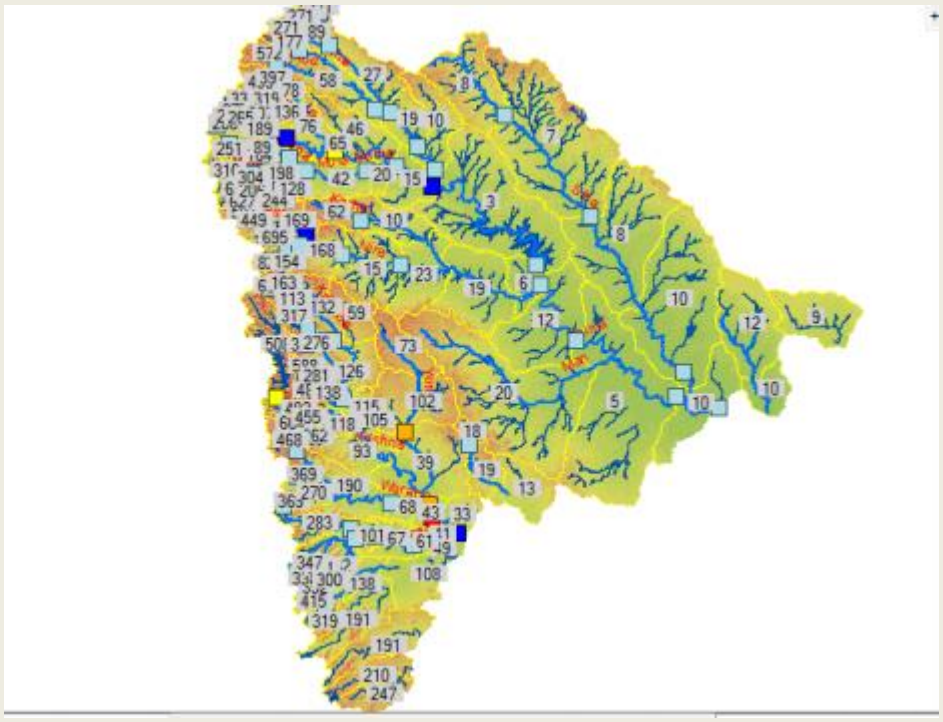
Report on

Real Time Streamflow Forecasting and Reservoir Operation System for Krishna and Bhima River Basins in Maharashtra (RTSF & ROS) for Monsoon 2018.



Government of Maharashtra
Executive Engineer
Basin Simulation Division
Pune

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1: ABSTRACT

The geographical area of Maharashtra state is 3, 08,000 sq.km. Major river basins in the state are Krishna, Godavari, Tapi and West flowing rivers of Konkan strip. The river Bhima is one of the major tributaries of Krishna. Maharashtra receives rainfall from both south-west and north-east monsoon. The Krishna and Bhima sub basins experience highly variable rainfall both in space and time ranging from 6000 mm in upper catchments to 400 mm in rain shadow areas (lower catchments). The state experienced flash floods particularly in Western Ghats including Krishna and Upper Bhima basins. The 2005 and 2006 floods caused heavy damages to the lives and properties in the basins. The problems are caused by the release of water from the reservoirs located in the Upper reaches of Krishna basin. Its prerequisite, the integrated operation of multiple reservoirs for multiple uses including flood management is expected for establishing optimal operational decision. The Real Time Stream Flow Forecasting and Reservoir Operation System (RTSF & ROS) for Krishna and Bhima Basin having an area 70000 sq. km is developed in 2013 for optimal flood forecasting and reservoir operation. This System is integrated with the real time Data Acquisition System (RTDAS), meteorological forecasts (from IMD), flow forecast modelling, analysis and decision support. The MIKE 11 modelling system consists of 1) A hydrological model (Rainfall-Runoff Model) for generating runoffs from a number of catchments schematized in the two basins. The entire area of the two basins is subdivided into 122 catchments 2) A Hydrodynamic Model for routing flows through the river and reservoir system to compute flows, water levels and a Structure Operation module which incorporates Reservoir Operation Schedule (ROS) and Gate Operation Schedule (GOS).The River schematic with 1550 cross sections and 46 reservoirs in the basin is used for hydrodynamic model. Model runs regularly twice daily in morning and afternoon and as per the requirement during monsoon (June- October) of every year by WRD officers. Model gives 3 days forecast of rainfall, reservoir inflows & outflows, river water levels and discharges. Calibration of the existing model with best use of historical data is done every year. Web based Real Time Stream flow Forecasting & Reservoir Operation System (RTSF&ROS) is established & operational in the Control Room (Data center) located at Sinchan Bhavan, Pune since 2013.

The Real Time Stream flow forecast results are being used by all stakeholders and the WRD officers for decision making, scenarios management, early flood warning & reservoir optimization. These results are made available on website http://www.rtsfros.com/mahakrishna in Real time Forecast menu. This helps field officers in proper flood monitoring and issuing warning to probable flood affecting areas well in advance by 72 Hours.The basic outputs of the MIKE 11 hydrodynamic model are discharges and water levels in the main rivers at important locations and inflows and outflows in and out of the reservoirs. However, the frequency of the output has to be compatible to the frequency of input data. Hydrographs at daily, hourly and 15 minutes may be produced once the RTDAS

provides data at every 15 minutes.This System is in use from 2013 monsoon and found to be very useful.Due to the available system, ability has been developed in the reservoir operators to act faster before and during floods. There is improved communication and coordination between stake holders & flood management officia

2 : INTRODUCTION

FEATURES OF REAL TIME STEAM FLOW FORECASTING AND RESERVOIR OPERATION SYSTEM (RTSF &ROS)

The objective of the project was to equip the Water Resources Department, Government of Maharashtra with a web-based Real Time Stream Flow Forecasting System and Reservoir Operation System (RTSF&ROS) for flood management in the Krishna and Bhima basins in Maharashtra.

The principal outputs of developed the systems are:

- A Knowledge Base System comprising historical as well as real time hydro-meteorological data and GIS data.
- A Forecasting System for reservoirs and river systems including inflows and floods levels efficiently utilising weather forecasts and real time data from the RTDAS.
- A Reservoir Operation Guidance System.
- A web based interactive Communication System allowing access to the Knowledge Base, and the Forecasting and Guidance Systems for WRD offices and stakeholders.
- A comprehensive Capacity Building programme for WRD comprising formal training courses, on-the-job training, workshops, study tours and support.

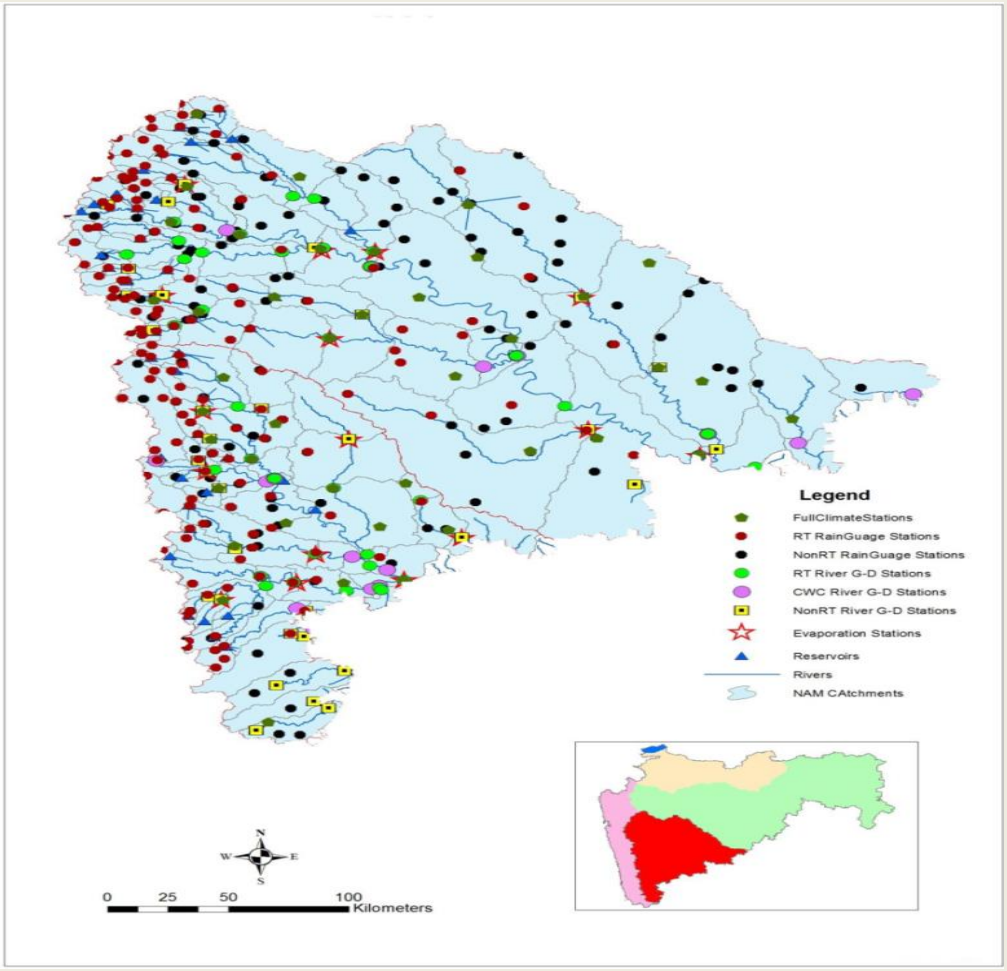


Fig2: Two sub basins subdivided in to 122 sub-catchments

Knowledge base system (KBS)

All data used for modeling purpose i.e. physical features, hydrological, real time, forecast and water demand are stored and maintained in the database of KBS. Also output from model simulations are stored and maintained in the database of KBS. KBS provides functionalities for working with data like Database input output tools, data visualization and data processing.

1.1. Knowledge Base System (KBS),

KBS is designed and installed with all historical hydro-meteorological data, river flows and levels, irrigation data, available satellite images and other GIS data collected and populated in the database. The GIS data include topographic data, satellite imageries showing administrative/land use/land cover/cropped and irrigated areas, soils. Data from the reservoirs have been collected and included in the database. The database system is flexible to receive any additional data from other sources. For the real time data, facilities and links have been developed to import RTDAS data. The knowledge base also has the capability of analyzing historical hydro-climatic time series data. In addition to providing

the input data for the mathematical models, the database will also store the results from the models. The database will be used to store historical hydrologic data on the basin and data collected through the RTDAS, definitions of the various scenarios that WRD will utilise for short and long term planning, and input that can be used to operate the dams and other controls

1.2. Modeling system

The RTSF &ROS Modelling system developed in the project consists of:-

- A Hydrological model (Rainfall-Runoff model) for generating runoff from a number of catchments schematized in two sub basins.
- A Hydrodynamic model for routing flows through the river and reservoir system to compute flows, water levels.
- A real time flood forecast model for computing stream flow and flood forecast for period of 3 days from the time of forecast.
- A river basin water resources simulation model for water allocation including optimizing water use and reservoir operation.
- A user interface integrating the above models for forecasts, and for providing reservoir operation guidance, scenarios management and flood warning and dissemination.

The MIKE software system, developed by DHI Water Environment Health, which have Advanced data assimilation for optimal flood forecasting, options for reservoir operation, has been used for this project.

Hydrological Model

The NAM (Rainfall- runoff11) model is used and coupled with the MIKE models forming part of the integrated modeling system. To simulate the spatial variation in the lateral inflow to the river system, the two sub basins have been subdivided in to 122 sub-catchments as shown in fig no 2. The hydrological model has been calibrated to replicate the historical observed hydrographs on the basis of the historical input. The final model parameters were chosen so the best compromise was achieved between the three criteria i.e. matching the peaks, Matching the cumulative water balance (Wbl) curve and higher coefficient of determination (R2). Fig no 3 shows the excellent calibration of NAM rainfall-runoff model for the Koyna catchment for the years 2005 to 2010.

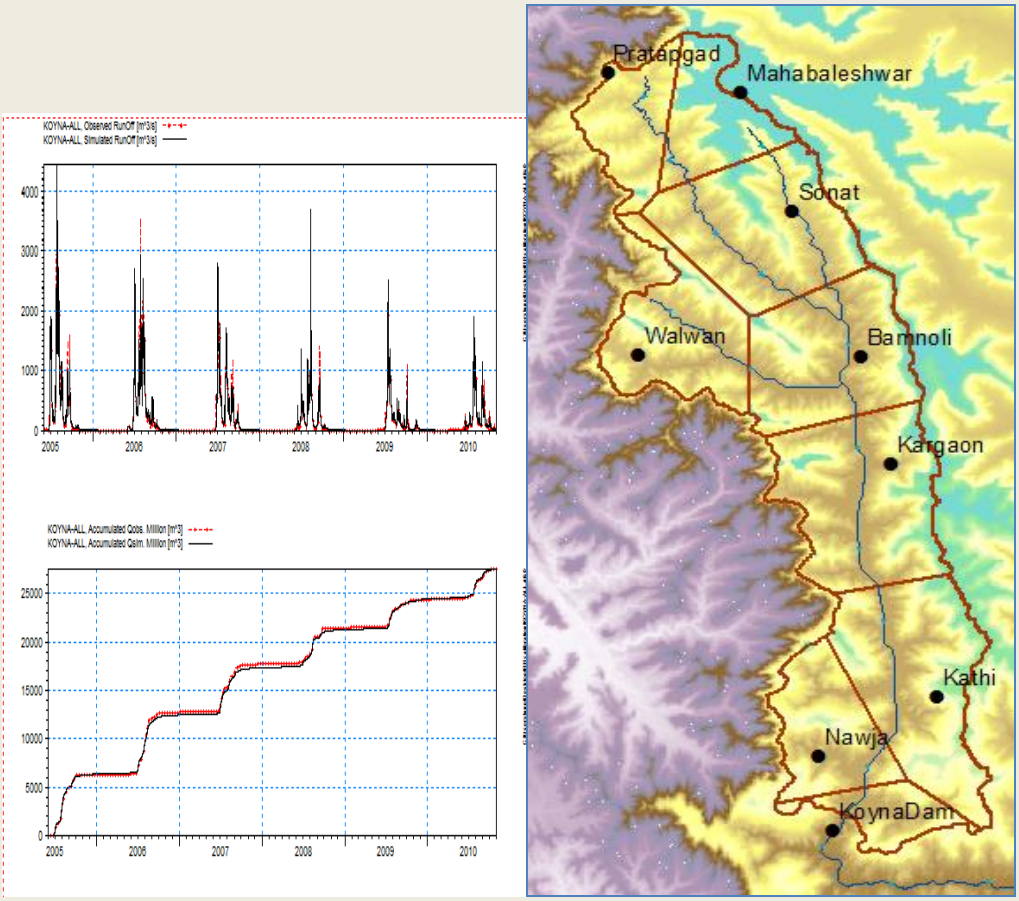


Fig 3: Calibration of NAM rainfall-runoff model for the Koyna catchment for the years 2005 to 2010

Hydrodynamic Model

The hydrodynamic River model takes the rainfall- runoff from the NAM, and carries out a continuous routing of the flows and flood waves through the main rivers and reservoirs of the basin The MIKE 11 hydrodynamic model is used for the two basins combined. The model describes the propagation of flood waves through the river and reservoir system.

a) A total of 1550 cross sections are applied in the model. Fig no 4 shows MIKE 11 schematic of the hydrodynamic model with river network. Catchment runoff from the NAM Rainfall – Runoff model is used as upstream boundaries and intermediate inflows. The hydrodynamic model has an automatic coupling to the NAM model. Each catchment is connected to the river model either by a point connection in the case of major tributary, or distributed in the case of minor tributaries. A total no of 43 reservoirs are included in the model. The MIKE 11 structure operation module simulates the control structures like spillway gates and all types of outlets. Reservoir operation schedule (ROS) and gate operation schedules (GOS) are applied through the structure operation module. The model outputs discharges and water levels in the main rivers and reservoirs. Output can be obtained to any time step; however the frequency of the output is made compatible to frequency of RTDAS input

b) The short Term Forecasting Model

Converting the predicted precipitation to runoff hydrographs, the model provides a quantitative response to the predicted weather forecast. Output from the Hydrological model is fed in to the MIKE 11 river model for forecasts. Thus the hydrodynamic model, incorporating data assimilation at all the real time discharge and water level stations, is used in real time stream flow and flood forecasting. The setup of the model is such that the model handles both historical data and estimated future inflows and scheduled releases. The period during which historical data are applied is termed the hindcast period, and the period representing the future is termed the forecast period. It has three days advance forecasting system which forecasts Inflow, outflow and water levels of reservoirs with discharges and water levels in the river on d/s of reservoirs at various locations, critical from flood point of view. Three days Quantitative Precipitation Forecast (QPF) available from IMD/RIMES is used in the model. Fig no 4 illustrates the concepts and steps of a short term forecasting system.

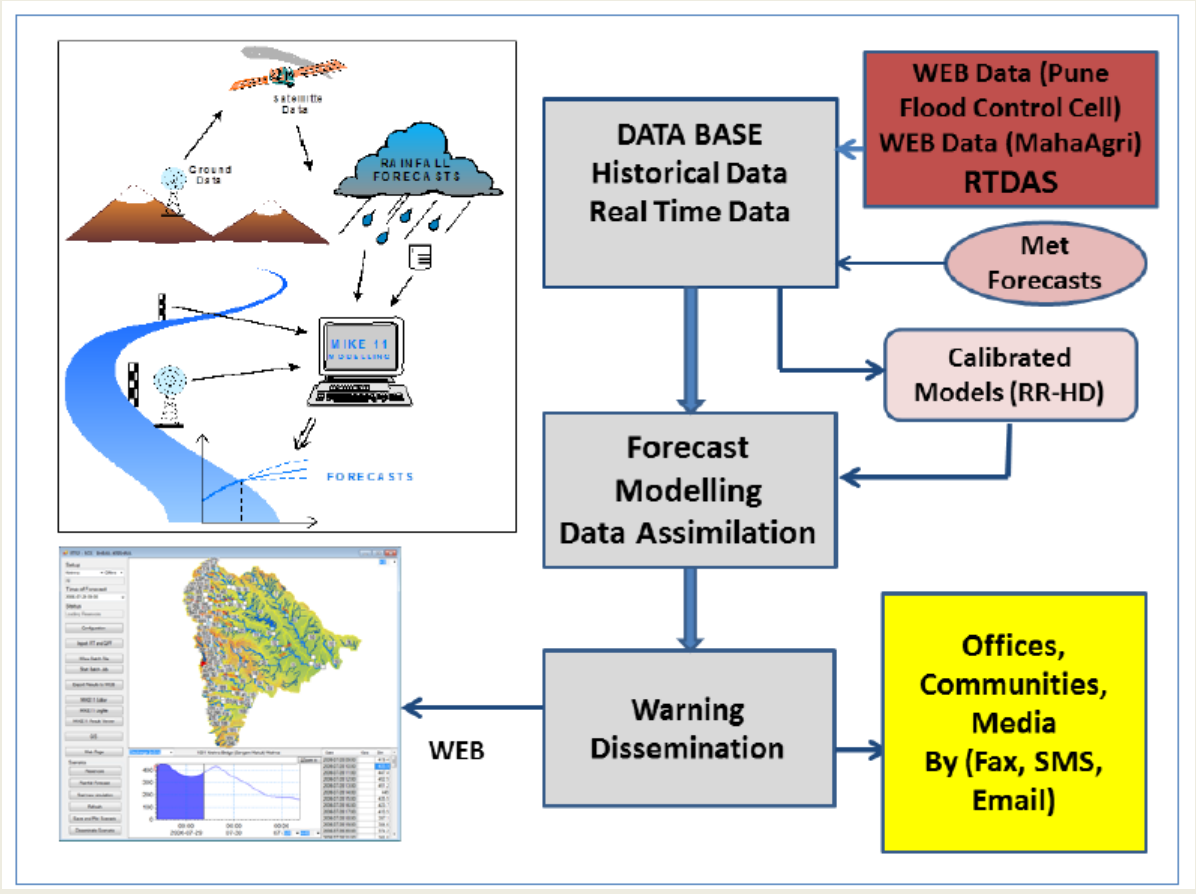


Fig 4: Illustration of a short term forecasting system.

1.3. Reservoir operation system

The simulation models are integrated with a suit of optimization tools for optimum operations of the reservoirs for the short term operation during the flood seasonfor inflow forecast, long term operation for round the year for planning and water management, and seasonal operation to minimize downstream flooding while considering the need of keeping the reservoir full at the end of the rainy season.

Three sets of optimization exercises have been carried out for developing optimum reservoir operation guidance system. The first set is the short term optimization, which is aimed at providing improved reservoir operation guidance during floods when an inflow forecast is available from the RTSF&ROS. The recommended short term rule curve is a switch from the long term rule curve established by WRD for the major reservoirs in the Krishna and Bhima River basins. It has been demonstrated that using the short term optimization of reservoir operation a considerable reduction in flood release can be achieved during the forecast period without compromising on the storage at the end of the forecast period. In a way, the reservoir state follows the prescribed rule curve at the end of the optimization/forecast period.

The second type of optimization model developed is for long term reservoir operation guidance system. The optimization system is developed for round the year water allocation for irrigation and water supply considering power development.

The third type of optimization model developed is seasonal operation of the reservoirs to minimise downstream flooding while considering the need of keeping the reservoirs full at the end of the rainy season. The reservoir operation guidance derived from the second and third types of optimization models are incorporated in the overall basin simulation model (MIKE BASIN) for the entire Krishna and Bhima basins in Maharashtra.

The reservoir operation can be performed via the reservoir operation module. The model can be used in Online and Offline modes. When running in online mode, the overviews are automatically updated as soon as new forecast is ready. When running in offline mode it is possible to test various scenarios like rainfall forecast scenario and Reservoir forecast scenarios. The scenario management tools allow the user to run the forecast model with different data and compare the results from scenario simulations with the original simulation.

1.4. User interface in form of Website

The Real Time Stream flow forecast for viewing/use of all stakeholders of the basin is made available on project website; http://www.rtsfros.com/mahakrishna in Real time Forecast menu. All results from the forecast simulations are presented on a WEB portal. The web page has provision for display of four different data types: discharge, water level precipitation and data from reservoir (water level, inflow and outflow.

3: Objectives & Achievement

3.1) **To run RTSF & ROS Model in monsoon & save the results.**

In monsoon season (June-Oct 2018) model was run twice in a day & results were saved. Also during the above mentioned period model could not run and faced technical problems on the days mentioned in the table below:

Sr.No	Date	Details
1	3 June 208	Model could not run due to no electricity.
2	6 , 7 Aug & 4, 5, 22 & 27 Sept 2018.	To run the model real time data is required as an input.This data is available to model PC in form of Script.But during this period there was error in the script so the real time data could not be made available to the model PC to run.simulation

Also RTSF & ROS model was run till 31st Oct, 2018.

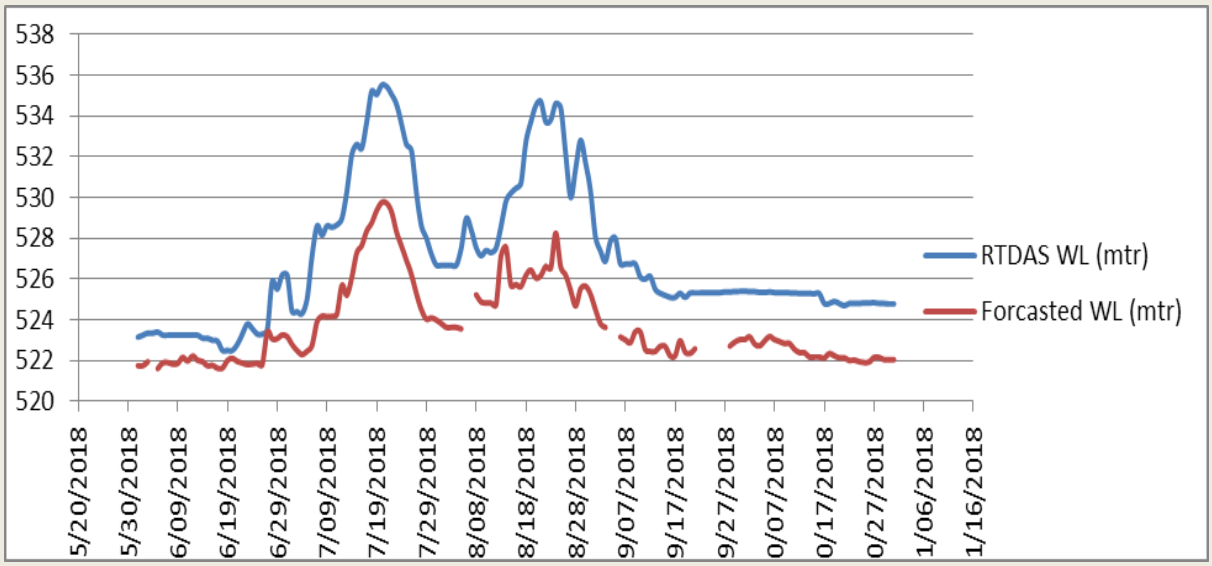
3.2) Study of comparison of forecasted water level/discharge & observed water level/discharge for gauge discharge stations under Krishna & Bhima basin.

- Study of comparison of forecasted water level/discharge & observed water level/discharge for gauge discharge stations under Krishna & Bhima basin RTSF & ROS was carried put in graphical format & attached in (Annexure-A). Observations are as follows,
- For some gauge discharge stations results of forecasted water level/discharge & observed water level/discharge are similar.Eg:1)Wadange 2)Balinga 3)Koregaon bhima
- Gate sensors are installed on 26 reservoirs under RTDAS developed for Krishna & Bhima basin. During the 2018 monsoon, the model didnot feth the actual discharge data as per the opening of the gates due to some technical problem, the corerect spills could not be availed to model continuously & correctly. Therefore, there is difference in results of forecasted water level/discharge & observed water level/discharge.
- Due to technical fault in some rainfall & water level sensor Gauge discharge station did not receive real time data (Refer point no 3.4 for plots Nitawade, pg. no 22 & Dattawdi pg. 38 GD station)
- K.T.Weir are not incorporated for Gauge discharge station like Shivade,Mhaisal,Kagal,Sangli Bypass,Navarasta, & Karad in Krishna basin & Pargaon,Pandharpur,Late in Bhima basin .Due to absence of structures in the model, back water effect seen. Due to back water effect of K.T.weir water level remains stagnant. Therefore difference in results seen. Hence, it is necessary to incorporate missing structures in the model to get accurate results. For this expert in MIKE 11 is required.
- To run the model real time data is used as input, this data is available to model PC in the form of Script.But during this period there was error in the script so the real time data could not be availed to the model PC to run.
- Due to unavailability of real time spill in 2018 monsoon, the daily discharge was obtained from Pune flood control website and the model was run & calibrated.

  It is therefore inferred that, if the real time data would have been available continuously & correctly it would have helped in getting better results in the model.

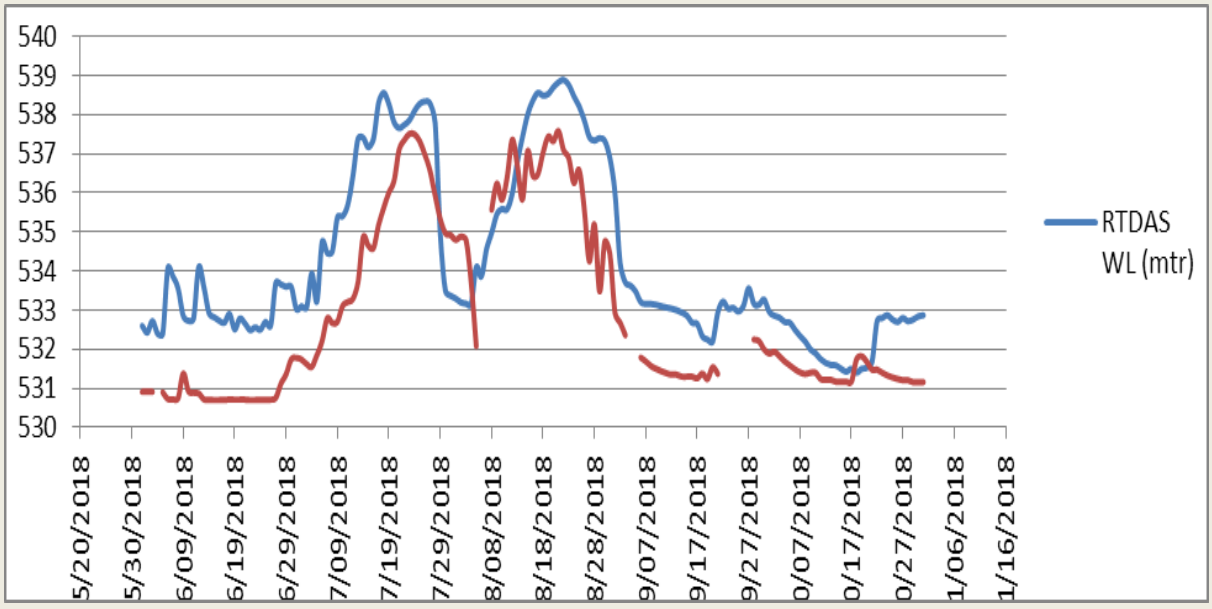
  Some of plots are given below;

1Mhaisal



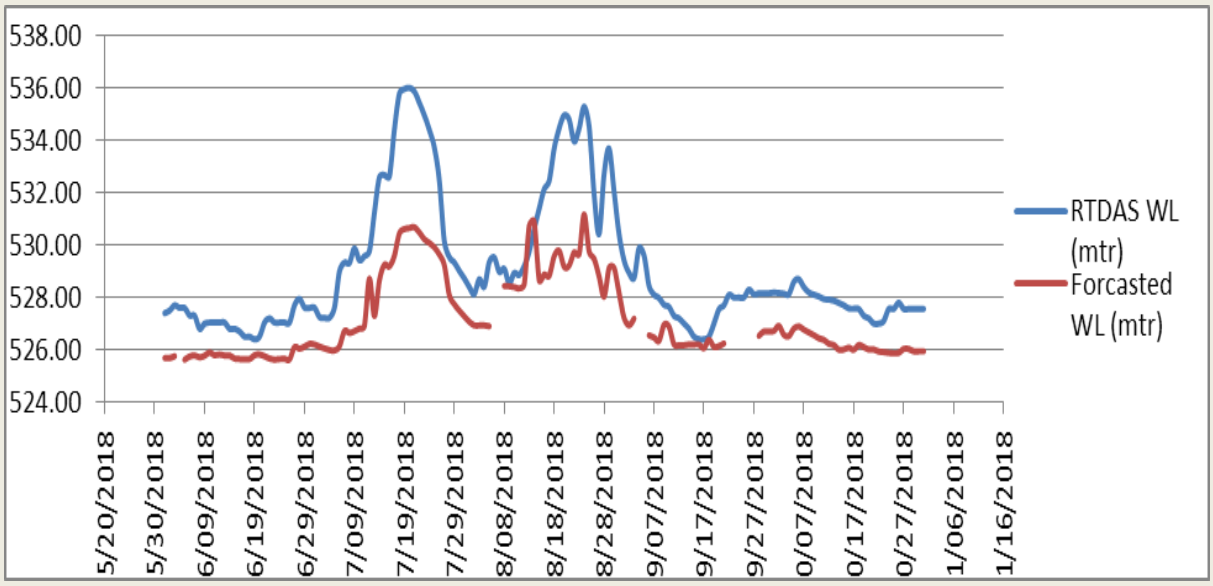
Plot of comparison between Forecasted and observed discharge at Mhaisal

2. Kagal



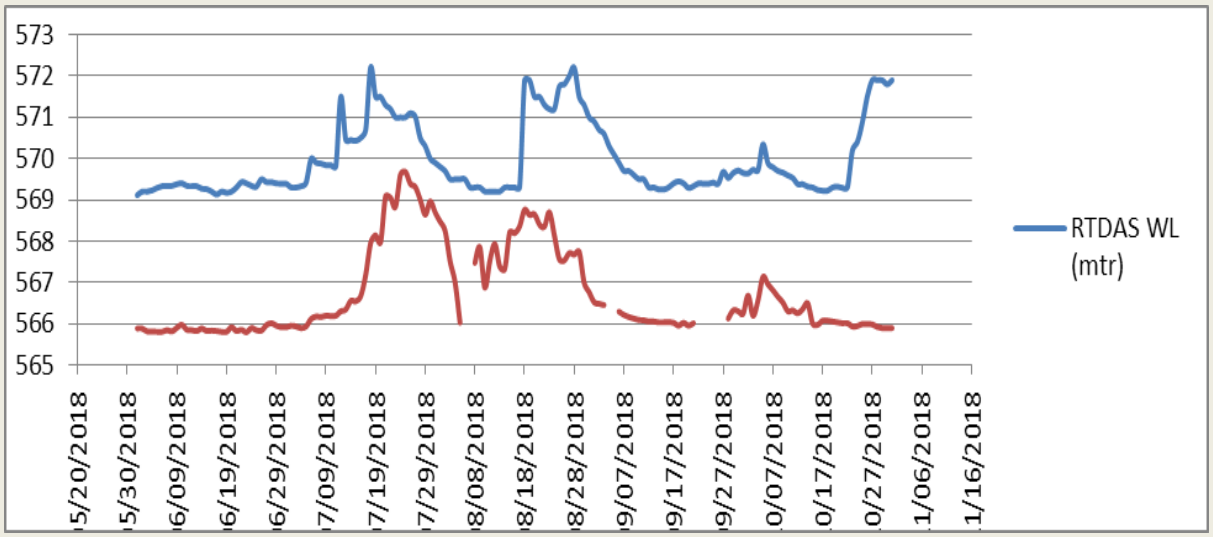
Plot of comparison between Forecasted and observed discharge at Kagal

3. Ankali Bridge



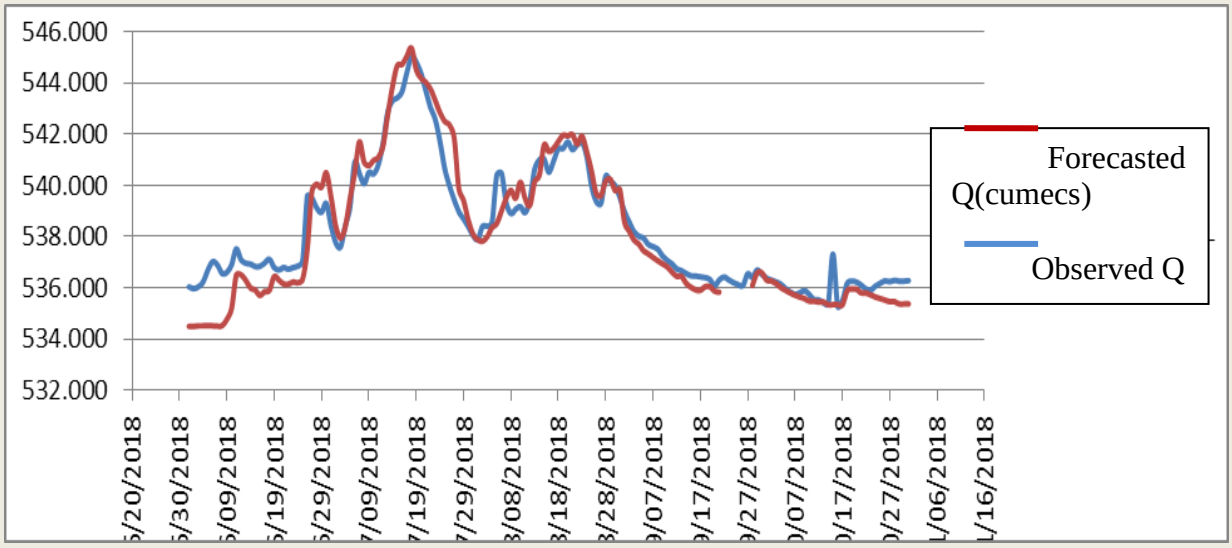
Plot of comparison between Forecasted and observed water level at Ankali Bridge

4. Shivade



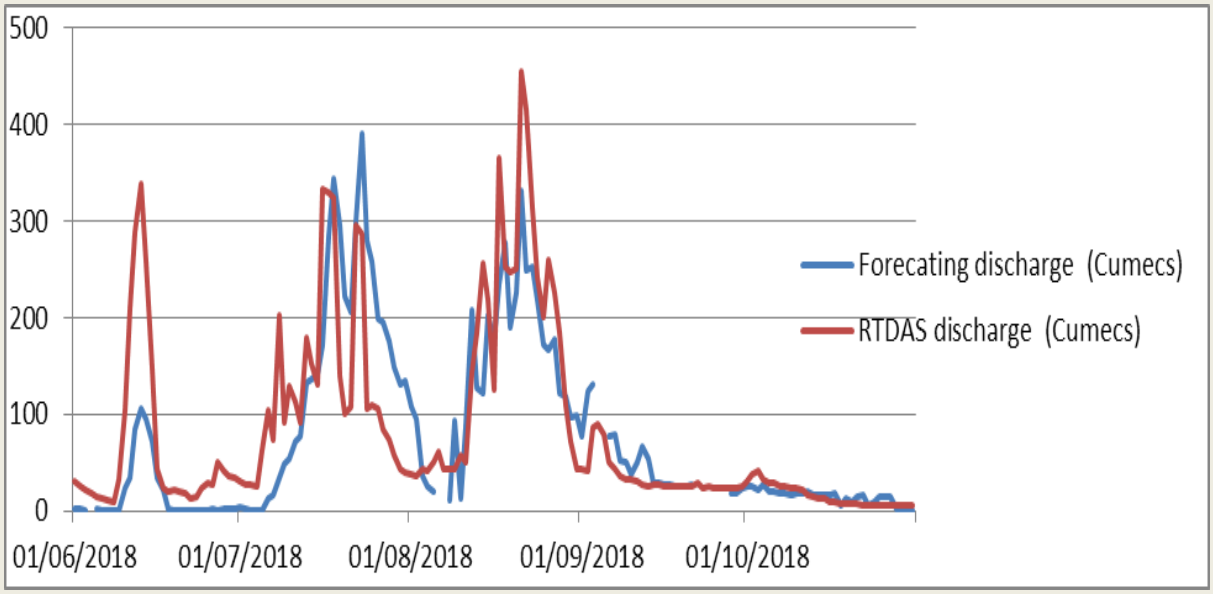
Plot of comparison between Forecasted and observed discharge at Shivade

5. Balinga



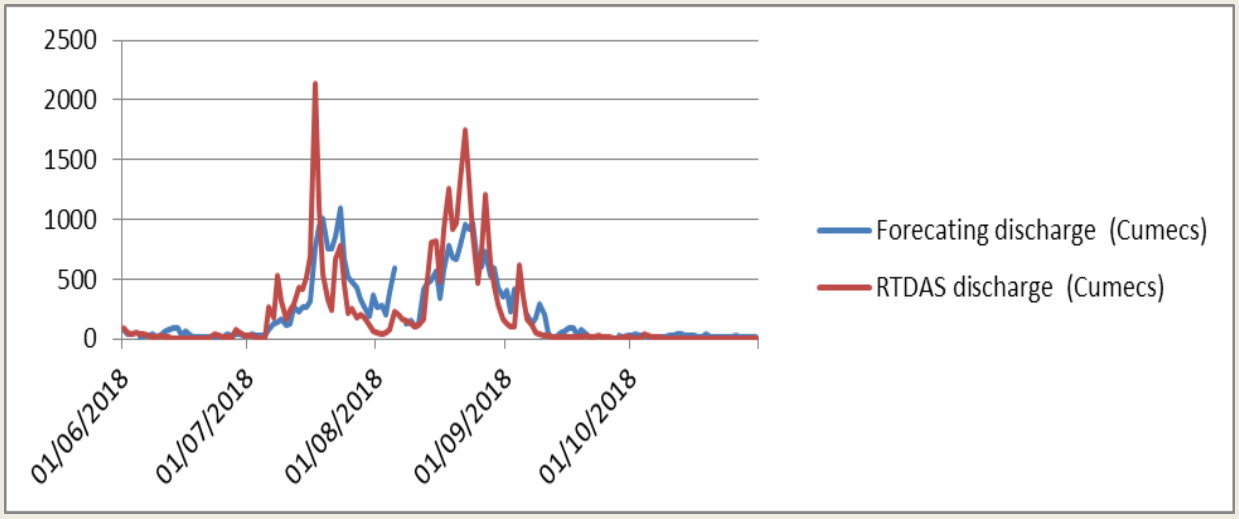
Plot of comparison between Forecasted and observed Water level at Balinga

6.Koregaon Bhima



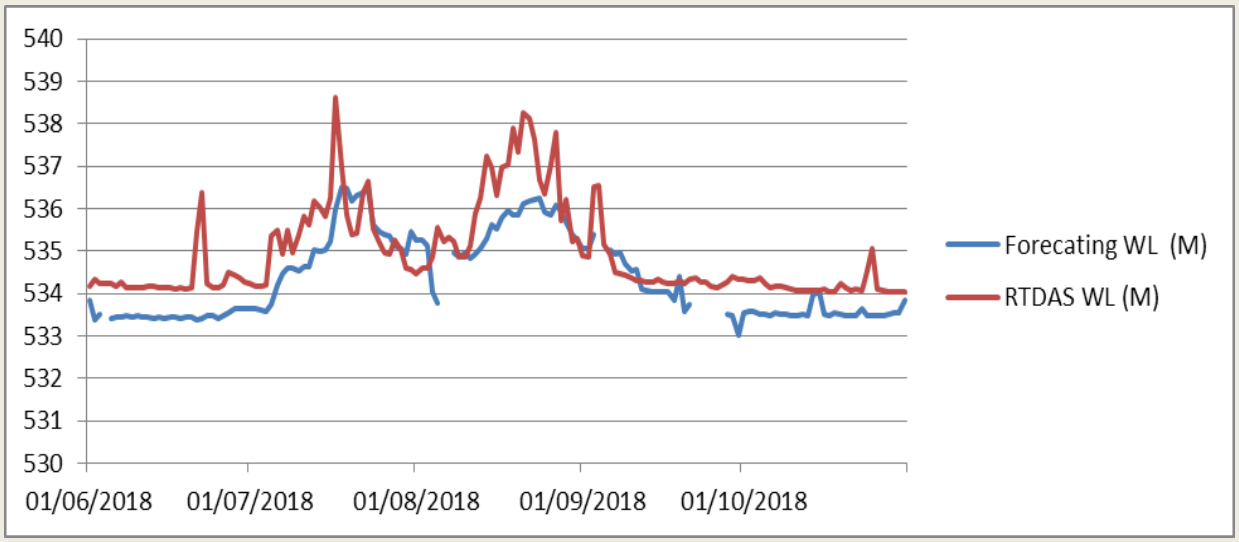
Plot of comparison between Forecasted and observed discharge at Koregaon Bhima

7. Pargaon



Plot of comparison between Forecasted and observed discharge at Pargaon

8. Kalyani Nagar



Plot of comparison between Forecasted and observed Water level at Kalyani nagar

3.3) **Study of comparison of forecasted Inflow & observed inflow for reservoir stations under Krishna & Bhima basin .**

Evaluation Study of reservoirs Koyna & Radhanagari in Krishna basin & Khadakwasla & Ujjani in Bhima basin are attached herewith.

Evaluation study in Krishna & Bhima basin for monsoon 2018 for 20 Gauge discharge stations & 4 reservoir stations is carried. .

Sr No	**Gauge Discharge Station**	**Pearson correlation coefficient r**	**Coefficient of Determination R2**	**Nash-Sutcliffe Efficiency NSE**	**Willmott Index of Aggrement D**
Krishna Basin	**Range**	Should be Between +1 To -1 for model acceptance	Should be more than 0.5 for model acceptance	Should be between 0 to 1 for model acceptance	Should be between 0 to 1 for model acceptance
1	Krishna Bridge /Sangam Mahuli	0.58	0.33	-0.34	0.72
2	Navarasta	0.74	0.55	0.42	0.83
3	Nitawade	0.95	0.9	0.53	0.83
4	Balinga	0.97	0.95	0.79	0.95
5	Wadange	0.95	0.91	0.89	0.97
6	Shigaon	0.91	0.83	0.37	0.74
7	Shivade	0.59	0.35	-1.58	0.66

8	Mhaisal	0.88	0.77	0.08	0.57
9	Ankali Bridge	0.9	0.82	0.17	0.7
10	Kagal	0.83	0.69	0.57	0.9
11	Koyna	0.77	0.59	0.52	0.86
12	Radhanagri	0.71	0.51	0.2	0.83
Bhima basin					
1	Koregaon Bhima	0.73	0.53	0.38	0.84
2	Nighoje	0.74	0.63	0.30	0.81
3	Pimple Gurav	0.89	0.91	0.56	0.63
4	Paud	0.71	0.50	0.85	0.78
5	Dattawadi	0.69	0.68	0.88	0.82
6	Kalyani nagar	0.72	0.91	0.79	0.81
7	Khamgaon	0.98	0.96	0.53	0.88
8	Pargaon	0.81	0.65	0.38	0.88
9	Kashti	0.50	0.56	0.38	0.48

10	Pandharpur	0.78	0.88	0.79	0.86
11	Khadakwasala	0.40	0.82	0.91	0.57
12	Ujjani	0.81	0.66	0.57	0.89

Ref: "D. ***N. Moriasi, J. G. Arnold, M. W. Van Liew, R. L. Bingner, R. D. Harmel, T. L. Veith " MODEL EVALUATION GUIDELINES FOR SYSTEMATIC QUANTIFICATION OF ACCURACY IN WATERSHED SIMULATIONS"***

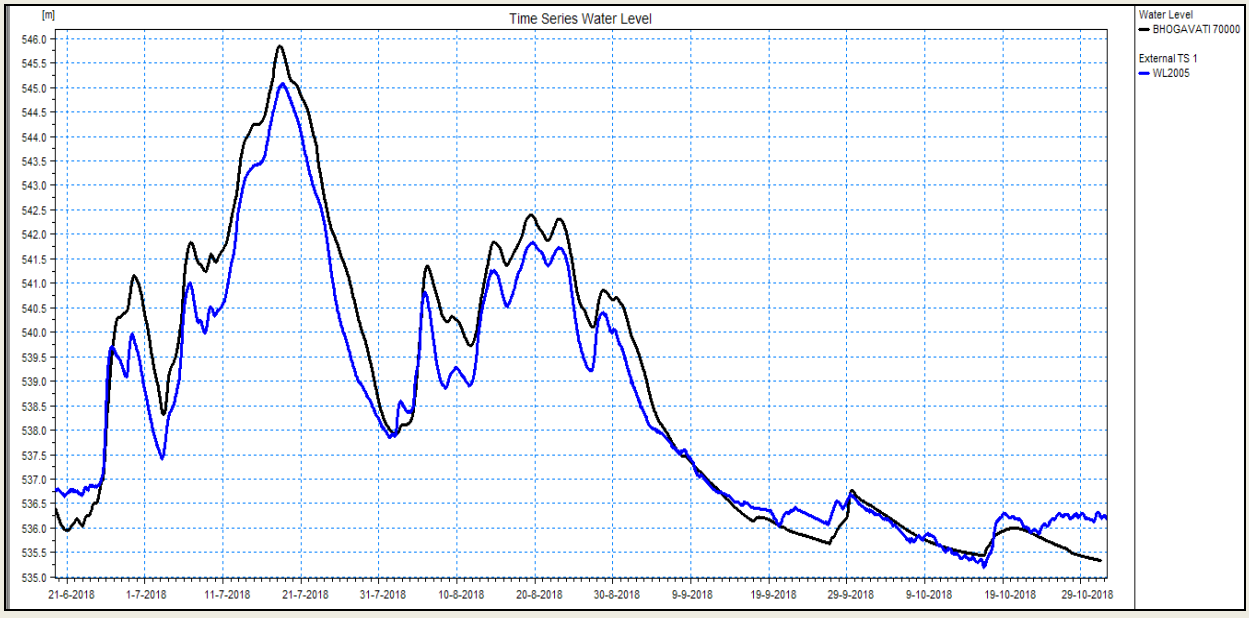
3.4) Calibration & Fine tuning of RTSF & ROS model 2018

For refinement of NAM model, the spills of reservoirs upstream of catchment were collected for entire run period from Dam Authority and Pune flood control officials. The time series of collected data has been prepared in MIKE ZERO. The accuracy of refinement of NAM model depends mainly on the frequency of reservoir spill data and observed discharge data collected from individual officials (if not available in Real Time data System).

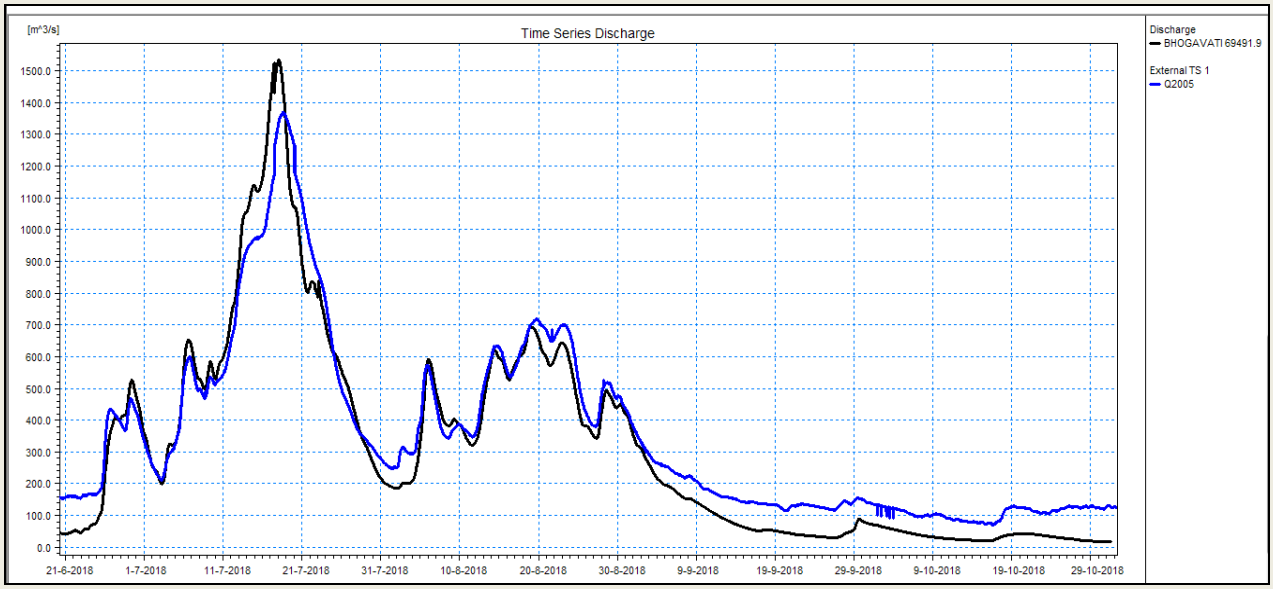
All the real time data of Rainfall, Water level, Discharge, observed spill available are extracted from database using script "Export for Model". The input required to run scripts are; full path of folder from which time series should be exported, Path of windows directory where the data to be stored and number of days of the data to be exported. Prepare a hotstart file as input to the model. The real time data collected during monsoon period from June to Oct-2018 is used to compare observed and simulated results.

Graphical presentation for calibration of Krishna Basin is given below:

- **Balinga on river Bhogavati -** The simulated discharge at Balinga GD location has been compared with observed water level from Real Time database. The results of comparison, which shows a fair matchof Water level and discharge , are as shown in figure.(Fig..)

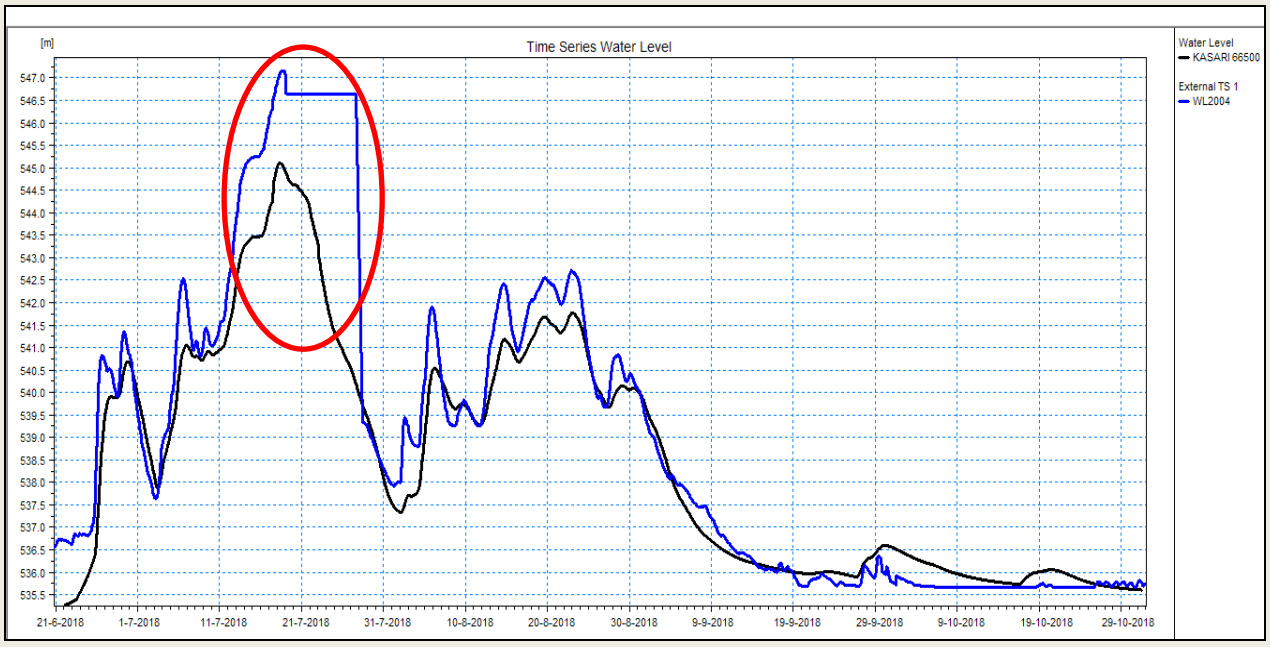


(Fig..) Plot of comparison between simulated and observed water level at Balinga

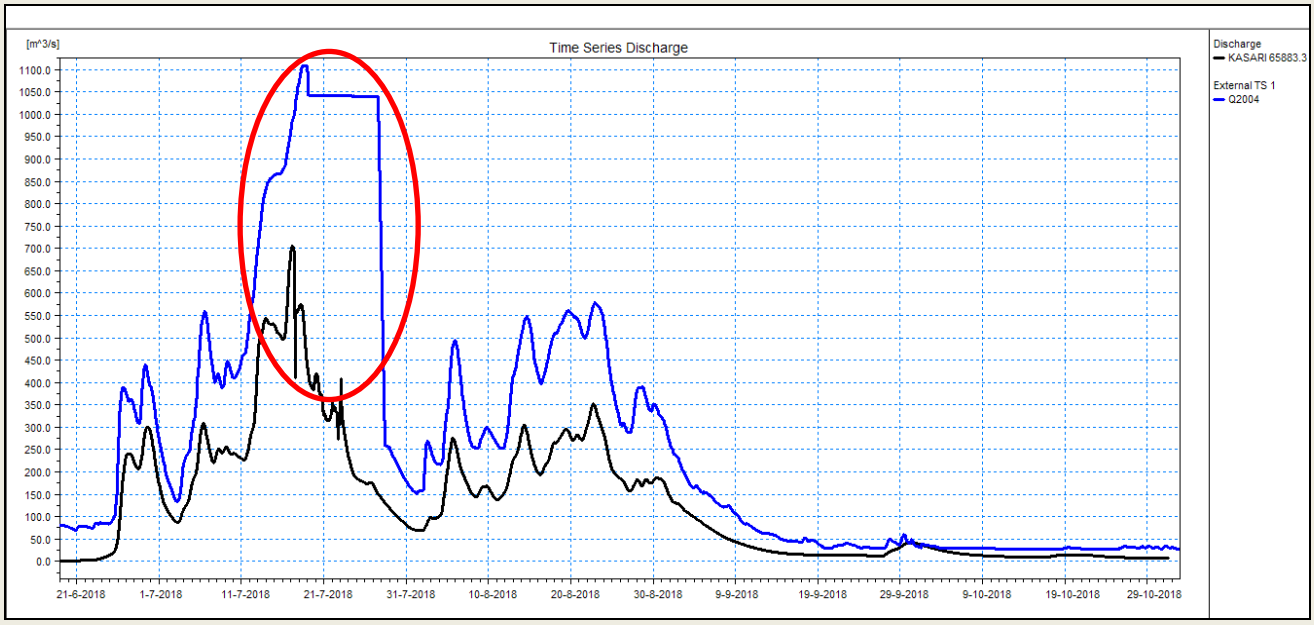


Plot of comparison between simulated and observed discharge at Balinga

- **Nitawade on river Kasari**-Releases from Kasari reservoir has been updated to compare the simulated discharge of Nitawade station to that of the observed discharge data. The graph of comparison is shown in figure. Erroneous RTDAS Water level (Fig...) data was received to model database which led to erroneous discharge hydrograph as shown in fig ... below .

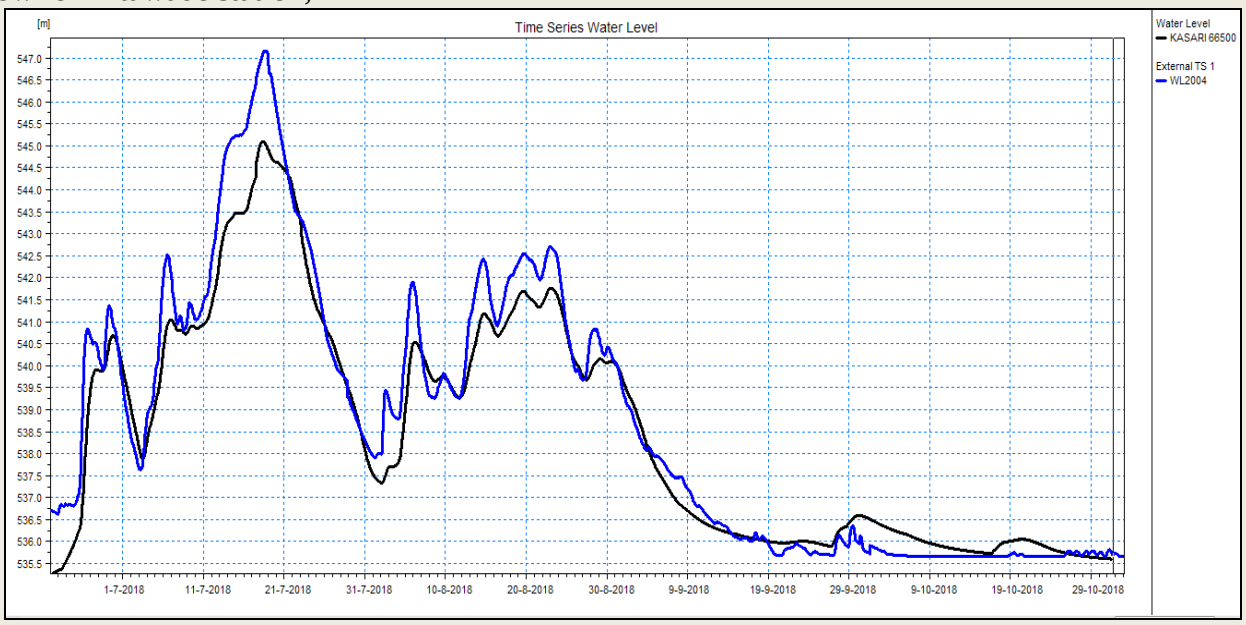


Plot of comparison between simulated and observed water level at Nitawade

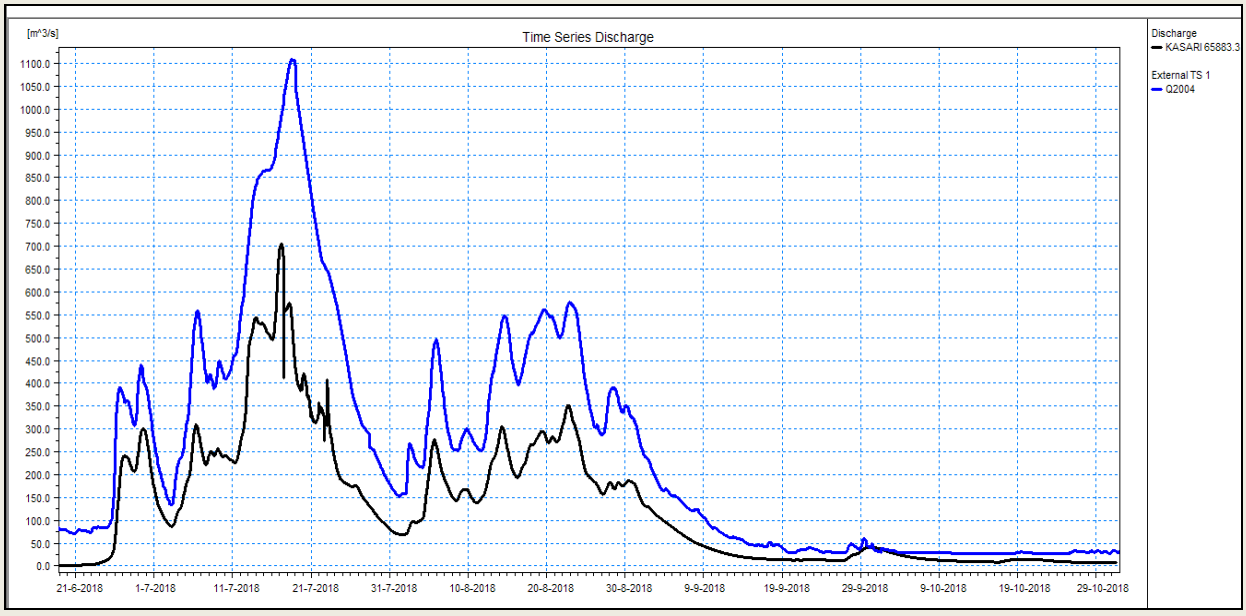


Plot of comparison between simulated and observed discharge at Nitawade

After addition of spilling data from Kasari reservoir & corrected Real time data. Plots are given below for Nitawade station;

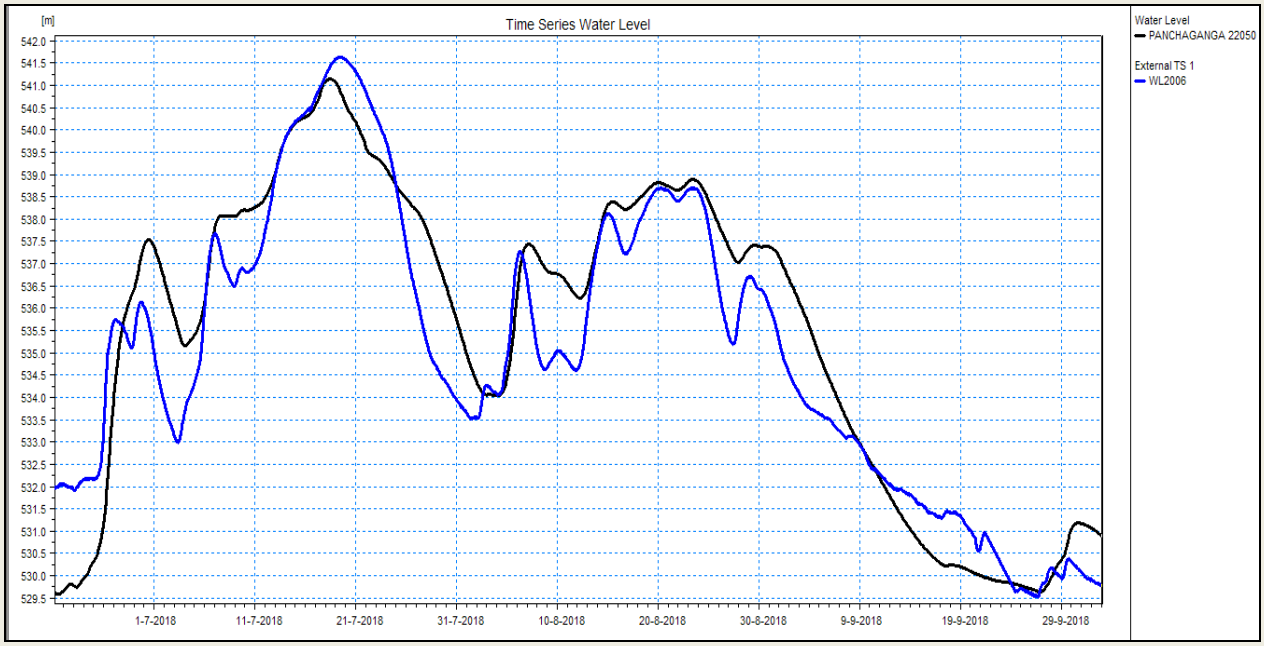


Plot of comparison between simulated and observed water level at Nitawade

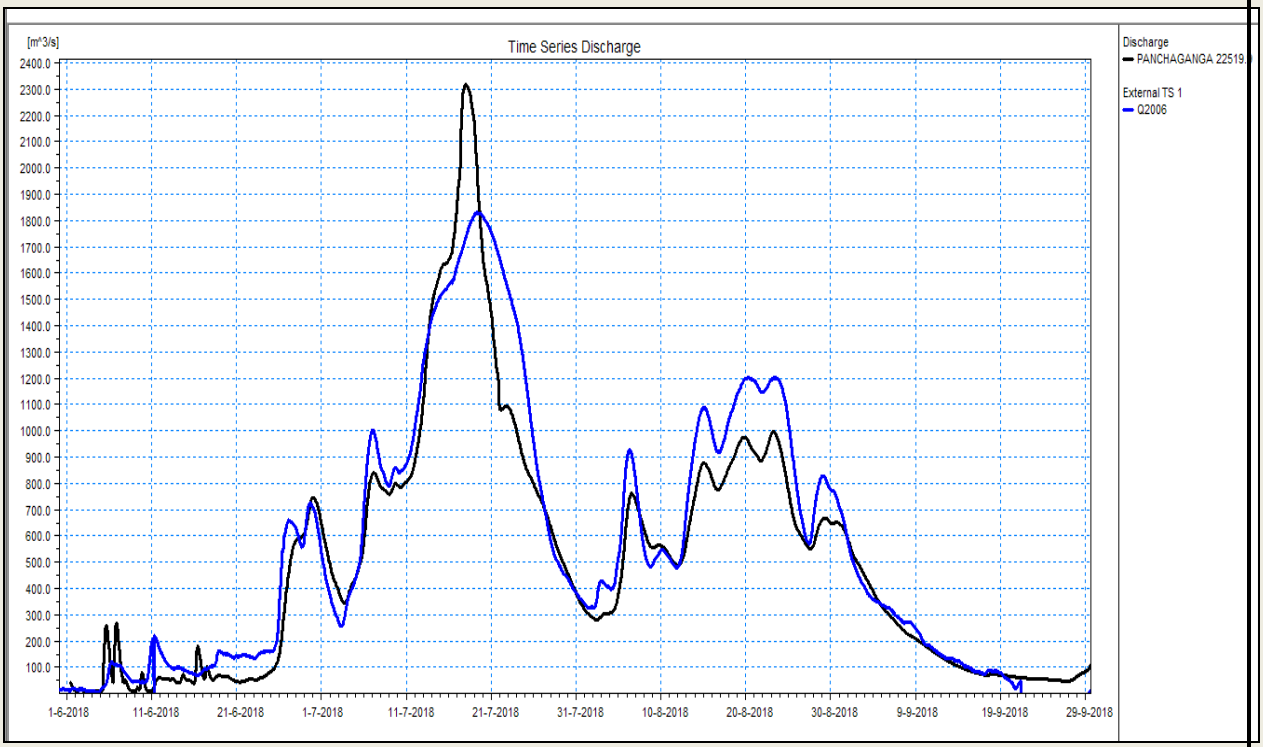


Plot of comparison between simulated and observed water level at Nitawade

❖ **Wadange on river Panchganga-**Figure shows plot of comparison between simulated and observed Water level and Discharge at Wadange GD station.

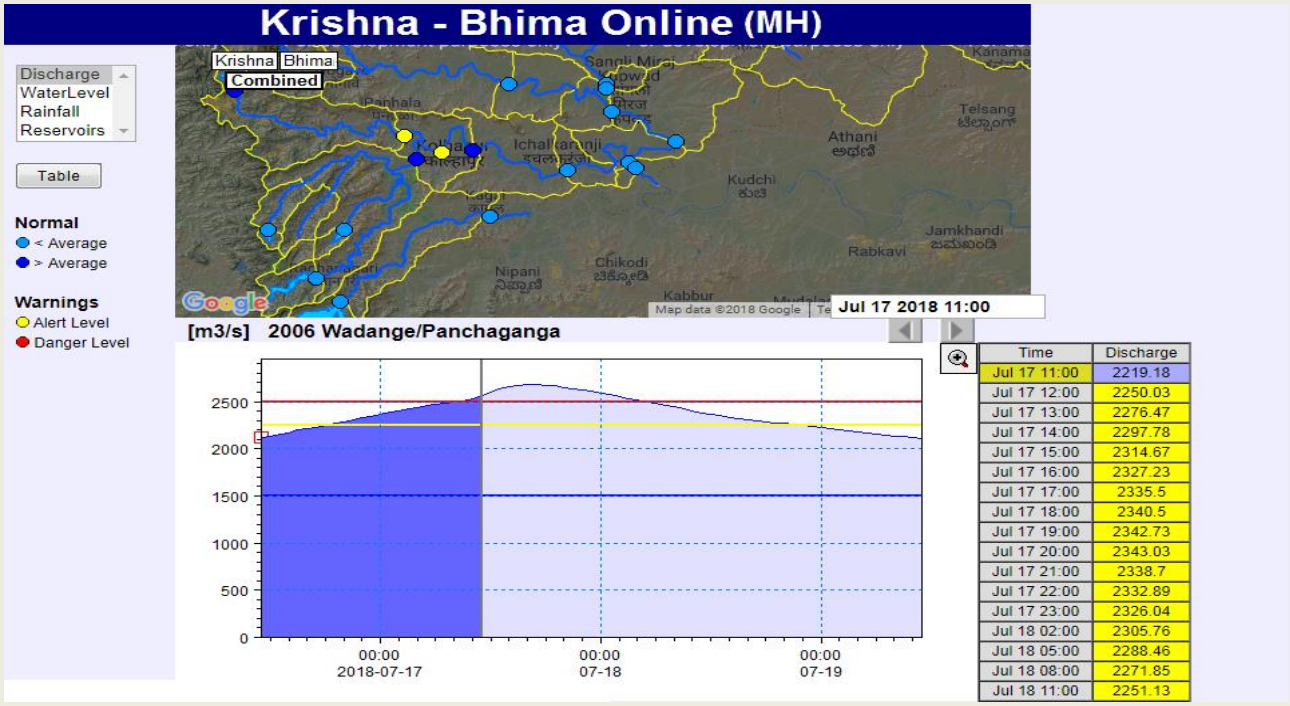


Plot of comparison between simulated and observed water level at Wadange

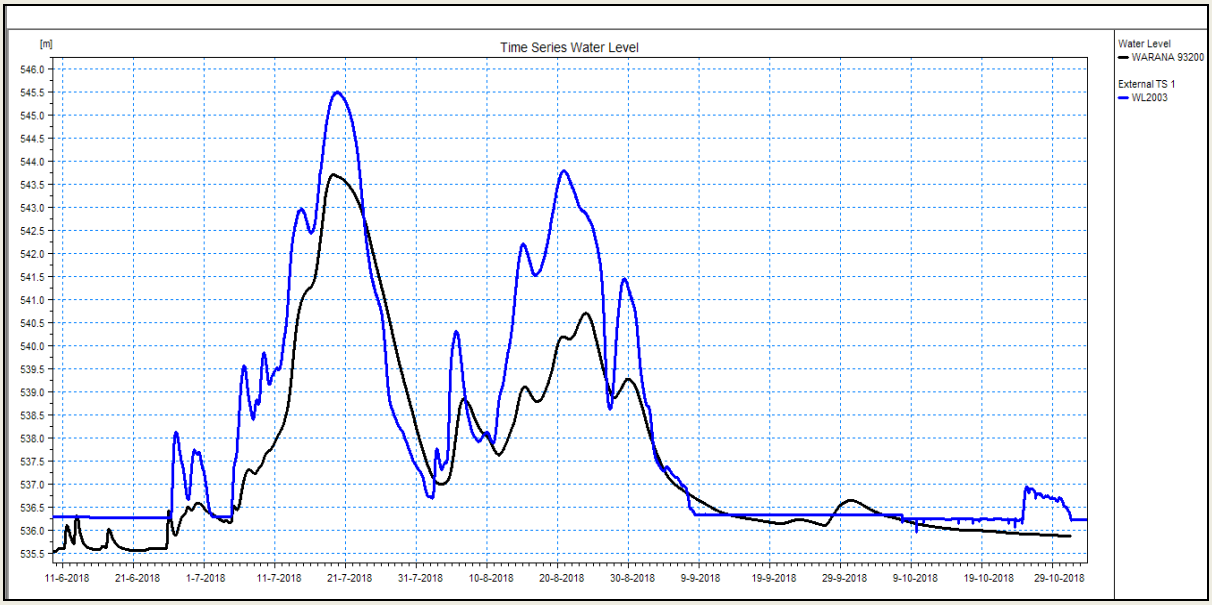


Plot of comparison between simulated and observed Discharge at Wadange

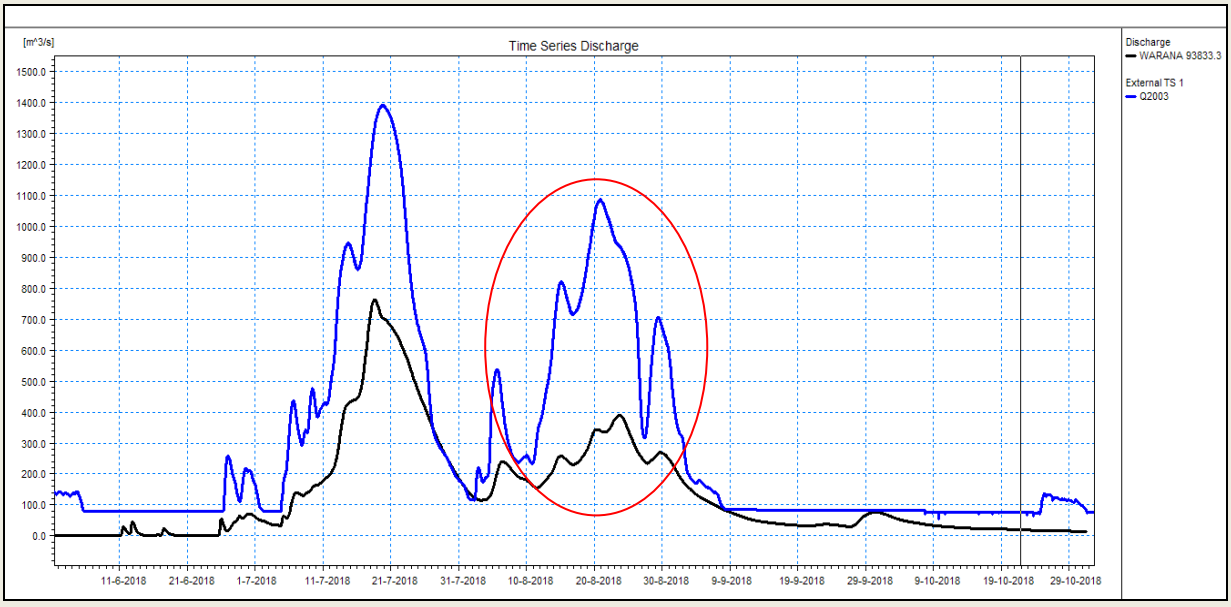
Model gives alert levels on river Panchganga near Kolhapur city on 17 July ,2018.



❖ **Shigaon on river Warna:** The graph of comparison is shown in figure.

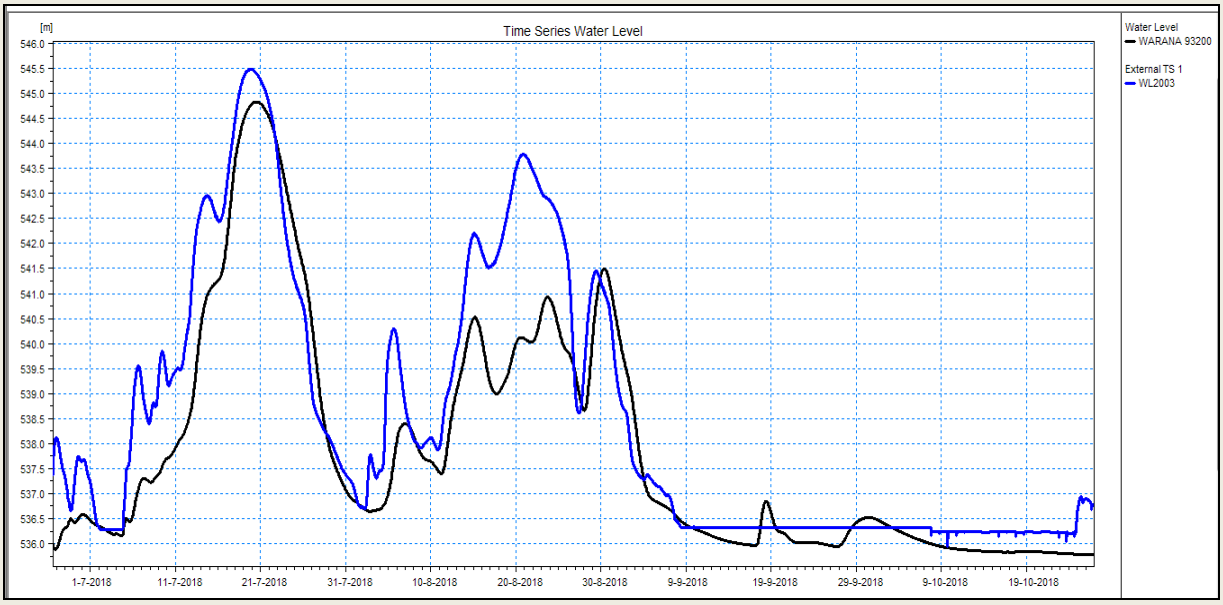


Plot of comparison between simulated and observed Water level at Shigaon

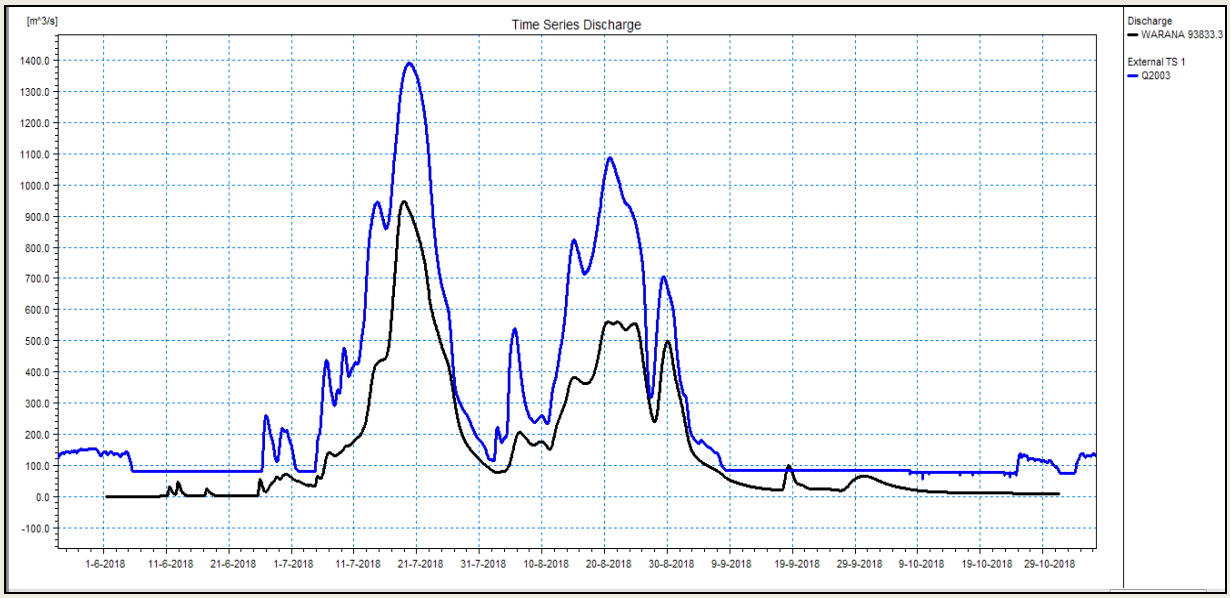


Plot of comparison between simulated and observed discharge at Shigaon .

After addition of accurate spilling data from Warna reservoir. Plots are given below for Shigaon station;

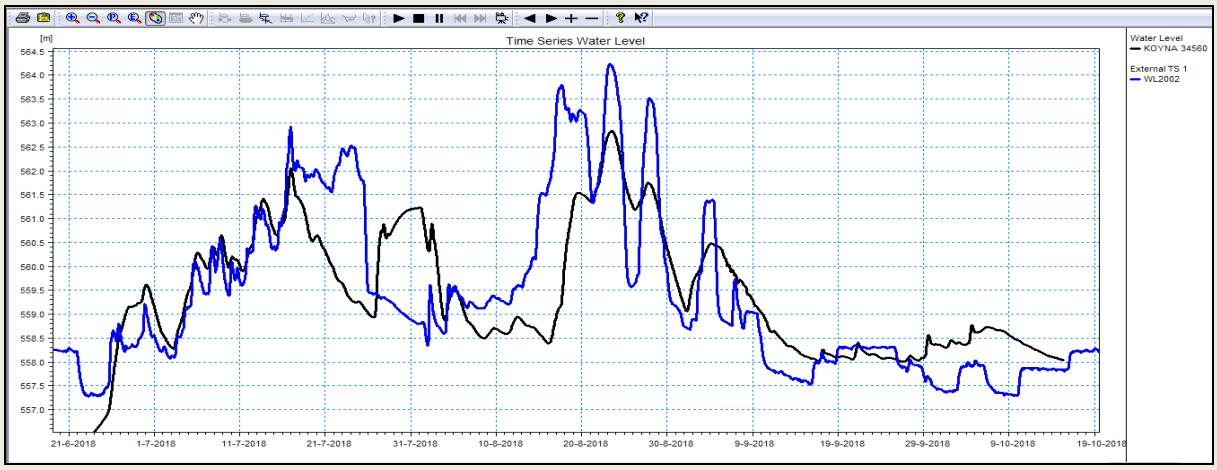


Plot of comparison between simulated and observed Water level at Shigaon

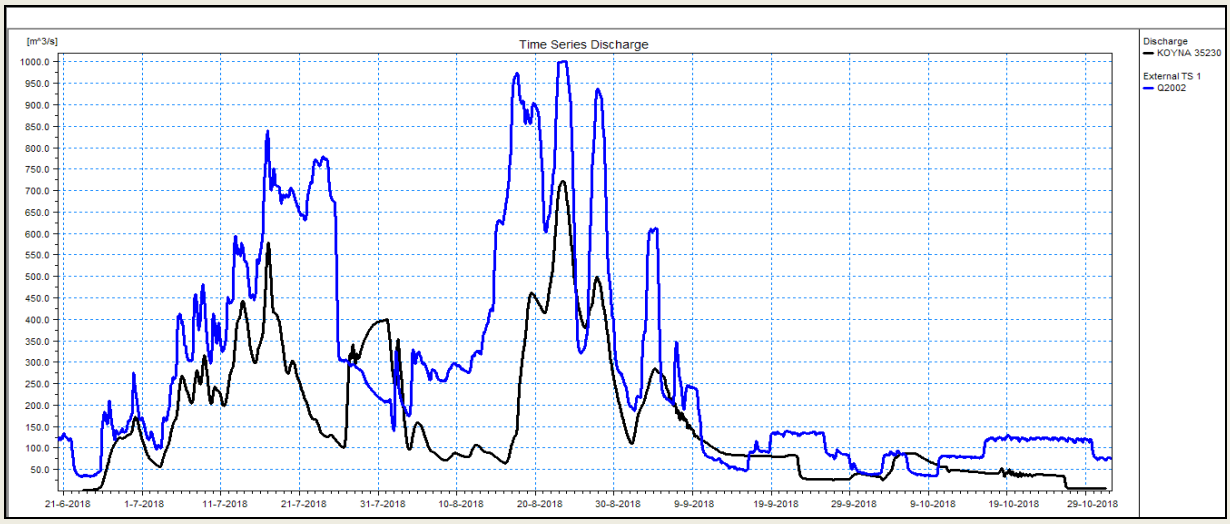


Plot of comparison between simulated and observed discharge at Shigaon

❖ **Navarasta on river Koyna:** The graph of comparison is shown in figure.

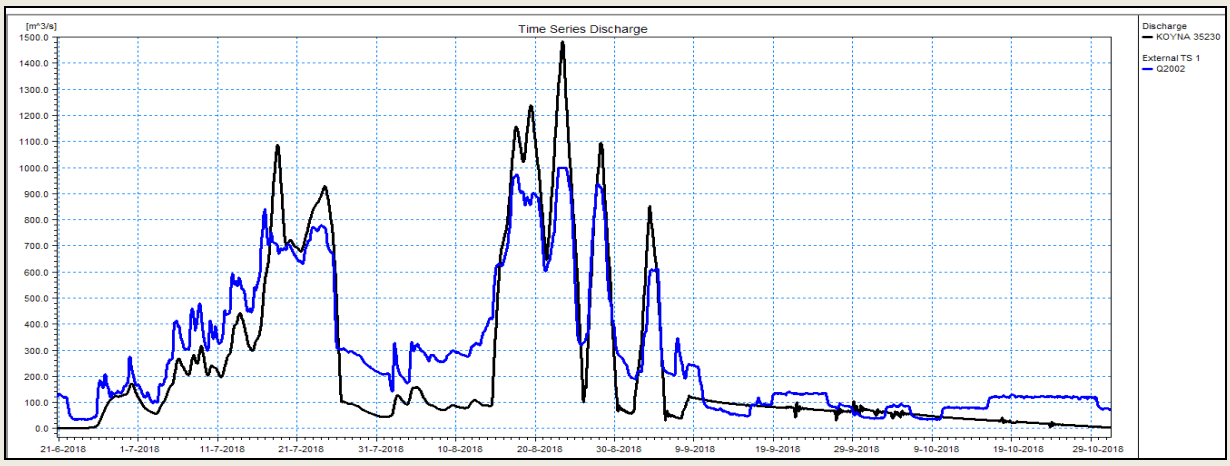


Plot of comparison between simulated and observed Water level at Navarasta.



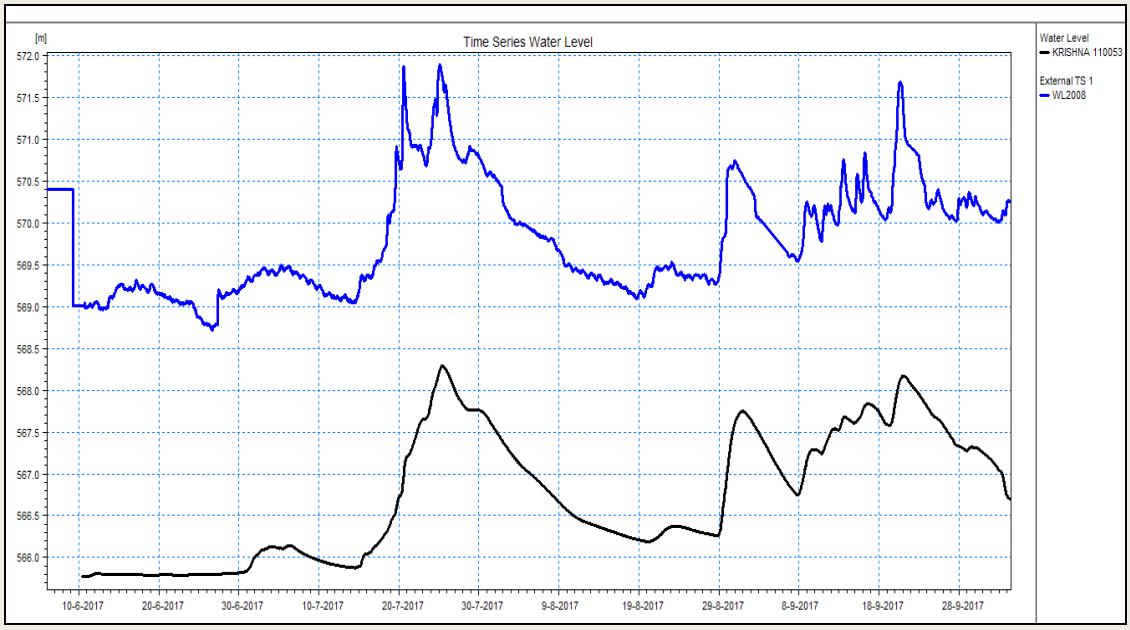
Plot of comparison between simulated and observed Discharge at Navarasta.

After addition of accurate spilling data from Konya reservoir. Rating curve of Navarasta is up to water level 564 mtr; so there is need of updation for above levels. Therefore difference is seen.

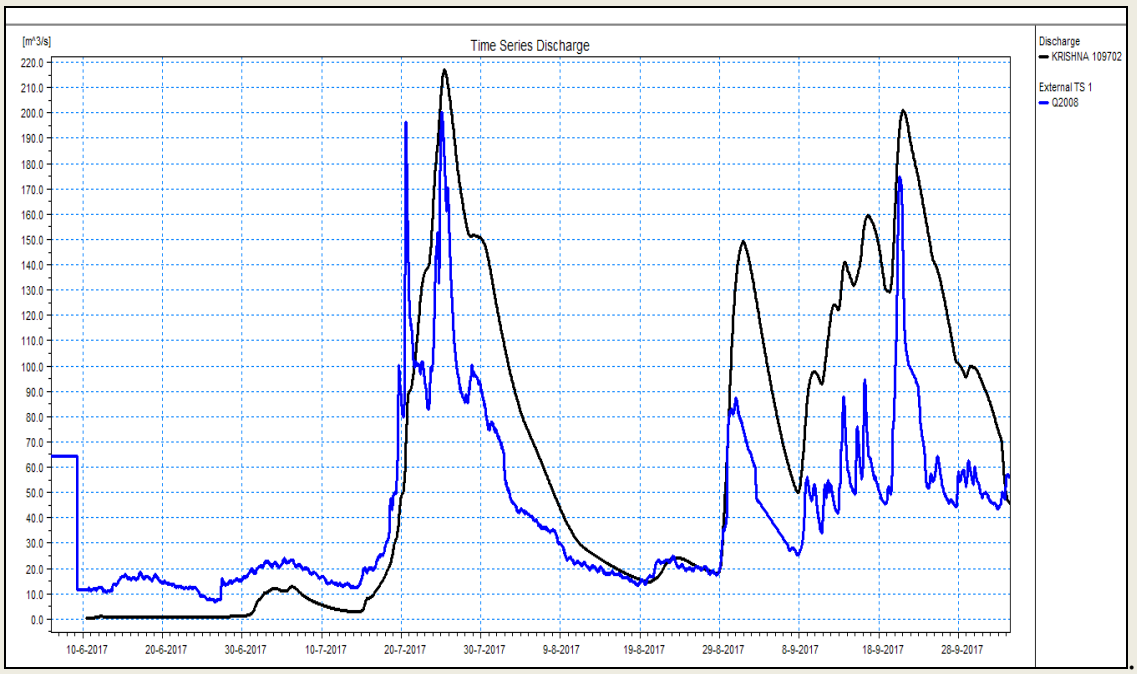


Plot of comparison between simulated and observed Discharge at Navarasta.

- **Shivade on river Krishna:** The graph of comparison is shown in figure. As per discussion had with Assistant Engineer grade I, Satara, Subdivision RTDAS data checked & verified; It shows water level difference because up to level 569 mtr there is stagnant water due to KT weir.

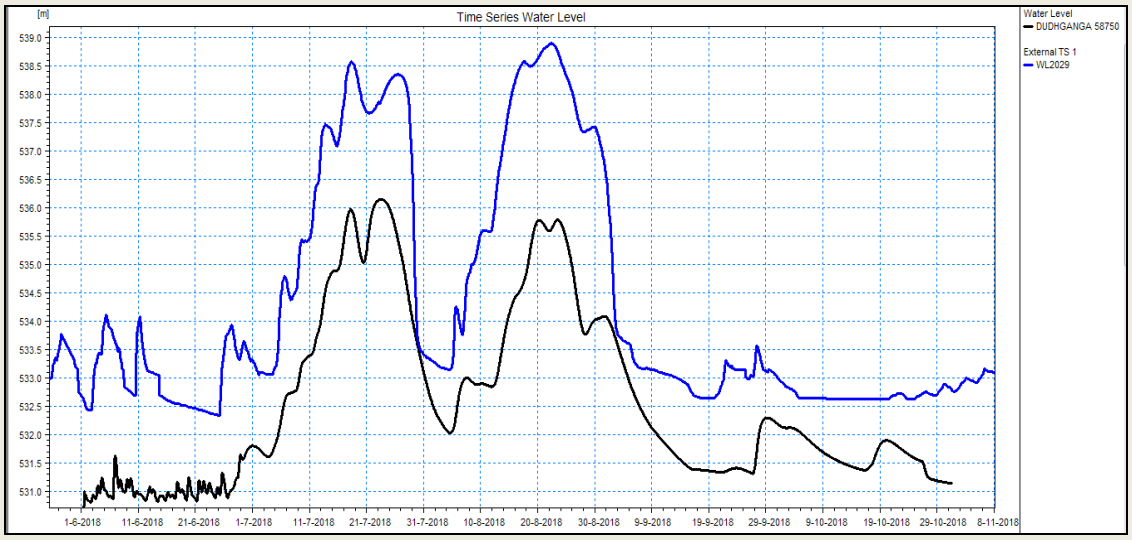


Plot of comparison between simulated and observed Water level at Shivade

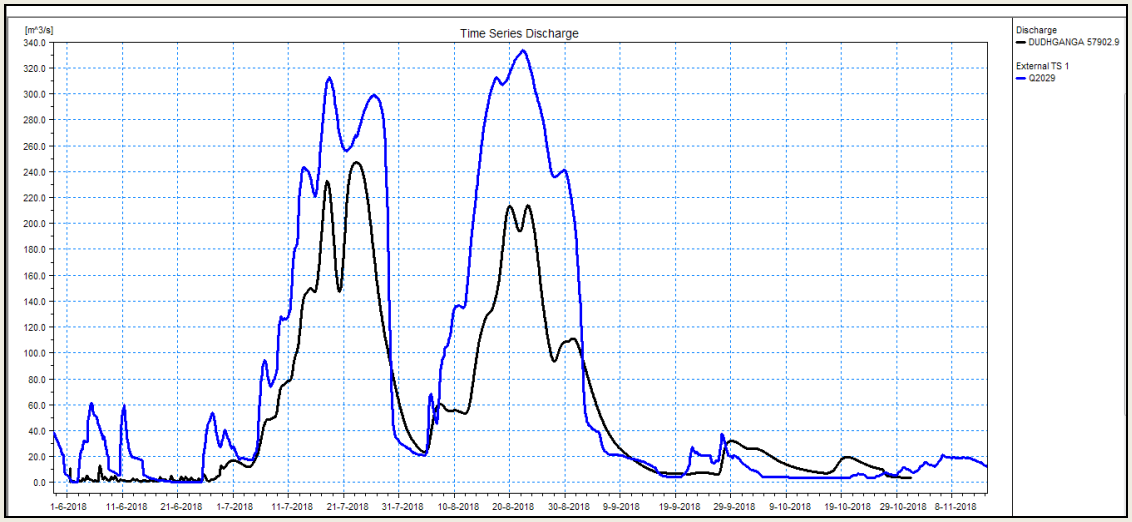


Plot of comparison between simulated and observed Discharge at Shivade

❖ **Kagal on river Dudhganga:** The graph of comparison is shown in figure. There is difference of Water level 2.5 mtr because of stagnant water due to KT weir.

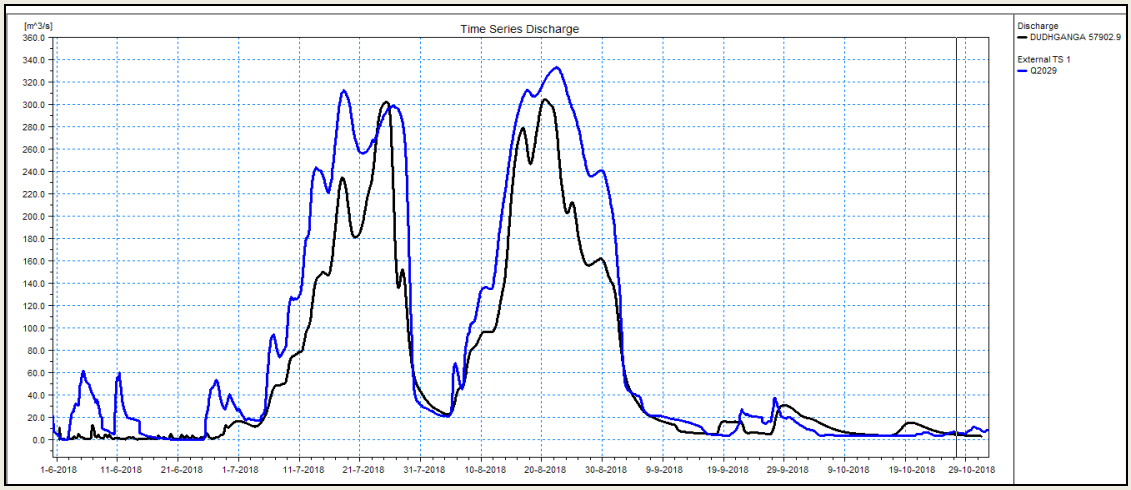


Plot of comparison between simulated and observed Water level at Kagal.

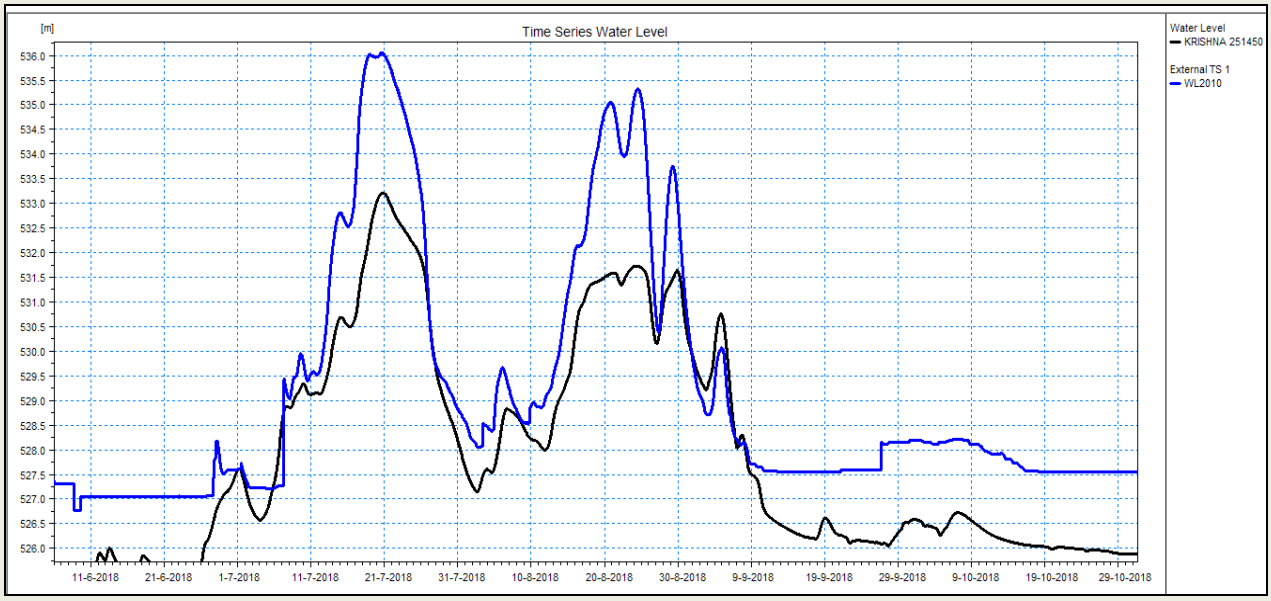


Plot of comparison between simulated and observed Discharge at Kagal.

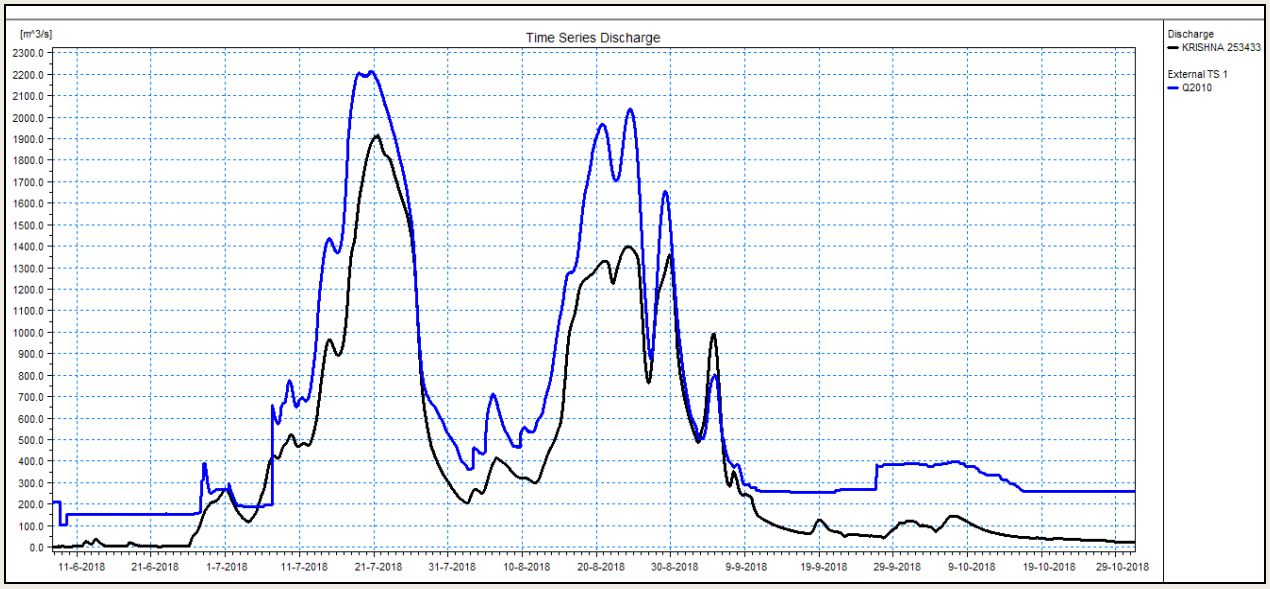
After addition of accurate spilling data from Dudhganga reservoir.



❖ **Ankali Bridge on river Krishna:** The graph of comparison is shown in figure.

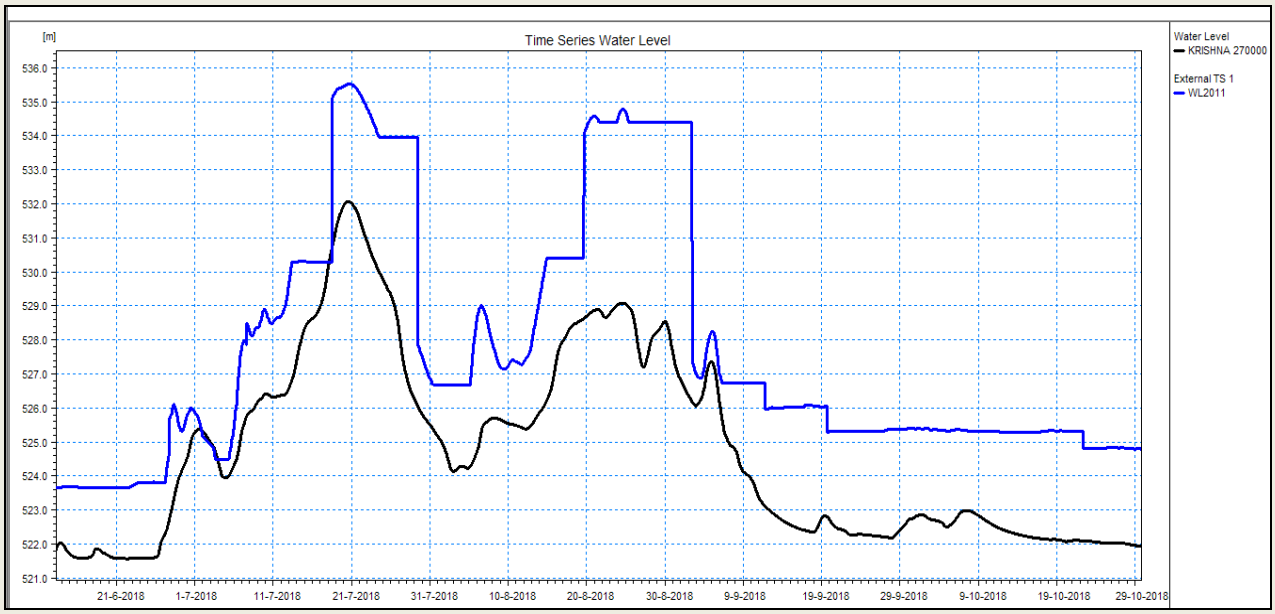


Plot of comparison between simulated and observed Water level at Ankli Bridge.

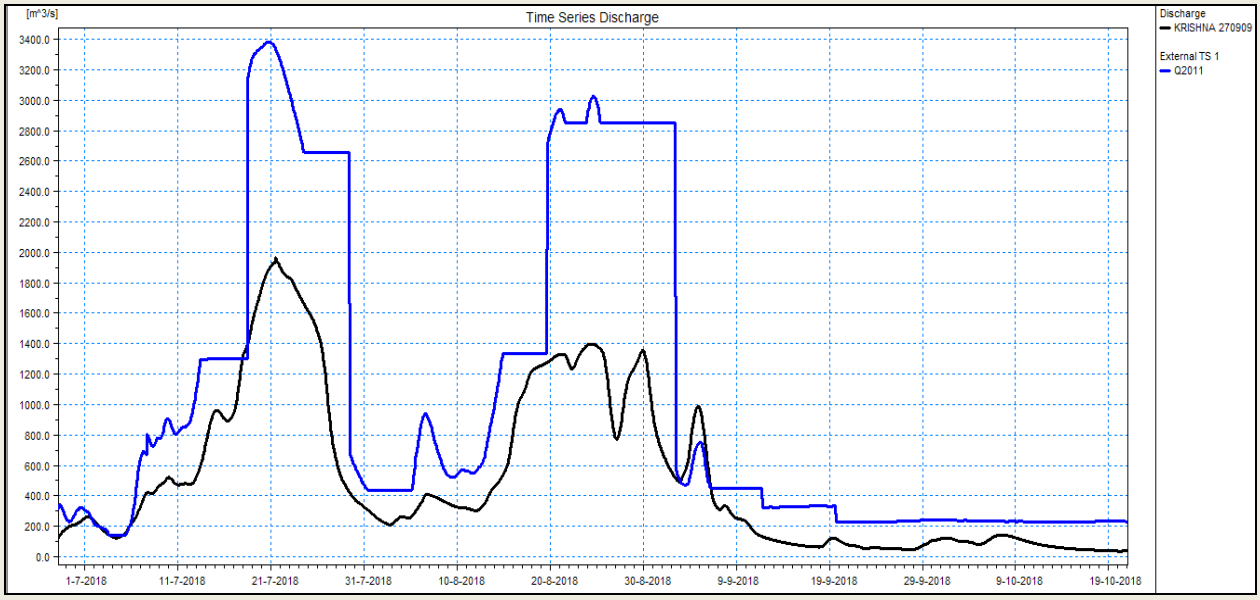


Plot of comparison between simulated and observed Discharge at Ankli Bridge.

- **Mhaisal on river Krishna :** The graph of comparison is shown in figure.



Plot of comparison between simulated and observed Water level at Mhaisal.



Plot of comparison between simulated and observed Discharge at Mhaisal.

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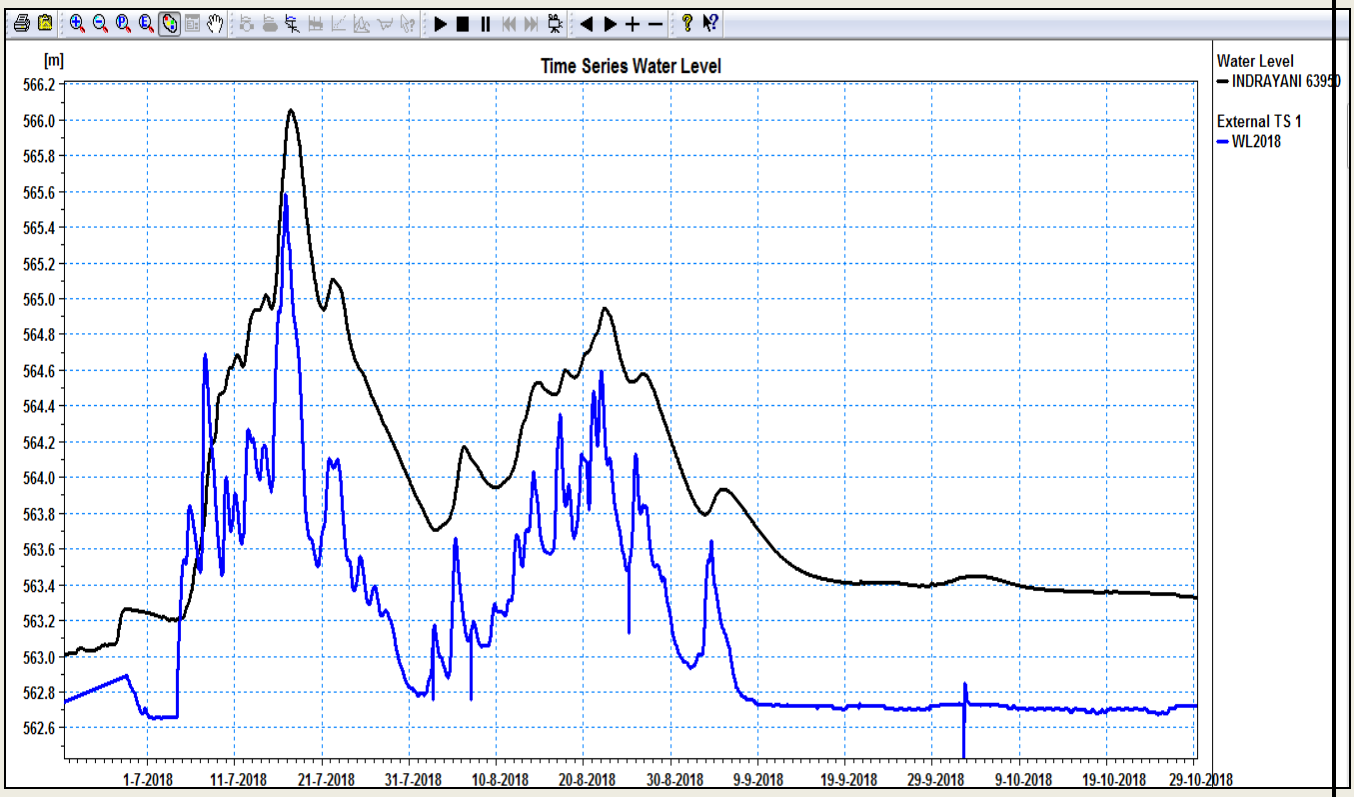
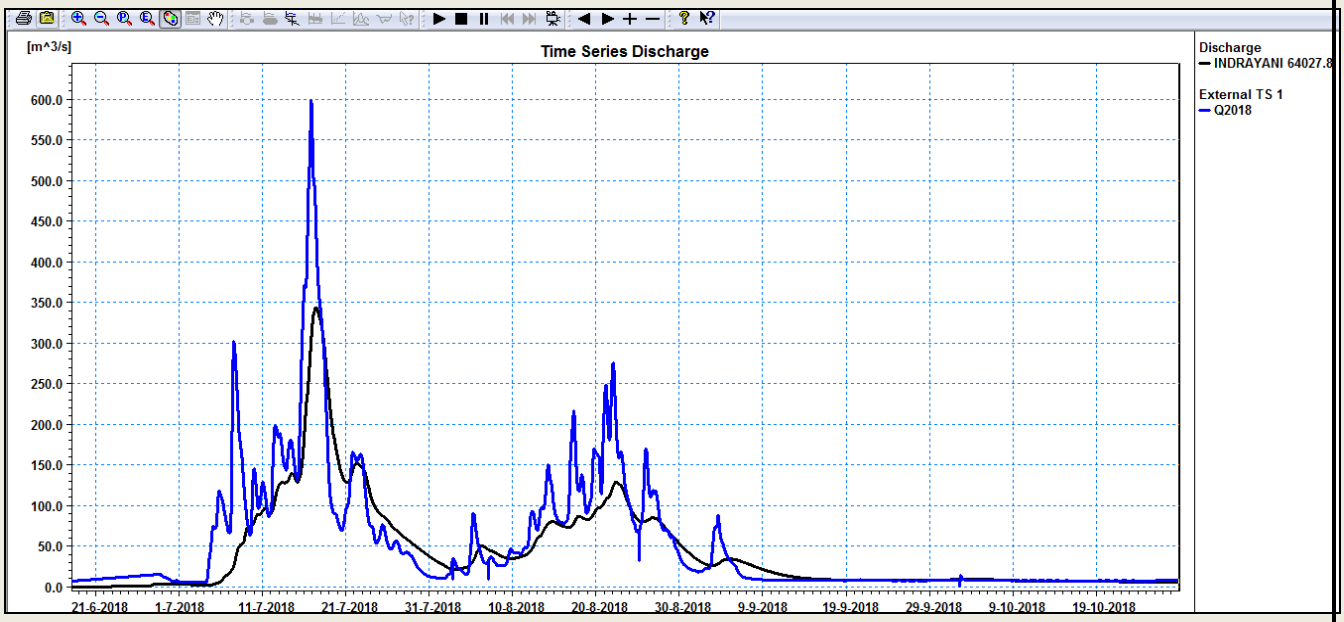
Graphical presentation for calibration of Bhima Basin is given below:

❖ **'<u>Nighoje on river Indrayani</u>'** -For the refinement of site 'Nighoje' observed spill data for upstream reservoirs Valavan, Shirota, Wadiwale and Andhra was required.Only Real time data of spilling of Wadiwale and Andhra are available.The figure below shows the plot of simulated water level & discharge at Nighoje is compared with calculated discharge from Real Time data.



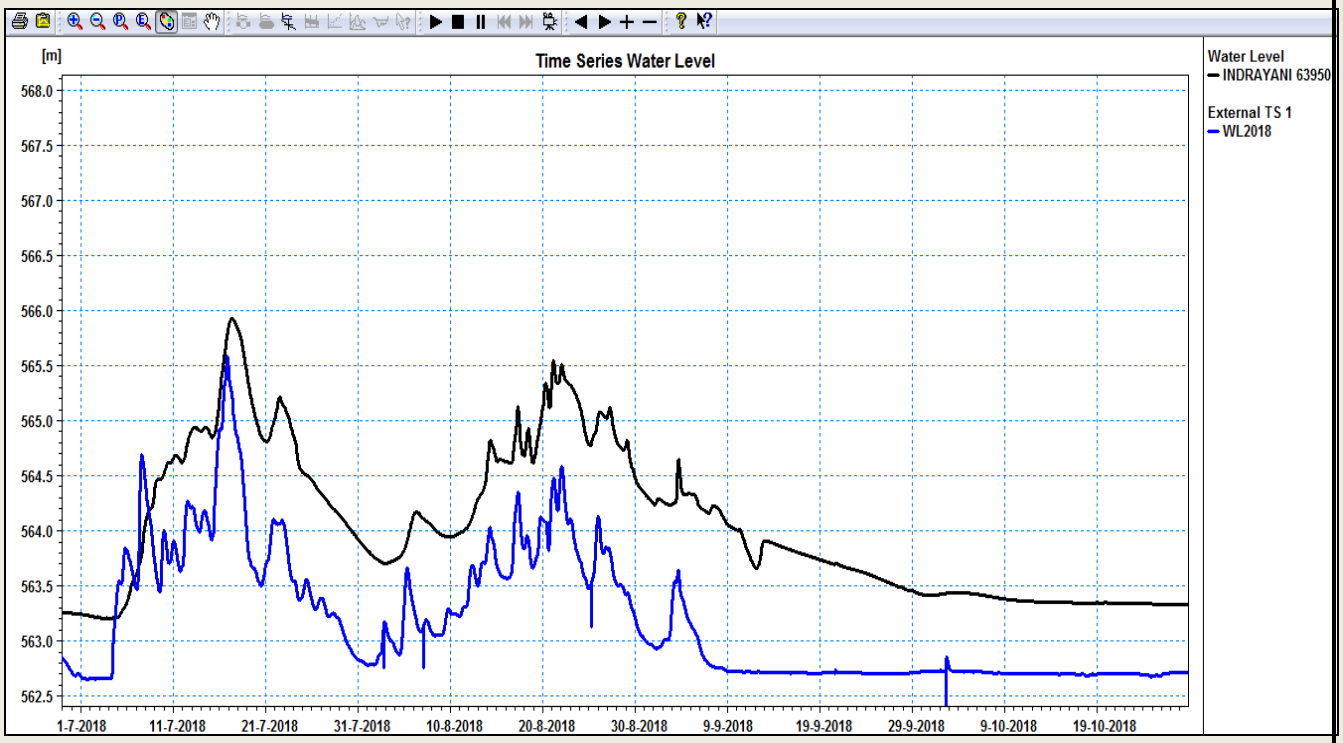
Plot of comparison between simulated and observed water level at Nighoje



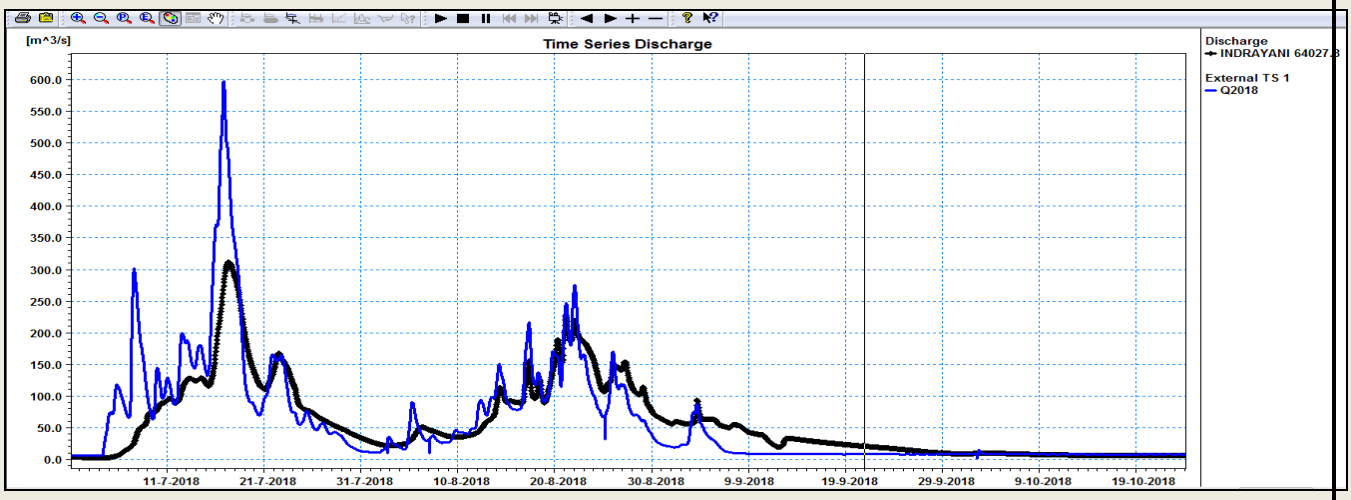
Plot of comparison between simulated and observed discharge at Nighoje

After adding Real Time spill from Wadivale dam. Spill from Walwan & Shirota are not available.

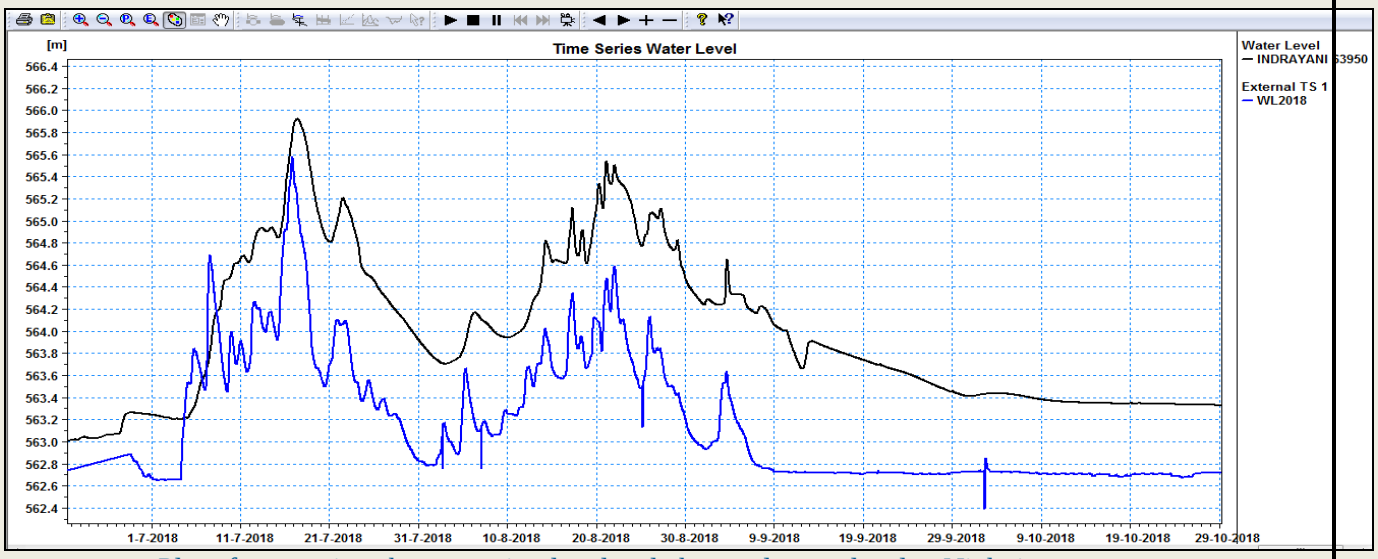
Plots are as below



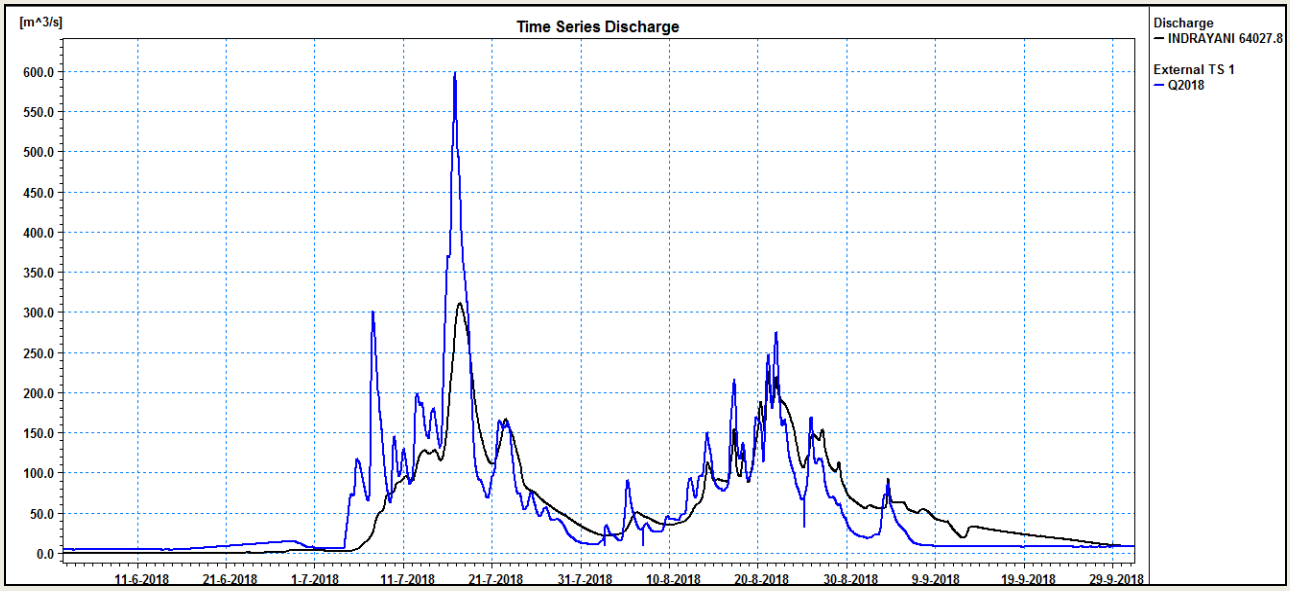
Plot of comparison between simulated and observed water level at Nighoje



Plot of comparison between simulated and observed discharge at Nighoje

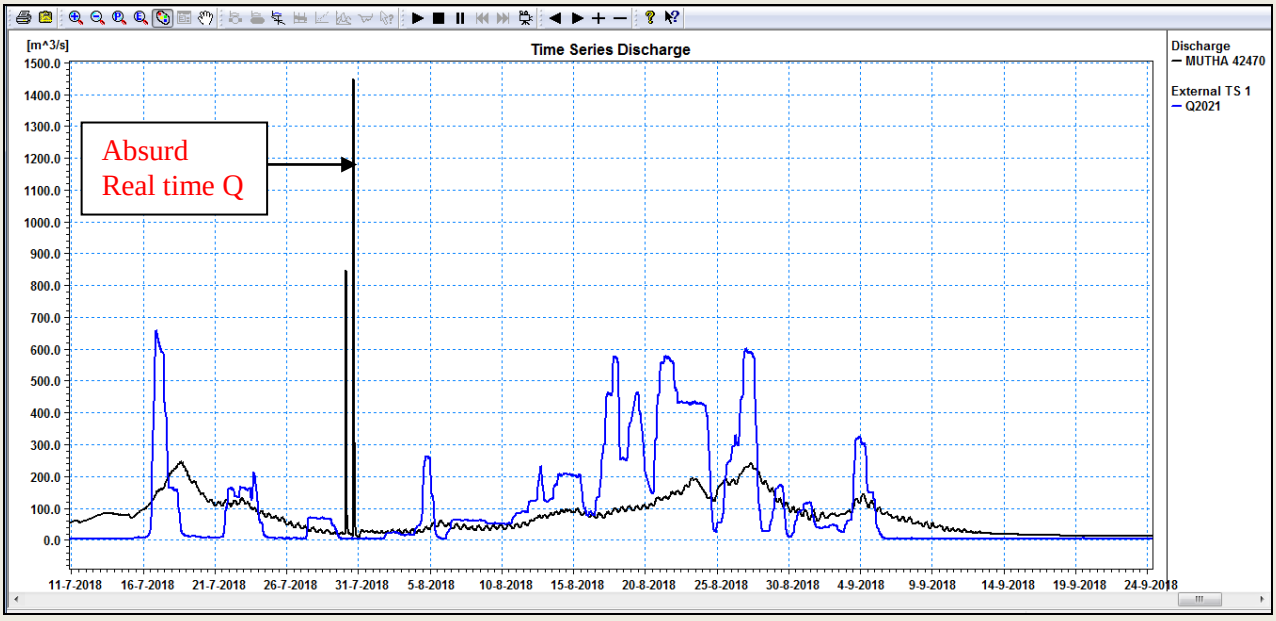


Plot of comparison between simulated and observed water level at Nighoje



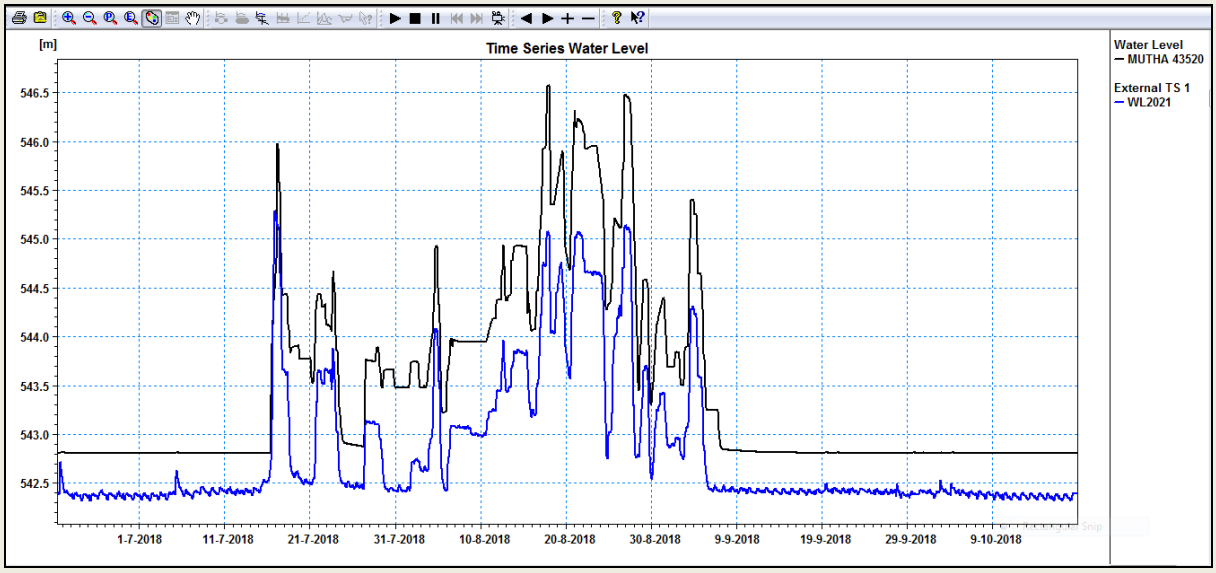
Plot of comparison between simulated and observed discharge at Nighoje

- **Dattawadi on river Mutha-** It is difficult to fine tune model at Dattawadi. Due to absurd Real time discharge values. Plot below shows the plot of observed and simulated discharge at Dattawadi station.

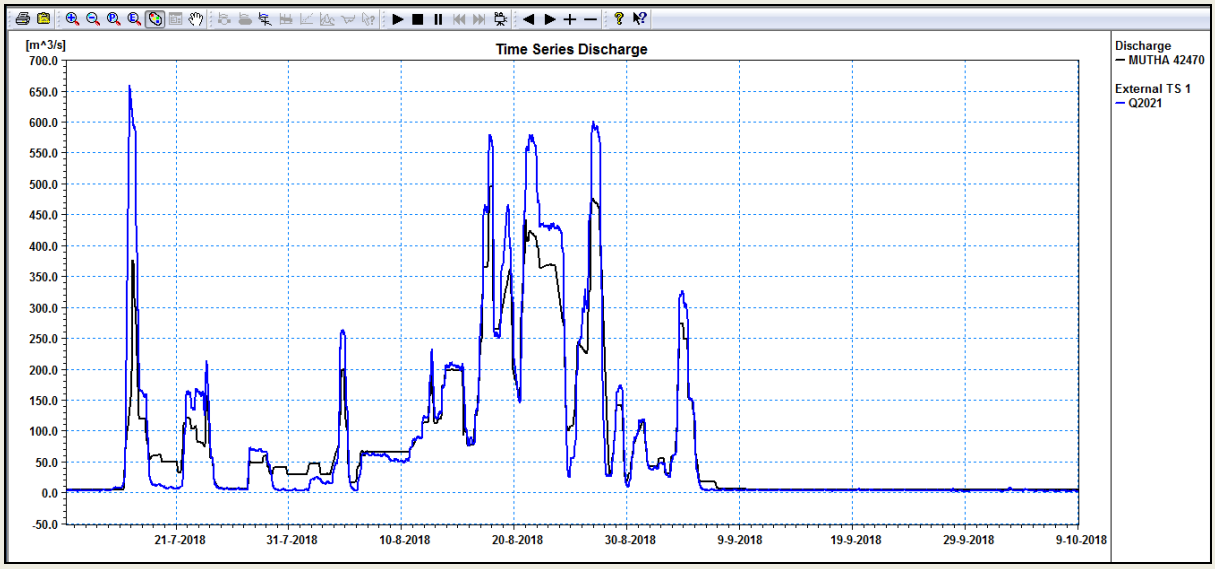


Plot of comparison between simulated and observed discharge at Dattawadi

After adding Spill from khadakwasala reservoir and corrected real time spill, plots are as below

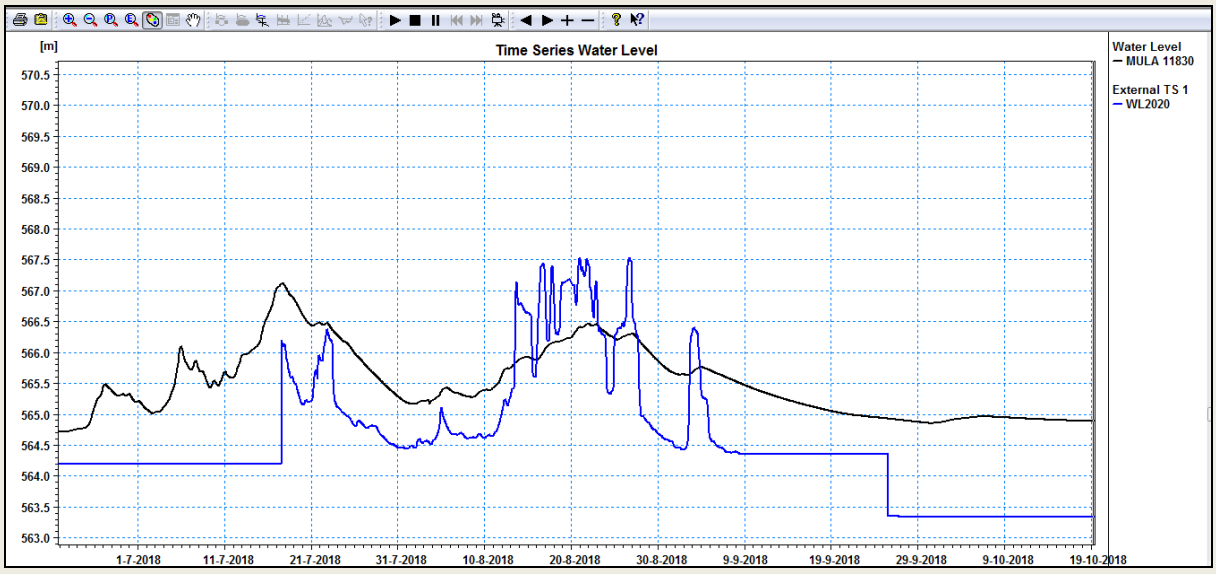


Plot of comparison between simulated and observed water level at Dattawadi

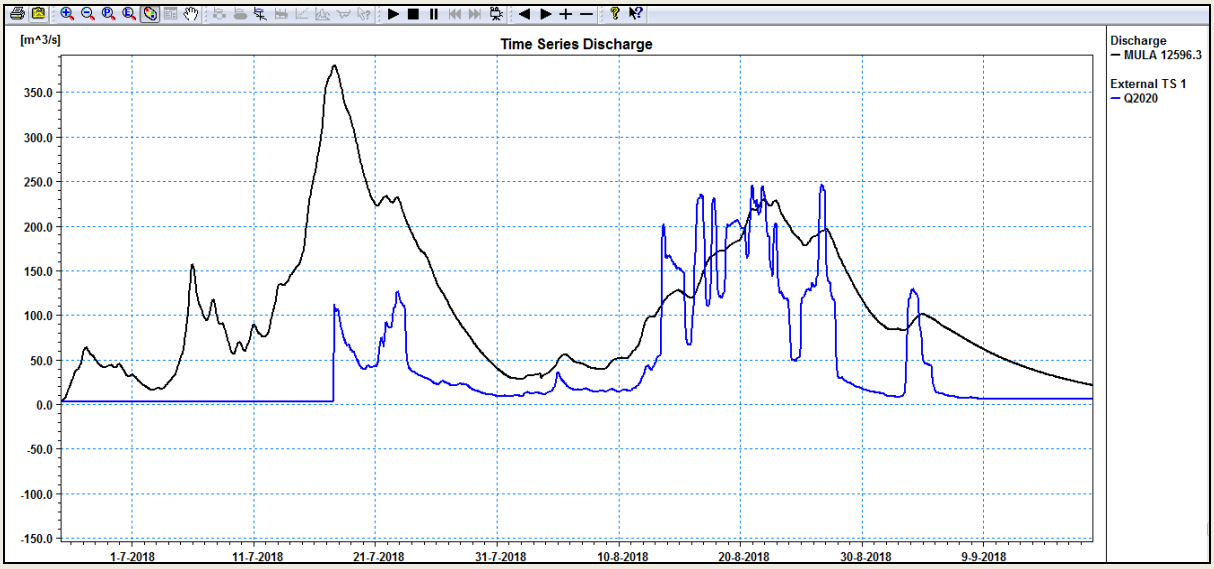


Plot of comparison between simulated and observed discharge at Dattawadi

- **Paud on river Mutha-** It is difficult to fine tune model at Paud due to absurd Real time values. Plot below shows the plot of observed and simulated Water level at Paud station

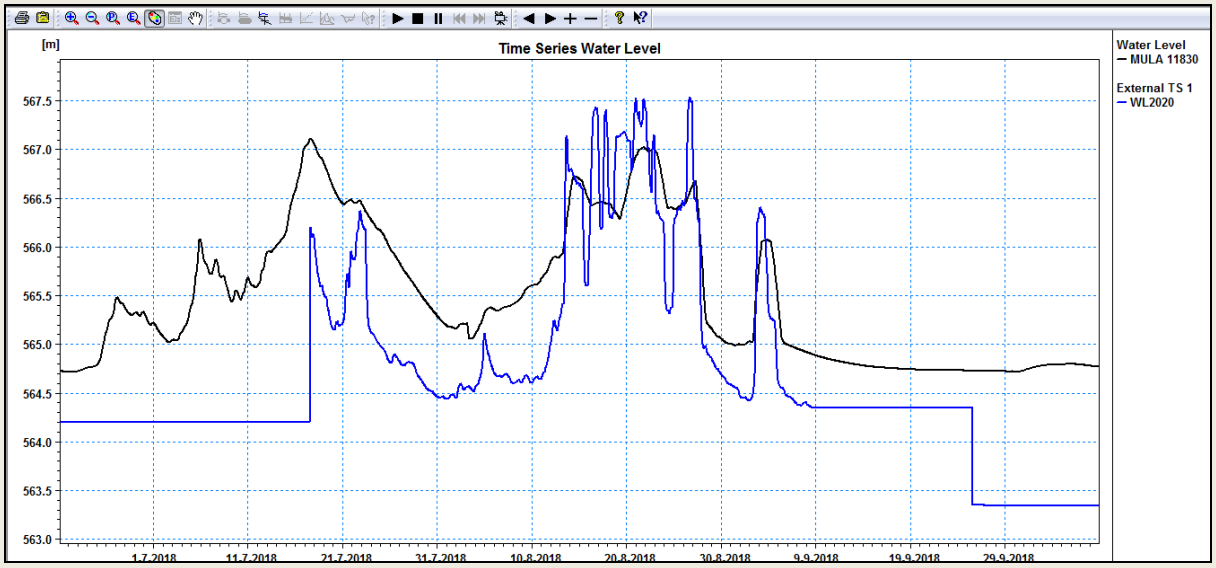


Plot of comparison between simulated and observed water level at Paud

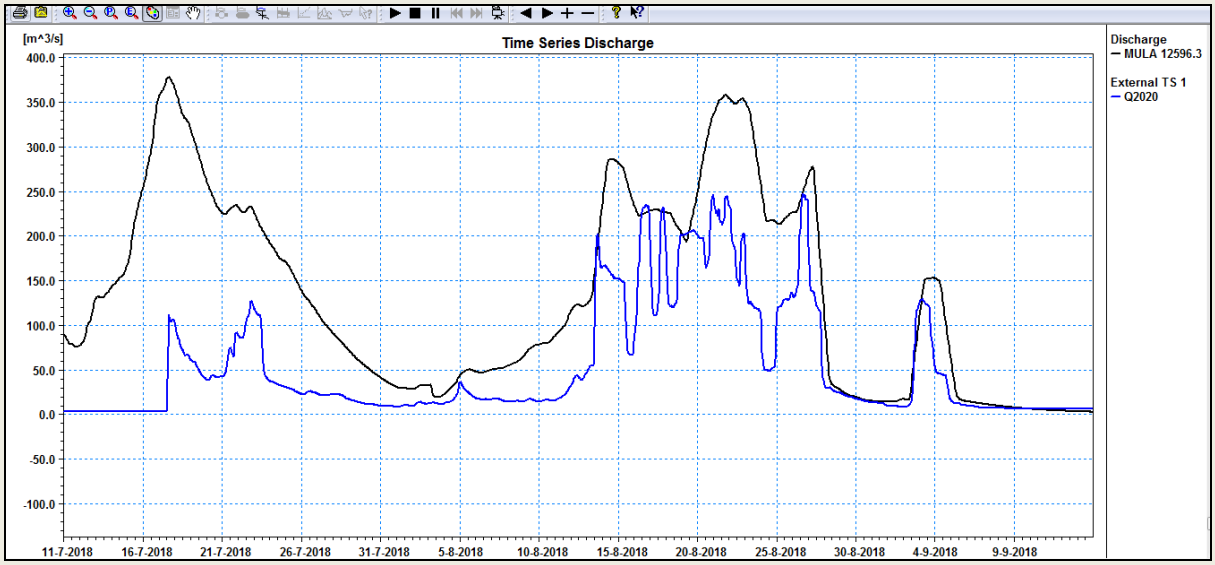


Plot of comparison between simulated and observed discharge level at Paud

After adding spill from Mulshi reservoir, plots are as below

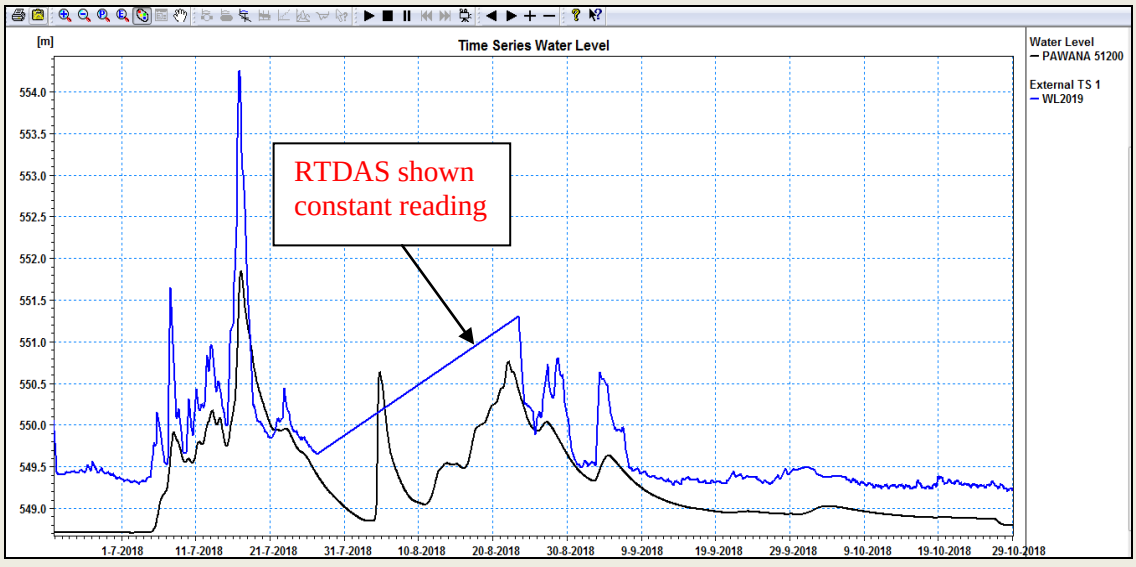


Plot of comparison between simulated and observed water level at Paud

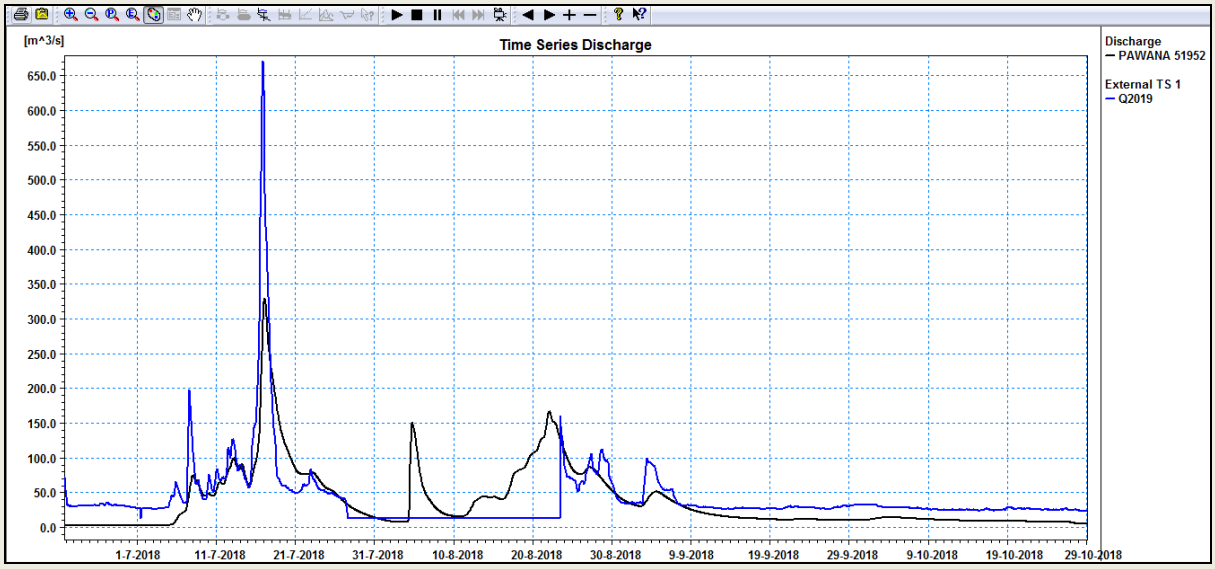


Plot of comparison between simulated and observed Discharge at Paud

❖ **Pimple gurav on river Pawna-**Below figure shows the plot of simulated water level, discharge and observed water level, discharge. RTDAS shown upsard WL value in July month and RTDAS shown constant reading till 1 month (31/7/18 to 21/8/18 ,WL = 548.80m & Q =12.54)

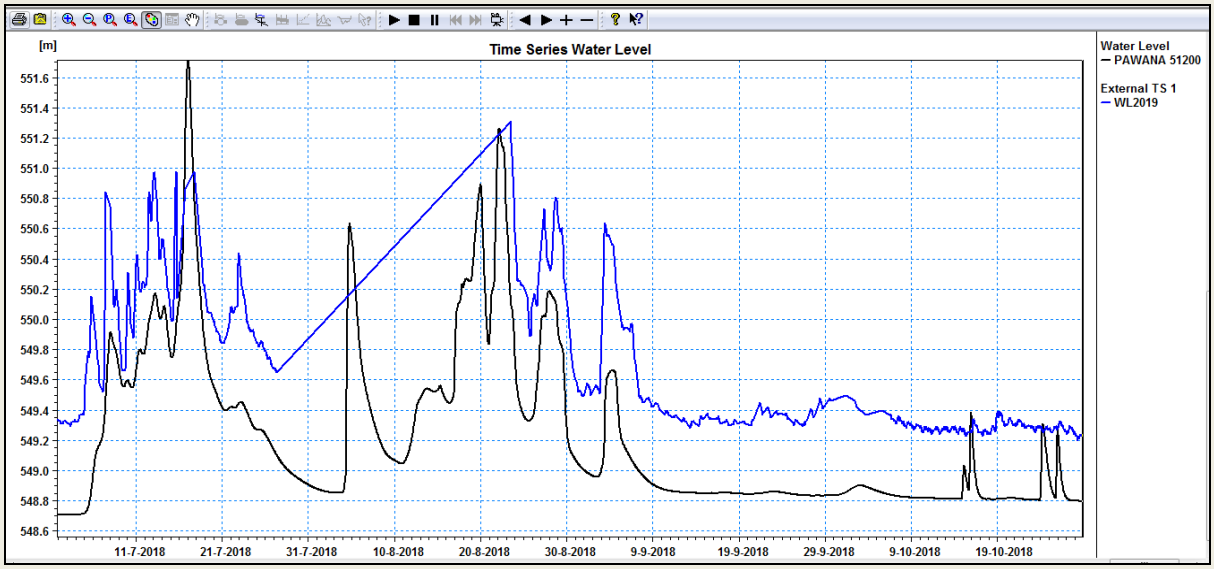


Plot of comparison between simulated and observed water level at Pimple Gurav

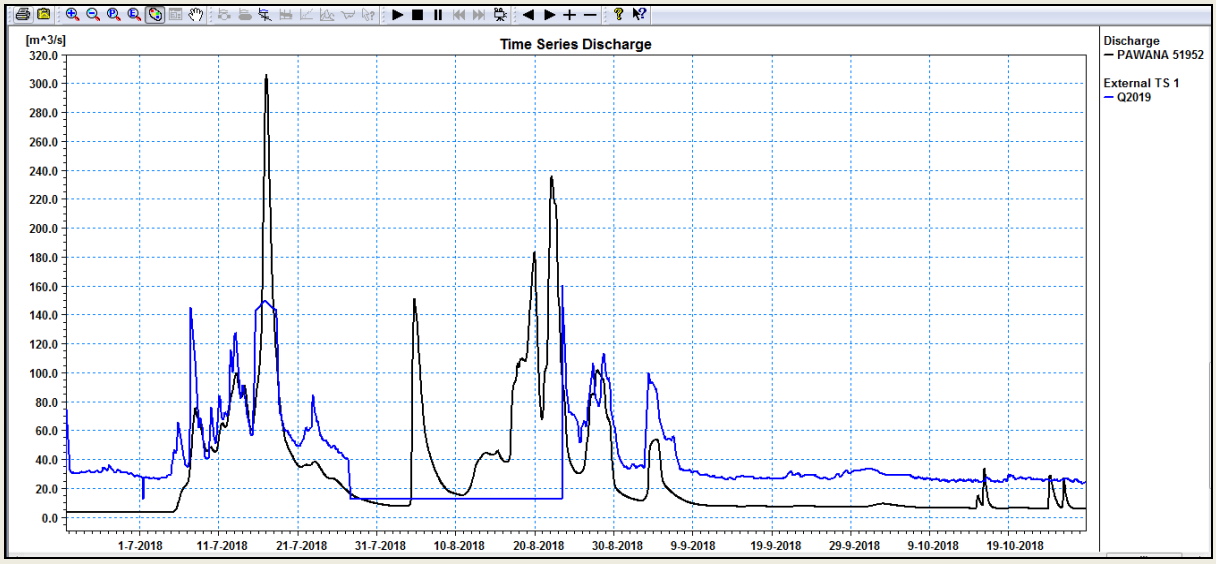


Plot of comparison between simulated and observed discharge at Pimple Gurav

Adding spill from Kasarsai reservoir, plots are as below

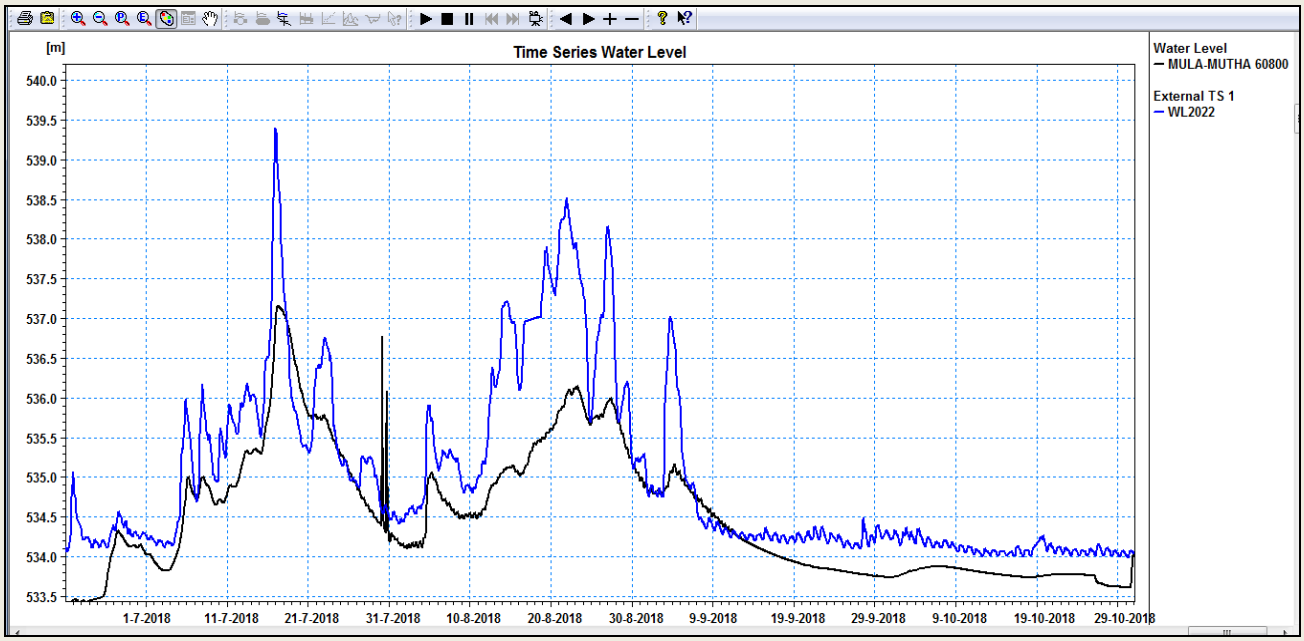


Plot of comparison between simulated and observed water level at Pimple Gurav

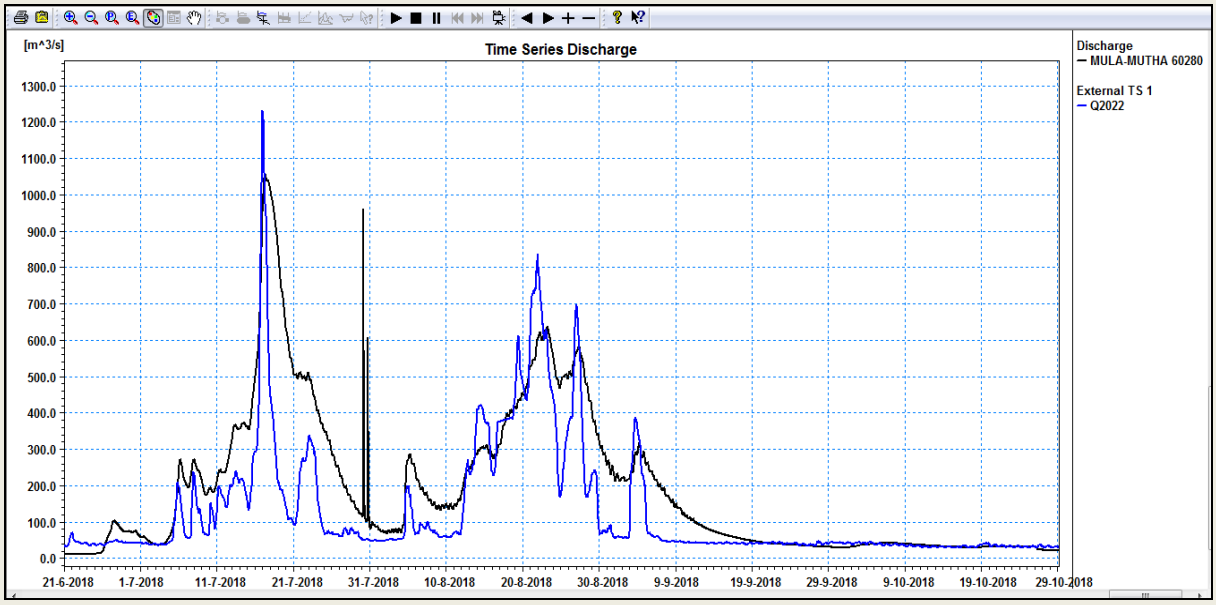


Plot of comparison between simulated and observed Discharge at Pimple Gurav

❖ **Kalyani nagar on river Mula-Mutha-**Below figure shows the plot of simulated water level,discharge and observed water level,discharge at Kalyani nagar According to graph both the plots having good correlation.

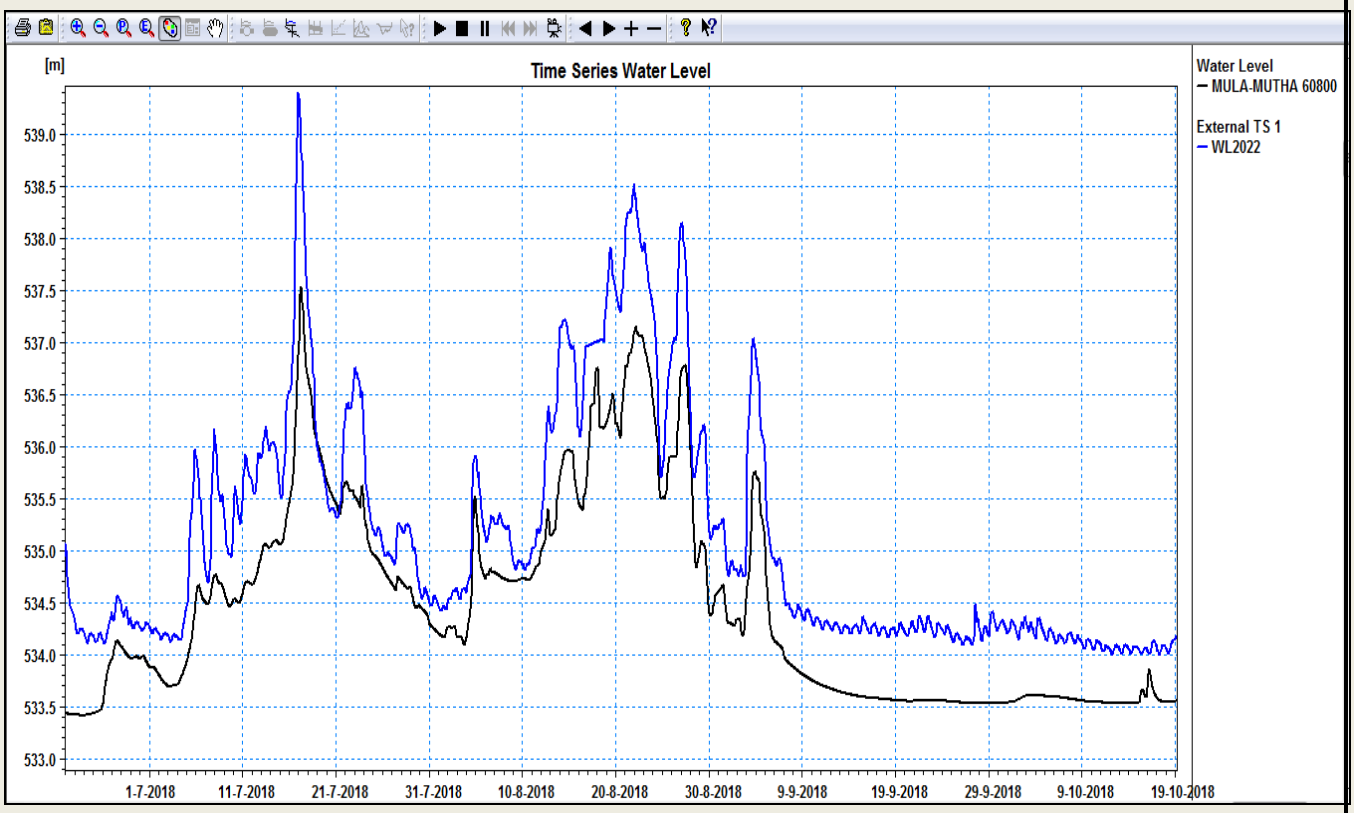


Plot of comparison between simulated and observed Water level at Kalyani nagar

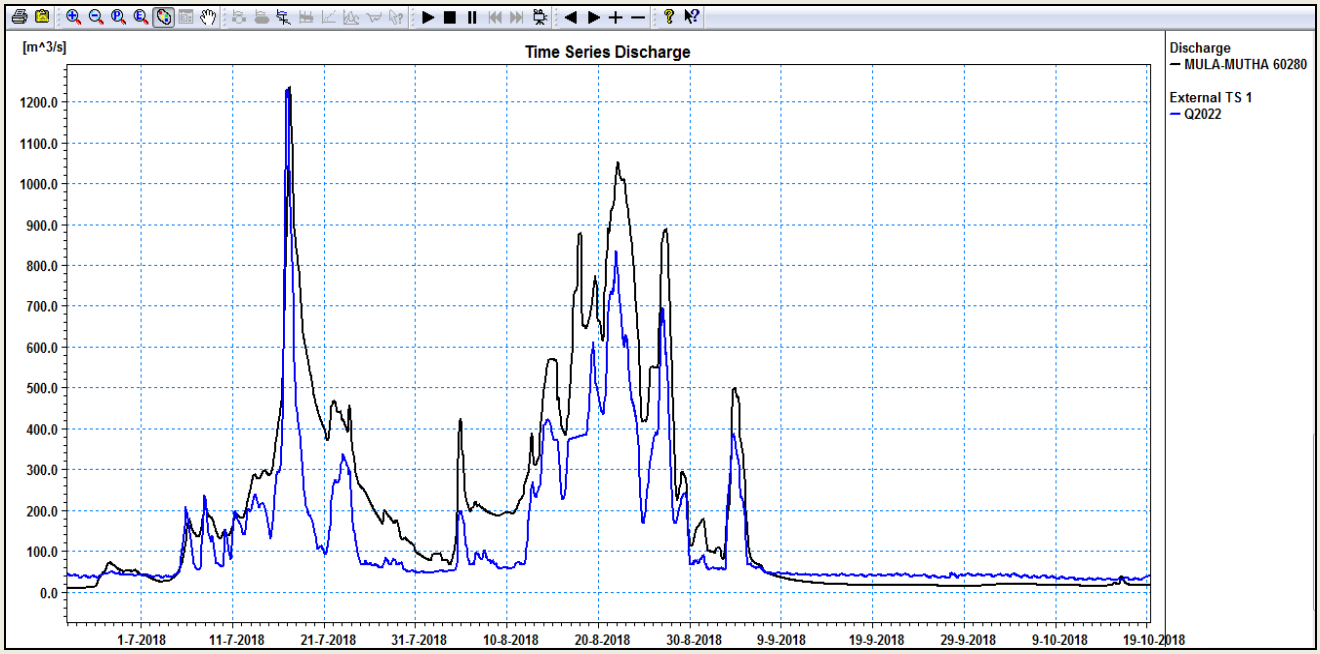


Plot of comparison between simulated and observed discharge at Kalyani nagar

After adding spill from Khadakwasala and Mulshi reservoir,plots are as below

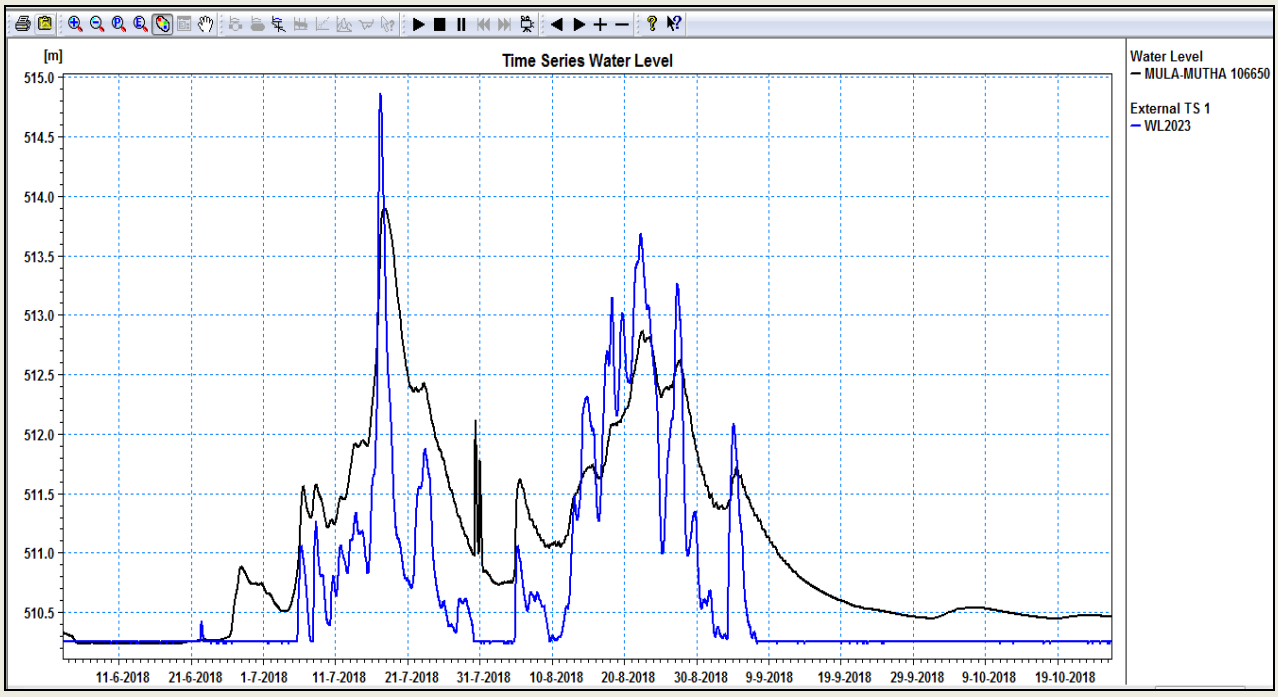


Plot of comparison between simulated and observed Water level at Kalyani nagar

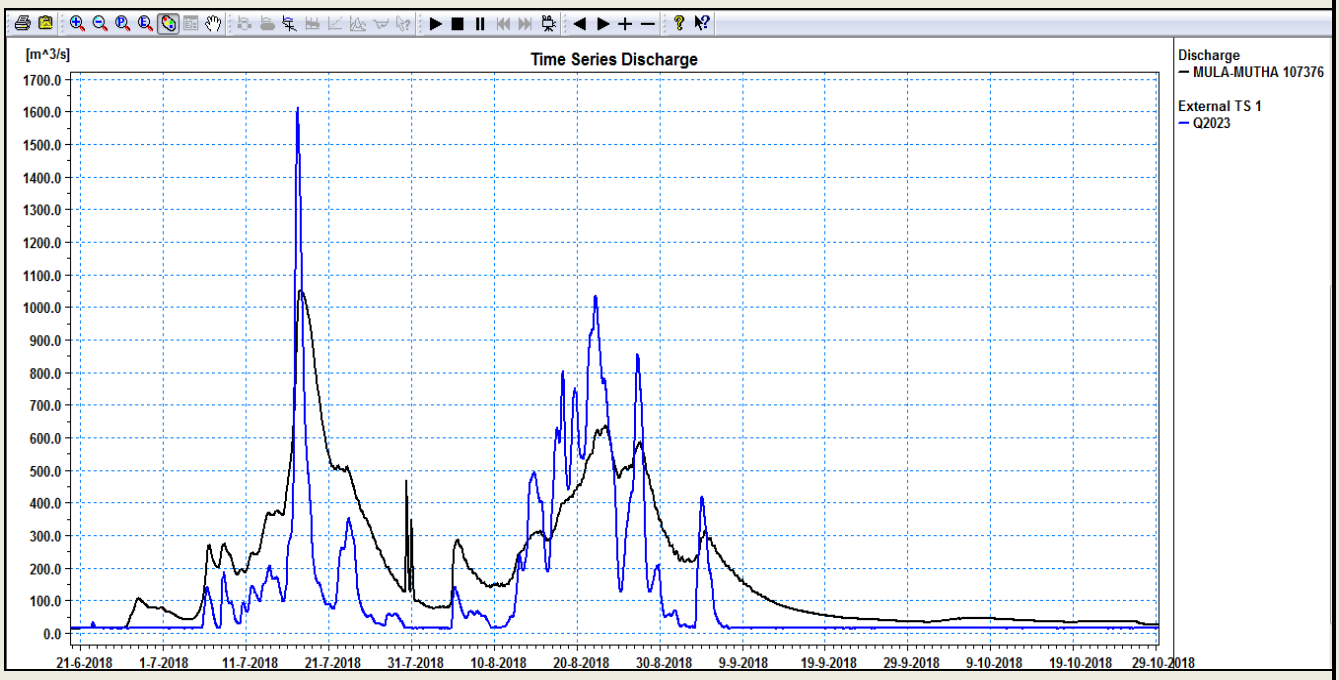


Plot of comparison between simulated and observed discharge at Kalyani nagar

❖ **Khamgaon on river Mula-Mutha** -Figure below shows the plot of simulated and observed water level & discharge at Khamgaon station. The plot shows good correlation between observed and simulated water level & discharge.

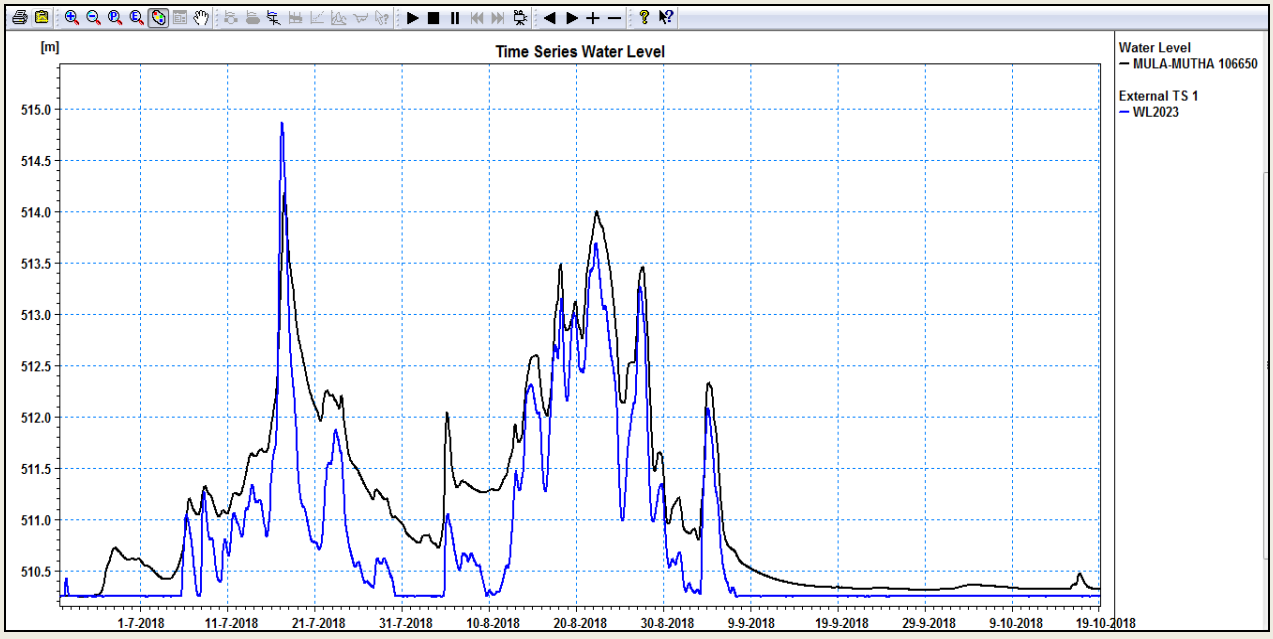


Plot of comparison between simulated and observed water level at Khamgaon

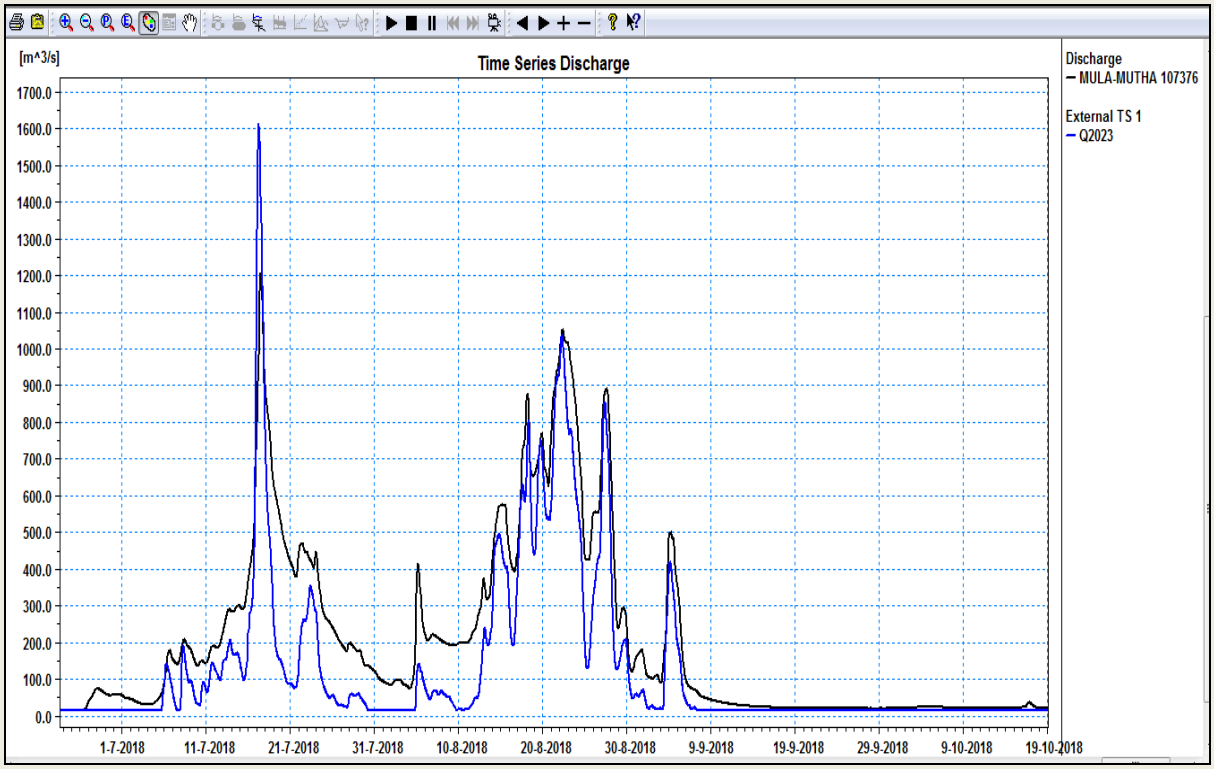


Plot of comparison between simulated and observed discharge at Khamgaon

After adding spill upstream reservoir, plots are as below

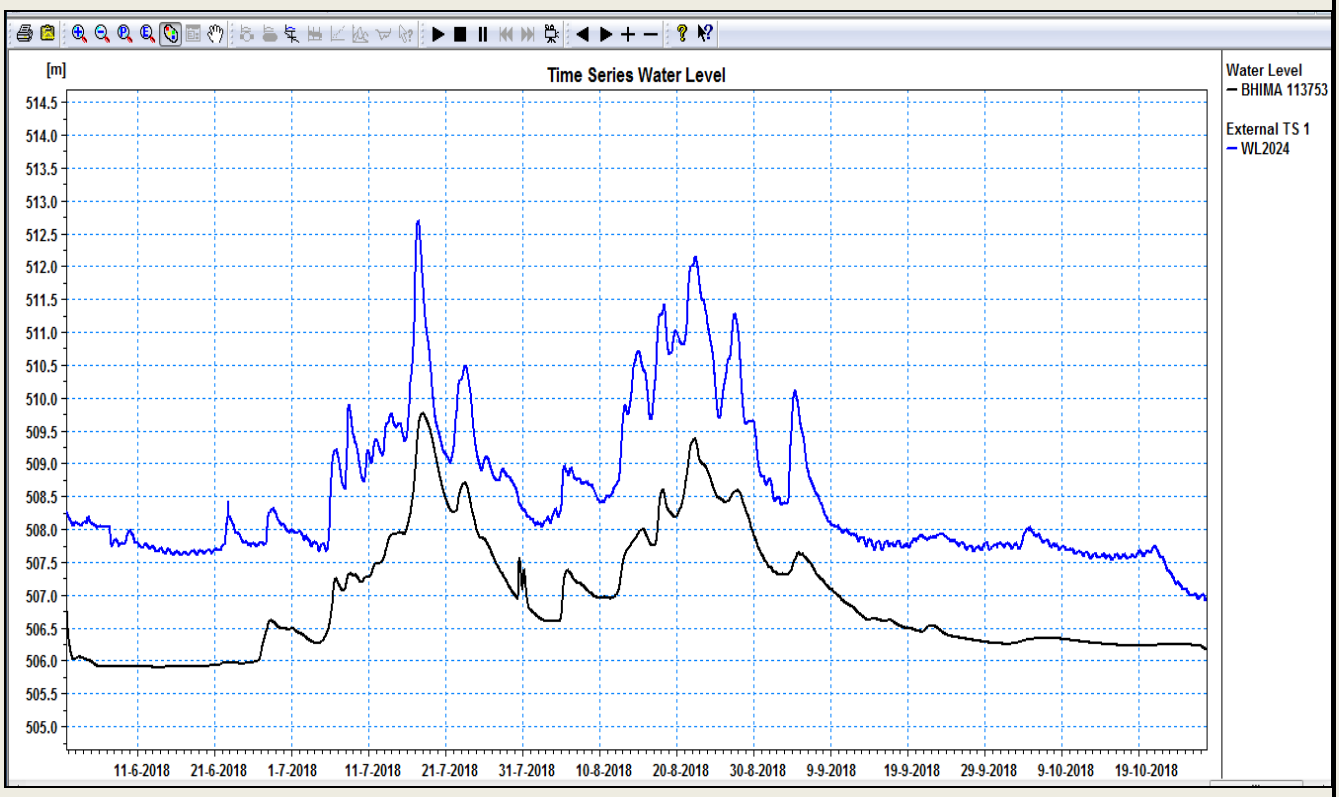


Plot of comparison between simulated and observed water level at Khamgaon

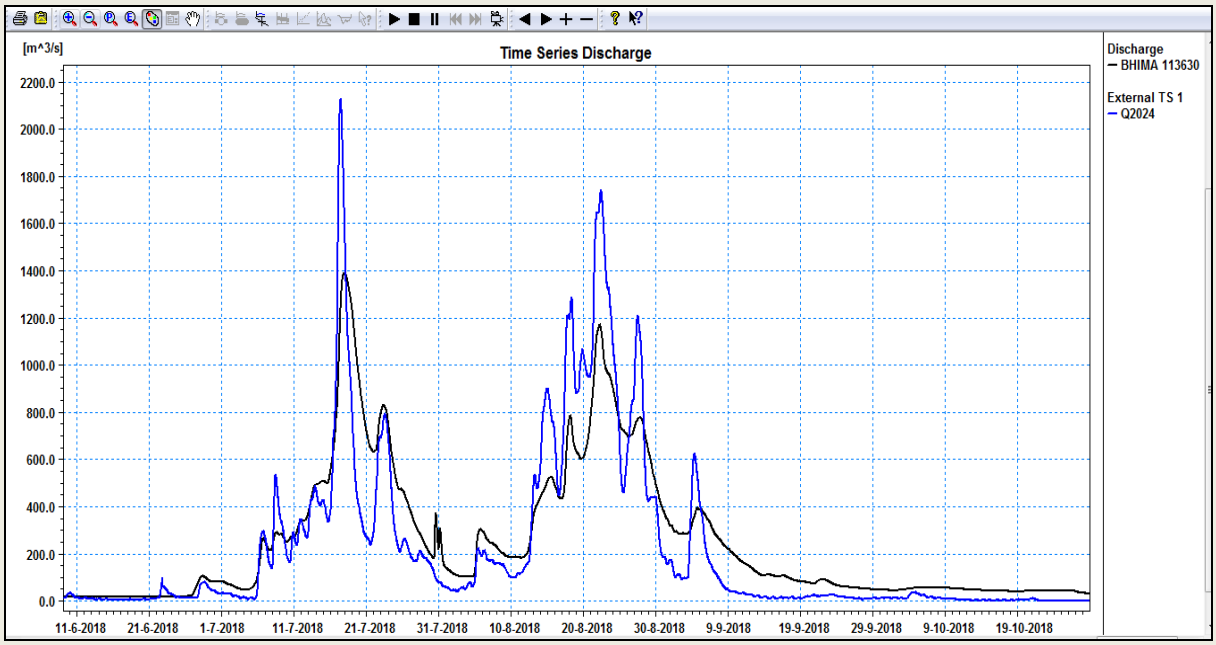


Plot of comparison between simulated and observed discharge at Khamgaon

Pargaon on river Bhima -The below figure shows the comparison plot of observed and simulated water level & discharge at paragon station.

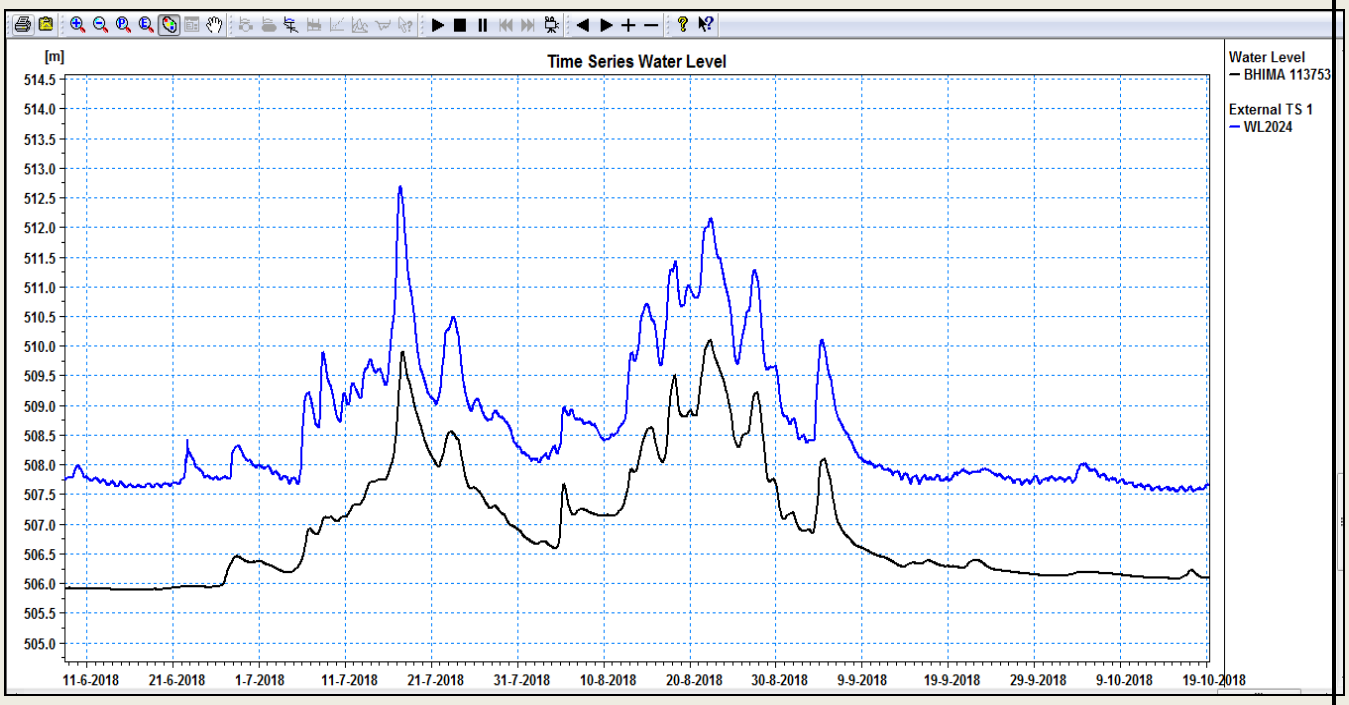


Plot of comparison between simulated and observed water level at Pargaon

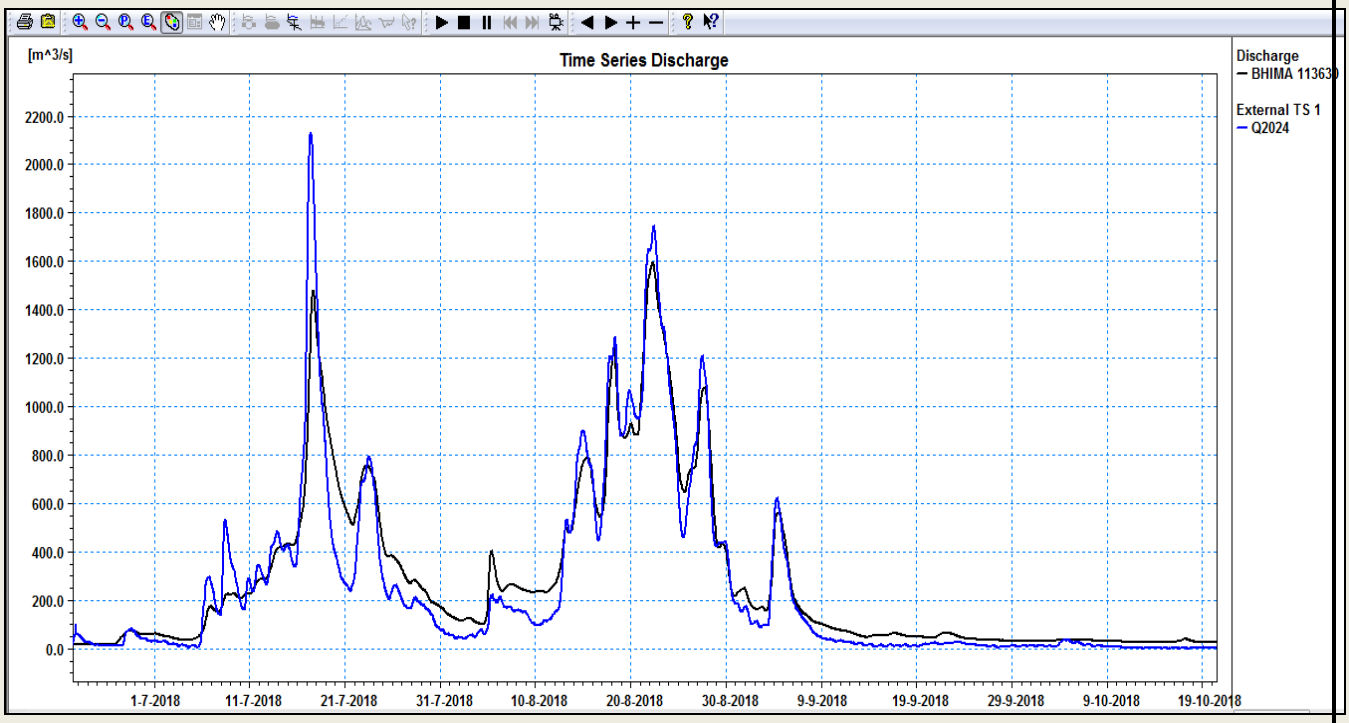


Plot of comparison between simulated and observed discharge at Pargaon

After adding spill upstream reservoir, plots are as below

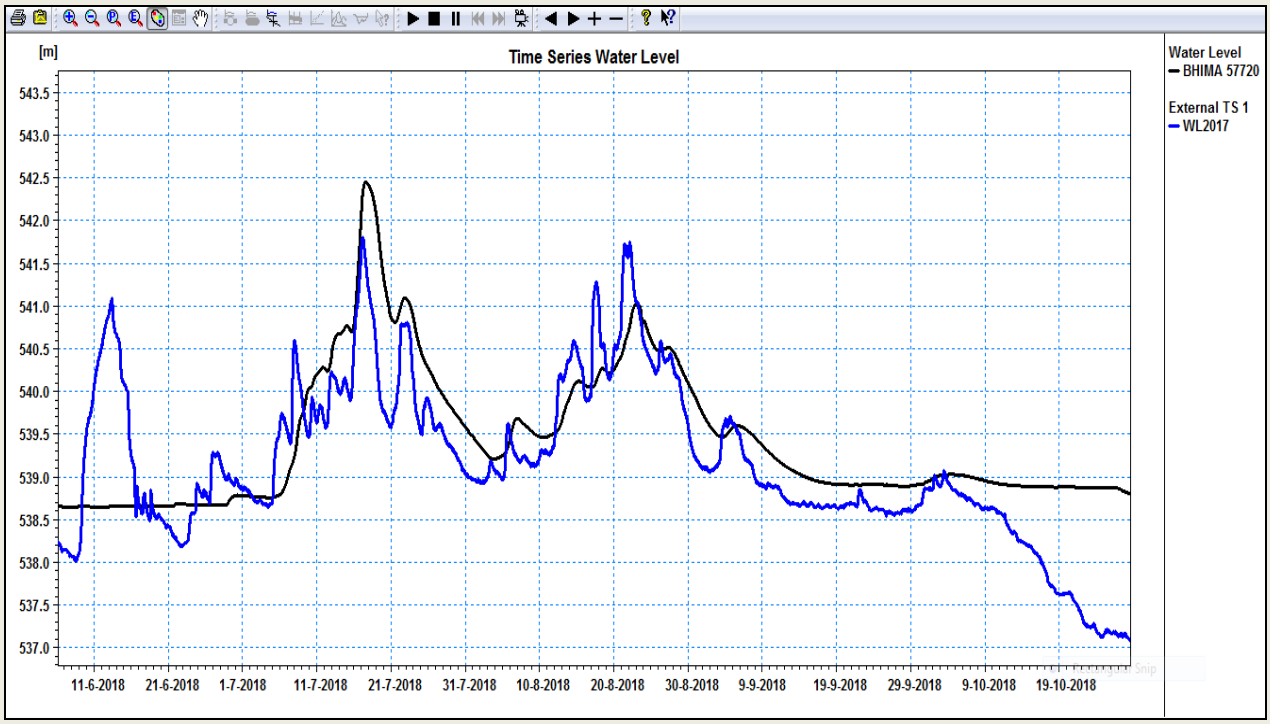


Plot of comparison between simulated and observed water level at Pargaon

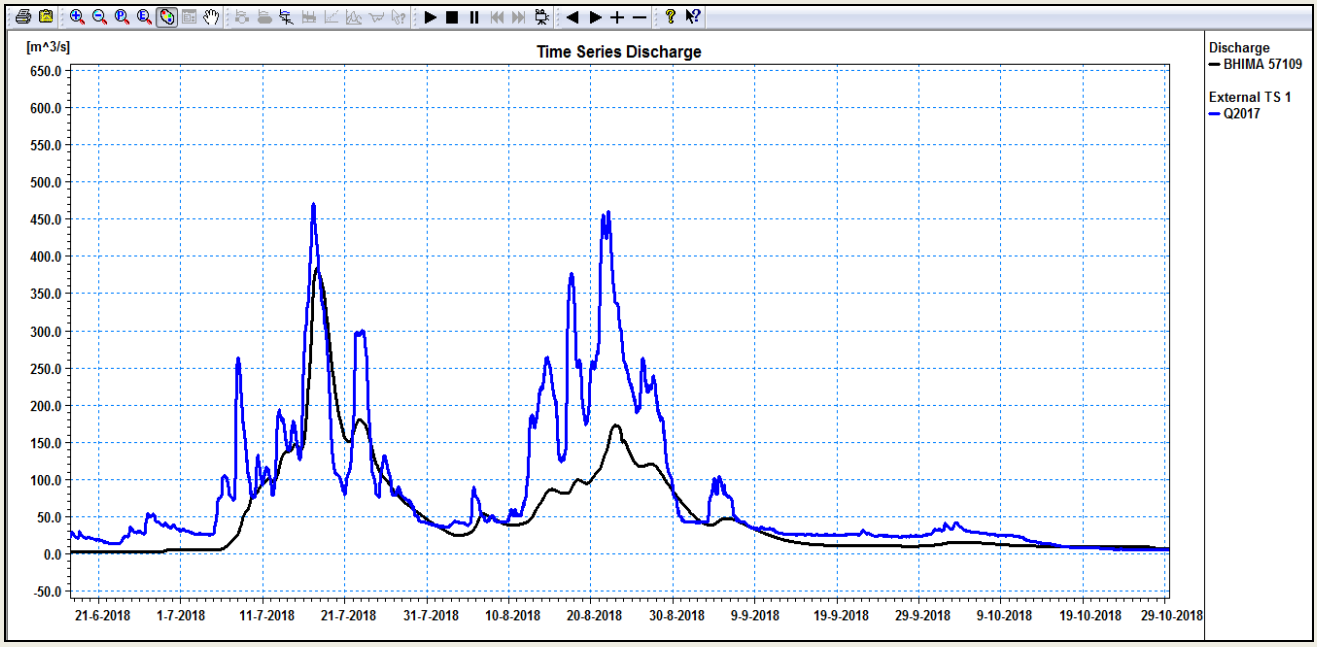


Plot of comparison between simulated and observed discharge at Pargaon

❖ **Koregaon bhima on river Bhima** - -Figure below shows the plot of simulated and observed water level & discharge at Koregaon bhima station. The plot shows good correlation between observed and simulated water level & discharge.

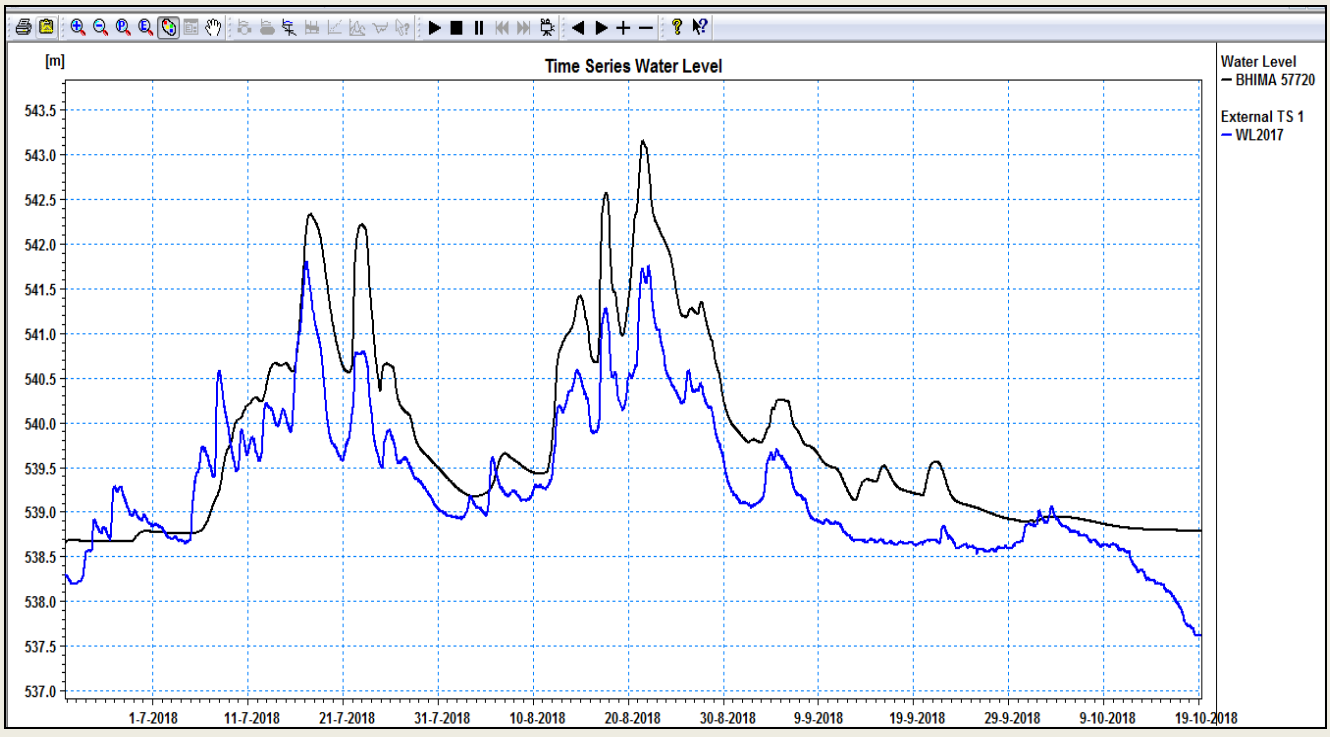


Plot of comparison between simulated and observed water level at koregaon bhima

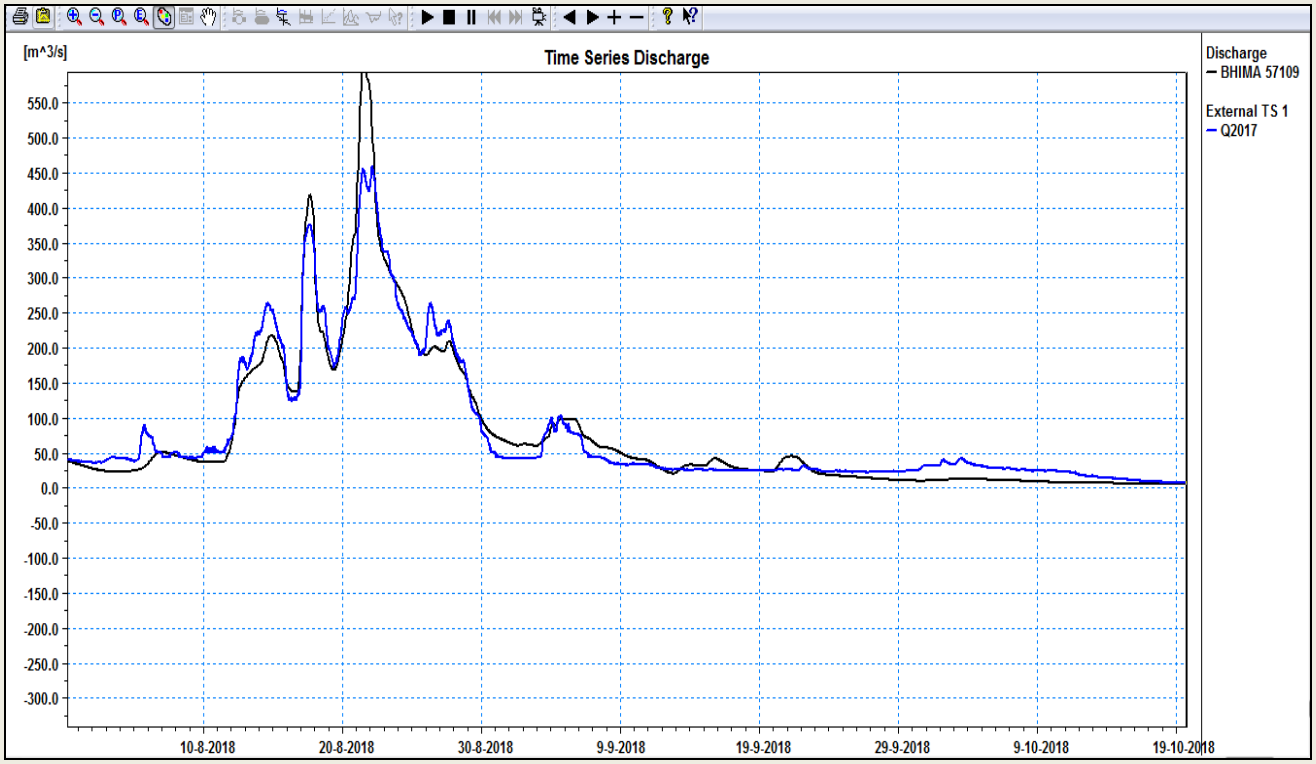


Plot of comparison between simulated and observed discharge at Koregaon bhima

After adding spill from Chaskaman and Bhama askhed reservoir

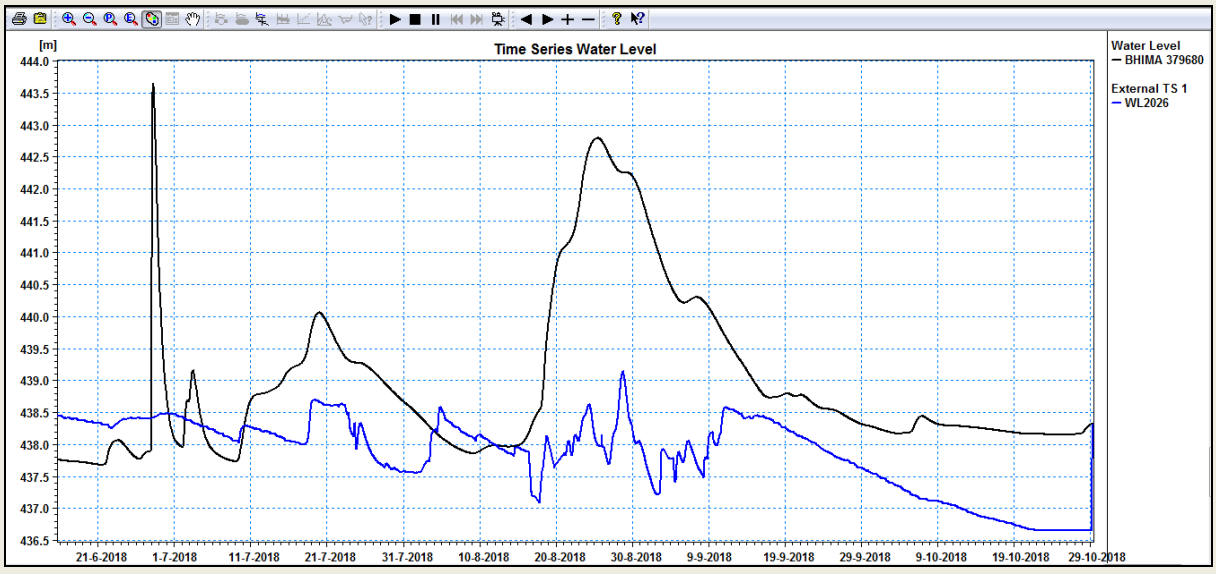


Plot of comparison between simulated and observed water level at koregaon bhima

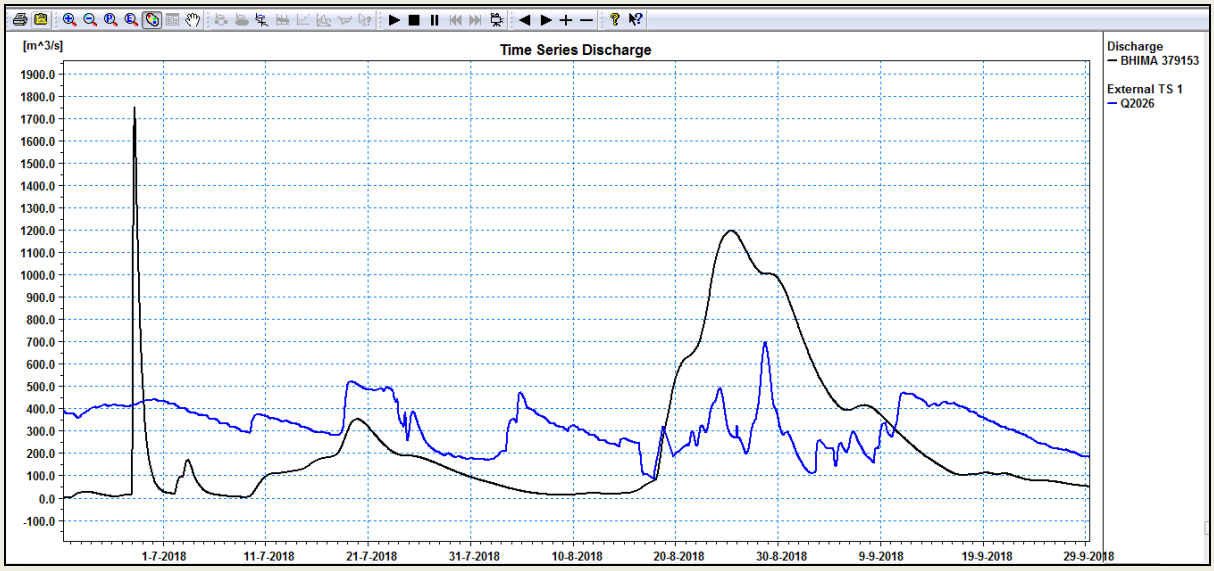


Plot of comparison between simulated and observed discharge at Koregaon bhima

❖ **Pandharpur on river Bhima - fi**gure shows the plot of observed and simulated water level and discharge of Pandharpur station.

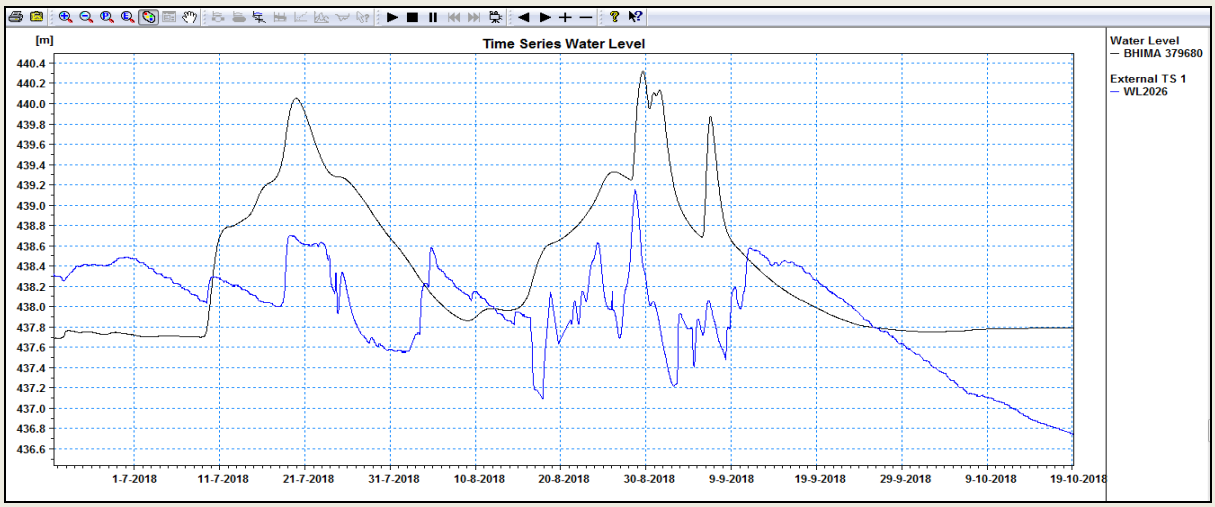


Plot of comparison between simulated and observed water level at Pandharpur

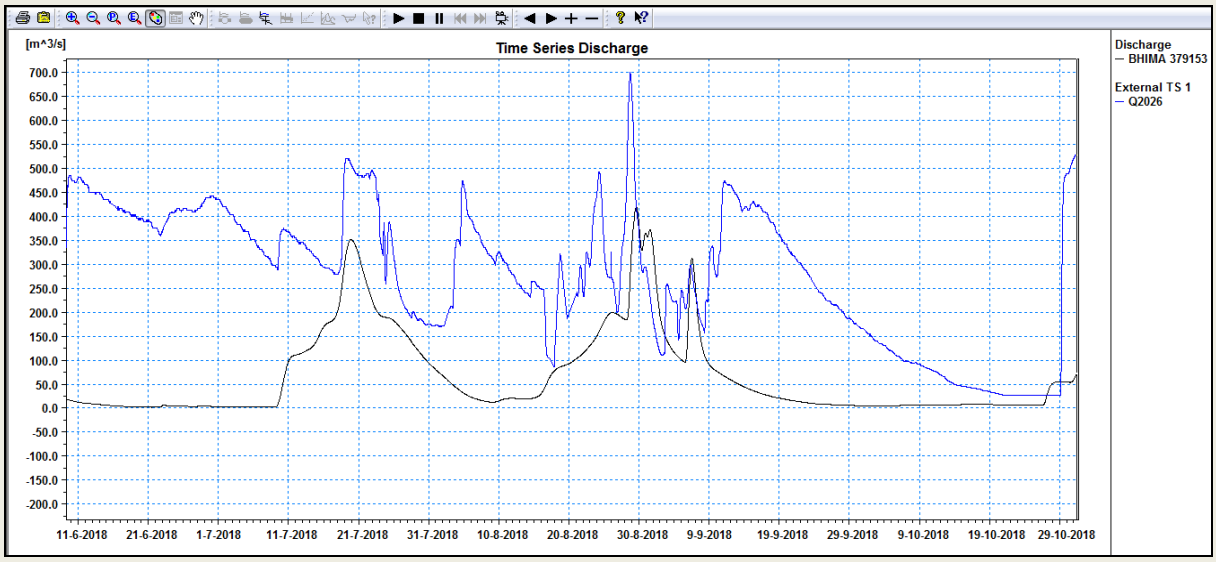


Plot of comparison between simulated and observed discharge at Pandharpur

After adding spill from Ujjani

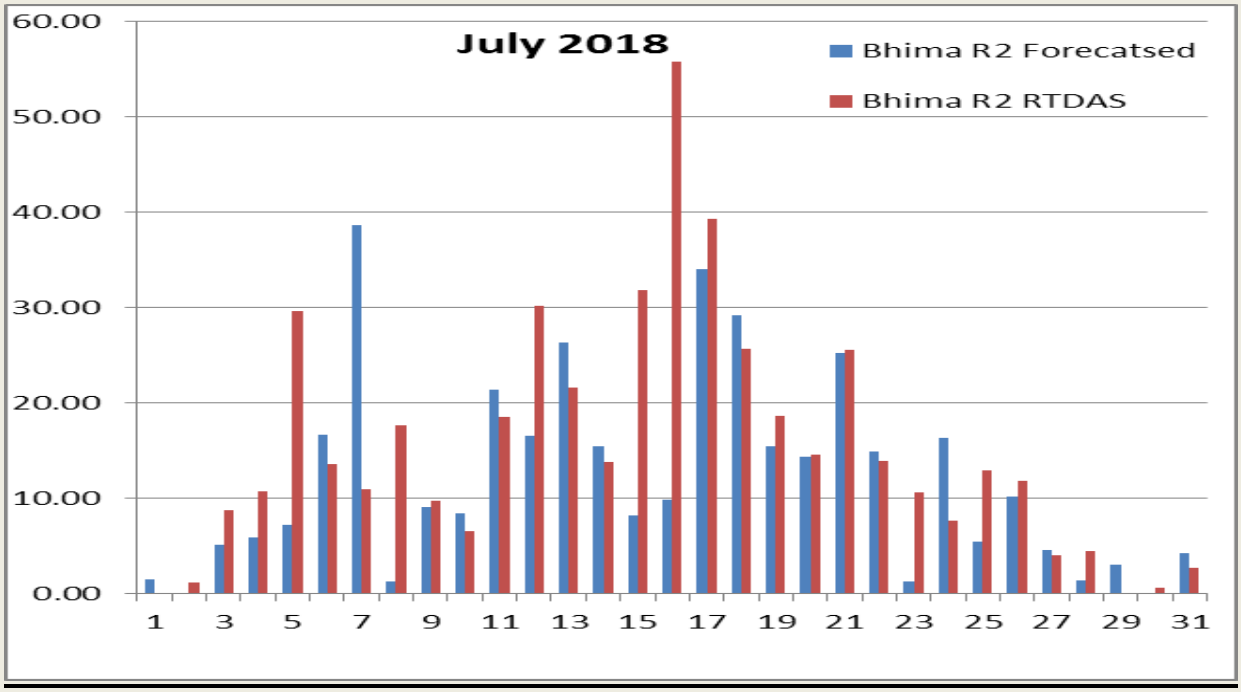


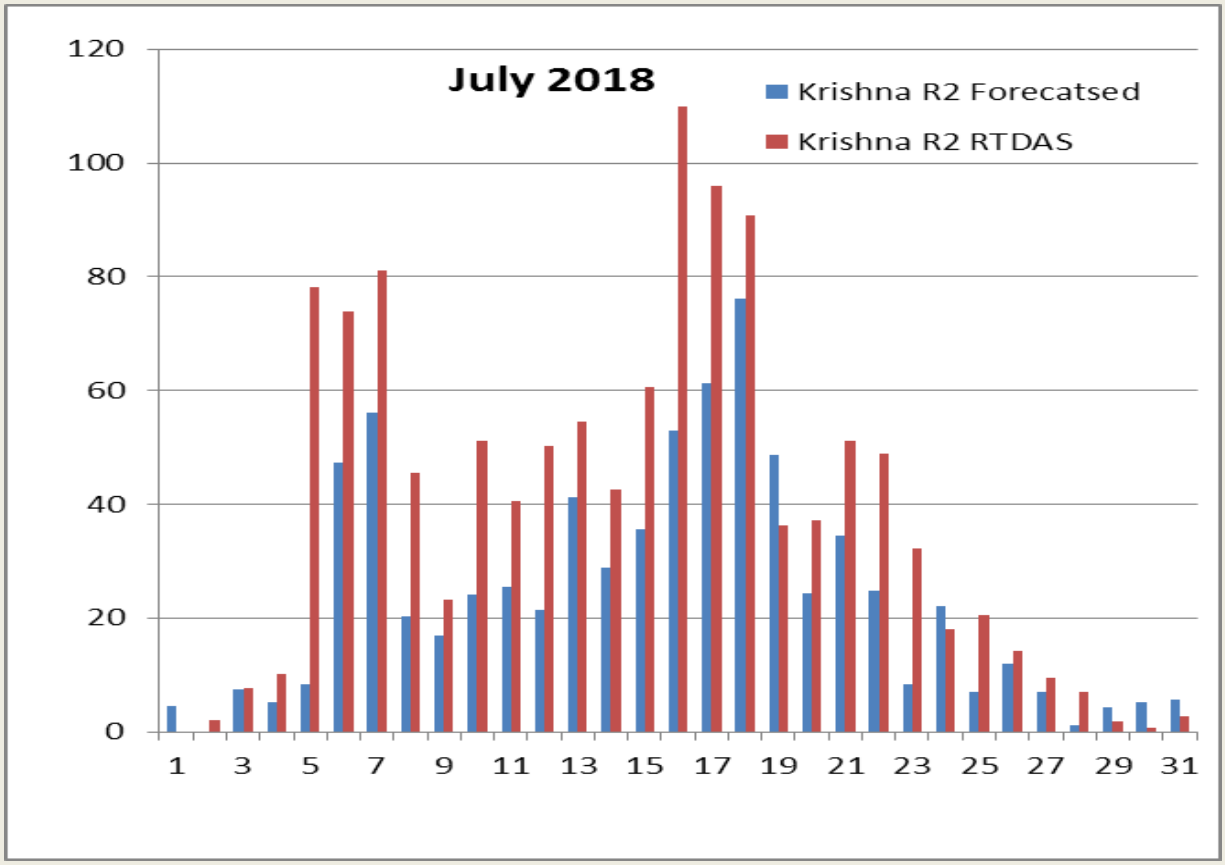
Plot of comparison between simulated and observed water level at Pandharpur

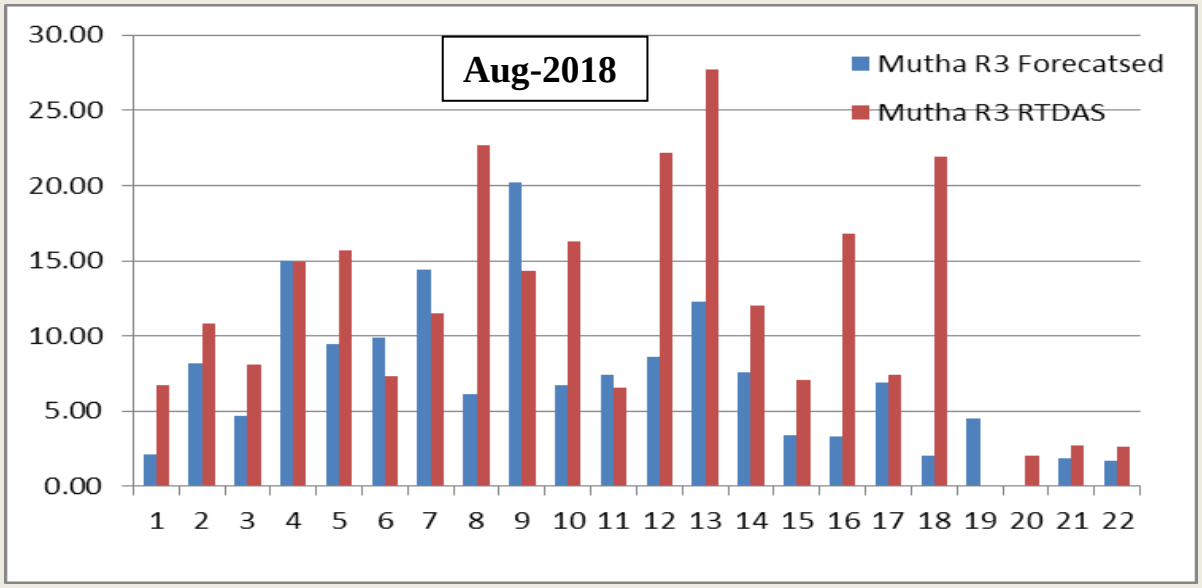


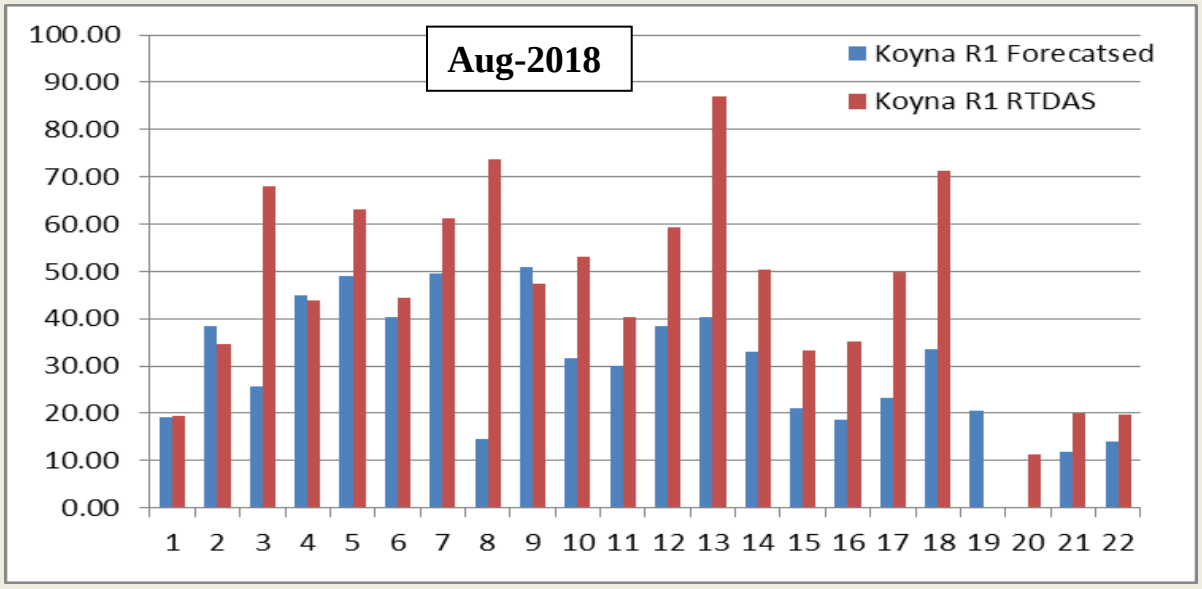
Plot of comparison between simulated and observed discharge at Pandharpur

3.5) <u>Study of Forecasted Rainfall & actual rainfall in 10 catchments of Krishna & Bhima basin is carried out. Few Examples are given below;</u>






Aug-2018
Mutha R3 Forecatsed
Mutha R3 RTDAS
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22


Aug-2018
Koyna R1 Forecatsed
Koyna R1 RTDAS
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

4 : Recommendations

- For better management of floods it's been recommended that Seven days rainfall forecast product should be used.
- Flood forecasting model should be developed after completion of RTDAS, as quality assured data is main input to model.
- Plot of comparison of actual data & forecasted data should be available on Flood forecasting website.
- Permanent on call support of IT expert & modeler should be proposed at the time of bidding. Dedicated team is at most necessary.

5 : Challenges:

- No. of times dams are not operated as per ROS.
- Limitation of accuracy for Quantitative Precipitation Forecast (QPF) .
- Difficulties in Incorporation & checking of new forecast product.
- Guidance required for addition of new structures like K.T weirs, Bridges & to add new cross sections.
- Updation in RTDAS data script is required.
- Continuous help desk facilities required.

6 : CONCLUSIONS:

Following are the conclusions after implementation of system:-

- It is found that in general system fulfils all the objectives set before development of the system.
- Now there is good understanding of flood modeling and forecasting among the engineers using the system.
- Engineers take consistent overview of the flood situation through measuring and modelling.
- Ability is developed to act faster before and during floods.
- There is improved communication and coordination between stake holders of flood management.
- **Model run efficiency for Monsoon 2018 is approximately 93%.**