maintain the continual functionality and growth of the system.

It is recommended that the team performs a periodical risk assessment exercise along all four critical lenses to update the list and identify mitigation actions as needed. This holistic approach in managing risks will not only help to recognize potential challenges early, but also pave the way for the lasting success of the Baguio City FEWS.

6 CITY GRADUATION

Source: Ramboll

Under the AASCTF program umbrella, a three-tiered approach to graduation guides the participating city's journeys. The graduation approach appreciates that all participating cities should have the possibility to graduate (on an equal and fair basis) when the conditions for graduation are met. Participating cities have an opportunity to take significant steps towards smarter more livable cities. The graduation journey offers a pathway for cities to generate increasingly transformative outcomes through enhanced AASCTF support.

The three-tiered approach include:

- Gold Tier: Scaling at governance levels of intervention/program resilience potentials, and support to access investment funding.
- Silver Tier: City-specific pilot projects and capacity building, including extended sustainment support and scaling at operational levels.
- Bronze Tier: Participation in regional networking and knowledge sharing activities.

AASCTF Cities' readiness for graduation to the next tier is evaluated based on established evaluation criteria outlined in the City Report Card to guide decision-making around the AASCTF city graduation journey. The City Graduation Journey is depicted in Figure 6-1.

Figure 6-1 City Graduation Journey
Source: Ramboll

As an active AASCTF City, Baguio City is part of the graduation journey. Since the pilot project commenced in 2020, Baguio City has demonstrated commitment and ongoing engagement to enhance its capacity for implementation of smart and livable solutions as well as ownership of the pilot project outputs.

As part of the Baguio FEWS consolidation phase, the ambition has been for Baguio City to achieve readiness for Gold City graduation. Thus, efforts to further strengthen the system governance, secure top-level endorsement and funding for operationalization, and enhance system sustainment has been made to support Baguio's resilience - and program graduation - journey.

Baguio fully meets the criteria for graduation from Bronze to Silver city. A summary of Baguio's bronze to silver report card is shown in Table 6-1 and the full City Report Card can be found in Appendix E. Thus, Baguio shows top-level endorsement of AASCTF objectives, has established a project steering committee and super-user group (i.e., the FEWS O&M team), and completed a smart city baseline survey.

Table 6-1 Summary of City Report Card - Bronze to Silver Graduation (Achievement Assessment)

KPI	Score
Top-level endorsement of AASCTF objectives and outcome targets *25 points*	25
Commitment to establish a Project steering committee *15 points*	15
Clear institutional, policy and regulatory framework proposed by the local government *15 points*	10
Smart City Champions and/or Superuser group nominated, and commitment made with clear responsibilities to support AASCTF smart city initiatives *15 points*	15
Commitment to taking part in AASCTF e-learning courses by Smart City Champions and Superusers *10 points*	10
Completion of smart city baseline survey *10 points*	10
Active participation in regional knowledge sharing activities *10 points*	10
Total	95/100

Source: Ramboll

Following the prospective graduation to Silver Tier, the readiness for Gold City graduation has been assessed throughout the consolidation phase as efforts on system testing/validation and sustainment advanced. A summary of Baguio's silver to gold report card - assessed from a readiness (not achievement) perspective at this time - is shown in Table 6-2 and the full City Report Card can be found in Appendix E. As evident from the report card, the team has confidence in Baguio fulfilling the graduation criteria (once this is more officially communicated/requested of them to do so), therefore the city is deemed ready to graduate to Gold Tier (readiness for graduation above 80 points). Given this is only a readiness assessment, we concur that most of the evaluation criteria are not in fact fully evidenced, primarily because the top-level government has not been formally asked to make the commitment (and thus it would likewise not be appropriate to do so ahead of confirmation by the program/ADB/DFAT that this graduation pathway is in fact now open to them).

Table 6-2 Summary of City Report Card – Silver to Gold Graduation (Readiness Assessment)

KPI	Score
Top-level endorsement of AASCTF pilot project *20 points*	20
Effective and sufficiently resourced and responsive project organization (steering committee, champions, superusers) *15 points*	10
Financially/technically feasible pilot project with outputs/tools embedded into regulations/ governance at appropriate levels *15 points*	15
Mid-term outputs/tools operations budget secured by city *15 points*	10
Meaningful progress toward GEDSI outcomes is demonstrated *15 points*	15
Commitment to engage in City Twinning secured *10 points*	10
Completion of all AASCTF e-learning courses by Smart City Champions and Superusers *5 points*	-
Commitment to mentor/peer support other AASCTF cities *5 points*	5
Total	85/100

Source: Ramboll

The key take-aways from the Gold City graduation readiness assessment of Baguio are outlined in Figure 6-2. It is evident that Baguio is highly committed to securing the success of the established FEWS and the financial/technical feasibility beyond the pilot project. Baguio has demonstrated top-level endorsement of the AASCTF program and continues to excel in their ability to effectively implement the project. Furthermore, the identified Smart City Champions and Super Users demonstrate high dedication, self-determination, self-organization, curiosity, and consistency which is crucial for project sustainment.

If/when graduation to Gold City is endorsed and given future opportunities for AASCTF engagement, there is high confidence that Baguio will continue to make meaningful progress towards enhancing resilience through participation in AASCTF activities. Within the Philippines, Baguio City is often used for benchmarking of the Smart City concept due to its many smart initiatives anchored at the SCCC and the SCCC is often visited by neighbouring LGUs. Thus, further outreach and dissemination perspectives of AASCTF activities are wide, underlining the great potential of Baguio to utilize the benefits of the Gold Tier and serve as a true smart city ambassador.

Baguio: Silver to Gold City Assessment – Readiness

- ☑ Top-level endorsement of AASCTF pilot project
- ☑ Effective and sufficiently resourced and responsive project organization (steering committee, champions, superusers)
- ☑ Financially/technically feasible pilot project with outputs/tools embedded into regulations/governance at appropriate levels
- ☑ Mid-term outputs/tools operations budget secured by city
- ☑ Meaningful progress toward GEDSI outcomes
- ☑ Commitment to engage in City Twinning
- ☑ Completion of AASCTF e-learning courses by Smart City Champions and Superusers
- ☑ Commitment to mentor/peer support other AASCTF cities

Figure 6-2 Key take-aways from the assessment of Baguio's readiness for graduation from Silver to Gold City
Source: Ramboll

Source: Ramboll

7 RECOMMENDATIONS

Source: Ramboll

7.1 RECOMMENDATIONS FOR FURTHER TECHNICAL SUPPORT

There is a need to test the FEWS throughout multiple monsoon seasons to trouble-shoot, adjust and calibrate the system, which requires experience and expertise in FEWS. During feedback sessions, the O&M team has expressed concerns about being unable to meet expectations and are anxious to be "left alone" without technical support beyond 2023.

Thus, further technical support for finetuning, testing, and operating the system will be needed beyond 2023.

Training needs
The capacities within the FEWS O&M team steadily increased during the 2023 Baguio FEWS training program. However, they are not yet at the technical level required to enable the team to be fully responsible for the operation and maintenance of the FEWS. Thus, further training and technical support for finetuning, testing, and operating the system will be needed beyond 2023. The idea would be to keep an overview of the activities detailed in the SOPs and step in to solve issues that the team is unable to resolve. Considering that the models are calibrated against new stations with data currently available from a single monsoon period and that the system still needs to be tested and updated for a few more monsoons, there could be new issues not yet documented in the updated SOPs which would require resolution. While the experts would be required to identify and resolve these, the O&M team needs to develop an instinct to be able to independently identify when the system is not performing as expected and be technically capable to find implement solutions.

A repetition of the training plan as carried out in 2023 will be beneficial for further strengthening the technical capabilities in the team. However, the focus of the training in 2024 should less on traditional classroom trainings and designed to inculcate independent problem-solving capacities in the O&M team. The training activities will need to be planned such that the technical leads for the modelling team, IT team and instrument team coordinate and lead the activities with guidance and shepherding from experts. One way of achieving the required outcome would be temporarily integrating the experts in the O&M team structure. The goal would be to shift from the experts carrying out the troubleshooting and updates in silos and later training the team to the experts prompting the technical resolutions required during the operation and maintenance which would be carried out mainly by the core team.

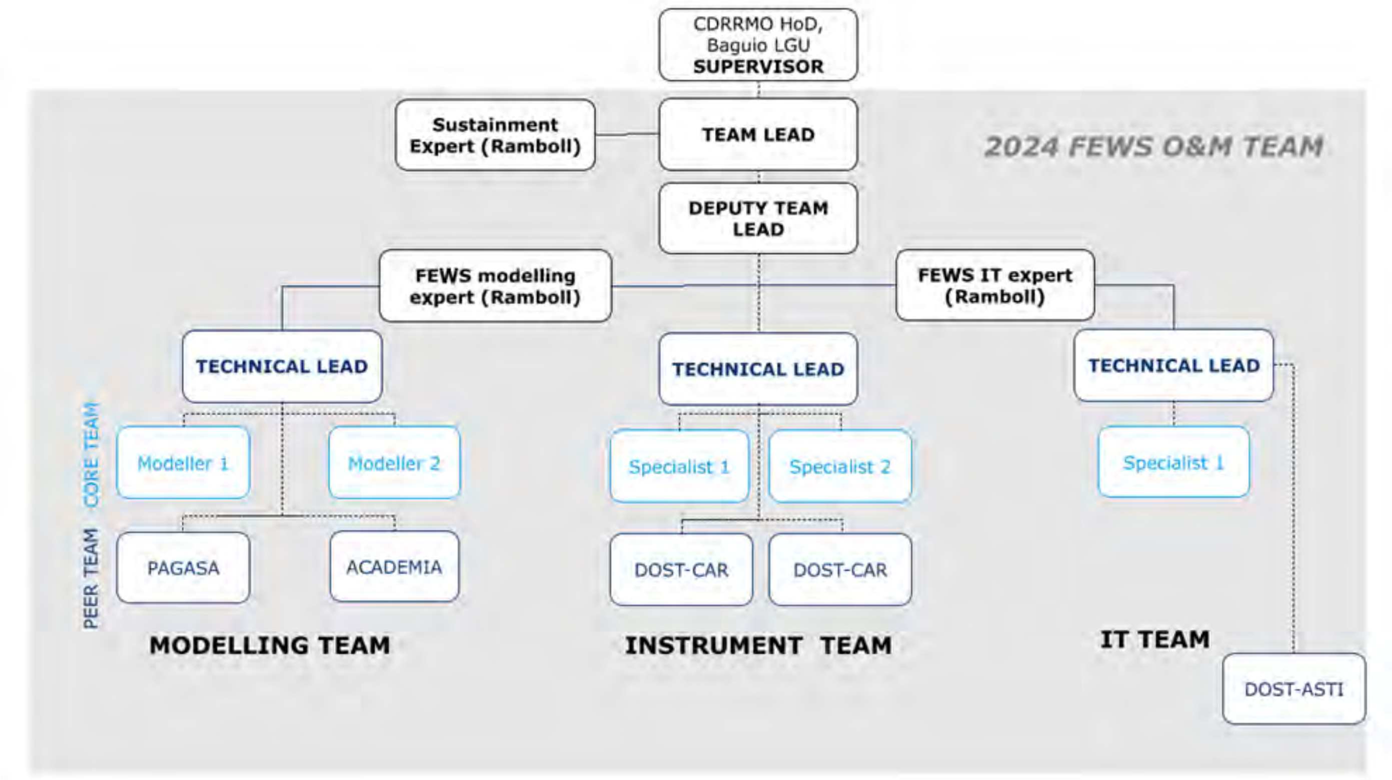


Figure 7-1 Inclusion of experts to co-lead O&M tasks with the Team Lead and Technical Leads
Source: Ramboll

The following annual training activities are recommended for 2024-2025:

- Pre-monsoon: Experts co-leading with the team leads in completion of pre-monsoon SOPs and pre-monsoon in-person OTJ training to ensure proper initiation of real-time monsoon operation
- Monsoon: Experts co-leading with the team leads in real-time operation, maintenance and troubleshooting of the FEWS
- Post-monsoon: Experts co-leading with the team leads in completion of post-monsoon SOPs and post-monsoon in-person OTJ training to ensure proper assessment of system performance and implementation of post-monsoon SOPs.

A detailed assessment of current confidence against different operation and maintenance activities is found in the Sustainment Plan (Appendix D).

7.2 RECOMMENDATIONS FOR FUTURE FEWS UPDATES

It has been seen that the performance of the FEWS system has improved with continued updates during the consolidation phase. However, the system is still in the initial test phase as shown in Figure 7-2 and requires updates to proceed to the next phases. To be able to take the system to the second phase, updates will need to be made over the next few years in the following areas in addition to improving the accuracy and dependability of the system:

1. Front end updates to the dashboard with a focus on the wider warning dissemination plan
2. Including rainfall-based warnings so that barangay level warnings may be generated by the system and not limit the system to river overtopping warnings.

Figure 7-2 Organisational set-up during the test phases
Source: Ramboll

To further solidify the long-term sustainability of the Baguio City FEWS, the following activities are recommended for the LGU to be fully ready to launch the system publicly and operate it independently.

WRF correction for levels greater level 3 of the forecasted rainfall input - implementation and testing the automated real-time process for WRF correction

In 2023, the forecasted rainfall input has been improved for 3 levels, i.e. for 9 hours post the time of forecast. The same should be replicated for the remaining levels of forecast to increase the model accuracy with greater lead times. The WRF correction should also be included as an automated real-time process in the monsoon phase in 2024.

System performance assessment and updates

As the purpose of the FEWS is to continuously get better coverage of rainfall data and more water-level, it is recommended that the additional data collected for the new stations installed be used for improvements in model calibration post-monsoon in 2024. It is also recommended that the impact of the updates made in 2023 are monitored in monsoon 2024 and post-monsoon updates are again made based on the system performance assessment data prepared from the period.

It is also recommended to update, operate and maintain the Model 3 for Bued, Galiano and Ambalanga rivers in 2024 as has been done for Model 1 for Balili River in 2023.

Updates to warning thresholds
The currently applied thresholds for overtopping warnings need to be updated based on assessment such as rate of increase of water level at different vulnerable reaches and the associated flood risks.

Rainfall based warnings and surveys of water levels and discharges for development of stage-discharge relationship
It has been observed that majority of the floods in Baguio are not due to overtopping of riverbanks which limits the reach of solutions provided by the current FEWS. The FEWS will be able to provide city wide flood warnings if rainfall-based warnings are included.

To be able to validate the rainfall-based warnings, calibration against just the water level data is not sufficient and will require validation against observed discharge data. Measurements should be taken in the next few monsoons and non-monsoon seasons to have sufficient data to apply this system improvement and develop accurate stage discharge curves.

WRF data, which have been 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. This will allow the FEWS to benefit areas in the city which experience flooding not just due to the riverine flooding but also due to other issues such as insufficient or blocked urban drainage infrastructure. For identifying the at-risk barangays with greater reliability, flood maps will need to be prepared for more return periods as required and the ones prepared already will need to be prepared again based upon new rain data analysis using only most appropriate station data. The same stations would be used for the bias correction of the WRF data to ensure proper correlation.

Support for validation of data dissemination and outreach plan including integration of GEDSI actions
The Data Dissemination and Outreach Report outlined three testing and validation phases, starting from an initial trial only including the FEWS Operation and Maintenance team, and gradually expanding groups of recipients and using more varied dissemination channels, eventually reaching the end users. A thorough testing of the warning dissemination component over multiple monsoon seasons is crucial to ensuring an equitability and credibility of the FEWS. As stated in the final recommendation of the Gender and Social Inclusion (GESI) Study, the implementation of GESI actions must be an ongoing process spanning multiple years which will be continued in 2024 and beyond. The front end of the FEWS should be updated to support and validate the data dissemination and outreach plan including integration of GEDSI actions, relevant to the current stage of the project.

7.3 RECOMMENDATIONS FOR LINKAGES TO OTHER PROJECTS

There is a great potential to enhance the FEWS in partnership with other ongoing projects in the city. In close collaboration with the LGU departments, potential synergies and linkages between the FEWS project and other projects were explored with particular focus on linkages to the Baguio Resilient City Tourism Project. Awareness of the synergies provides an opportunity to enhance the outcome of projects and streamline resilience efforts across LGU departments and partner organizations.

The identified linkages to other projects are outlined below:

- Integration of network of real-time monitoring stations; the Baguio Resilient City Tourism Project provides an opportunity for enhanced data collection on urban drainage/sewers including real-time monitoring stations. The data collection and management could be integrated in the network of monitoring stations installed under the FEWS project. Currently, the FEWS forecasts riverine flooding, but the urban drainage component could be integrated in the FEWS, if data is available, which would enhance the output of the FEWS. Many areas are frequently affected by urban flooding, and thus, such an expansion of the FEWS would allow the LGU to provide early warnings to these areas benefiting a great number of citizens and tourists in Baguio.

- Capacity building on climate change awareness and disaster resilience; There is a clear link between this component of the Baguio Resilient City Tourism Project and the many capacity building and workshopping activities undertaken in the FEWS project. Building on the knowledge the LGU staff have acquired as part of the FEWS, they could be equipped (through additional capacity building sessions) to facilitate trainings/workshops/awareness programs for workers in the tourism sector.

- Streamlining O&M of monitoring stations across LGU departments; the FEWS O&M team have undergone extensive training in O&M of the system including the real-time stations. The FEWS O&M team will be able to provide peer-to-peer training, assist in preparation of SOPs, and pass on lessons learned which will enhance the effective operation of new monitoring stations.

- Peak-flow modelling/forecasting; Using the real-time rainfall data collected by the monitoring stations installed under the FEWS project a simple model for forecasting peak flows to the STP could be set up which would increase resilience of the STP and enhance effective plant operation.

- Potential to integrate with new design and operation of blue-green infrastructure in upgraded parks; The City of Baguio has received funding from the Department of Health (DOH) to implement improvements to Emilio Aguinaldo Park, based on the pilot concept design developed in the Flood Mitigation Action Plan in the FEWS project. The conceptual designs will be community developed, intended to provide an improved space for residents, as well as a potential tourism destination. As the park is a natural depression, the park designs will incorporate nature-based solutions for stormwater management and climate resilience. The redevelopment of the park is the first step by the LGU in implementing the recommendations of the Flood Mitigation Action Plan and demonstrates the ownership the LGU has taken of the plan.

- Integrated GEDSI planning; There are strong links between the Baguio Resilient City Tourism Project and the work completed under the Gender Transformative FEWS project and particularly in taking forward and building on key actions identified therein. Key links include expanding assessment and understanding of gender and inequality vis-a-vis climate risk and vulnerability in the city – from FEWS to sanitation, tourism and beyond; develop and strengthen capacity / expertise of city agencies on integrated GEDSI planning and service delivery for tourism and sanitation through customised training and mentoring programmes.

It is recommended that these linkages are explored further as the projects are matured and ahead of project implementation. Actively integrating learnings and seeking to maximize synergies across projects are expected to enhance cost-effectiveness and benefits while ensuring further reach of the project outcomes.

8 CONCLUSION

Source: Ramboll

This report summarizes the performance, achievements, and learnings and subsequent updates from the first real-time full-scale test of the Baguio FEWS during the 2023 monsoon. Furthermore, the report presents the plan for system sustainment and Baguio City's graduation journey as part of the AASCTF program. The main conclusions are presented below.

System Performance Assessment

The performance assessment of the 2023 real-time monsoon operation was successfully completed to identify strengths and weaknesses of the system to further improve the accuracy and dependability of the Baguio FEWS. The key components which were evaluated to assess the overall FEWS performance were: station performance, data quality, model performance, real-time setup, and operation and maintenance.

Key conclusions from the performance assessment include:

- All stations demonstrated good performance with operational periods exceeding 80%, with the exception of the City Camp Lagoon, Camp 7 and Eagle Crest stations. However, there is room for improvement in enhancing the monitoring and maintenance of stations. The gaps included were identified, including lack of proper understanding of specific SOPs, and addressed during post-monsoon updates and trainings.
- The real-time monitoring water level and rainfall data exhibited jumps or outlying values which were introduced during the station maintenance activities. These discrepancies were identified and resolved during the post-monsoon updates.
- The WRF data, in general, exhibits significant variation from the observed rainfall values. However, the application of bias correction to the model successfully rectified the forecasted rainfall values, resulting in a system that provided acceptable water level forecasts.
- The model exhibited satisfactory performance during the entirety of the 2023 monsoon operations, with incidents of model failure observed in less than 10% of cases throughout the operations.
- The model experienced inaccuracies in real-time data, leading to occasional false warnings of elevated water levels in the Balili River, impacting the precision of the model. This issue has to be addressed through careful management and maintenance during real-time operations, and the procedures has been incorporated into the Monsoon SOPs for resolution.
- The 2023 Monsoon operation Balili river model was calibrated for Balili Bridge station. The model demonstrated satisfactory performance, achieving R2 values exceeding 0.6 for the initial 12 hours of the forecast and surpassing 0.8 for the initial 3 hours of the forecast.
- The real-time setup of FEWS performed well with less than 10% of job failures throughout the 2023 monsoon operations.

Post-monsoon Updates

Following the performance assessment, post-monsoon updates were successfully made to the different components that make up the system: data, model, real-time set-up, and SOPs.

Key system updates in the post-monsoon phase include:

- Issues with datum jumps have been justified and resolved for water level stations.
- Issues with sudden erroneous peaks in the real time rainfall data has been justified and corrected.
- Issues with model precision have been identified to be sudden outliers in the observed water level data which then is taken by the DA process to initialize the models prior to simulations in real time. SOPs have been updated to monitor and correct the same in real time monsoon operation.
- 49 grids of the WRF data are tested for the first three levels (i.e. up to 9th hour of forecast) to attain the best possible permutation of weightages against each grid in order to obtain the closest correlation with the observed rainfall data for each sub-catchment.
- The Balili river model has been operated and run in 2023 monsoon in real time in the FEWS setup. Data for the new water level and rainfall stations has been collected for 2023. Using this addition data, the model has been recalibrated in the post-monsoon phase.
- During the recalibration of the model in the post monsoon period, data from the new stations as well as the corrected WRF data for level 2 to 4 have been used as input rain is separate scenarios such that the model parameters remain the same while giving the best possible correlations between the modelled and simulated water-levels in all cases.
- To address the identified problem of instable internet license problem, a physical dongle has been utilized to operate the MIKE software replacing the earlier internet license resulting in significant improvement of license stability.
- Email and message alerts from the system have been updated and additional alerts have been set up. Throughout the 2023 monsoon, the system had been sending all the alerts to all the team members for testing. Post-monsoon, these alerts have been segregated and specific alerts are now sent to specific team. The FEWS O&M sub-teams receive separate alerts suited for their responsibilities.
- A script has been developed to automate the arrangement of simulated and station data into a desired format for all stations, creating an Excel spreadsheet. This spreadsheet includes the simulated, observed and their difference for all the simulations for each station for each simulation run in real time. This data can then directly be used to carry out post monsoon model performance assessments.
- MIKE OPERATIONS has been setup to autonomously generate emails in the event of a flood corresponding to selected warning levels, disseminating them to all members listed in the contact roster.
- SOP’s have been updated based on the lessons learnt during monsoon 2023.

System Sustainment Plan

Significant progress has been made in implementing and operationalizing the Flood Early Warning System (FEWS) in Baguio City to set the stage for continuous improvement and long-term viability of the system. A detailed sustainment plan has been developed, focusing on four critical lenses: human resources, institutional, technical, and financial sustainment.

- The sustainment plan was co-developed with the O&M team to ensure that the team members take ownership of future sustainment activities, play an active role in planning them, and are well informed of all recommendations post-2023. A sustainment workshop took place in October 2023 to agree on components of the plan and collect inputs, further strengthening the sense of local ownership of the FEWS.
    - Human resources sustainment takes into consideration the crucial role of the FEWS O&M team and describes actions to ensure the availability of well-trained and dedicated staff and clear and up to date SOPs. The plan provides recommendations on the organization of future training.
    - Institutional sustainment addresses anchoring of the FEWS within the existing institutional setup in Baguio and provides recommendations on enhancing the governance of the system, as well as establishing formal partnerships with partner organizations.
    - Technical sustainment relates to activities that aim to maintain and further develop the technical components of the system, such as stations, ITC equipment, software, data security. It also outlines the upcoming testing phases of the system and the data dissemination and outreach activities.
    - Financial sustainment outlines the O&M budget and current and potential future sources of funding for the FEWS.
- Regular risk assessments across the four critical lenses of sustainment have been completed and the most critical risks and mitigating actions have been identified. A thorough risk assessment is vital for anticipating and addressing potential challenges, paving the way for the lasting success of the Baguio City FEWS.

City Graduation
As an active AASCTF City, Baguio City is part of the three-tiered (Gold, Silver, Bronze) graduation journey the participating cities. Since the pilot project commenced in 2020, Baguio City has demonstrated commitment and ongoing engagement to enhance its capacity for implementation of smart and livable solutions as well as ownership of the pilot project outputs.

Baguio fully meets the criteria for graduation from Bronze to Silver city and scores 95/100 on the City Report Card. Following the prospective graduation to Silver Tier, the readiness for Gold City graduation was assessed throughout the consolidation phase as efforts on system testing/validation and sustainment advanced. The team has confidence in Baguio fulfilling the graduation criteria (once this is more officially communicated/requested of them to do so), therefore the city is deemed ready to graduate to Gold Tier with a score of 85/100 (readiness for graduation above 80 points).

If/when graduation to Gold City is endorsed and given future opportunities for AASCTF engagement, there is high confidence that Baguio will continue to make meaningful progress towards enhancing resilience through participation in AASCTF activities. Within the Philippines, Baguio City is often used for benchmarking of the Smart City concept due to its many smart initiatives anchored at the SCCC and the SCCC is often visited by neighbouring LGUs. Thus, further outreach and dissemination perspectives of AASCTF activities are wide, underlining the great potential of Baguio to utilize the benefits of the Gold Tier and serve as a true smart city ambassador.

Recommendations
Based on the lessons learned throughout the consolidation phase, recommendations for further technical support and future FEWS updates as well as synergies for co-development aligned with other citywide projects in Baguio to maximize impact.

There is a need for the LGU to receive technical support finetuning, testing, and operating the system in the coming years, as the team does not yet have the experience to independently operate and maintain the FEWS. The team can fully undertake most of the SOPs but need sparring for quality assurance and complex trouble shooting. Furthermore, the team also need experience in planning and executing the various activities throughout the operational activities. The extent of the technical support is expected to gradually decrease in the coming years as the experience of the team advances.

To further strengthen the technical capacity of the O&M team, the training activities for 2024 will need to be planned such that the technical leads for the modelling team, IT team and instrument team are able to coordinate and lead the activities with guidance and shepherding from the technical external experts.

The recommended future FEWS updates focus on improving the accuracy and dependability of the system to mature the system for the next test phase, which include wider dissemination of warnings to additional stakeholder groups. 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.


Source: Adobe Stock

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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