



Updating and improving of existing hydrologic and hydraulic models and configuring a Flood Early Warnings System (FEWS) in Sudan

Enhanced FEWS Design Report

Report

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Prepared for General Administration of Nile Water Affairs, Ministry of Irrigation and Water Resources, Sudan

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1 Introduction

This report is a deliverable of the CTCN Technical Assistance “Updating and improving of existing hydrologic and hydraulic models and configuring a Flood Early Warnings System (FEWS) in Sudan”.

The objective of the technical assistance is to update and improve the existing hydrologic and hydraulic models and configure Flood Early Warning System (FEWS) setup by the Nile River basin regional entity the Eastern Nile Technical Regional Office (ENTRO) for Sudan as well as to strengthen the capacity of the staff of the General Administration of Nile Water Affairs, Ministry of Irrigation and Water Resources, and link the systems with concerned stakeholders.

The objective will be achieved by:

- Expanding and enhancing the components of the existing FEWS in Sudan for increased coverage, efficiency, and lead time in the Blue Nile, White Nile, Main Nile upstream of Dongola), Setit-Atbara, Dinder and Rahad national sub-basins.
- Assessing potentials and opportunities of the Eastern Nile Flood Forecast and Early Warning System EN-FFEWS of ENTRO available to Sudan - as well as its current protocols/procedures and institutional framework - to supplement the FEWS in Sudan.
- Training system operators and enhancing the capacities of key stakeholders of the FEWS to improve and benefit the country’s disaster management framework.

The scope of work under this technical assistance comprises three outputs to be achieved through three activities.

- Output 1: Assessment of the existing FEWS system protocols and identifying existing data gaps and needs.
 - Activity 1: Stakeholder consultation, assessment of available data and existing FEWS
- Output 2. Enhanced FEWS
 - Activity 2 – Enhancement of the FEWS
- Output 3. Strengthened capacity and sustainability for uptake and effective use of the upgraded FEWS.
 - Activity 3 – Capacity building for use of the enhanced FEWS

This report “Enhanced FEWS design report” (Deliverable associated with Activity 1.5 – Model and FEWS review) is a concise documentation of the enhancements and improvements made to the EN-FEWS. It documents the enhancements and improvements that have been made to the software system.

The structure of this report is as follows:

- **Chapter 1** explains the context of the report (this chapter).
- **Chapter 2** documents the software enhancements and improvements of EN-FFEWS.
- **Chapter 3** summarizes the enhancements with reflections on the way forward.

2 Software Enhancements and Improvements of the EN-FFEWS

The EN-FFEWS has been migrated to a development server and is accessible to the public: <https://entro-ffews-dev.westeurope.cloudapp.azure.com/>. When all enhancements and improvements, including the replacement of the embedded (registered) old models with the new improved and enhanced ones, are concluded, the final version will be deployed on a cloud server of the General Administration of Nile Water Affairs' choice.

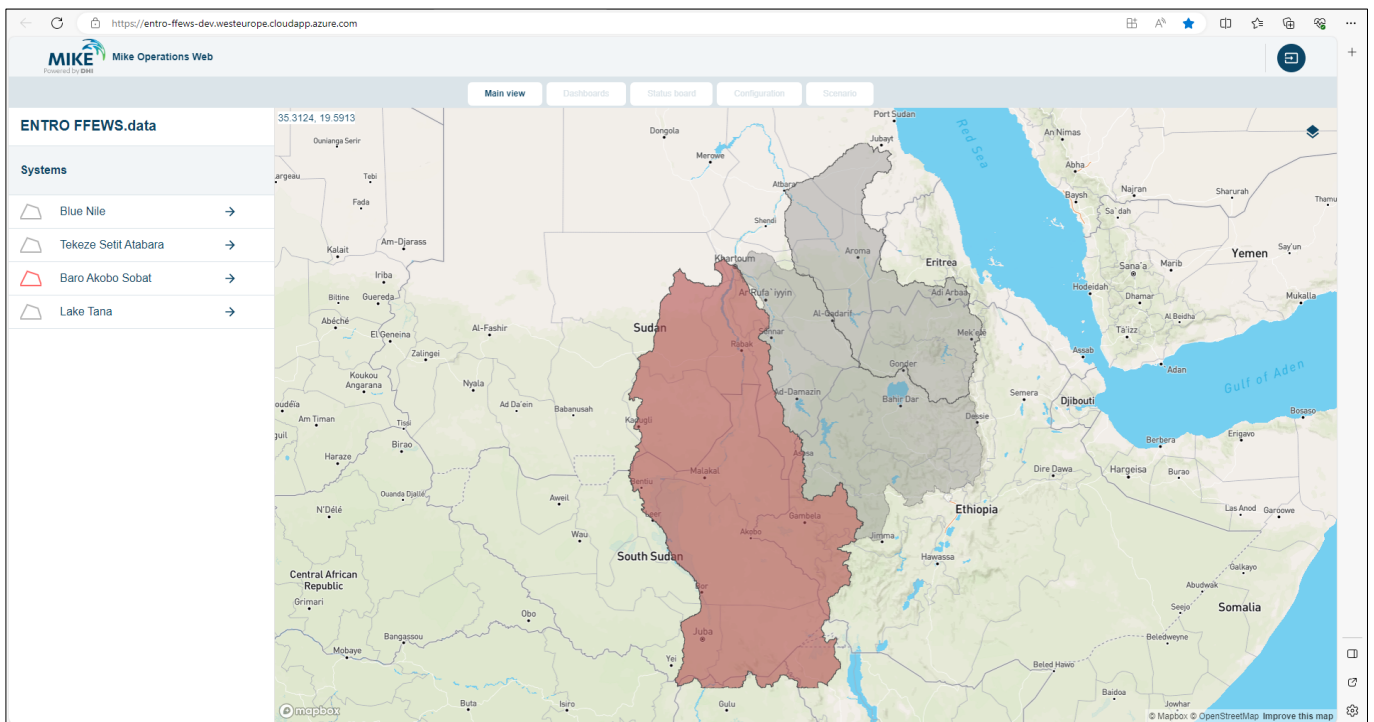


Figure 1 Screenshot of the start page of the enhanced EN-FFEWS

The implementation status is the following:

Required Enhancements and Improvements (Longlist)	Status/Remark
<p>1. Server</p> <p>a. ENTRO's four flood forecasting systems used to run on the same server as the NBI river flow forecasting system. Currently. The NBI river flow forecasting system is storage and CPU intensive. Therefore, the recommendation is to use a different server for the flood forecasting systems to get appropriate storage and CPU capacity. This will be done when moving to production.</p>	<p>The EN-FFEWS (with operational forecast models for Blue Nile, Tekeze-Setit-Atbara and White Nile) is implemented on a development server: https://entro-ffews-dev.westeurope.cloudapp.azure.com/</p>
<p>2. MIKE Software</p> <p>a. Update the MIKE Software to the latest version.</p>	<p>Implemented</p>
<p>3. MIKE Workbench Configuration</p> <p>a. Some python scripts were stored outside of the MIKE Workbench database. To facilitate maintenance and migration of the forecasting systems the python scripts have been integrated in the Script Manager of MIKE Workbench.</p> <p>b. Four models¹ of the Blue Nile, Tekeze-Setit-Atbara, Baro-Akobo-Sobat (including White Nile), and Tana basins run now in one database, to ease maintenance and reduce duplication of code.</p> <p>c. Many more output timeseries were included in the MIKE Workbench simulation than presented in the MIKE Operations Web or MIKE Operations Desktop. To reduce storage size and increase database performance the number of output timeseries has been reduced to only include relevant forecast locations - only the timeseries of interest have been added to the scenarios.</p> <p>d. The script manager has been structured with folders for easier understanding and maintenance of scripts.</p> <p>e. There wasn't any database maintenance and archiving. An easily configurable database maintenance and archiving has been implemented. It will have the following advantages:</p> <ol style="list-style-type: none"> 1. Database performance (with database archiving, the database size will be controlled not to exceed a critical size that would compromise database performance). 2. Easy to migrate and share copies of the real-time system. 3. Improve forecasting system stability in the long-term future. 4. No problem to keep the forecasting system online throughout the year. 	<p>Implemented for Blue Nile, Tekeze-Setit-Atbara, Baro-Akobo-Sobat (including White Nile), and Tana basins</p> <p>Operationalization of the forecast models for Dinder, Rahad, and Main Nile between Khartoum and Dongola are outstanding.</p>

¹ The complete system contains the basins of Lake Tana and Baro-Akobo-Sobat. When deploying the Sudan FEWS, these two basins can easily be deactivated, after consulting with the client.

Required Enhancements and Improvements (Longlist)	Status/Remark
<p>4. High-level user interface to flood forecasting systems</p> <p>a. All systems are set up in MIKE Operations Web 2.0. Forecast locations and threshold definitions have been adopted from MIKE Operations Desktop as much as available. The operator view is now the MIKE Operations Web 2.0 website and MIKE Operations Desktop is no longer needed.</p>	<p>Implemented for Blue Nile, Tekeze-Setit-Atbara, Baro-Akobo-Sobat (including White Nile), and Tana basins</p> <p>Threshold definitions are yet to be verified and confirmed by the client and stakeholders.</p>
<p>5. Observed real-time rainfall</p> <p>a. Observed Rainfall was not up to date. The recommendation is to run the forecasting system with observed rainfall as close as possible to time of forecast. Real-time satellite products such as GPM Late and GPM Early could be used and implemented in the real-time flood forecasting systems. If station data are available, then the satellite rainfall observations could also be bias-corrected with respect to station observations.</p> <p>The new development database uses GPM Late rainfall as observed rainfall product up to time of forecast.</p>	<p>Implemented</p>
<p>6. Dissemination</p> <p>a. The review did not identify routines for disseminating automatic messages of flood warnings and alerts to relevant stakeholders. The recommendation is to implement automatic notifications via established notification channels (e.g. email and/or dedicated mobile app) to relevant stakeholders.</p>	<p>Not implemented yet.</p> <p>This will be carried out when all models and forecast locations are implemented. For this, names and e-mail addresses of recipients of messages/notifications will be compiled in collaboration with the client.</p>
<p>7. System Monitoring</p> <p>a. It is recommended to introduce automatic messages on the system status, i.e. the job status of the scheduled jobs in the real-time forecasting system.</p>	<p>Not implemented yet.</p> <p>This will be carried out when all models and forecast locations are implemented. In that course, designated operators will be identified.</p>
<p>8. Data Assimilation</p> <p>a. It is recommended to introduce data assimilation in appropriate model locations if real-time water level or flow observations are available.</p>	<p>This will be investigated when all necessary data becomes available</p>
<p>9. Visualization of Gridded Rainfall</p> <p>a. The web presentation of the real-time flood forecasting systems should be improved by visualizing the input gridded rainfall products.</p>	<p>Implemented</p>

Required Enhancements and Improvements (Longlist)	Status/Remark
<p>10. Ensemble Forecasting</p> <p>a. To capture the uncertainty of the real-time water level and flow forecasts, ensemble forecasts could be produced using other products of available rainfall forecasts, e.g. national rainfall forecast products.</p>	<p>This is not necessary and hence will be discarded. WRF is a tailored deterministic numerical weather prediction model. It does not have an ensemble of forecasts.</p>
<p>11. Forecast Performance</p> <p>a. The use of the real-time flood forecasting system could be informed by collecting and reporting on the forecast performance with respect to measured water level and/or flow, if available.</p>	<p>The tools for this will be configured before June 2024, so that the performance evaluation can be carried out during the next flood season.</p>
<p>12. Bias-Correction</p> <p>a. The performance of the real-time flood forecasting systems could be improved by applying bias-correction to the observed and forecasted rainfall.</p>	<p>This is not necessary and hence will be discarded, but the consultant is ready to advise on this matter if/when necessary. WRF is a tailored, downscaled and bias-corrected numerical weather prediction model.</p>
<p>13. Deployment</p> <p>a. It is recommended to deploy the system (Water Tools Portal, MIKE Operations Web 2.0, MIKE Workbench, and the embedded modelling tools) in the cloud. The consultant shall support the client in the selection of and adequate cloud service provider.</p>	<p>Not implemented</p> <p>The system will be deployed on a cloud server of the client's choice when the forecast system is technically ready for migration.</p>

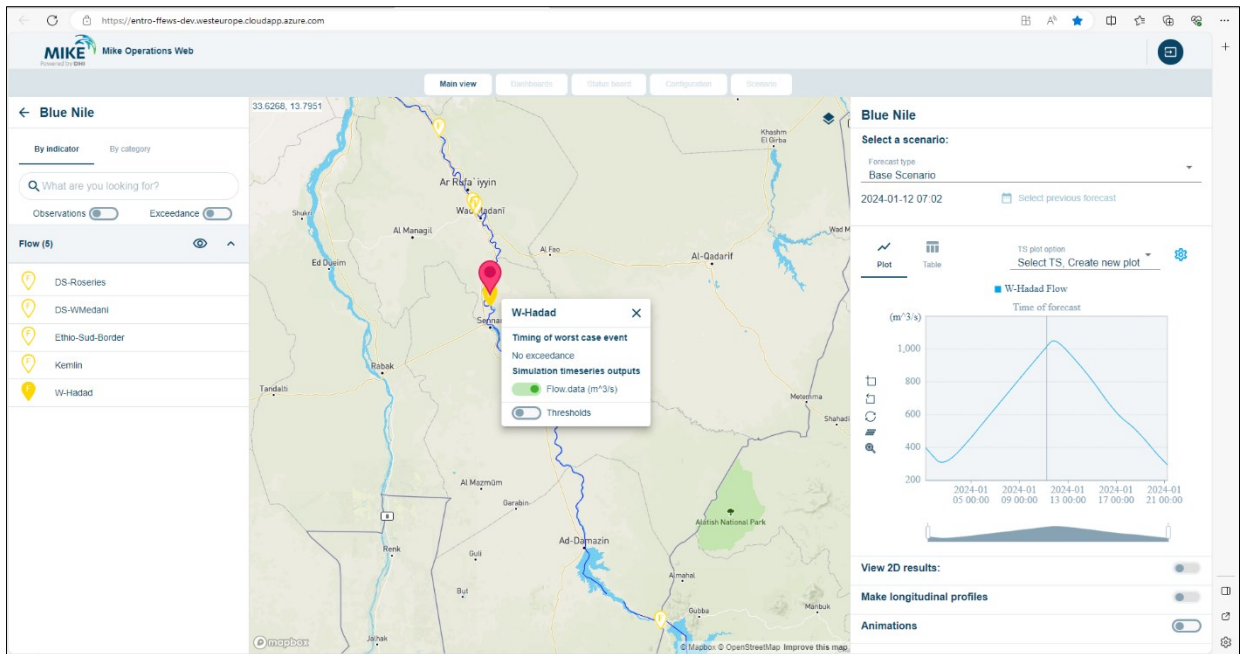


Figure 2 Screenshot of exploring forecasts with the enhanced EN-FFEWS

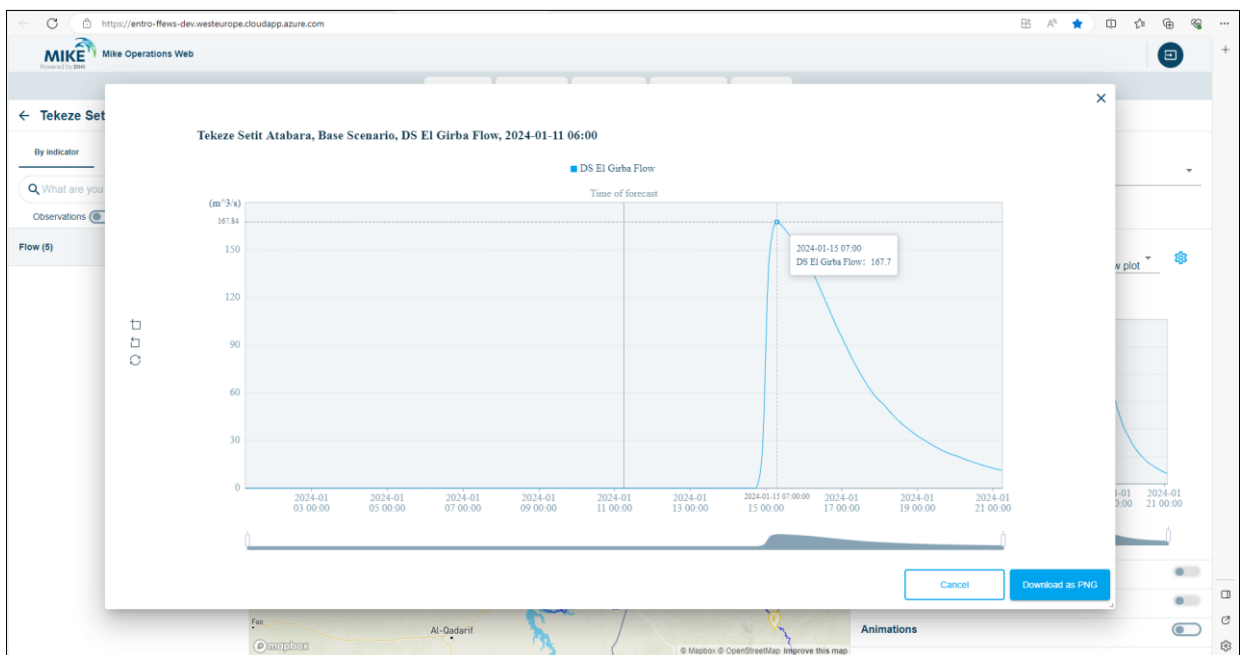


Figure 3 Screenshot of visualizing forecasts with the enhanced EN-FFEWS

The rainfall products used as input to the forecasting models are as follows:

- GPM: the Global Precipitation Measurement rainfall product is a dataset that provides information about rainfall distribution and intensity on a global scale. It is derived from data collected by the GPM satellite constellation, which includes microwave sensors capable of measuring precipitation from space.
- WRF: the Weather Research and Forecasting rainfall product is a dataset generated by the WRF model; a widely used numerical weather prediction system. It provides information about

rainfall distribution and intensity over specific regions and time periods. The WRF model simulates atmospheric processes to forecast weather conditions, including precipitation.

- GFS: the Global Forecast System rainfall product is a dataset produced by the GFS model; a numerical weather prediction system operated by the National Centers for Environmental Prediction (NCEP). It provides forecasts of rainfall distribution and intensity globally and at various spatial and temporal resolutions.

The following terms are defined to aid understanding of the generation of input rainfall to the models:

- SOS: Start of Simulation, the first date and time of the simulation.
- TOF: Time Of Forecast, representing the specific date and time at which a forecast is made or is valid from. In other words, it indicates the moment where observations end, and predictions start.
- EOS: End Of Simulation, the last date and time of the simulation.

In the real-time operations, the concatenation of rainfall products occurs in the following order:

- GPM rainfall, with a factor of 0.7, from SOS to TOF.
- WRF rainfall, from TOF to EOS.
- If the resulting time series does not cover until EOS, GFS rainfall is used to complete the input.
- If the resulting time series still does not cover until EOS, zero rainfall values are appended to ensure the model has the correct input.
- If there is any missing data between the first GPM value and SOS, the input time series is filled with zero rainfall values to ensure the model runs correctly.

3 Summary and Conclusions

The EN-FFEWS **software** has been:

1. consolidated to one coherent system,
2. upgraded to the latest version of the forecasting system (MIKE Workbench in the backend + MIKE Operations Web in the front end),
3. optimized, and
4. migrated to a development site in the cloud.

The system contains the improved models for Blue Nile, Tekeze-Setit-Atbara, Lake Tana, and Baro-Akobo-Sobat (including White Nile).

The remaining activities regarding the software system are:

1. embedding the models for Dinder, Rahad and Main Nile between Khartoum and Dongola (the models are developed and ready for operationalization)
2. configuration of thresholds for alerting purposes,
3. configuration of the dissemination system,
4. testing, and
5. migration to a cloud server of the General Administration of Nile Water Affairs' choice.