# 3 APPLICATIONS TO THE UPPER BHIMA

The DSS and the associated river basin model have been set up for the pilot model area, the Upper Bhima. Different applications have been initiated as described in the following.

## 3.1 Data import and illustration

## 3.2 Model applications

A river basin model has been developed for the Upper Bhima basin as described in Appendix A. The model divides the area in 30 sub-catchments and includes 39 years of daily surface runoff and groundwater recharge for each sub-catchment, so that the climatic variation in the area is well described.

A range of planning and management decisions may be tested in the model to help identify the most appropriate way forward. Selected examples, which have been defined in cooperation with Maharashtra State, are described below. Some of these focus on the Khadakwasla complex, which is an area of special interest to the states and represent a case of four jointly operated reservoir with multiple users with different priority, see below.

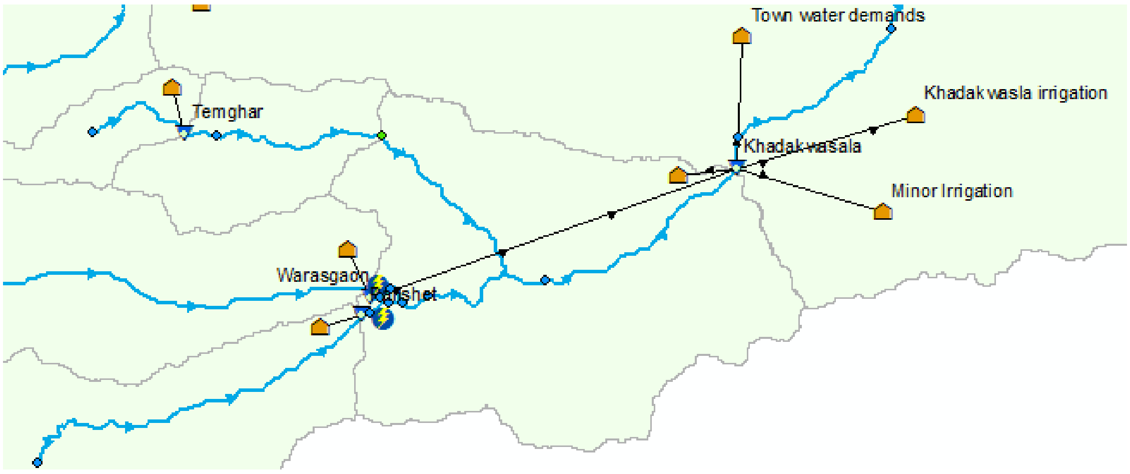



*Figure 3-1 The Khadakwasla complex*

The largest of the four reservoirs are Panshed and Waresgaon, located very close to eachother upstream of the smaller Khadakwasla reservoir. The upstream reservoirs, including the new Temghar, release water through their hydropower plants whenever water is required by the users downstream Khadakwasla.

### Seasonal planning

Maharashtra state has specifically requested this application to help assessing the potential water use in the dry season when the available reservoir storage is known by mid October. The application should help assessing the possible supply of water considering the demands and availability.

Some inflow is seen to occur in some years even after mid October, so the possibility of supplying the requested demands may not be exactly be the same for all scenarios of reservoir inflow. The analysis is therefore set up to apply all the 39 years as possible scenarios of inflow over the comming months. The calculation may be seen as 39 separate simulations. First, the model will set the storages in all reservoirs according to the actual values and simulate the reservoir performance over 12 months, starting 15$^{th}$ October in the first year, i.e. 1971. The reservoir storages are then reset to the initial values and the same calculation made for the 12 months starting 15$^{th}$ October 1972. This is then repeated for all 39 years. Technically in MIKE BASIN, these 39 calculations are all made as part of a single simulation for all years, operated in stochastic mode. Statistics on the results will then show the success of the suggested water allocation in terms e.g. of the average amount of water supplied to each user and the average deficits. A user of the system can test various combinations of water allocation, considering the available storage at the start time, to identify the preferred allocation plan.

This has been established for the Khadakwasla complex, which includes four reservoirs and – in this example – three separate users:

| Priority | Name | Water Use |
|---|---|---|
| 1 | Town user | The domestic and industrial use of Pune city and other urban areas |
| 2 | Irrigation user | All irrigation from the reservoirs in all seasons |
| 3 | Tank filling | The filling of minor irrigation tanks in the area from the reservoirs |

All users are supplied from the Khadakwasla reservoir, which draws upon the upstream reservoirs as required. This is in the model described as a combination of standard releases, which are provided when possible by the upstream reservoirs, and additional releases, which occur automatically when the Khadakwasla reservoir is falling below a critical level.

A poor monsoon has been assumed, filling the reservoirs only to the following levels by 15$^{th}$ October:

Temghar 698
Panshet 633.9
Waresgaon 633
Khadakwasla 580.9

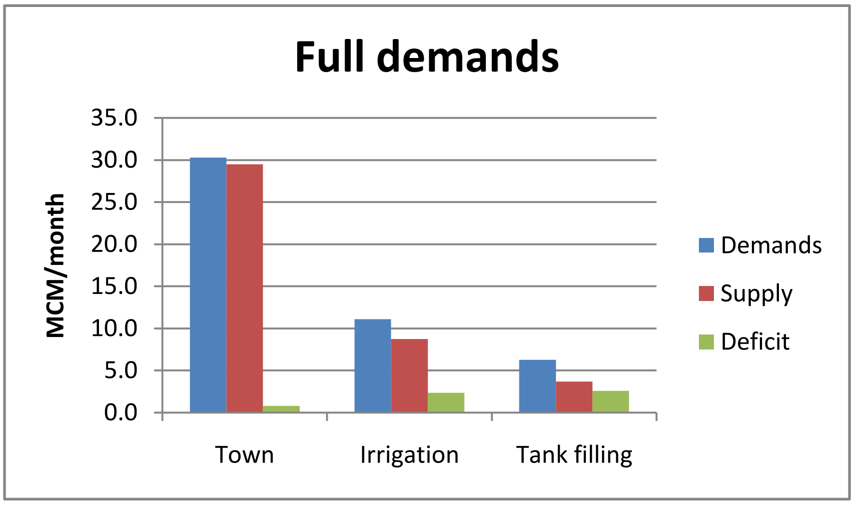
The following water requirements are assumed:

| MCM | Town | Irrigation | Tanks |
|---|---|---|---|
| Jan | 27.6 | 22.3 | 2.2 |
| Feb | 27.6 | 22.3 | 2.2 |
| Mar | 33.4 | 10.5 | 2.2 |

| | | | |
|---|---|---|---|
| Apr | 33.4 | 10.5 | 6.0 |
| Maj | 33.4 | 10.5 | 6.0 |
| Jun | 30.5 | 0.0 | 6.0 |
| Jul | 30.5 | 0.0 | 6.0 |
| Aug | 30.5 | 0.0 | 13.1 |
| Sep | 30.5 | 0.0 | 13.1 |
| Okt | 30.5 | 22.3 | 13.1 |
| Nov | 27.6 | 22.3 | 2.2 |
| Dec | 27.6 | 22.3 | 2.2 |

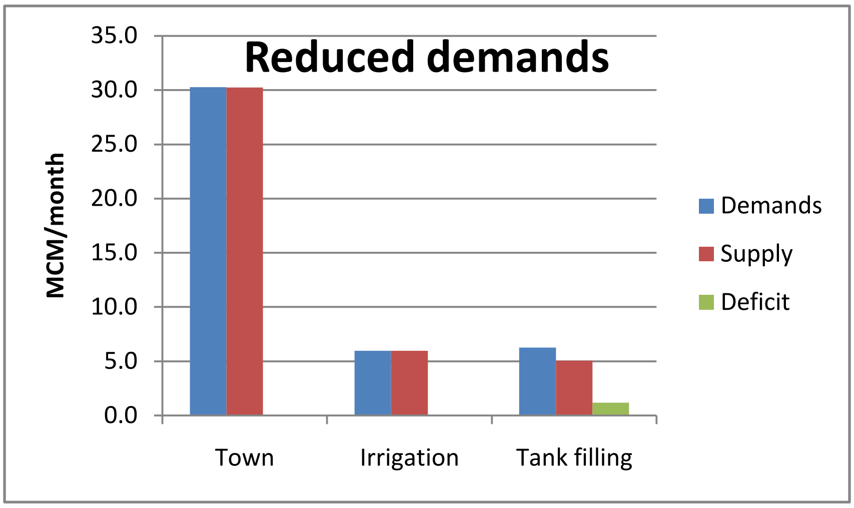
Model simulations have shown that it is not possible to supply the amount of water required to satisfy the full demands of all the users.

| MCM/mth | Town | Irrigation | Tank filling |
|---|---|---|---|
| Demands | 30.3 | 11.1 | 6.3 |
| Supply | 29.5 | 8.7 | 3.7 |
| Deficit | 0.8 | 2.4 | 2.6 |

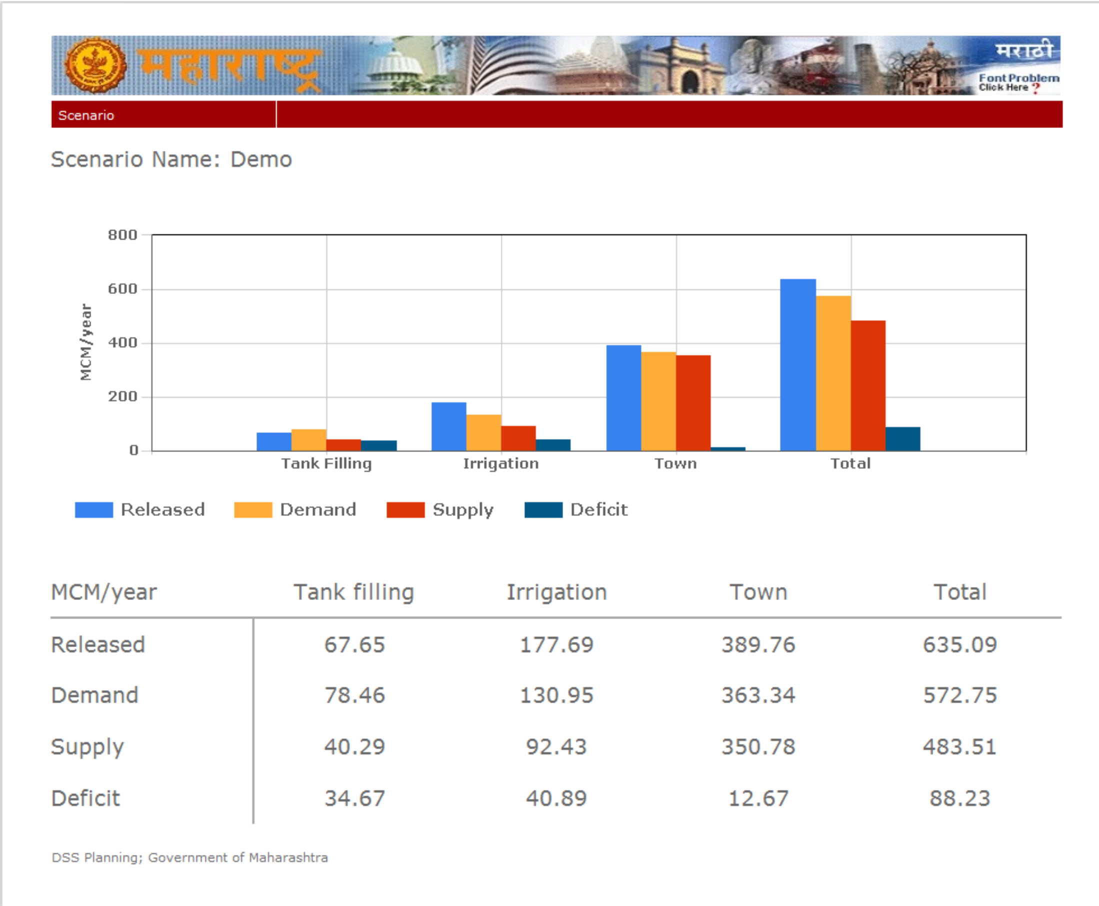



Various scenarios of reduced demands have been tested. Considering the high priority of the town water supply, it is the irrigation which has been reduced, partly by eliminating summer crops and partly be reducing the rabi allocation. The results show that the deficits for the town water supply and the reduced irrigation are eliminated while some deficits still occur for the tank filling.

| MCM/mth | Town | Irrigation | Tank filling |
|---|---|---|---|
| Demands | 30.3 | 6.0 | 6.3 |
| Supply | 30.2 | 6.0 | 5.0 |
| Deficit | 0.0 | 0.0 | 1.2 |




Note that this type of application may be performed any time e.g. to adjust delivery to the users after unexpected changes in demands or availability of water. For reservoir operators it may be relevant to perform this analysis regularly and they may wish to do this from the remote site using readily available hardware. Provided that a VPN connection can be made it is possible to set up the DSS to enable performing the analysis over the intranet using a dedicated Dashboard application. This has been tested for the Khadakwasla Complex. A few screenshots are shown below.




| MCM/year | Tank filling | Irrigation | Town | Total |
|---|---|---|---|---|
| Released | 67.65 | 177.69 | 389.76 | 635.09 |
| Demand | 78.46 | 130.95 | 363.34 | 572.75 |
| Supply | 40.29 | 92.43 | 350.78 | 483.51 |
| Deficit | 34.67 | 40.89 | 12.67 | 88.23 |

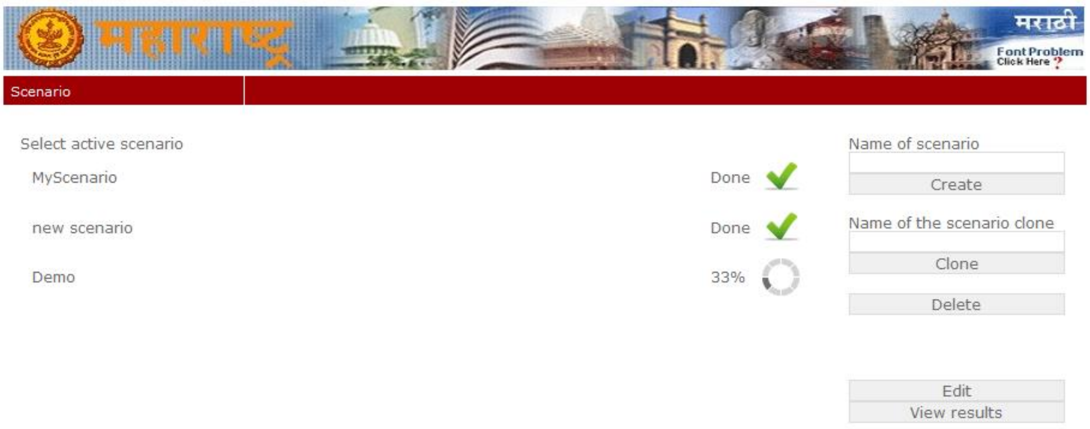



*Figure 3-2 The scenario "Demo" is being calculated*

## Long-term planning

The *DSS Planning* will often be applied to analyse the impact of future changes in the demands for water or available infrastructure. Two cases have been analysed for the Khadakwasla complex, on request from the government of Maharashtra, i.e. 1) an increase in the urban water demands from Pune city and 2) the impact of enabling a transfer of water from the Panshet to the Waresgaon reservoir.

These hve been analysed using the available river basin model and *key output* from the DSS designed to be presented to decision makers.The results are given in the following.

**Increased town water demands**
The demands for domestic and industrial water supply is increasing with the growth in the urban population particularly in Pune. Various inititives are being launched to reduce this increase in demands, such as reducing the losses between the reservoir and the town. It is expected never the less that the demand for water to the town will be 25% higher than today in a not too distant future and that it will reach 50% increase later on. These scenarios are analysed in the following.

The model set-up described above is applied. The town water has highest priority, followed by the irrigation and the tank filling.

The present demands are first compared to the scenarios of increased demands assuming no changes in the water requirements from the other users. Since these scenarios are not sustainable, alternatives are tested in which the planned water delivery to the others users is reduced.

The scenarios are:

A Town water requirements now

B Town water requirements increased by 25%

C Town water requirements increased by 50%

These are combined with modified requirements from the irrigated area and for filling minor irrigation tanks. Various reductions in the rabi and summer supply have been introduced for these users as follows.

"1" No reduction

"2" Low irrigation and tank filling

"3" Medium irrigation and tank filling

Scenario B2 is thus with 25% increase in town water supply and low irrigation and tank filling. The details are given below.

*Table 3-1 Applied water demands for the selected scenarios*

| | Town water demands | | | Irrigation demands | | | Tank filling demands | | |
|---|---|---|---|---|---|---|---|---|---|
| MCM | A | B | C | 1 | 2 | 3 | 1 | 2 | 3 |
| jan | 27.6 | 34.5 | 41.4 | 22.4 | 22.4 | 22.4 | 2.2 | 0.0 | 2.2 |
| feb | 27.6 | 34.5 | 41.4 | 22.4 | 22.4 | 22.4 | 2.2 | 0.0 | 2.2 |
| mar | 33.4 | 41.8 | 50.1 | 20.5 | 0.0 | 10.5 | 2.2 | 0.0 | 2.2 |
| apr | 33.4 | 41.8 | 50.1 | 20.5 | 0.0 | 10.5 | 6.0 | 0.0 | 2.2 |
| maj | 33.4 | 41.8 | 50.1 | 20.5 | 0.0 | 10.5 | 6.0 | 0.0 | 2.2 |
| jun | 30.5 | 38.1 | 45.7 | 20.5 | 0.0 | 10.5 | 6.0 | 0.0 | 2.2 |

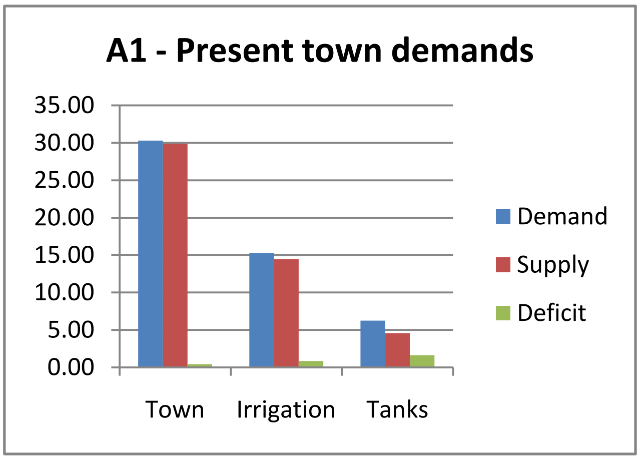
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| jul | 30.5 | 38.1 | 45.7 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 | 2.2 |
| aug | 30.5 | 38.1 | 45.7 | 0.0 | 0.0 | 0.0 | 13.1 | 13.1 | 13.1 |
| sep | 30.5 | 38.1 | 45.7 | 0.0 | 0.0 | 0.0 | 13.1 | 13.1 | 13.1 |
| okt | 30.5 | 38.1 | 45.7 | 22.4 | 22.4 | 22.4 | 13.1 | 13.1 | 13.1 |
| nov | 27.6 | 34.5 | 41.4 | 22.4 | 22.4 | 22.4 | 2.2 | 0.0 | 2.2 |
| dec | 27.6 | 34.5 | 41.4 | 22.4 | 22.4 | 22.4 | 2.2 | 0.0 | 2.2 |
| Annual | 363 | 454 | 544 | 194 | 112 | 154 | 75 | 39 | 59 |

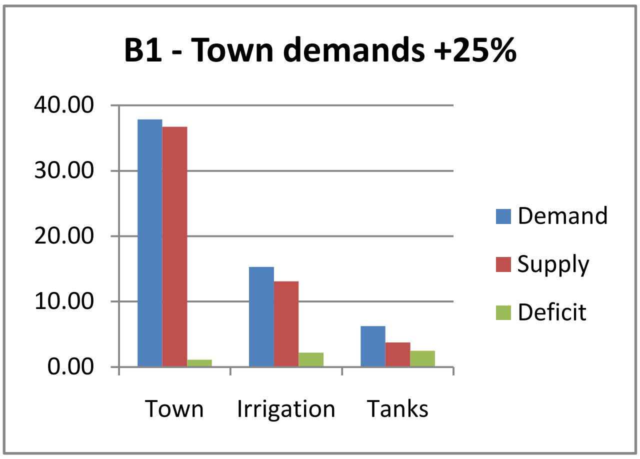
The likelihood of the system to be able to supply water according to the given demands depend also on the latest monsoon, which may not have filled the reservoirs. In order to assess the average performance of the system for the prevailing climatic conditions, the model is run for the full period 1970-2009 and statistics made of the results. The key output, to be generated by the DSS for presentation to decision makers, could be as shown below.

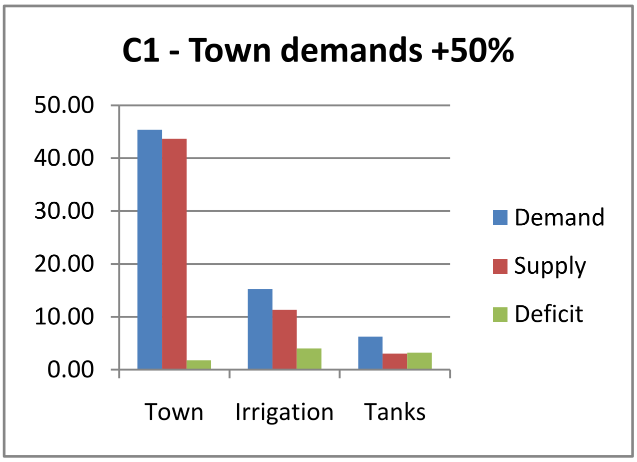
*Table 3-2 Average water demands, supply, and deficit for scenario B1*

| MCM/month | Town | Irrigation | Tanks |
|---|---|---|---|
| Demand | 37.84 | 15.29 | 6.25 |
| Supply | 36.71 | 13.11 | 3.78 |
| Deficit | 1.13 | 2.21 | 2.47 |

Graphical presentation of the scenarios A1, B1, and C1 are given below.






It is noted that the deficits of all users increase with the increasing town water demands, indicating that these scenarios are not feasible. If the high priority of the town water supply is maintained it will be necessary to reduce water delivery to the other users. The scenarios B2 and B3 are shown below, representing 25% increase in town water requirements and reduced delivery to the other users.

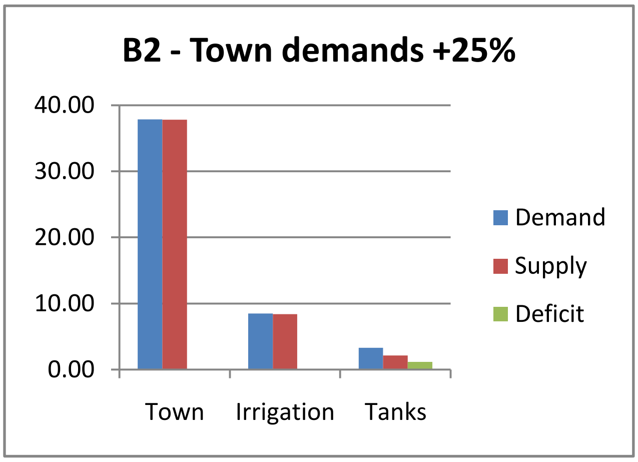



*Figure 3-3 The deficits are limited as the demands by irrigation and tank filling have been drastically reduced*

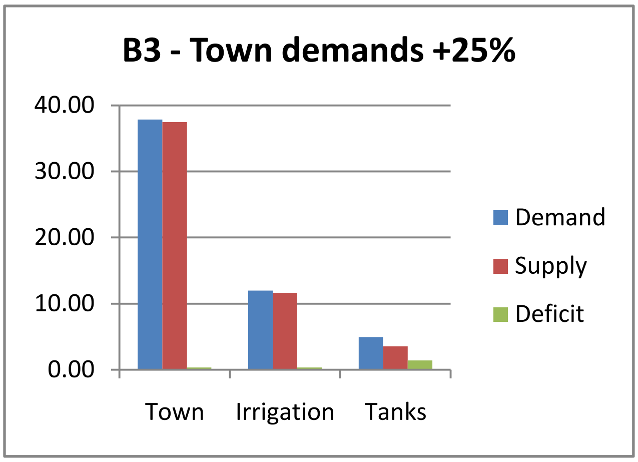



*Figure 3-4 With only medium reduction in the other demands it is still possible to meet the town water demands most of the time*

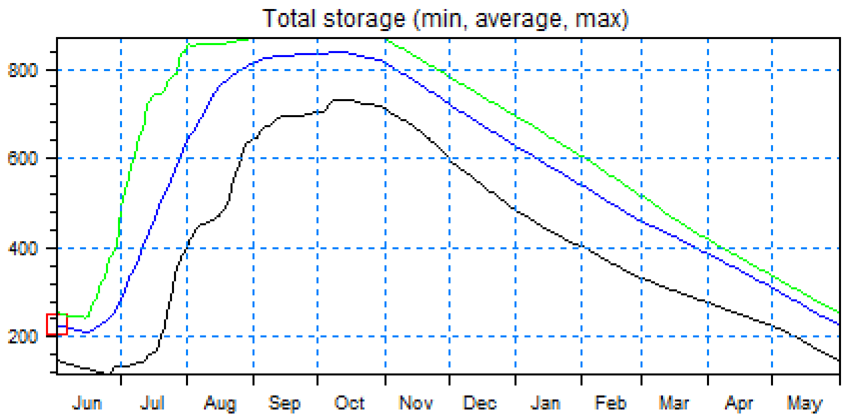



*Figure 3-5 The minimum, average, and maximum accumulated storage in the four reservoirs over the year (MCM)*

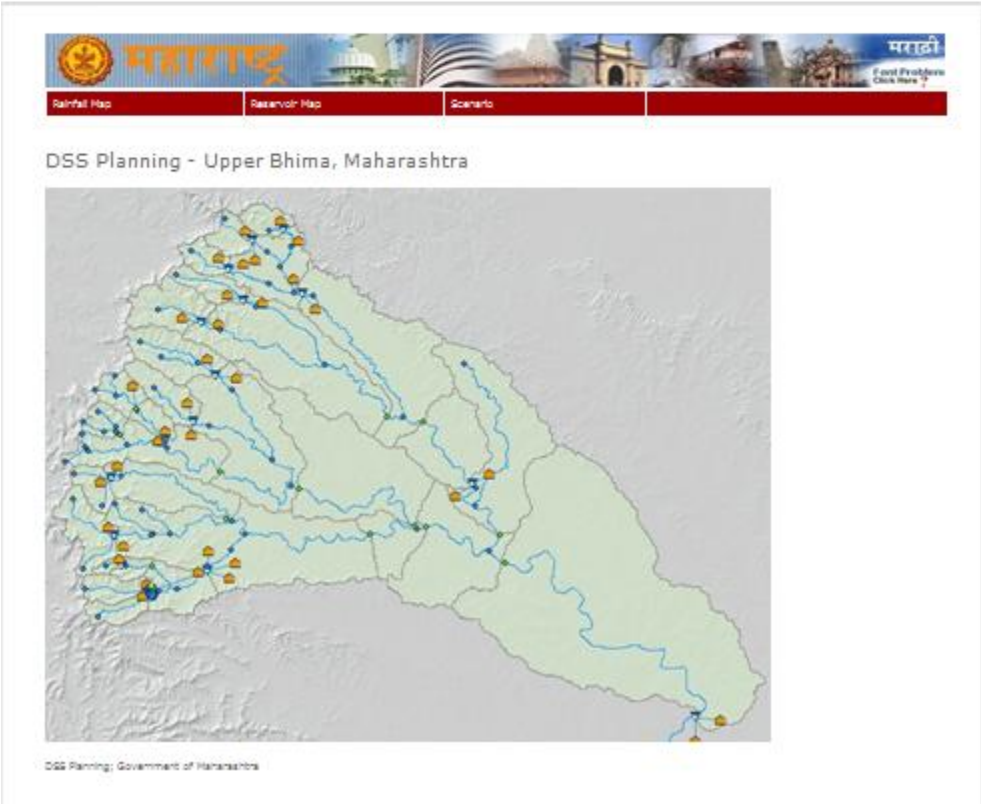
**Linked reservoirs**

The reservoirs Panshet and Waresgaon are located closer to each other than any other pair of dams in the world. It has been observed that Panshet dam is often filling earlier than Waresgaon and is spilling in some years, when Waresgaon doesn't fill. A transfer of water between the reservoirs could therefore potentially increase the storage of water during the monsoon.

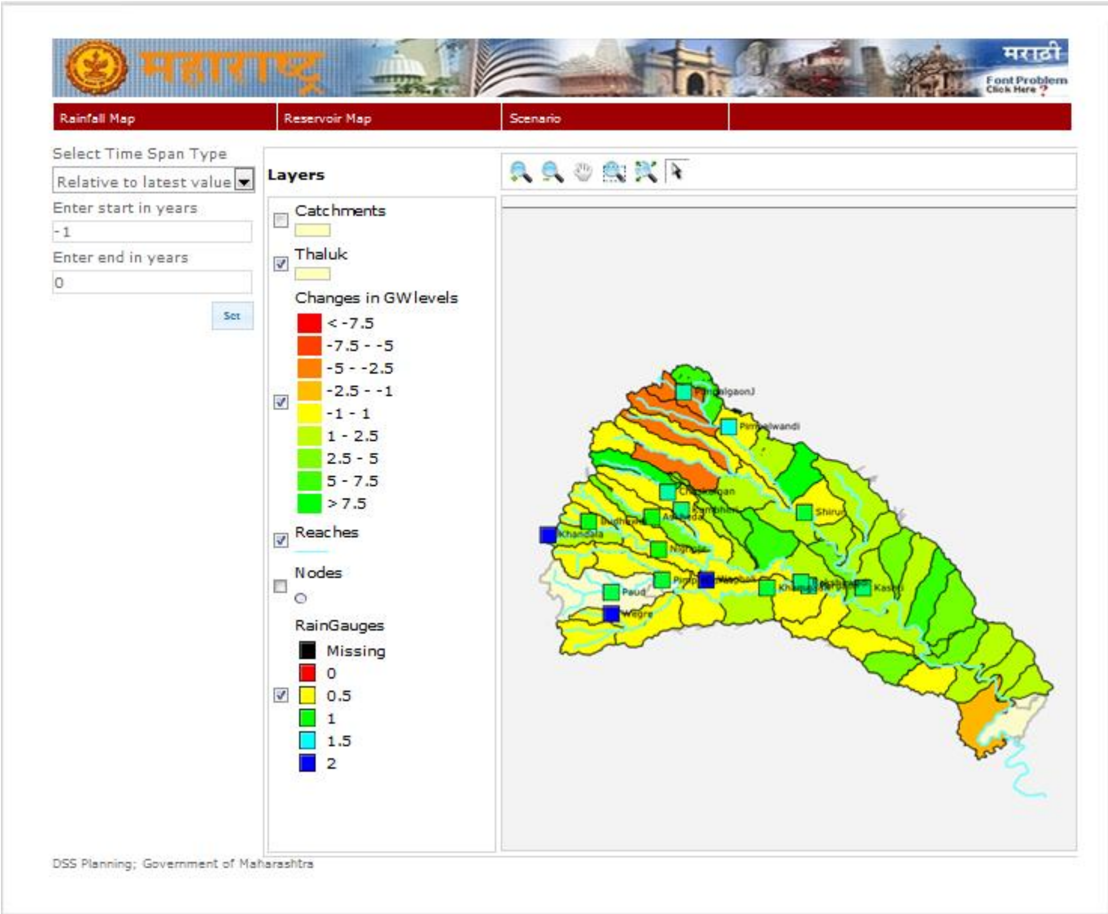
DHI's Carter Borden is analysing this and will report on it shortly.

## Drought monitoring

It is important for the states to monitor the water availability and be ready to take appropriate action in critical situations. The DSS may be applied to highlight indicators of possible drought occurrence using different data type such as the rainfall, the groundwater levels, and the reservoir storage.




See nih.dhigroup.com for examples.



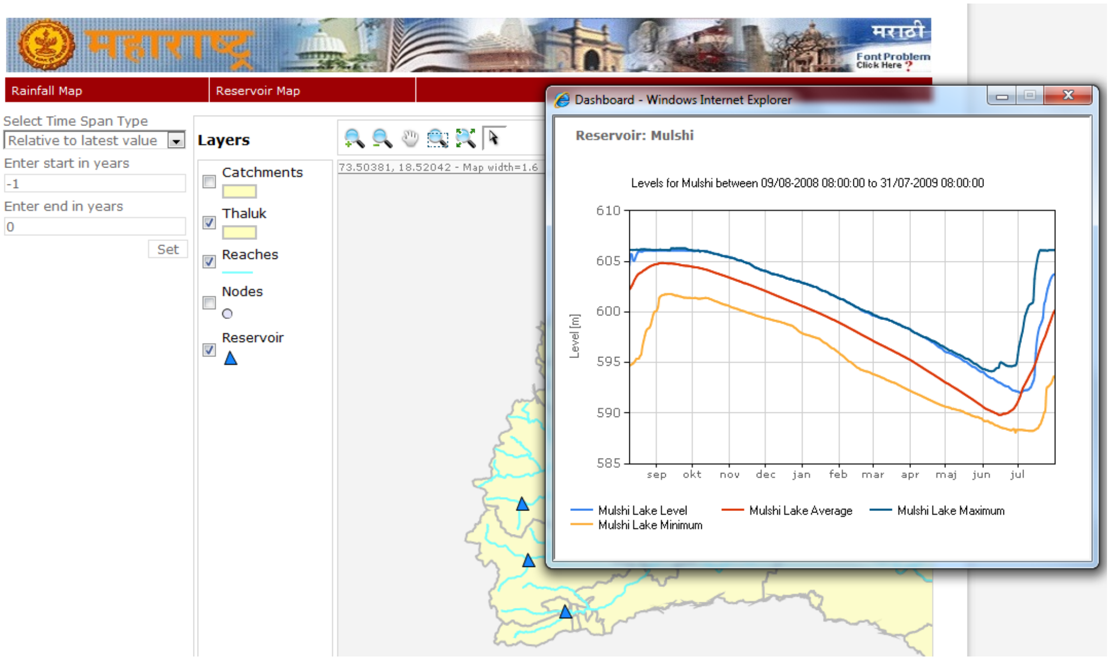
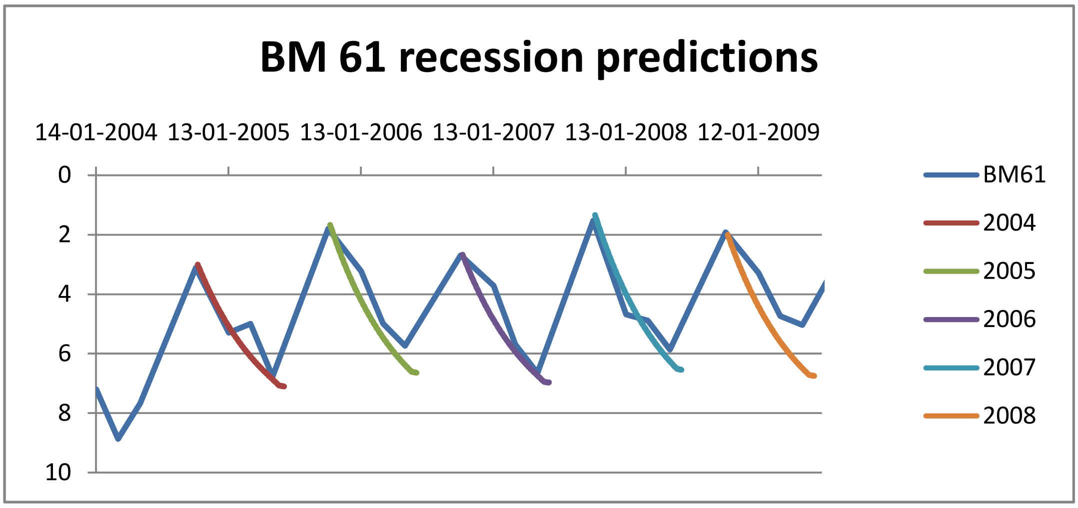




*Figure 3-6* *The current level of a reservoir is displayed when clicking on the reservoir on the map. The current level is compared to the average, minimum, and maximum levels.*

## Seasonal groundwater planning

The Government of Maharashtra has requested a facility to predict the likely development of the groundwater level in an area once the post-monsoon levels have been measured. This has been tested as shown below for the BM-61 watershed. The simulated level variations, starting at the post-monsoon level, is shown for five years in comparison with the observed level.




## Artificial recharge

Two cases of artificial recharge are considered:

1. Infiltration of local runoff through e.g. check dams, groundwater wells, tanks or other means. The amount of water which can be infiltrated is assessed on the basis of the estimated capacity of the infiltration facilities and the variation of surface runoff, as estimated in the hydrological analysis. Evaporation losses from these facilities is also taken into account.

   An example of artificial recharge has been calculated for an area based on the following assumptions:

   - The desired increase in groundwater abstraction is 50%
   - The total capacity of the infiltration facilities can divert up to 4 $m^3/s$ of which 20% is lost to evaporation.
   - It is possible to abstract groundwater down to a depth of 16 meters

   The groundwater level variation has been simulated for the increase draft with and without the artificial infiltration as shown below.

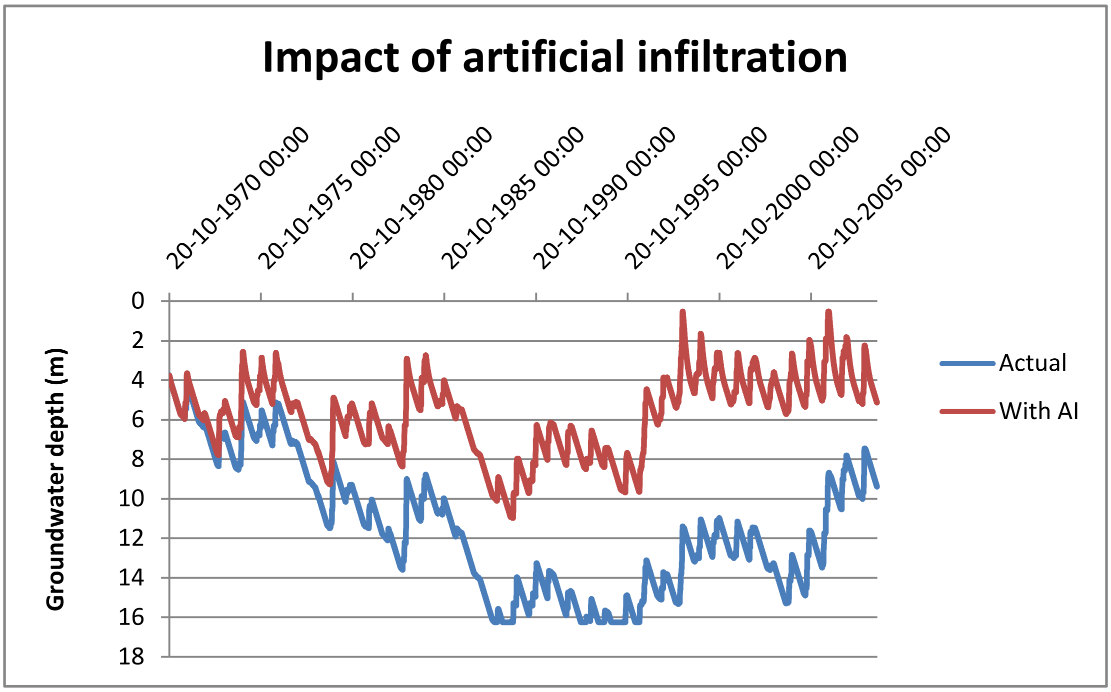



*Figure 3-7  simulated groundwater depth with and without artificial infiltration*

The simulations indicate that increased draft will only be sustainable with the artificial recharge in place. Note that an analysis based only on recent years would have given the false impression that increased groundwater pumping would be possible also without the artificial recharge.

2. Infiltration of water released for this purpose from an upstream reservoir.This would typically occur outside the monsoon season from reservoirs with surplus storage and would enable a reduction in evaporation losses.

The Government of Maharashtra is seeking to identify a suitable reservoir and infiltration area within the Upper Bhima as a test case for this analysis.