Upgradation of the existing RTSF and ROS System for the Krishna Bhima Basin in Maharashtra using DSS(PM) with O&M

Inception Report

June 2022

Prepared for Hydrology & DAM Safety
Govt. of Maharashtra

This report has been prepared under the DHI Business Management System certified by Bureau Veritas to comply with ISO 9001 (Quality Management)

Approved by

Dr. Tirumaleswara Reddy
Head of Water Resources, International Development

Upgradation of the existing RTSF and ROS System for the Krishna Bhima Basin in Maharashtra using DSS(PM) with O&M

Inception Report

June 2022

Prepared for Hydrology & Dam Safety, Govt. of Maharashtra

Represented by Chief Engineer

Report Author	Mr. Manish Kumar
Quality Supervisor	Dr. Tirumaleswara Reddy

Project number	63802634
Approval date	07.06.2022
Revision	2.0
Classification	Confidential

DHI (India) Water & Environment Pvt Ltd • Unit No. 815 • Eighth Floor • DLF Prime Tower • Plot No. F-79-80
Okhla Phase-1 • New Delhi-110 020 • India • Telephone: +91 11 4704 6256 • www.dhigroup.com

Contents

List of figures

List of tables

1 Introduction

The Water Resources Department (WRD) of Government of Maharashtra (GoM) is entrusted with the surface water resources planning, development, and management. A large number of major, medium and minor water resource development projects (reservoirs and weirs) have been constructed in Maharashtra. Real Time Stream Forecasting (RTSF) and Reservoir Operation System (ROS) was developed for operational management of these reservoirs under World Bank aided Hydrology Project Phase II (HP-II) initiated by the Ministry of Water Resources (MoWR), Government of India.

The geographical area of Maharashtra state is 3,07,713 km^2. Major river in the state is Krishna River with its major tributary as Bhima, Godavari, Tapi and the West flowing rivers of Konkan strip. Maharashtra receives rainfall from both south-west and north-east monsoons. The state has very highly variable rainfall ranging from 6000 mm in upper catchments to 400 mm in shadow areas of lower catchments. Majority of rainfall mainly occurs in a four-month period between June to September with the number of rainy days varying between 40 to 100.

The hydrological, hydrodynamic, and real time flood forecasting modules are main features of existing RTSF & ROS. The system has been developed by DHI (India) Water & Environment Pvt. Ltd., New Delhi as a lead consultant with DHI A/S, Denmark and Riverside Technology, USA subsidiaries as a part of contract *RTDSS: HPII/MAHA (SW)/2/2011* signed on 27 July 2011. The RTSF & ROS is in use since 2013 monsoon season. The existing RTSF & ROS process is summarized below:

- The existing flood forecasting system for Krishna & Bhima basin was developed using MIKE 11 suite in 2012-13
- Presently 3-day Numerical Weather Forecast is being provided by IMD with 3 X 3 km resolution.

The state experiences flash floods particularly in Western Ghats including Krishna and Upper Bhima basins. For instance, Sangli and Kolhapur districts in Krishna Basin and Pune and Solapur districts in Bhima basin experienced severe flood several times during recent decade.

WRD, Govt. of Maharashtra intends to upgrade the existing Real Time Stream Flow (RTSF) and Reservoir Operation System (ROS) for operational management of reservoirs in Krishna – Bhima basin of Maharashtra. For this, a contract with DHI has been signed on 7th of April 2022 and project initiated from 14th of April 2022.

1.1 Project objective

a. Upgrade the existing Real Time Streamflow Forecasting and Reservoir Operation System developed for Krishna and Bhima Basins into latest available version of the Software, as a part of DSS(PM).

b. Develop reservoir operation plans for flood moderation, considering synchronous operation of complex reservoirs.

c. Develop capabilities for inundation forecasting in the downstream reaches through 2D or coupled 1D-2D modelling for the flood affected areas in the basin for example over Sangli, Pandharpur, Kolhapur and Pune.

1.2 Scope of work

The scope of the work as per the contract is as follows,

a. Upgrade the existing database for improved hydrological forecasts (including flood forecasts and inundation forecasts at specified locations). This will include inputs from historical data in the HIS, inputs from real time systems (RTDAS for stations measuring precipitation, climate, reservoir and river flow stage levels) and manual systems (e.g. via SMS/manual entry etc.) and inputs from satellite-based estimates and numerical weather forecasts from IMD as well as other sources of rainfall forecasts.

b. Provide one monsoon season maintenance of existing RTSF and ROS

c. Export & upgrade the existing hydrological and 1D hydrodynamic models developed in MIKE 11 to MIKE Hydro River for the Krishna Bhima Basin.

d. Upgrade the existing MIKE Customized version of the database platform of RTSF & ROS into MIKE Operations.

e. Upgrade the existing web-portal www.rtsfros.com as per WRD, Maharashtra requirements

f. Develop a customized dashboard system to display the historical as well as real-time hydrometeorological data and streamflow forecast.

To achieve these objectives, the work has been divided into following 5 tasks:

1. Task 1: Review of Current RTSF & ROS System
2. Task 2: Upgrade MIKE 11 version/MIKE HYFDRO River & Current RTSF & ROS System
3. Task 3: Capacity building
4. Task 4: Operation and Maintenance of RTSF and ROS
5. Task 5: AMC and O&M support of Upgraded RTSF and ROS for 2023 monsoon seasons

This report summarizes the work done in Task 1.

1.3 Current Report Structure

The various activities in Task 1 include a review of existing forecasting systems for weather and river flows, compilation of current practices with reservoir operation and flood management practices in the Krishna and Bhima basins, and identification of flood management and reservoir operation scenarios.

The detailed tasks include:

i. Review the available historical data in data base and update the existing data base.

ii. Review the existing hydrologic and 1D hydrodynamic model. Review the available Numerical Weather Forecasts from various sources and suggest using the appropriate weather forecast products in addition to NWF from IMD and further incorporation of suggested NWF into the model. Also, IMD rainfall forecast (weighted average rainfall forecast of all sub basins) should be compared with actual telemetry point rainfall of respective sub basin.

iii. To solve issues related with scripting or programming if any, it requires additional/new

script for smooth and uninterrupted functioning of the system; like auto saving of the model simulation result & forecasting result in excel or as per required format by a WRD officer.

iv. Develop a new script for quality checking of real time data before it updates/appends in database.

v. Identify any improvements required for forecast result dissemination.

vi. To suggest for Procurement of Satellite Images for River Basins in Maharashtra to carry out calibration and validation of flood inundation predicted through the modelling exercise. Even though limited provisions would be available from the state for this purpose, the focus should be to make best utilisation of the optical and radar sensor images available in the public domain.

vii. Review of existing I.T infrastructure/hardware and software at data center, and appropriate suggestions for efficient and long-lasting working of system at the earliest.

Output 1 - Inception Report: Findings from the review of the current RTSF & ROS System including process report of consultations and actions taken for its upgrade. It includes fortnightly Gantt chart of work plan to ensure timely delivery of outputs as well as plans for deployment of personnel.

2 Review of Existing RTSF & ROS

A visit to the Basin Simulation division, Pune under Chief Engineer, Hydrology and Dam Safety of Govt. of Maharashtra from 02nd to 06th May 2022 was made by DHI expert Manish Kumar. During this visit, several tasks for deliverable 1 have been accomplished. This includes reviewing the available historical data in database, RTDAS, IMD rainfall forecast and existing hydrologic and hydrodynamic models. The current practices and shortcomings with the operational management of reservoirs were reviewed.

Also, the current practices of RTSF and ROS, details of job scheduling, scripts utilized for various processes and results dissemination were reviewed. The various scenarios that are required for successful operation of RTSF and ROS were also explored.

The following limitations are highlighted during the review of exiting RTSF & ROS:

One major limitation of the existing RTSF & ROS is database size and system performance capabilities. The database stores all simulation files since 2014 as a back-up in the database and these files are also saved on workstation which is used for offline scenario generation. This leads to utilization of huge data storage and if the same continues, there will be no storages available after few years.

Another limitation is performance of the existing RTSF & ROS in its current version. It has been observed that the system is frequently slowed or hung, and the Platform shell crashes.

Some other limitations are the inability to use the system while a specific process in Platform shell is running.

Considering 2D flood inundation model need to be included for some of the downstream areas, there will be a shortage of spaces if remedial measures are not taken.

Client also wanted to explore the option of multiuser working on the databases for better and improved analysis especially during scenario generation and post monsoon.

2.1 Evaluation of the existing system

Based on the input from client and best practices followed for real time operational management of RTSF and ROS or other similar system, the existing system was reviewed.

A. Hardware review

The first step was to evaluate the workstation configuration, hard-disk space, files, and folder's structure.

Device specifications

Device name	RTSFROS-FS
Processor	Intel(R) Xeon(R) CPU E31220 @ 3.10GHz 3.10 GHz
Installed RAM	12.0 GB
Device ID	96ED4C79-958C-426A-86BA-80F40CC917EE
Product ID	00330-80000-00000-AA385
System type	64-bit operating system, x64-based processor
Pen and touch	No pen or touch input is available for this display

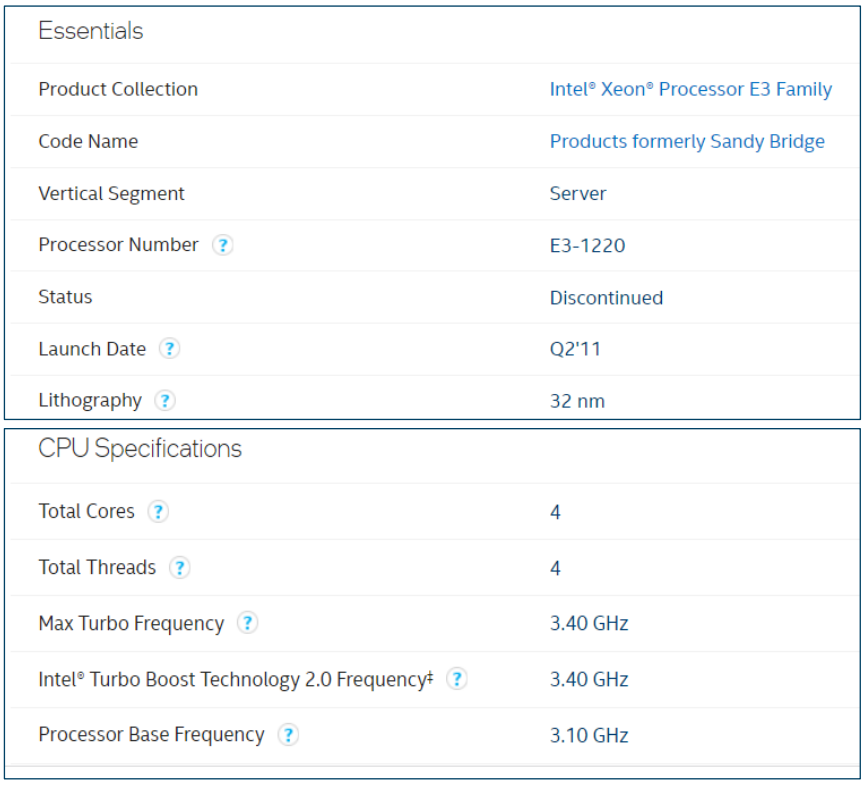
Copy

Rename this PC

Windows specifications

Edition	Windows 10 Pro
Version	21H1
Installed on	24/09/2020
OS build	19043.1645
Experience	Windows Feature Experience Pack 120.2212.4170.0

Figure 2.1 Workstation Configuration.



Essentials

Product Collection	Intel® Xeon® Processor E3 Family
Code Name	Products formerly Sandy Bridge
Vertical Segment	Server
Processor Number	E3-1220
Status	Discontinued
Launch Date	Q2'11
Lithography	32 nm

CPU Specifications

Total Cores	4
Total Threads	4
Max Turbo Frequency	3.40 GHz
Intel® Turbo Boost Technology 2.0 Frequency‡	3.40 GHz
Processor Base Frequency	3.10 GHz

Figure 2.2 Processor specification

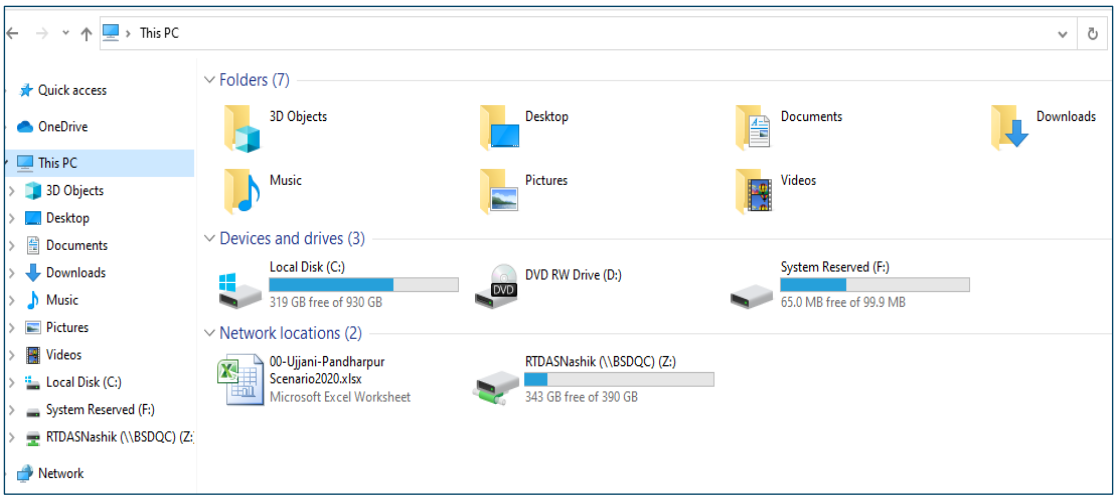


Figure 2.3 Available space in hard disk

With 12 GB RAM and more than 300 GB space available on hard disk, the system should perform fine but considering the regular operation of RTSF and ROS, it will not take much time to consume these spaces. The intel processor was launched in 2011 and a better processor is available in the market now. The number of CPU cores is four and it is suggested to have higher core system for fast performance especially during 2D flood inundation modelling.

A better performance modelling server would have been required for the operational management of desktop version of RTSF and ROS. Server also provides multiuser access i.e., more than one person can login to the same system and database and work on it simultaneously. However, once RTSF and ROS are upgraded as part of DSS (PM), it can be operated though web dashboard, and so new modelling server is **not** required for operational management of upgraded RTSF and ROS. An advanced workstation (proposed new workstation) will provide enough capabilities to perform various analysis and manual scenario generation or other system performance related studies while the complete operational RTSF and ROS will be uploaded on NIH based server with access to client through web based DSS (PM) platform.

The existing website www.rtsfros.com will be updated and published through existing web server in RTSF and ROS center only. The existing web server is more than 8 years old and without AMC. Scope of hosting the website from NIH server will be explored and in case it is not permitted, then client can purchase another web server for hosting the website and use the existing webserver as a backup. Consultant will provide the latest hardware configuration for the web server.

B. Software review

Current workstation is using MIKE 11 - 2014 version Service Pack 3 and MIKE Customized – Platform Shell version 2014.5 with PostgreSQL 9.0 and PostGIS 2.0. Lots of advancement has been made since 2014 both in modelling software as well as windows operating system. MIKE software packages upgrades are compatible with windows upgrades. Since client does not have any SMA (Software Maintenance Agreement) package for modelling software upgrades, it is a challenge to check If existing MIKE software package can be installed on new workstation.

Since existing workstation is using same windows, there is a scope that existing MIKE software package may work on this system. DHI does not provide guarantee of software reinstallation on new hardware when not in SMA, however under this project, DHI will help client to install the existing software on new hardware with the following configuration:

Dell Intel Core i9 11900 32 GB/ 1000 GB HDD/ Windows 10 Professional Dell[R]
(Dell OptiPlex 7090 Tower)
Processor Make Intel
Processor Generation11
Number of Cores per Processor8
Processor Description Intel Core i9
Processor Number Intel Core i9 11900
Chipset Series Intel Q Series
Chipset Number Intel Q570
Operating System (Factory Pre-Loaded)Windows 10 Professional
RAM Size (GB)32
RAM Expandability up to(using spare DIMM Slots in GB)128
Type of Drives used to populate the Internal BaysHDD ,SSD
Total HDD Capacity (GB)1000
Total SSD Capacity (GB)512

Figure 2.4 New workstation configuration which client is expected to purchase

C. Database maintenance and review

A new workstation with high RAM and CPU cores is expected to improve the performance of the system. Additionally, there is also a need to evaluate the database. MIKE Workbench is an interface developed over postgres DBMS. Database Manager utility tool of MIKE Workbench is used to create, update, backup or restore databases, However the same can also be assessed directly using pgAdmin. It has been observed that there are two databases created for this project namely KB_2016 and KB_Test. KB_2016 is operational while KB_Test is an older database and not used for any real time operation.

Figure 2.5 below shows both the databases as viewed through PgAdmin while Figure 2.6 shows the space consumed by both these databases.

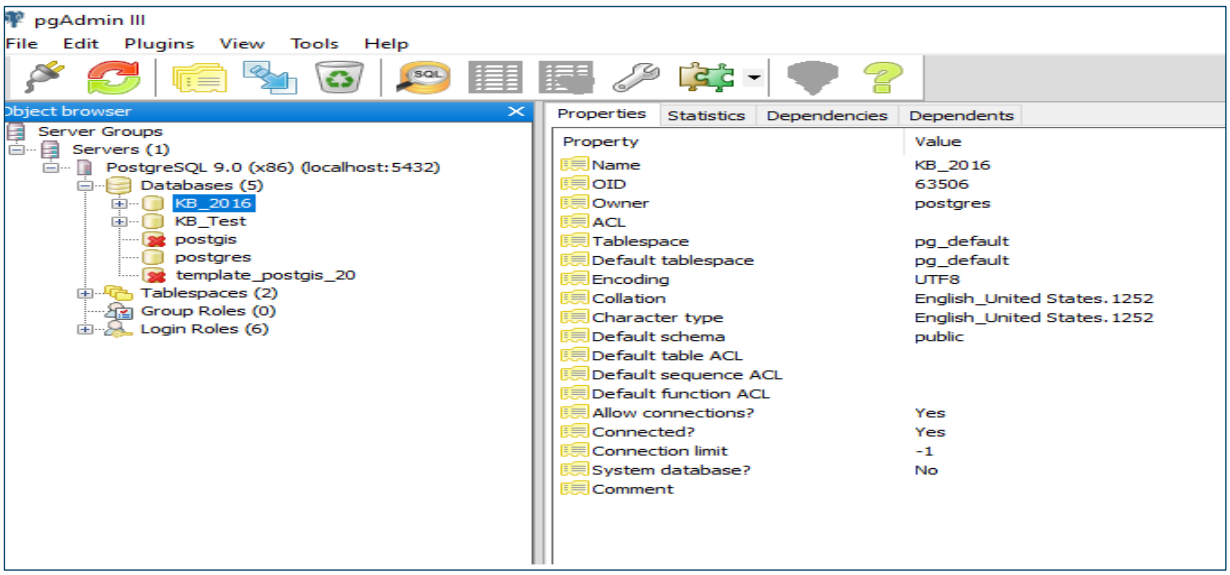


Figure 2.5 PgAdmin screenshot showing available databases

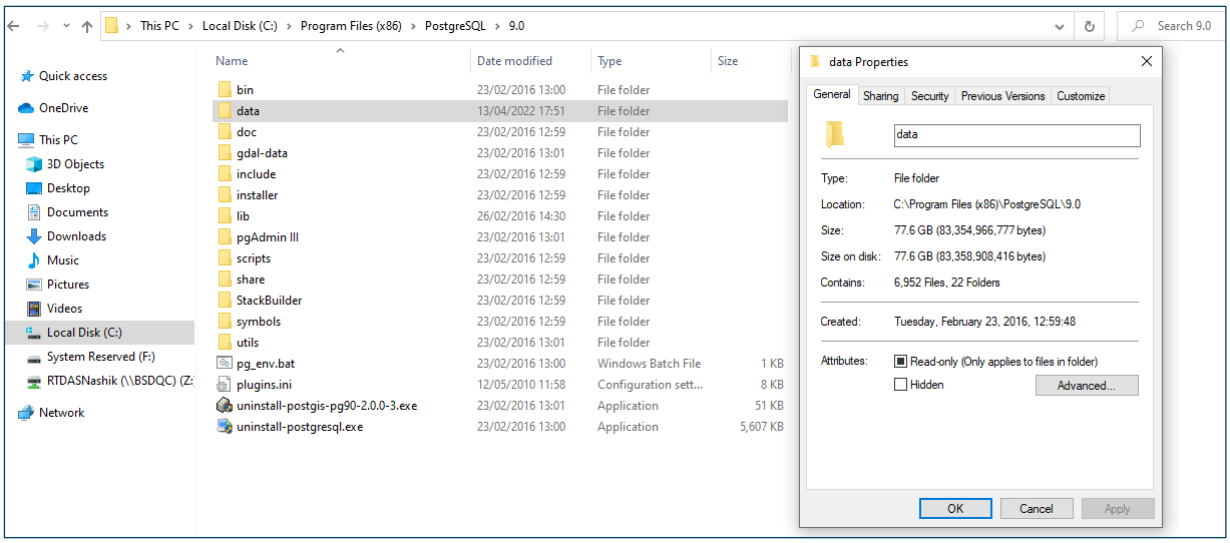


Figure 2.6 Hard disk spaces occupied by Database (Postgres DBMS)

As the database was not maintained (vacuum) for a long period, it may also lead to slow performance and jobs getting hung. The database was last vacuumed by consultant Kavita Patil during the period 2019-2020 only. So, full vacuum of the KB_2016 database has been applied. It took almost an hour for full maintenance of the database. Figure 2.7 and 2.8 shows maintenance of the database.

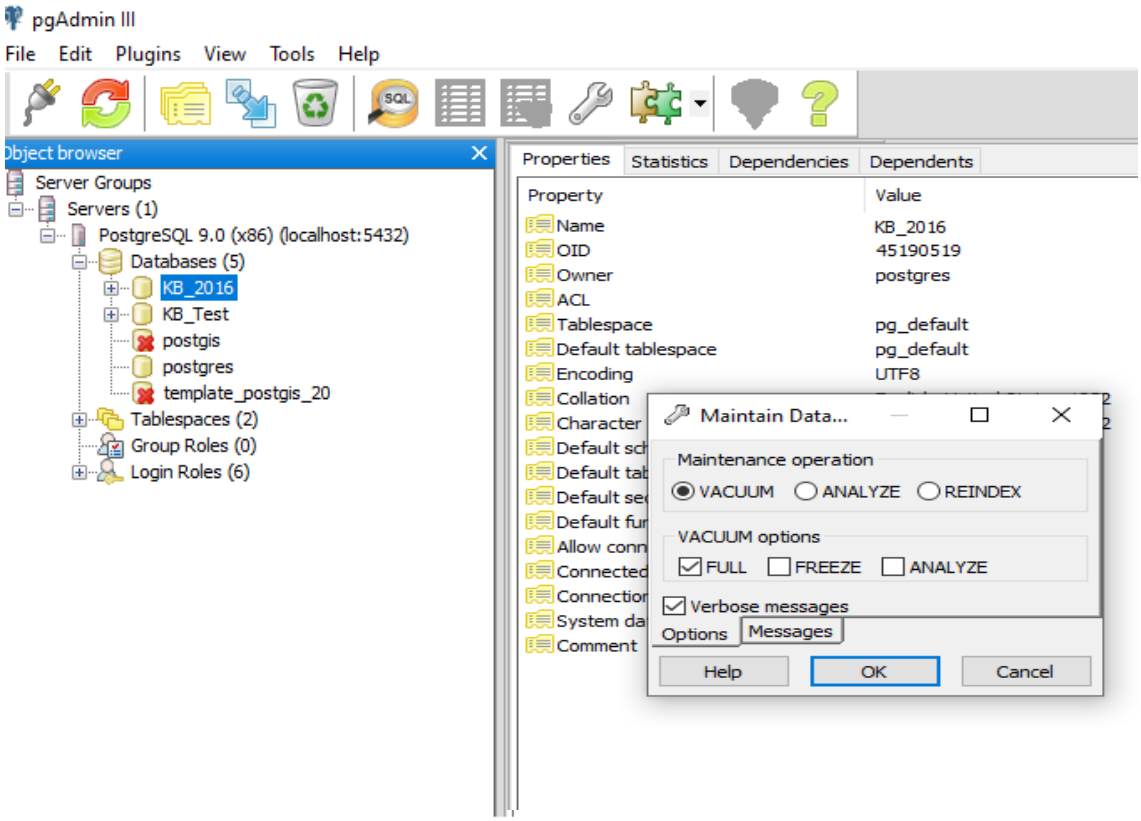


Figure 2.7 Maintenance of the database

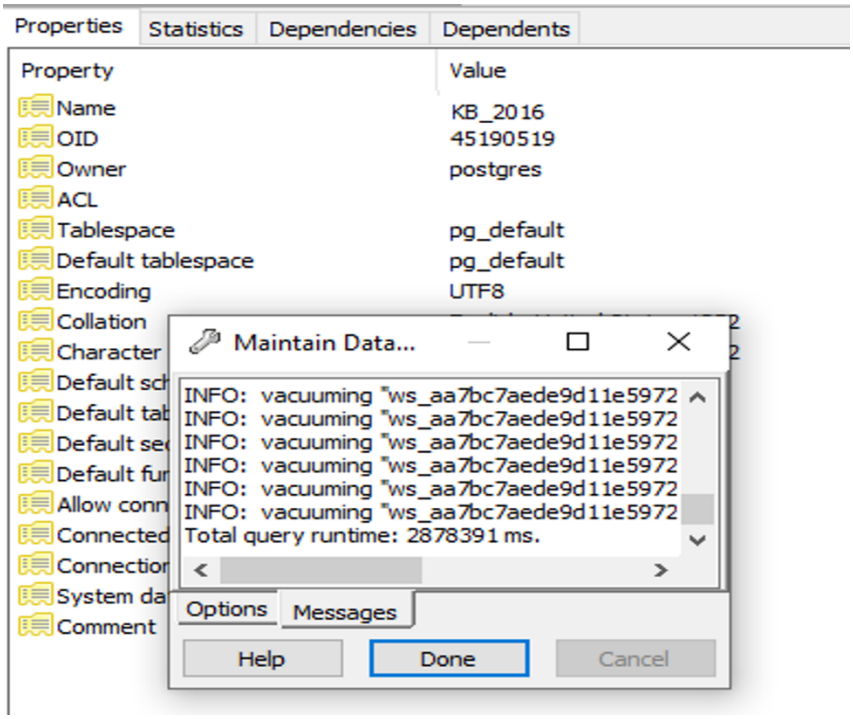


Figure 2.8 Maintenance complete report

After maintenance of the database, KB_Test database was deleted as it was not used and only kept as a test case. Once the database was deleted, the next task was to check if backup of the existing database can be restored. It is a very important task and one of the major capabilities of this system. The whole database can be backup in one file and can be restored within hours on any system. This helps transfer of database to another system or restored to last saved database in case of fire, flood or any other force majeure which leads to crashing of system or database. So, it is very important that the database can be restored back.

To test this, a back of the KB_2016 database was made. Figure 2.9 shows the screenshot of backup of the database using DSS Manager Utility application of MIKE Workbench.

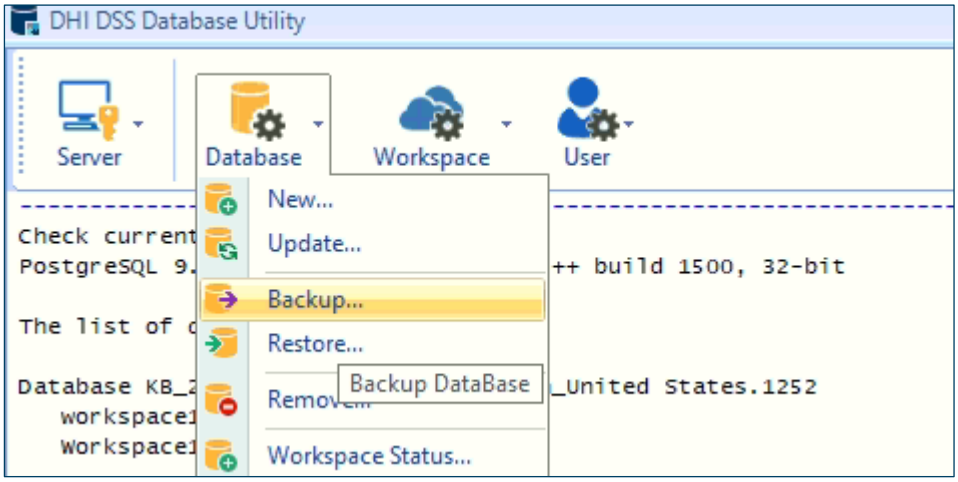


Figure 2.9 Backup of the KB_2016 database

This backup database was then restored as KB_2022_update1. Figure 2.10 shows the list of both KB_2016 and KB_2022_update1 database.

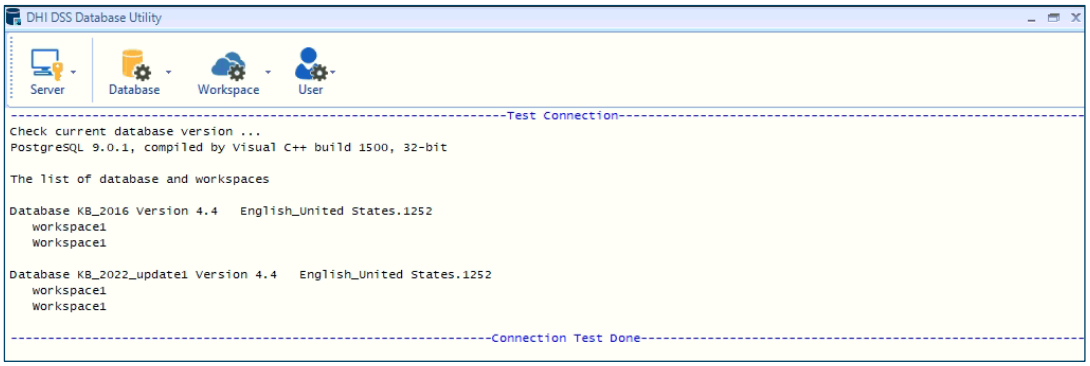


Figure 2.10 List of the database including restored database

However, there was an issue while accessing this restored database using platform shell. The database was compared with a running database, and it has been observed that there was an issue in restoring the master schemas.

When an object is created, it is assigned an owner. The owner is normally the role that executed the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, privileges must be granted. There are different kinds of privileges: SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, TRIGGER, CREATE, CONNECT, TEMPORARY, EXECUTE, and USAGE. The privileges applicable to a particular object vary depending on the object's type (table, function, etc).

There were no privilege types in ACL (Access control List), so access was provided to admin, workspace_lead, workspace_member and workspace_reviewer using Grant All and Usage access as shown in figure below:

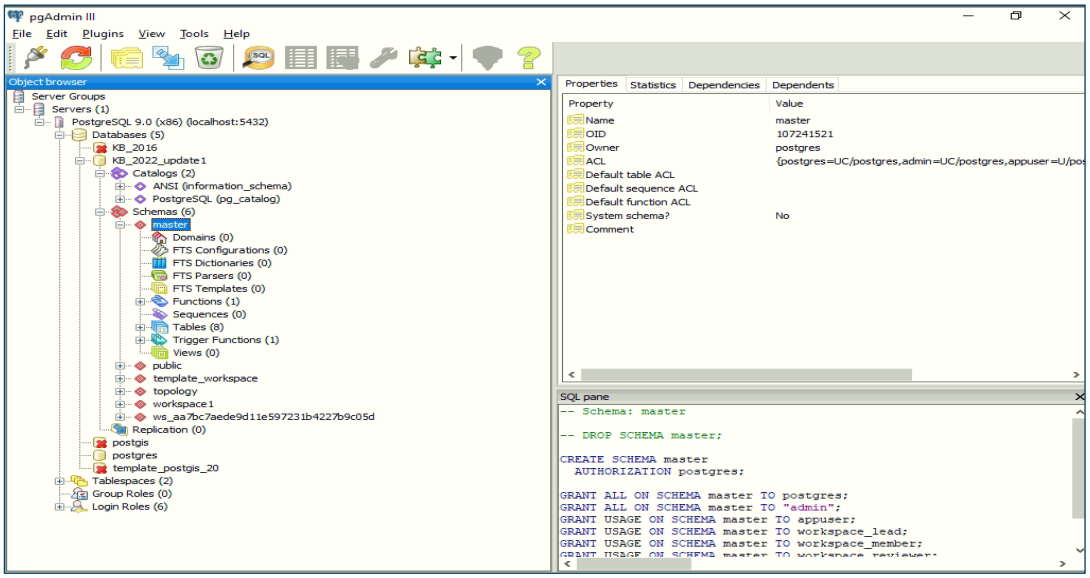


Figure 2.11 Grant privileges to different users in Access Control list in master schemas

After providing privileges, the database can be accessed using Platform shell. Figure 2.12 and Figure 2.13 show connection to KB_2022_update1 database.

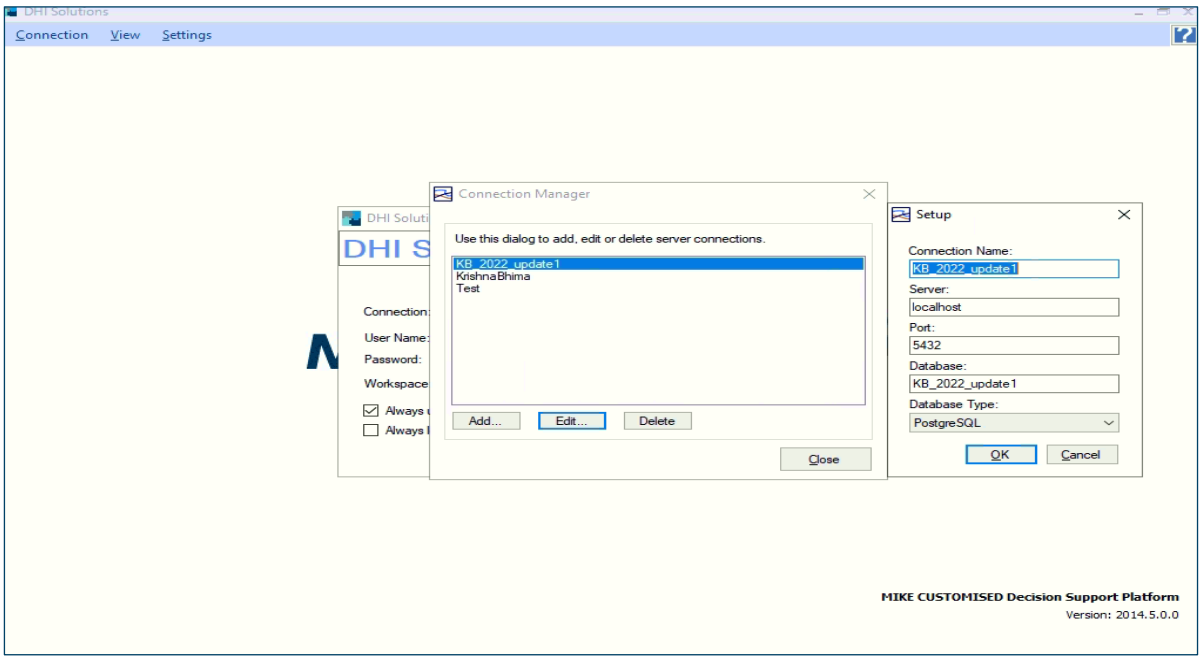


Figure 2.12 Connection to KB_2022_update1 database in platform shell

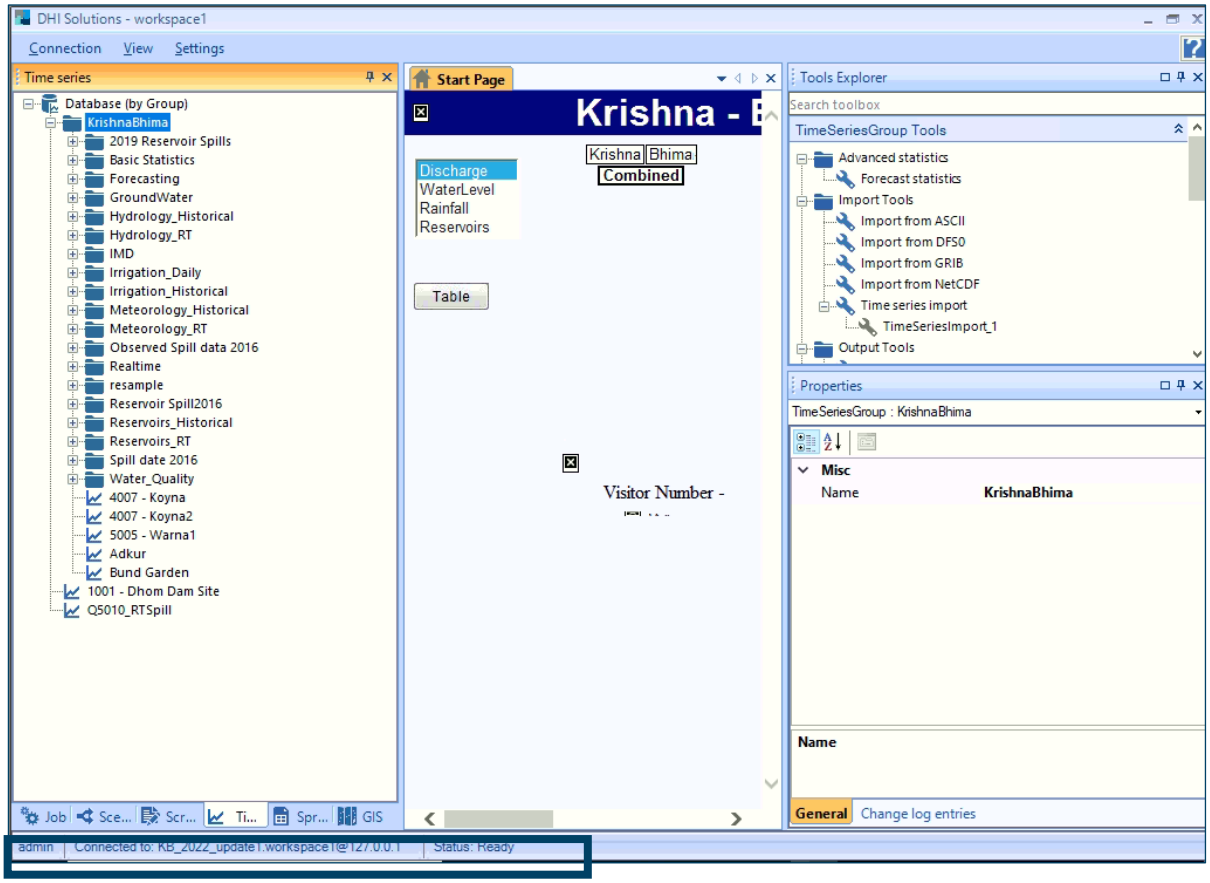


Figure 2.13 KB_2022_update1 database connected in platform shell

After restoring capabilities of the existing database is checked, this database can be restored on other system in modelling center especially during post-monsoon for offline scenarios and performance study. However, the restored database on other systems will not get regularly updated as no jobs are scheduled on their system and so every time for new analysis with latest data, backup from active database and restoring it on other system should be performed. To work simultaneously on the same database with the same workstation is possible only through a server. However, considering the fact that the existing system has to be maintained only till 2022 monsoon and afterward the database can be accessed through web dashboard, it is not suggested to go for modelling server purchase and only workstation is suggested for modelling center. Also, the Windows server will require an updated MIKE software package. In future it is a viable option to upgrade MIKE Software packages for desktop versions as well for enhanced performances and additional modelling capabilities especially after 2023 monsoon or after completion of this project.

D. Database structure review

After evaluation of the system and database, database structure was evaluated. It has been observed that copies of various time series have been made in the database. It was difficult to identify the files which are regularly updated, historical files and copy of the files which need to be deleted.

Figure 2.14 shows the original file structure and the updated file structure.

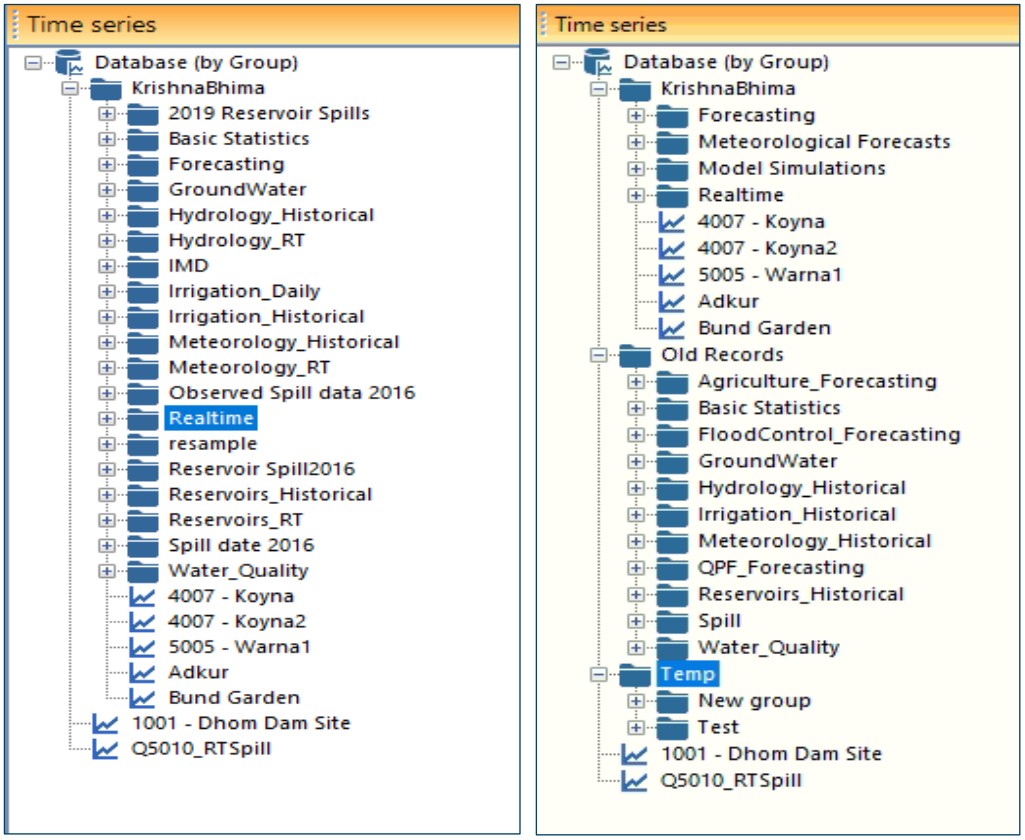


Figure 2.14 Timeseries explorer with original file structure (left side) and updated file structure (right side)

The original database had only one main folders. It was difficult to differentiate between timeseries which are updating regularly and timeseries which is just a copy for evaluation and analysis or part of old records. So, the folders were rearranged into 3 sub folders:

1. KrishnaBhima
2. Old Records
3. Temp

All old records and analysis folders were shifted to old records. Duplicate folders and files which are created for short analysis and are duplicates of original files/folders are shifted to Temp folder. Temp folder will be cleared after a regular interval of 3 months. The client is suggested to move all duplicate files/folder which is created for short term learning or analysis to Temp folder.

Only KrihsnaBhima folder is regularly updating with real time data and modelled results. KrishnaBhima Folder was further divided into sub folders namely

a) Realtime (showing Realtime RTDAS data),
b) Meteorological Forecasts (with IMD forecast as of now),
c) Model Simulations (catchment runoff, River discharge and reservoir inflows in real time and forecasted period) and
d) Forecasting (daily simulation results).

The Forecasting folder contains daily simulation modelled results from the start of simulation till date. This is taking up lots of spaces. A process will be developed to save results for each location in a single file for real time and forecasting periods. A script will be written to extract information of real time and forecasted result from previous simulated results saved in the Forecasting folder. Once this is completed, we can keep only last monsoon run files in this folder and delete the rest.

As Database has been maintained, it is comparatively fast to work without the system getting hung. Many statistical tools were applied on various time series processing. Statistics tools like such as periodic statistics, extract time series, shift timeseries, maximum, daily, monthly yearly average/maximum, and many other tools including creating own tools with multiple sub tools and it is explained to client. It has been observed that database tools can be used efficiently now.

Similarly, folder structure of Desktop and C drive is also updated removing duplicate folder and files. There was one folder with more than 100 GB space, it has been shifted to client hard disk. The client is expected to maintain these structures for easy handling of processes. Thousands of folders and sub folders with data analysis shifted to the folder named *Analysis files. To Delete* folder will be deleted after activation of the model for this monsoon in consultation with client.

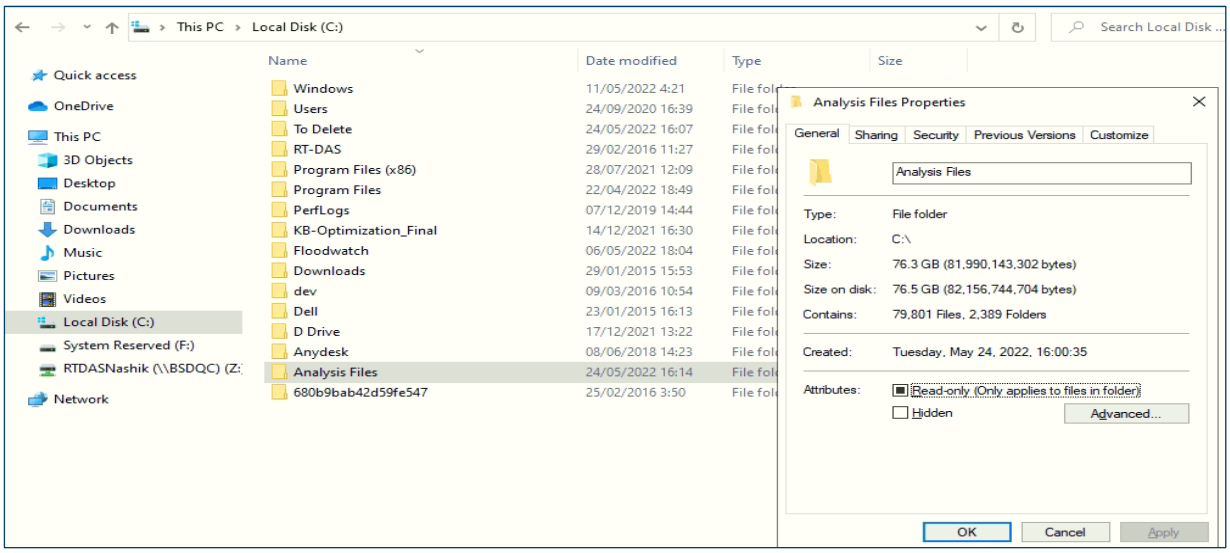


Figure 2.15 C Drive of the workstation with modified folder structure

E. Historical and RTDAS timeseries review

Once database is structured, real time and historical timeseries has been reviewed for its quality. It has been observed that there has been gaps in timeseries for certain period. The precipitation timeseries are step accumulated and if there are time gaps in timeseries, it will give a wrong representation and so it needs to be modified before use for modelling task. This will be done using a script where in a timeseries with gaps of more than 2 hour, a blank timestep will be introduced with no rainfall to make the step accumulation correct.

	Time	1:Dhom [millimeter]
144	6/16/2014 08:00:00	4
145	7/3/2014 08:00:00	0
146	7/9/2014 08:00:00	3
147	7/16/2014 08:00:00	16
148	7/17/2014 08:00:00	23

	Time	1:Dhom [millimeter]
144	6/16/2014 08:00:00	4
145	7/3/2014 08:00:00	0
146	7/9/2014 08:00:00	3
147	7/15/2014 08:00:00	
148	7/16/2014 08:00:00	16
149	7/17/2014 08:00:00	23

Figure 2.16 Timeseries correction in database

Also, while creating hourly timeseries from accumulated timeseries, it has been observed that when there is a gap of few months, an arbitrary rainfall is added to the timeseries leading to error in timeseries and this will be removed to correct the time series as shown in figure 2.17 and 2.18 below:

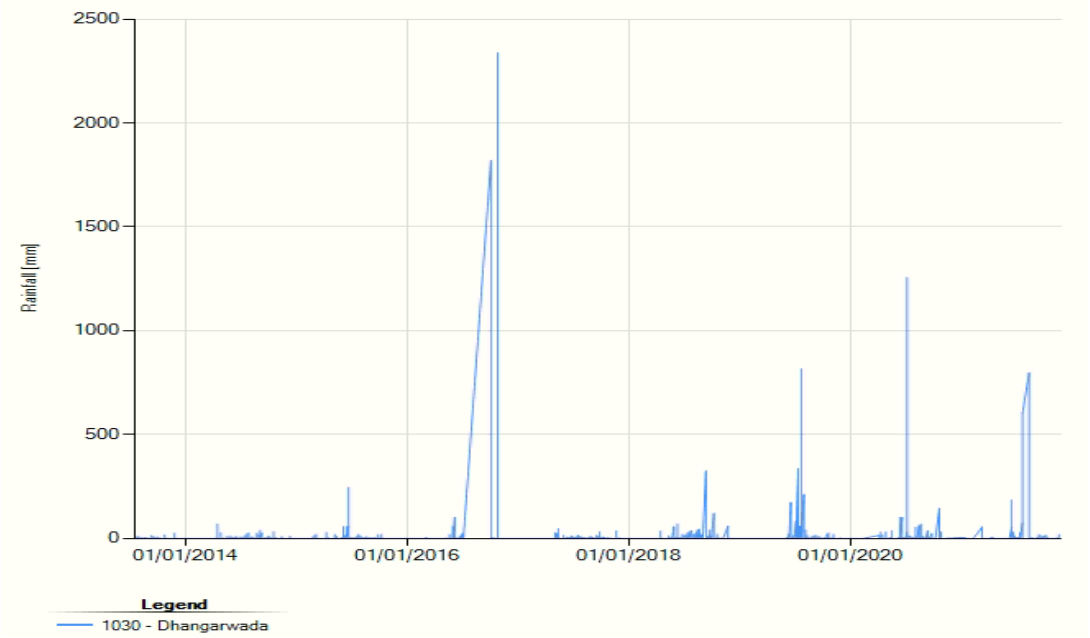


Figure 2.17 Precipitation time series in data base before correction

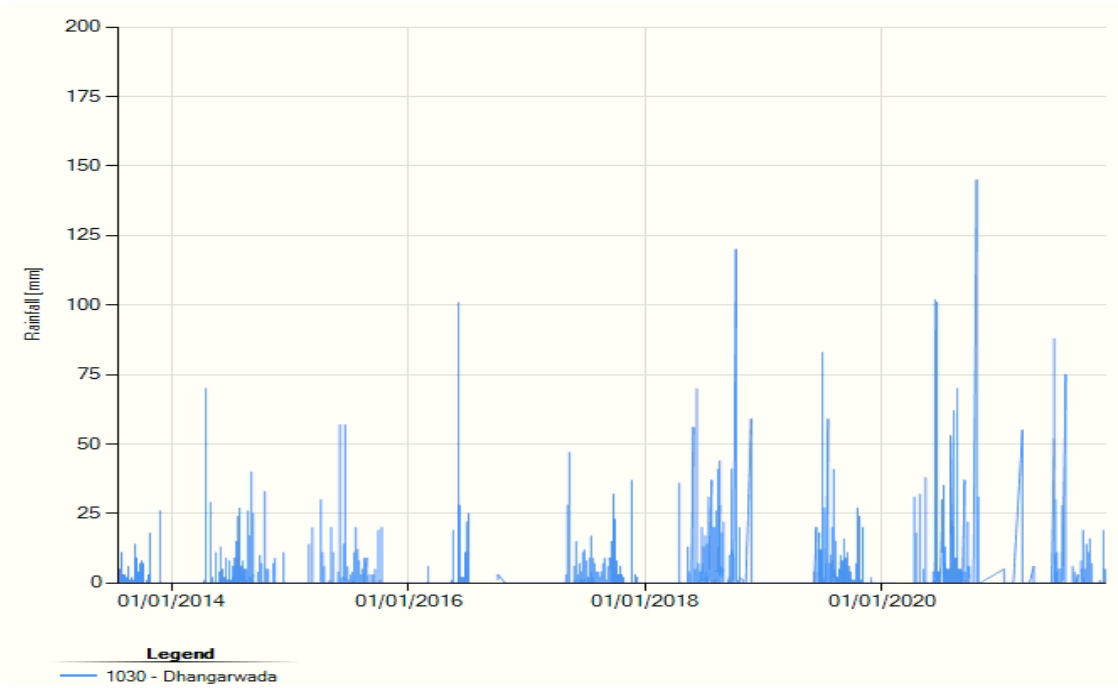


Figure 2.18 Precipitation time series in data base after correction

Similar corrections through script will be applied for all-timeseries before using it for model calibration.

F. Review of existing website

The existing website http://www.rtsfros.com/ has been reviewed and it has been observed that there are certain limitations in the existing web dissemination and so upgrading of website is also required. One of the improvements required is for presenting the result complex wise on web site.

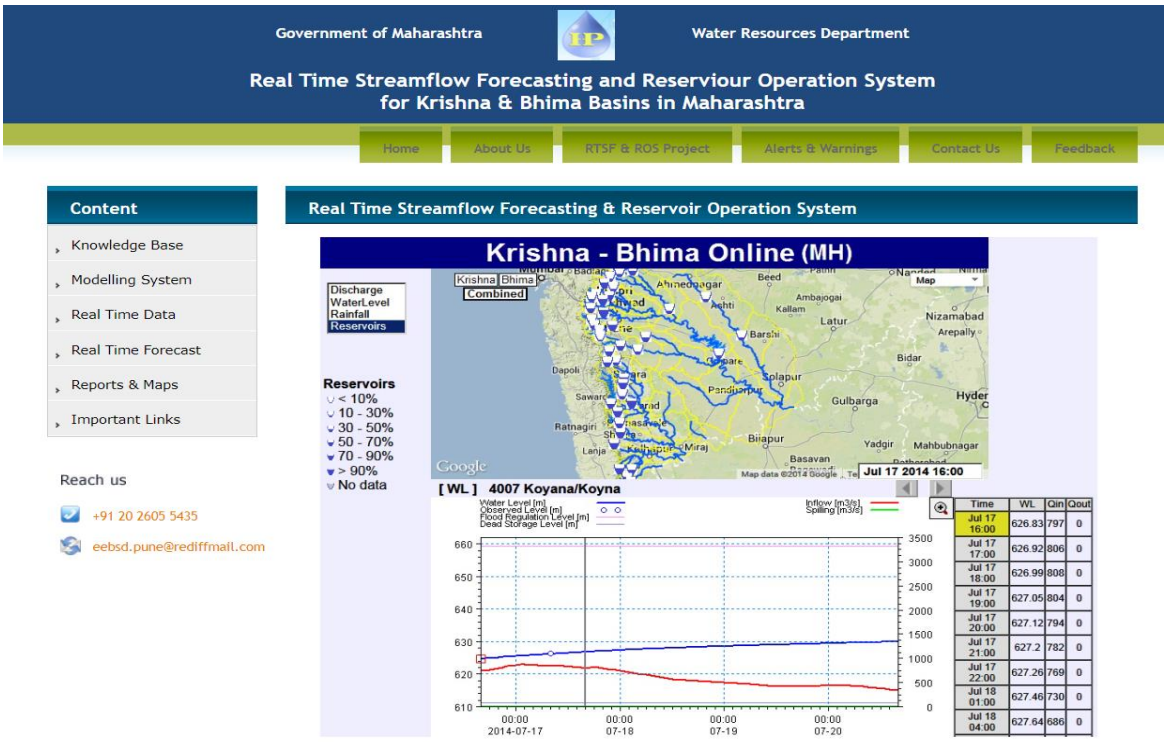


Figure 2.19 Existing website of RTSF and ROS

On selection of real time forecast from content will lead to a new page with forecasted discharge, water level, precipitation, and Reservoir data.

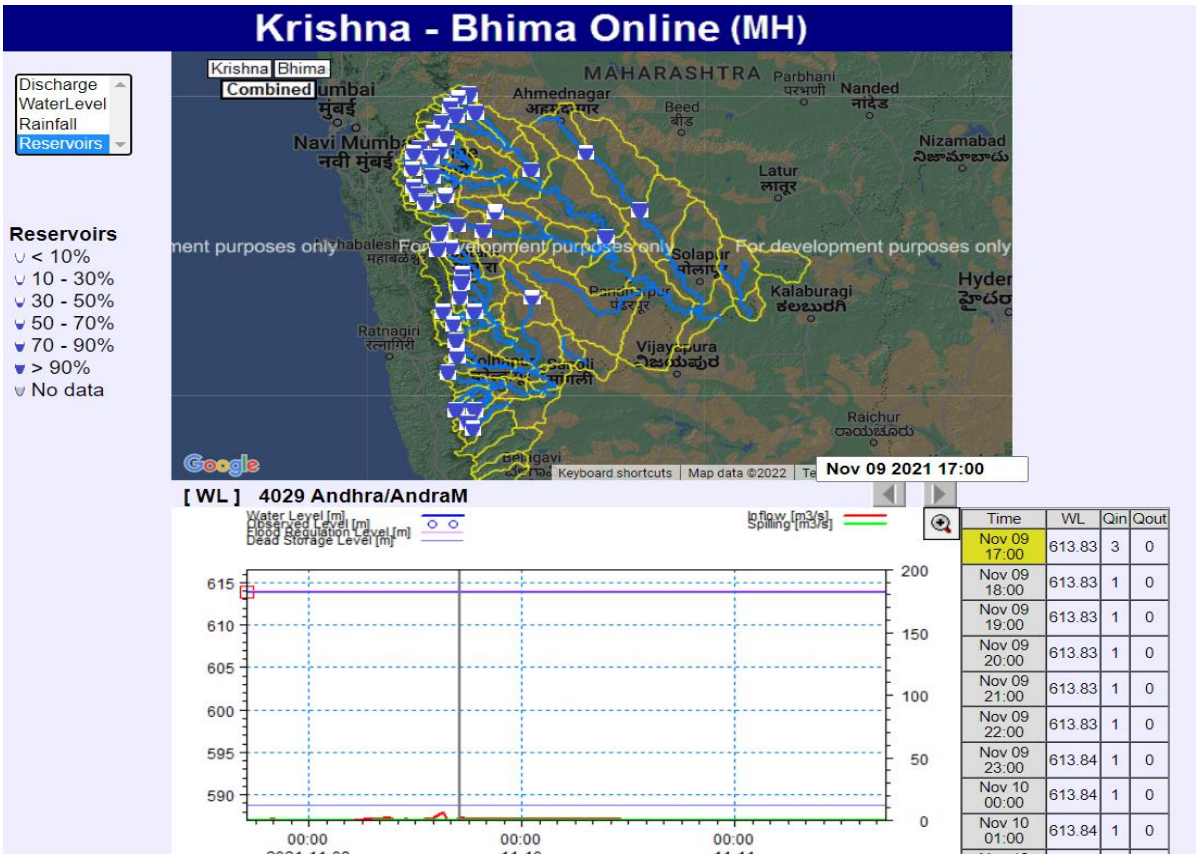


Figure 2.20 Existing website of RTSF and ROS showing real time forecast data

It also gives option to see the summary of forecasted water level and discharge data but it's not rearranged complex wise due to which comprehending the results become difficult. Also, Once the DSS (PM) is developed which is also a web-based dashboard where plotting and analysis of real time data, its use in model and result analysis will become easy for all client users. This website will be used for public dissemination of information and so complex wise reservoir level /flow dissemination will serve its purpose. During development phase a provision for updating the scenario result on website may also be analysed and accordingly provision will be made for 2023 monsoon.

2.2 System Limitations

Limitations observed during system review and as faced by client during regular maintenance of RTSF and ROS are presented below:

1. RTDAS

a) Failure of telemetry (GSM/GPRS network) in heavy rainfall event.
b) During peak monsoon some of the gate sensor does not work
c) Erroneous or absurd value observed in precipitation & other time series. Hence Quality Checking of real time data for absurd values before going to Platform shell
d) Csv header issue
e) Bifurcation of count of Csv files on daily basis according to categories

2. IMD Precipitation Forecast

IMD precipitation forecast data does not match with catchment rainfall. This leads to false modelled stream flow forecast.

3. Knowledge Base system

a. It is observed that while the model is in running condition it is difficult to retrieve data or work on the same model PC.
b. Database is huge which results in frequent system crash and hang.
c. Inability to use database for analysis and scenario generation.
d. Model output is not in usable format in database.
e. NAN (not a number) issue to be resolved

4. Forecasting system

a. The model is scheduled to run twice a day, however during heavy rainfall, the client intends to run simulation as per field requirements.
b. Offline scenario tool is not working.
c. Some flood control levels and cross-sections require updating.
d. Additional rainfall station data is available and needs to be incorporated in the model.
e. There is an issue in Auto saving of model results and checking of 'Forecast Zipping' file.

5. Communication and warning dissemination

a. Results should be disseminated complex wise instead of all reservoirs together.
b. There should be bulletin with colour code includes '*Alert*', '*Danger'* and '*Warning'* level for water level and discharge both.
c. These bulletins get replaced but they should be saved for future reference.
d. There should be provision to access historical model run results.
e. There should be a facility to disseminate results and bulletins though emails and SMS.

With the current proposal to upgrade the existing RTSF and ROS for the Krishna Bhima Basin in Maharashtra using DSS (PM) with an architecture which supports modelling, scenario building, and evaluation including scenarios for extreme climate events as well. Once the models are calibrated, validated, and integrated into the DSS (PM), this software can be run from the dashboard. The proposed solution will alleviate most of the issues faced by client in current desktop version. However, monsoon of 2022 (current year) needs to be managed using the existing RTSF and ROS. So, there is a need to balance the task between what minimum is required to successfully operate RTSF and ROS in current year while all new developments can be implemented after upgrading the existing RTSF and ROS as part of DSS (PM) under package B.

2.3 Suggested future upgradation

After reviewing the existing RTSF & ROS and identifying the current system limitations, a brain storming session was conducted with client to arrive suitable solutions and at the same time making a balance between what is required for operating the existing RTSF and ROS for current year while working on the upgradation under for monsoon 2023 and afterwards. The contractual requirement is to keep the existing system operational while providing updates for 2023 monsoon. However, to keep the existing forecasting system efficient and operational, there were certain issues which needs immediate upgrade before or during Monsoon 2022 maintenance and certain developments can be included while updating into DSS (PM) for 2023 monsoon.

The aim is to maintain the RTSF and ROS for 2022 monsoon efficiently with improved results. With the discussion with client on the issues faced by them during regular operation of RTSF and ROS and understanding of the system after its review, there is a need of certain improvement that will be implemented for enhanced performance of the system.

A. RTDAS improvement

There is an issue of missing real time precipitation and other hydro-meteorological data. RTSF and ROS team has requested to explore other sources of real time data. The team has suggested to use IMD, Mahavedh and other data sources. Model performance is heavily affected by telemetry performance, and an alternative data source should be available in the event that the existing RTDAS fails. For gap filling in real time data, there are alternative sources like IMD stations data, telemetry data from Mahavedh site, satellite-based GPM data etc.

A script can be written to download IMD and other source of real time data. To use these data set in the model, an analysis is requested. The data downloader will be applied in DSS (PM) and it will be tested and analysed for 2023 monsoon i.e., performance of these sources will be analysed and then accordingly decision on its incorporation in model for improved performance will be taken in next monsoon. However, Mahavedh source data summary will be helpful during model calibration process, and information will be utilized accordingly.

It is also discussed that there should be an alternative source of information for gated discharge. It was informed by team that they get regular mail during monsoon sometimes twice a day regarding gated discharge. A script can be written to download the data from mail and use it update the gated discharge time series. Another solution could be to create a google sheet where client will identify a responsible team / member of a department to update the gated discharge information of regular basis and the same can be processed through scripts to update the gated discharge timeseries. RTSF and ROS team will explore the option with concerned department for regular updating of google sheet and inform the consultant.

It has been observed that a quality check has been implemented during model simulation, which removes the erroneous value during timeseries export for model simulation. However, the same quality check is not applied in the database so absurd values are still reflected in the database. As a solution to this issue, an improved data quality check needs to be applied during time series updating itself and not during data export for model simulation. For each dataset, RTSF and ROS team (Client) has provided RoR & RoF for dams & Gauge discharge stations so that it can be implemented in the automation process.

B. Improvement in meteorological forecast

IMD Precipitation forecast value does not match with the catchment rainfall. This leads to incorrect modelled stream flow forecasting. Satellite based forecasted precipitation data will have some biasness and it needs to adjust in model in the form weighting factor during model calibration. Also, another source of Forecast precipitation needs to be utilized in RTSF and ROS system. GFS, NCMRWF, ECMRWF etc. are some of the global sources of datasets that can be utilized in real time forecasting of stream flows. It has been discussed that IMD forecast should be part of default scenario while NCMRWF / GFS forecast needs to be implemented in DSS (PM) for additional scenario of real time stream flow forecasting. A script will be written to download and process these data sources; however, it will be implemented for 2023 monsoon.

Bias correction in the form of correcting weighting factor during model calibration will be implemented this monsoon while new data sources of forecasts will be implemented in 2023 monsoon.

C. Updating of Knowledge Base system

Maintenance of the database has been implemented as described in chapter 2.2. The database is based on previous versions of postgres and MIKE Workbench, and hardware capabilities is also a limiting factor. New workstation will solve some of the issues. However, proper maintaining of database is also required along with system cleaning for optimized performance. The same has been implemented and tested. Many of the additional copies of original files were deleted from system and from database. The system is ready for monsoon 2022 operation and maintenance.

There is certain issue observed in offline scenario generation which needs dedicated input of a programmer to debug the tool. Offline scenario generation will be activated before 30th of June 2022.

As database has not been maintained for long (more than a year), it was slow and was crashing. However, after full vacuum maintenance, analysis of time series for various scenario was performed and database was observed to be stable. In order to fully optimize the database performance, a software upgrading is required. However, this desktop version of this RTSF and ROS is supposed to be maintained for 2022 monsoon only and from 2023 monsoon whole system will be developed into web based DSS (PM) which will be implemented in NIH server at Roorkee with very high configuration servers and other hardware. Client will need a good internet connection alone to access the database, analyse the results and run the online scenario. In addition, the client is planning to purchase a high-end workstation which will provide necessary support in implementing various analysis on the existing system.

For the current year, the system has been maintained and ready for 2022 operational maintenance of RTSF and ROS system. Also, provision has been made in the database to input the modelled output. Catchment rainfall has already been made part of database. A process will be developed to save results for each location in a single file for real time and forecasting periods. A script will be written to extract information of real time and forecasted result from previous simulated results saved in the forecasting folder. Once this is completed, we can keep only last monsoon run files in this folder and delete the rest. This script will be implemented during monsoon 2022 by the end of June 2022.

D. Improvement in Forecasting system

Model is scheduled to run twice but can be run as per user requirement. A system will be developed so that client can run more than twice during heavy rainfall events and use offline scenario to analyses flood situation and reservoir simulations. There is a bug observed in offline scenario and it will be resolved before 30th of June 2022 for its optimum use during this monsoon 2022. Flood control level and cross-sections will be updated if we receive the updated cross-sections from client before September 2022 to be implemented for monsoon 2023.

Also, RTSF and ROS team has prepared reports on RTSF and ROS for Krishna and Bhima River basin in Maharashtra for monsoon 2021. Also, a report was prepared by Consultant (Kavita Patil) in June 2021 for keeping the system operational for a year. Client has suggested to go through both reports and utilize the information for model calibration. The reports have been analysed and information will be utilized while model updating and calibration. The real time precipitation time series is analysed along with IMD forecast for its quality. Gap filling is considered with IMD data and model is being calibrated utilizing various information available. Client has also provided the real time data in excel format for last 9 years. DHI is already testing scripts for processing these files, applying data quality check, and using it for model calibration. Once testing is completed, it will be implemented in platform shell in data center.

Model calibration will be done in two stages. 1st model calibration will be completed by 15th of June 2022. In this calibration process, real time quality checked precipitation data, new rainfall station data will be used as a gap filling or additionally with shared weights in case some of the existing rainfall station is not performing well. Bias corrected IMD Forecast data in the form of change in weights will be utilized for model calibration. During calibration process, previous reports and few other data source information will be utilized. Then, Flood watch will be activated by 15th of June 2022 and forecast zipping for offline scenario will be corrected.

2nd Model calibration will be done as part of model updating. Pre-process that will lead to final model calibration are:

1. Mike 11 to MIKE HYDRO River updating.
2. Implementation of new rainfall stations in Rainfall Runoff model.
3. Gap filling with IMD and GPM precipitation data.
4. Cross-sections/Flood level updating.
5. Detailed IMD forecast and GFS/NCMRWF forecast bias analysis.

This model calibration will be the final model calibration for monsoon 2023 and same will be uploaded in the DSS (PM). During this phase only, Flood inundation model for flood affected are of selected cities will be developed. The DSS (PM) platform for flood forecasting will also be developed as part of model updating. Available public domain DEM will be evaluated for mesh creation. Client has shared survey lines in KML file format. These data may be used to improve the DEM along the flood plain area for better inundation maps. The target is to implement flood inundation model by mid of July and test the model with real time flood scenario during 2nd fortnight of July 2022.

E. Improvement in Communication and warning dissemination

There are various complexes of cascading reservoirs, and it needs to be analysed as a complex and not individually for better reservoir operation and optimization. There are 26

reservoirs in Bhima basin which can be put into 6 complexes. List of complex and its reservoirs in Bhima basin is presented in Table 2-1.

Table 2-1 Bhima Basin Complex

S.No.	Complex	Reservoir
1	Ghod Complex	Pimpalgaon Joge
		Manikdoh
		Yedgaon
		Wadaj
		Dimbhe
		Ghod
		Chilewadi
2	Bhima Sub Complex	Chaskaman
		Kalmodi
		Wadivale
		Andhra
		BhamaAskhed
3	MulaMutha Complex	Pawana
		Mulshi
		Temghar
		Warasgaon
		Panshet
		Kasarsai
		Khadakwasla
4	Nira Complex	Gunjawani
		NiraDeoghar
		Bhatghar
		Veer
		Nazare
5	Bhima Complex (includes complex 1,2 and 3 as described above)	Ujjani
6	Sina Complex	SinaNimgaon
		Sina Kolegaon

There are seven reservoirs in the Ghod and MulaMutha Complexes, five in the Bhima sub-Complex, and Nira Complex. Sina complex has two reservoirs, whereas Bhima complex has one reservoir and includes complex 1,2 and 3.

Similarly, Krishna Basin has 20 reservoirs which can be divided into into seven complexes, as shown in Table 2.2. Maximum six number of reservoirs is in Krishna sub complex, while three number of reservoirs is in Bhogvati complex The Koyna and Warna complexes

each have two reservoirs, while the Kasari, Doodhganga, and Yeralwadi complexes each have one reservoir.

Table 2-2 Krishna Basin Complex

S.No.	Complex	Reservoir
1	Krishna Sub Complex	Dhom
		Dhom Balkawadi
		Kanher
		Urmodi
		Tarali
		Uttarmand
2	Koyna Complex	Koyna
		Morna Gureghar
3	Warna Complex	Warna
		Kadavi
4	Kasari Complex	Kasari
5	Bhogovati Complex	Kumbhi
		Tulshi
		Radhanagari
6	Doodhganga Complex	Doodhganga
7	Yeralwadi Complex	Yeralwadi

The complex name has been proposed by the client. The nomenclature will be discussed with client again and model results will be presented and analysed complex wise from monsoon 2022 onward. Flood bulletin should include reservoirs level forecast, water level forecast and stream flow forecast with traffic colour code and complex wise for easy and efficient dissemination. Currently, only stream flow warnings and danger level are presented in colour code. This bulletin should be saved in the database for at least a monsoon for later references.

This monsoon reservoir will be sequenced to represent complex wise analysis and daily bulletin will be saved for referencing and analysis, however, full implementation of complex wise analysis and colour code representation will be implemented for 2023 monsoon. As model simulated results will be saved in the database in the form of real time, 24H and 48H forecasted flow for all the importation gauging sites and reservoirs. So historical model results can be accessed and analysed easily. These bulletins can be automated to be shared through emails. DHI will finalise dissemination through mail and SMS in consultation with client.

In addition to above issues faced by client and solutions plan as discussed above, there has been a discussion on the requirement for future updating in DSS (PM) specially with respect

to analysis of various results and scenario generation. Consultant has discussed the availability of high-quality DEM and suggested that a DEM with 5 m or higher resolution DEM will be useful for inundation in city area. Client has informed that they have prepared contour-based flood zone map and suggested to incorporate this information in inundation modelling. Consultant has agreed to look into the available data and utilize accordingly. Contour map has been shared by client and consultant will analyse the data by June 2022.

There are tasks which needs to be implemented in the existing system i.e., desktop based RTSF and ROS operations at the earliest for 2022 monsoon and other tasks needs to be implemented by September 2023 for its use in 2023 monsoon in DSS (PM) i.e., Fully web based RTSF and ROS operation.

2.3.1 Upgrade required for Monsoon 2022

Database updating and system review has already been implemented. Model calibration is currently under progress. Implementation of Flood watch activation for monsoon 2022 will start from 10th of June 2022 and will be completed on or before 15th of June 2022. The list of works that needs to be implemented immediately for monsoon 2022 operational management is listed below:

A. Tasks to be implemented before 15th of June 2022

1. Data Quality check script updating
2. Utilization of new stations of real time data as a gap filling in Model calibration
3. Script to download IMD real time precipitation data
4. Bias correction and implementation in weights of IMD forecast
5. Provision for modelled output saved for Realtime and forecasted period in database
6. 1st level Model calibration
7. Activation of monsoon simulation using existing flood watch
8. Bulletin saving in the database

B. Additional tasks which will be implemented during monsoon 2022 period:

9. Script to download gate discharge data from mail / google sheet (before 30th of June 2022)
10. Implementation of modelled output, 24H forecast and 48H forecast for selected gauging sites, reservoirs and for point of concern in database (before 30th of June 2022)
11. Complex wise reservoir operational analysis and results dissemination (before 30th of June 2022)
12. Offline Scenario Generation activation (before 30th of June 2022)
13. Processing of DEM (before 15th of July 2022)
14. Implementation of Flood Inundation model (before 15th of July 2022) and testing the model for a flood scenario (before 31st July 2022)

2.3.2 Upgrade required for Monsoon 2023

One of the major tasks of model updating is to develop the current RTSF and ROS under the component B of the DSS(PM) framework being developed under the NIH. A fully functional DSS (PM) will help the client in operating the system by logging into the DSS (PM) from any system with good internet after registration.

The tasks identified for monsoon 2023 are:

1. Cross-sections and Flood control level updating - (before 1st of September 2022).
2. 2nd level model calibration - (before 1st of September 2022).
3. Implementation of GFS forecasts / NCMRWF forecasts in addition to IMD forecasts in updated DSS (PM) - (before 1st of October 2022).

The major development for monsoon 2023 is fully functional DSS (PM) with following capabilities:

- Carry out of automatic runs.
- Automatizing ingestion of data from meteorological forecasts (bias corrected IMD, GFS / NCMRWF forecasts).
- Automatizing ingestion of data from real time data (precipitation, Water levels and gauged discharges).
- Exploring optimisation concept of WEB.BM on a selected reservoir complex to address optimized reservoir operations with the help of TAMC for synchronous operation of selected reservoir complex with particular focus on moderation of flood impacts, along with other benefits of consumptive water use.
- Developing an android based mobile application, that allows collection of geo-tagged, time-stamped photographs and water level information by the public to carry out further model calibration and validation (crowdsourcing).
- issuing alerts to the different levels of stakeholders depending on the perceived magnitude of flood inundation (yellow, orange, or red level alerts) through web portal/emails and SMSs

Client requirement from updated RTSF and ROS through DSS (PM) platform is to have provision for timeseries plotting with basic statistics, comparing real time, and forecasted flows, and online scenario generation. Features required for online scenario generation should include provision of scenario by changing catchment rainfall in real time /forecasted period, changing releases from a reservoir under different complex, running the simulation with different forecasted precipitation source and dissemination of scenario results on existing website.

During this project period, client needs to be involved in the development tasks. For these two types of trainings are proposed. Two weeks of formal trainings as per Task 3 of the contract and informal training during development process. While working on various tasks and after its completion, it needs to be explained to client. For this consultant in consultation with client has devised a fortnightly meeting of 1-2 hour for updating on the progress of the project.

Additionally, Informal training will be imparted to the team through online mode while working from home office and offline mode when a team visits the client office.

3 Work Plan and Deliverables

3.1 Work Plan

Based on the review of existing RTSF & ROS system and suggested future upgradation, an efficient implementation plan is presented below:

The study will be completed within 32 weeks for development & deployment; and operations & maintenance.

Work Plan for Phase 1:

- Review of Current RTSF & ROS System (Task 1 – Deliverable D1) - completed
- Upgradation of MIKE 11 to MIKE Hydro River & Current RTSF & ROS System (Task 2 – Deliverable D2 and D3) – In progress
- Capacity building (Task 3 – Deliverable D3) – yet to start
- RTSF and ROS testing and handing over (Task 4 – Deliverable D4 and D5) – yet to start

Work Plan for Phase 2:

- AMC and O&M support of Upgraded RTSF and ROS for 2023 monsoon seasons (Task 6 Deliverable D6) – yet to start

Phase 1 will be implemented by 1st of December 2022.

Phase 2 will commence from 15th June 2023 to 15th October 2023 for a period of 4 months and then Final report will be submitted by 1st November 2023.

In phase 2, The support can be through online/offline mode with the essence that performance of the system to be ensured. For problems beyond the scope of maintenance through virtual mode, immediate visit to the site (NIH office/Pune office) will be made to resolve the issue.

3.2 Deliverables Phase 1

		Fortnightly plan Phase 1																	
		April		May		June		July		August		September		October		November		December	
No.	Tasks, Deliverables and related activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
D-1	*Review of Current RTSF & ROS System*																		
	System and software review																		
	Data review and implementation plan																		
	Review Report																		
D-2	*Upgradation of MIKE 11 to MIKE Hydro River & Current RTSF & ROS System*																		
	MIKE 11 to MIKE Hydro River upgradation																		
	Development of Flood inundation model																		
	DSS (PM) Framework design and functionalities development																		
	Model configuration and data input automation on DSS (PM)																		
	Scenrio Generation facilities development																		
	Updation Report																		
D-3	*Capacity building*																		
	2 weeks of training																		
	Capacity building report																		
D-4	*Operation and Maintenance of RTSF and ROS*																		
	Preparation for 2022 monsoon maintenance																		
	Activation and implementation of floodwatch and updates																		
	Functional testing of RTSF and ROS during development year																		
	DSS (PM) Testing for oepration and maintenance																		
	Draft Final Report																		

3.3 Deliverables Phase 2

		Fortnightly plan Phase 2									
		June		July		August		September		October	
No.	**Tasks, Deliverables and related activities**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
D-5	***Operation & Maintenance of RTSF and ROS for 2023-year monsoon***										
	Operation and Maintenace support										
	O&M Report										

	Legends
	Tasks and Deliverables period
	Milestones/ Deliverables
	tentative period of activities
	Tasks -Monsoon maintenance (July to October only)
	tentative period of Activities - Monsoon Maintenance for 4 months only

4 Summary

The summary of the evaluation of the existing system and accordingly suggestions of future upgrading based on system evaluation and limitations faced by clients is summarized below:

i. Review of the available historical data in data base and update the existing data base.

Existing database has been updated as described in **Chapter 2.1 - C. Database maintenance and review**. The timeseries structure in the database has been rearranged (**chapter 2.1 - D. Database structure review**) and timeseries that is required for model calibration has been analysed (**chapter 2.1 – E**. **Historical and RTDAS timeseries review**). It has been observed that there is a need to write few scripts before 2022 monsoon for updating of historical and RTDAS data especially with respect to data quality as described in **Chapter 2.3 - A. RTDAS improvement.**

ii. Review of the existing hydrologic and 1D hydrodynamic model. Review of the available Numerical Weather Forecasts from various sources and bias correction in the forecasted precipitation.

Hydrological and hydrodynamic model has been reviewed as described in **Chapter 2.1 – B software review**. Client has older version of MIKE software license and so compatibility has been ensured for new workstation so that existing MIKE software can be installed on new workstation.

Similarly numerical weather forecasts timeseries has been analysed. As of now only IMD forecast has been used for hydrological forecasting, however it has been identified that GFS /NCMRWF forecasts will also be utilized for 2023 monsoon. All these forecasted precipitation source needs to be quality checked and biased corrected as described in **Chapter 2.3 - B. Improvement in meteorological forecast**. The weights of the forecasted precipitation for each sub-catchment will be modified as per the bias analysis and model will be calibrated accordingly. IMD forecast weights will be modified before monsoon 2022 while NCMRWF / GFS forecast bias correction will be implemented before monsoon 2023

iii. To solve issues related with scripting or programming if any, it requires additional/new script for smooth and uninterrupted functioning of the system; like auto saving of the model simulation result & forecasting result in excel or as per required format by a WRD officer.

There are certain scripts that needs to be implemented before 2022 monsoon for smooth and uninterrupted functioning of the system. **Chapter 2.1 – D. Database structure review** explains the process of saving modelled results in the database and all necessary scripts will be written and automated to achieve this target. Also, there is a need to process model simulated flows and forecasted flows for each discharge sites from daily simulated result files as described in **Chapter 2.3 – C. Updating of Knowledge Base system**. Once it is implemented the result timeseries can be exported or used for analysis in excel, or time series format as per client requirement. Also, limitations of existing scripts and programs has been identified and will be modified before monsoon 2022 especially existing data quality script and offline scenario generation tool. **Chapter 2.2** describes the complete list of limitations as observed in the existing system while **Chapter 2.3** describes the process that will be implemented for alleviating the limitations and improving the system performance.

iv. Develop a new script for quality checking of real time data before it updates / appends in database.

One of the main tasks that will improve the model simulation is real time data quality check. The current processing of real time data especially precipitation time series is not correct as described in **Chapter 2.1 – E. Historical and RTDAS timeseries review** and so new data quality check scripts need to be implemented before 2022 monsoon. **Chapter 2.3.1** describes the complete list of scripts in addition to data quality script that will improve model performance.

v. Identify any improvements required for forecast result dissemination.

Result dissemination is done though website www.rtstros.com and it is reviewed in chapter **2.1 – F. Review of existing website**. Complex wise result dissemination is one of the tasks that needs to be implemented during 2022 monsoon and the process of implementation is discussed in **Chapter 2.3 - E. Improvement in Communication and warning dissemination**. Also, **chapter 2.3.2** describes the process of automation and dissemination through mails/messages from DSS (PM).

vi. To suggest for Procurement of Satellite Images for River Basins in Maharashtra to carry out calibration and validation of flood inundation predicted through the modelling exercise.

Chapter 2.3 – D. Improvement in Forecasting system describes the development of flood inundation model and utilization of public domain DEM and client provided survey data. For a successful inundation model, a refined mesh or bathymetry file is required which should be generated for a DEM of 5 m or higher resolution. However, these DEMs are paid one and not freely available in public domain. There are 12.5 m, 30m and 90m DEM etc. are available in public domain and same will be evaluated for inundation modelling. The performance of these DEM will be analysed and for specific area higher resolution DEM or lidar survey may be proposed at later stage depending upon the performance of the model based on public domain DEM.

vii. Review of existing I.T infrastructure/hardware and software at data center, and appropriate suggestions for efficient and long-lasting working of system at the earliest.

viii. The existing workstation has been reviewed in **Chapter 2.1**. It includes review of hardware configuration, software installed on the workstation and the database of the RTSF and ROS and same has been described in **chapter 2.1 section A to C**. During review, the system hard space is recovered by deleting unwanted files and restructuring folders and files. Also, database maintenance was implemented, and old backup was deleted, and new backup were made and restoring capabilities checked. Also, it has been made sure that new workstation configuration allows old version of MIKE software to install on new workstation. DHI will help install this software on new workstation in case there is any issue faced by client on installation of old version of MIKE software.