WATER RESOURCES MANAGEMENT COMPANY
THE MINISTRY OF ENERGY
THE ISLAMIC REPUBLIC OF IRAN

THE STUDY ON INTEGRATED WATER RESOURCES MANAGEMENT FOR SEFIDRUD RIVER BASIN IN THE ISLAMIC REPUBLIC OF IRAN

Final Report

Volume III Supporting Report

November 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI Engineering International Co., Ltd.

GED
JR
10-122

WATER RESOURCES MANAGEMENT COMPANY
THE MINISTRY OF ENERGY
THE ISLAMIC REPUBLIC OF IRAN

THE STUDY ON INTEGRATED WATER RESOURCES MANAGEMENT FOR SEFIDRUD RIVER BASIN IN THE ISLAMIC REPUBLIC OF IRAN

Final Report

Volume III Supporting Report

November 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI Engineering International Co., Ltd.

THE STUDY ON
INTEGRATED WATER RESOURCES MANAGEMENT
FOR SEFIDRUD RIVER BASIN
IN THE ISLAMIC REPUBLIC OF IRAN

COMPOSITION OF FINAL REPORT

Volume I **Main Report**

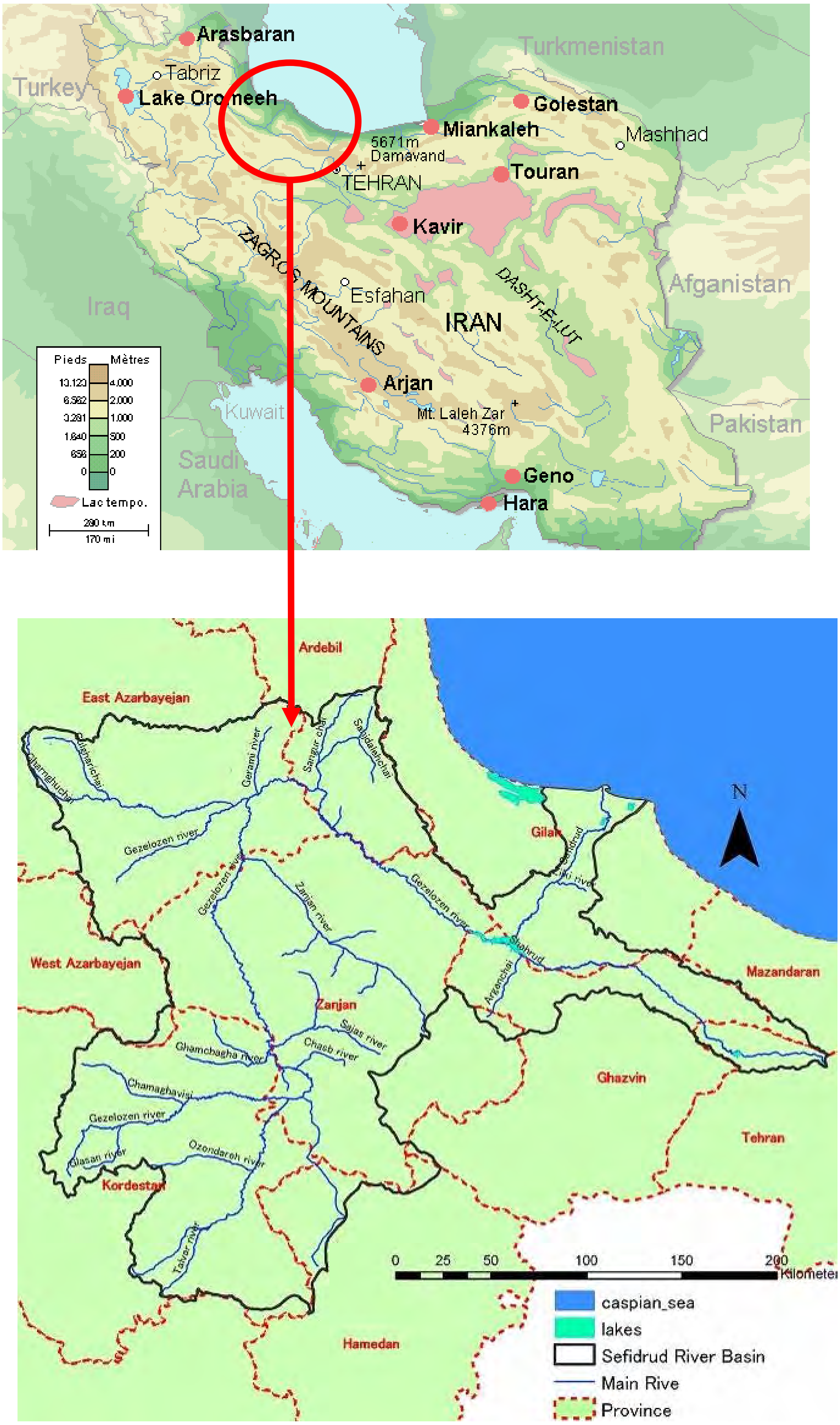
Volume II **Summary**

Volume III **Supporting Report**

Currency Exchange Rate used in this Report:

USD	1.00	= RIAL	9,553.59	= JPY	105.10
JPY	1.00	= RIAL	90.91		
EURO	1.00	= RIAL	14,890.33		

(As of 31 May 2008)



Location Map of the Study Area

ABBREVIATION

Abbreviation	:	English
C/P	:	Counterpart
DB	:	Database
DOE	:	Department of Environment
DF/R	:	Draft Final Report
DIC/R	:	Draft Inception Report
EHC	:	Environmental High Council
F/R	:	Final Report
FAO	:	Food and Agriculture Organization
GDP	:	Gross Domestic Product
GIS	:	Geographical Information System
GIS-DB	:	Geographical Information System Database
GRDP	:	Gross Regional Domestic Product
IEE	:	Initial Environmental Examination
IC/R	:	Inception Report
IRIMO	:	Isramic Republic of Iram Meteorological Organization
IT/R	:	Interim Report
IWRM	:	Integrated Water Resources Management
JICA	:	Japan International Cooperation Agency
MG	:	Mahab Ghodss Consulying Engineering Co.
MOE	:	the Ministry of Energy
MOJA	:	the Ministry of Jihad-e-Agriculture
M/M	:	Minutes of Meeting
M/P	:	Master Plan
OMC	:	Operation and Management Company
PANDAM	:	Pandam Consulting engineering
P/R	:	Progress Report
QPIP	:	Qazvin Plain Irrigatino Project
RBO	:	River Basin Organization
Reach	:	Catchment Area (includes Constructed, Under Construction, Under Study Dams)
RWA	:	Regional Water Authority
RWC	:	Regional Water Company
RWWC	:	Rural Water and Wastewater Company
SDC	:	Sustainable Development Committee
SEA	:	Strategic Environmental Assessment
SIDN	:	Sefidrud Irrigation and Drainage Network
SHM	:	Stakeholder Meeting
SRMB	:	Sefidrud River Basin Management Beauro
UWWC	:	Urban Water and Watstewater Company
WRC	:	Water Research Center
WRI	:	Water Research Institute (change d to WRC in 2002)
WRM	:	Water Resources Management
WRMC	:	Water Resources Management Company
WUA	:	Water User Association
WWC	:	Water and Wastewater Company

UNIT

(Time)			(Volume)		
h, hr	:	hour(s)	l, ltr	:	liter(s)
d, dy	:	day(s)	mcm	:	million cubic meter(s)
y, yr	:	year(s)	bcm	:	billion cubic meter(s)

THE STUDY ON INTEGRATED WATER RESOURCES MANAGEMENT FOR SEFIDRUD RIVER BASIN IN THE ISLAMIC REPUBLIC OF IRAN

FINAL REPORT

Volume III Supporting Report

SUPPORTING REPORT

<u>PAPER 1</u>

METEOROLOGY, HYDROLOGY AND WATER BALANCE SIMULATION

THE STUDY ON INTEGRATED WATER RESOURCES MANAGEMENT FOR SEFIDRUD RIVER BASIN IN THE ISLAMIC REPUBLIC OF IRAN

SUPPORTING REPORT

PAPER 1 METEOROLOGY, HYDROLOGY AND WATER BALANCE SIMULATION

Table of Contents

Page

Note: The Contents without any reference source were prepared by JICA Study Team.

List of Tables

List of Figures

Figures **Page**

CHAPTER 1. METEOROLOGY AND HYDROLOGY

1.1 DATA AVAILABILITY

1.1.1 Inventory Survey concerning Hydrological Data

The local people hired by MOE manually control the equipment for observation in the Most WRMC's meteorological and hydrological observatory stations. The observation items are precipitation, temperature, humidity, evaporation, wind velocity and so on. Sun radiation has been hardly observed in Sefidrud River basin.

The hydrological data is collected and delivered to RWC every month and RWC are supposed to deliver the data to WRMC every year, although before 2002 the delivery had been carried out every 3 months. In addition, since 2002, the data has been digitized to deliver it instead of the former paper-based conveyance because WRMC started to use the database software. The digital format for the data record was decided by WRMC which makes RWC input the collected data in database (Data Ease program). Then, every year, experts of WRMC check the contents of database which every province is equipped with.

The position of observatories in the Study Area and the condition of data collection are described below. Incidentally, the time series data for 40 years (1966 to 2005) is collected in this study because of the necessity of implementation of the long term runoff simulation to determine the water allocation.

1) Precipitation Gauging Station

The rainfall gauging stations are plotted on the figure below. The depth of rainfall is including that of snow and recorded on 2 times a day at 6:30 and at 18:30. In this Study, the data was collected from 167 stations administrated by WRMC and 102 stations by MOM.

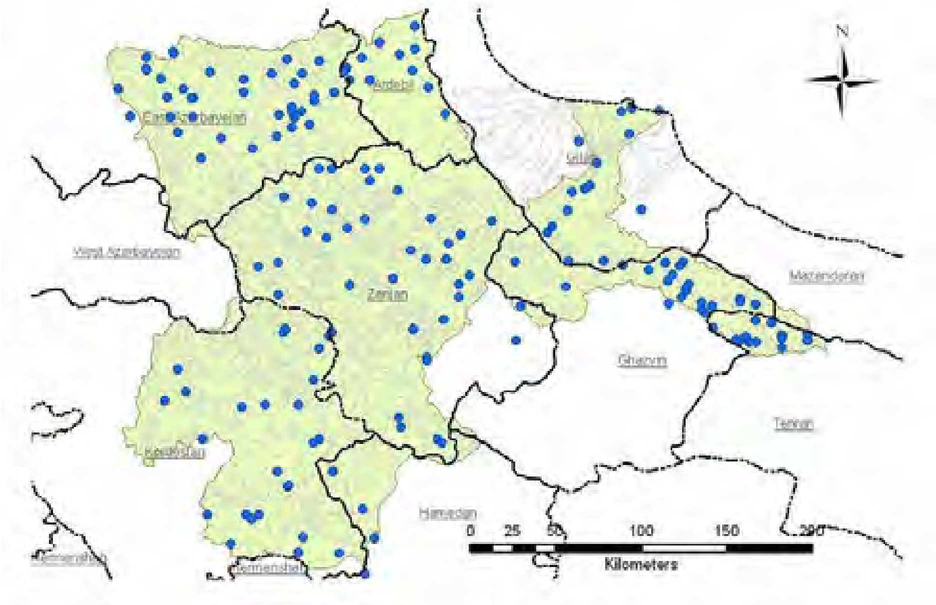


Figure 1.1.1 Location of Rainfall Station (WRMC and IRIMO)

2) Meteorological Observation Station

The distribution of meteorological observation stations administrated by WRMC is plotted in the Figure below. The precipitation, temperature, humidity, evaporation, wind velocity are measured and recorded once a day, among of which the precipitation, temperature and evaporation data are utilized as input data for the water balance and water allocation simulation.

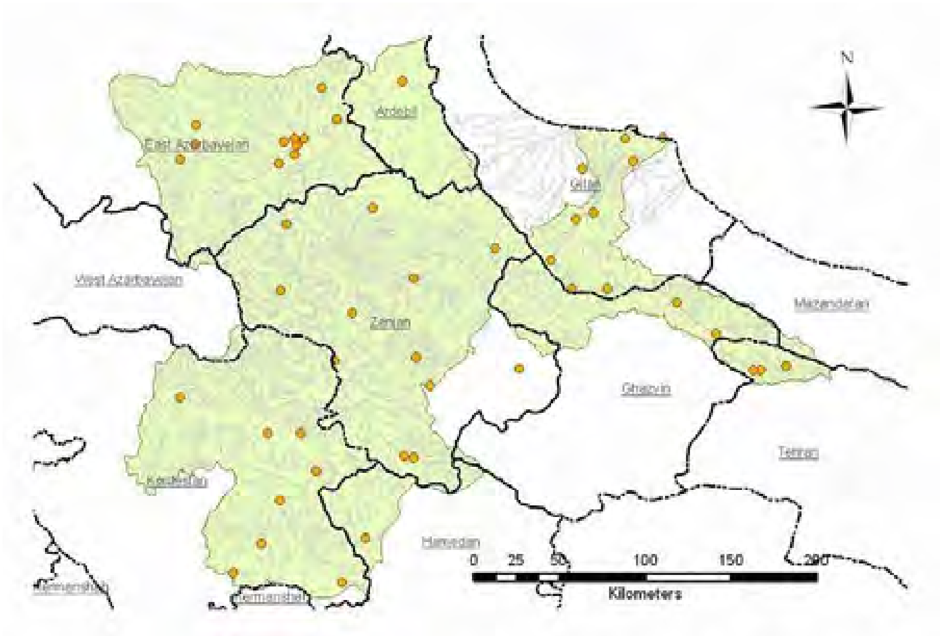


Figure 1.1.2 Distribution of Climate Station (WRMC)

3) Discharge Station

According to WRMC, the daily discharge is estimated by using a rating curve to convert the daily water level to the discharge. The rating curve is renewed once a year. Normally the discharge is observed 2 times per month; however, in the stations which are located near the dams or geographically considered the importance, the observation is done almost 10 times per month.

All daily, monthly and annual data collected by RWC, are received by WRMC at the end of hydrological year. Then, WRMC calculate the discharge by using the received data.

Ninety stations are installed in Sefidrud river basin. But the locations of 4 stations out of them are not identified. Many stations are distributed in Zanjan province but the most stations are installed in the last 10 years. In addition, East Azarbaijan and Gilan have a number of stations with long observation periods.

Station's status and periods of discharge are shown in Table 4.1.3 at the Annex.

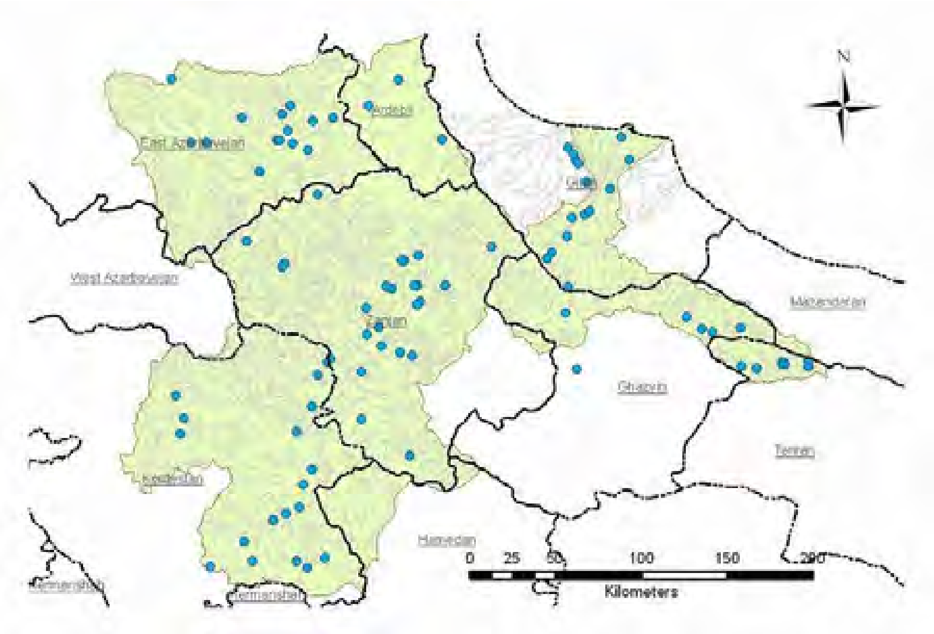


Figure 1.1.3 Location of Discharge Station (WRMC)

1.2 METEOROLOGY

Based on the collected data for the Study, the meteorological conditions in the Study Area are summarized in this chapter.

1.2.1 Precipitation

The annual average precipitation in the areas between the Caspian Sea and Albultz range (the north part of the Sefidrud River Basin) is estimated to be more than 1,000 mm while it is from 200 mm to 400 mm in its south. More than 90 % of the averaged annual precipitation in the southern part occurs during the seven months between November and May (Figure 1.2.1). On the other hand, at the northern Albultz, the seven month between September and March is considered being pluvial period although the clear variation of a precipitation pattern does not appear.

1.2.2 Evaporation

The annual evaporation in the south of the Albultz range is approximately 2,000 mm, which is about quadruple the annual precipitation. However, the annual evaporation in the northern area is estimated less than 1,500 mm. However, according to “Hydrology” issued by McGRAW hill, the value of evaporation measured by a pan with the influence of wind and humidity is maximum 70% larger than that under natural conditions in the semi-arid area. The pattern of evaporation is inversely proportional to the precipitation (Figure 1.2.1).

1.2.3 Temperature

The annual average temperature in the Study Area is between -5 and 25 Celsius, which tends to be warmer in the south than the north. The difference in annual averaged daily temperature between Rasht observatory located in the north of Albultz range and Naser Abad observatory at the south end of the Study Area is about 5 degrees centiglate (Figure 1.2.1). The lowest and highest temperatures tend to occur in February and August respectively.

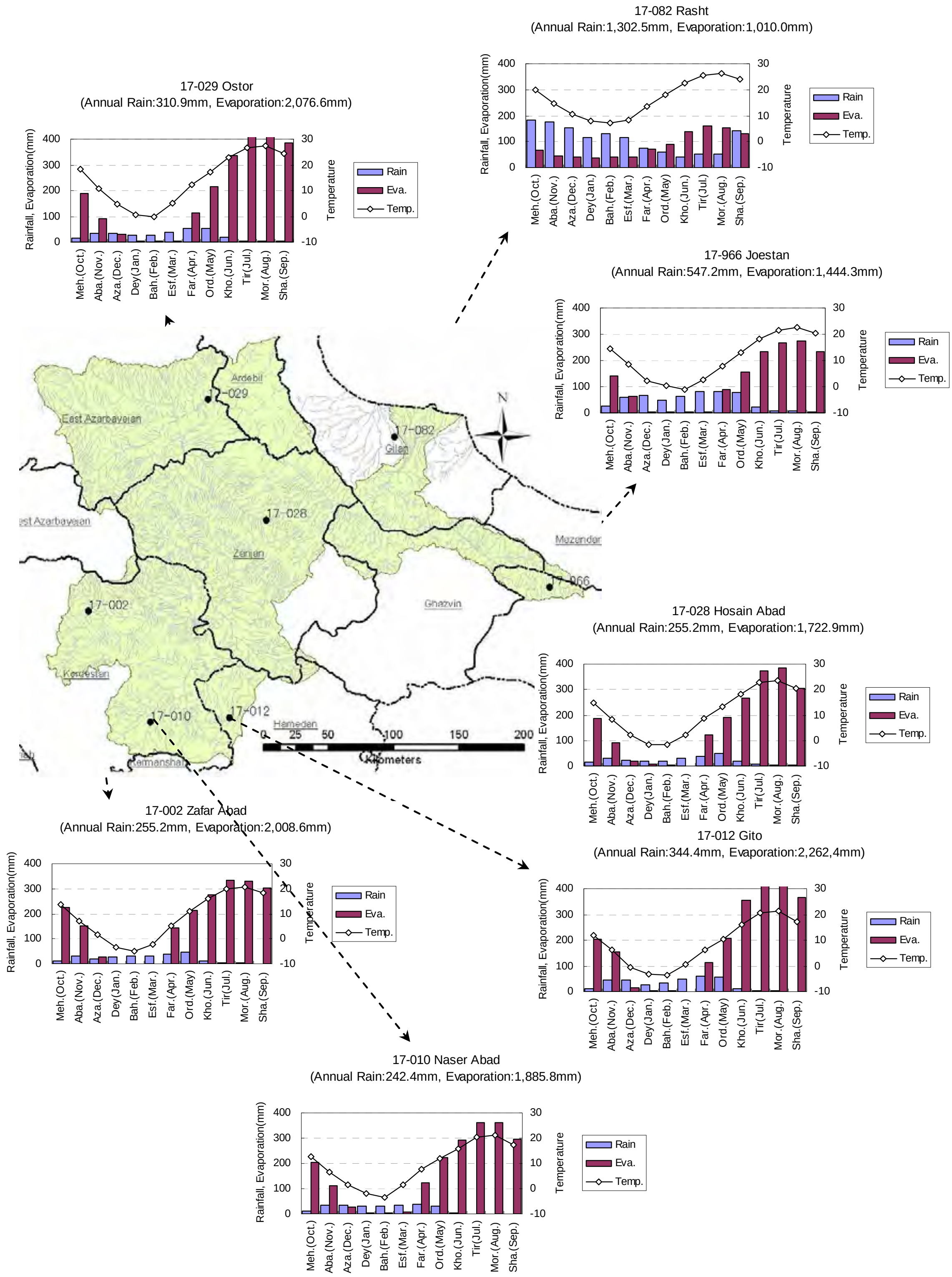


Figure 1.2.1 General Meteorological Condition

1.3 HYDROLOGY

1.3.1 River System

The Sefidrud River basin is in the northwest part of the country with the total area of 59,090km2. The Sefidrud River flows about 100 km from the Sefidrud dam to the river mouth and two main tributaries, Gezelozen River and Shahrud River flow into the Manjil dam. Based on the topographical map and GIS database which is established in this Study, the river system is lined out as shown Figure 1.3.1.

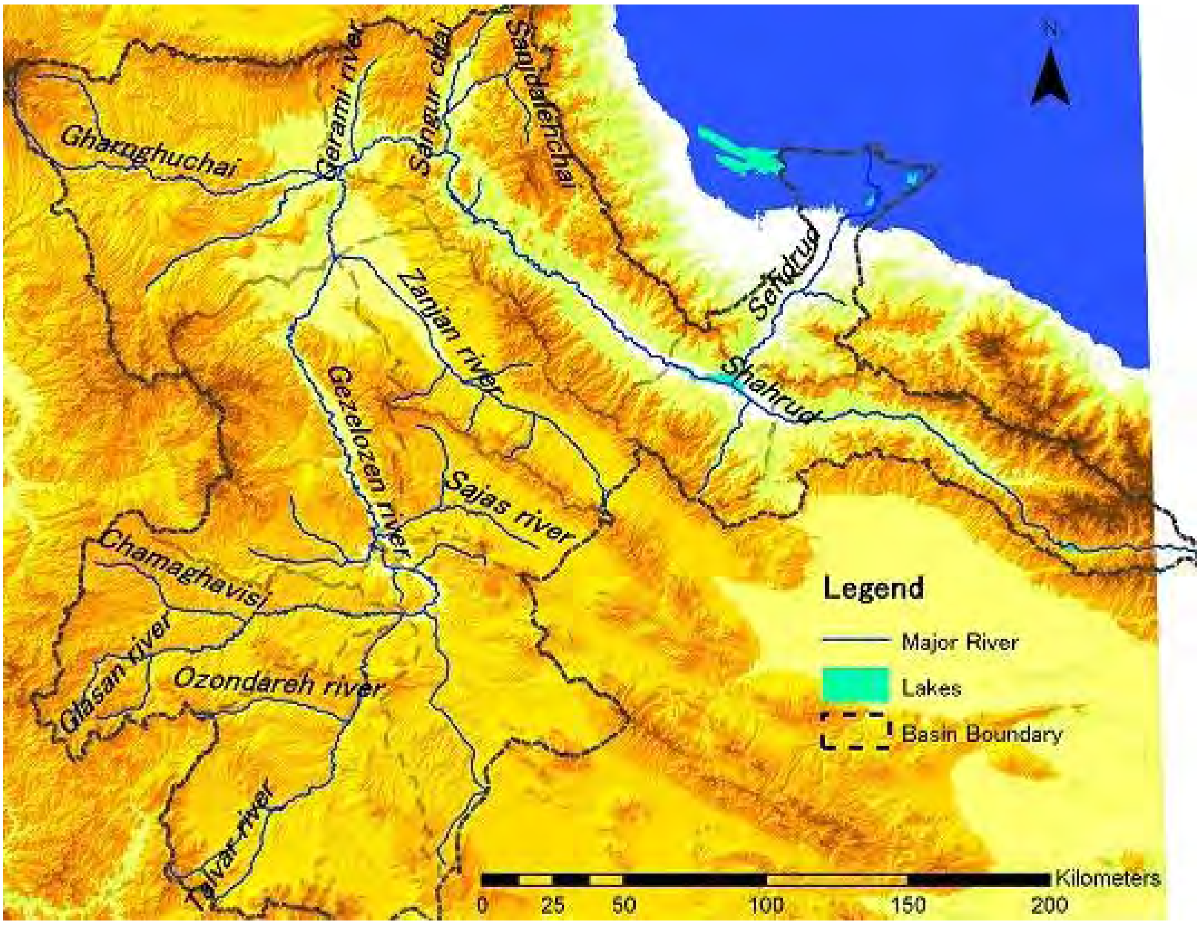


Figure 1.3.1 River System

1.3.2 River Features

The length of main river is estimated at 750 km from the Sefidrud River and Gezelozen River with the slope of 1/340. The feature of Sefidrud River and major tributaries are summarized in Table 1.3.1 and the river profile is presented as shown in Figure 1.3.2.

Table 1.3.1 Feature of Rivers

No	River	Catchment Area (km^2)	River length (km)	Average Slop (1/I)
1	Shahrud River	4,850	210	1/110
2	Ghezelozan River	48,600	670	1/340
3	Zanjan River	4,690	150	1/140
4	Talvar River	5,920	160	1/290
5	Main River	59,090	750	1/360

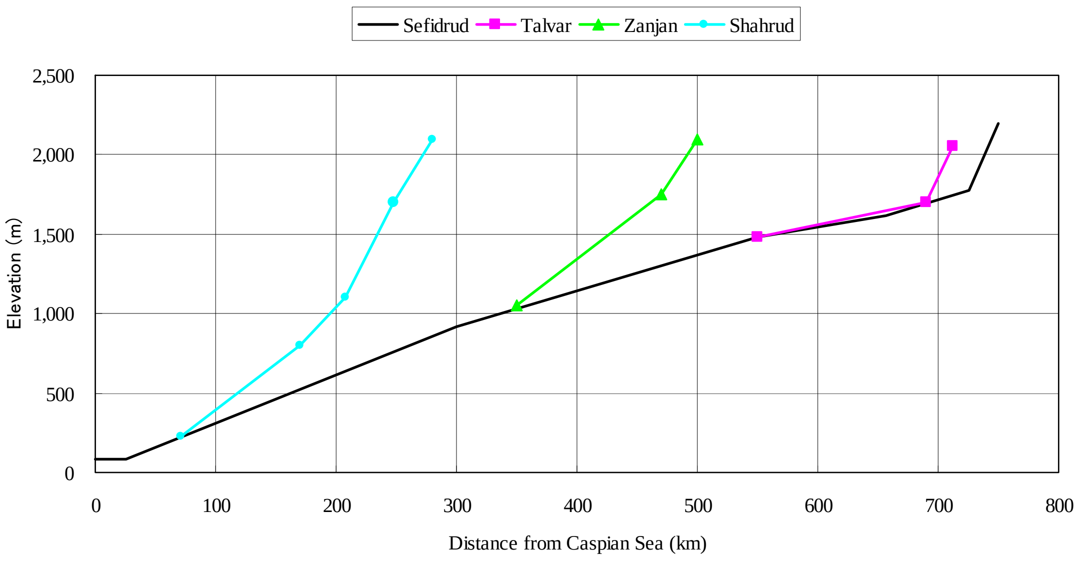


Figure 1.3.2 River Profile

1.3.3 Flow Regime

The flow regime at major rivers is summarized in Table 1.3.2.

Table 1.3.2 Flow Regime

(m^3/s)

No.	River	Code of Observatory	Average Annual Maximum	High-Water flow	Normal-Water Flow	Low-Water Flow	Draught Water Flow	Annual Average Flow	Period (year)
1	Shahrud River	17-041	224.5	42.4	16.8	10.0	7.0	32.9	34
2	Qezel Ozan at the end	17-033	814.9	109.9	60.3	19.1	6.6	105.7	39
4	Qezel Ozan at the middle	17-011	377.6	36.0	18.2	4.7	1.3	34.4	28
5	Zanjan	17-019	70.5	3.9	1.3	0.0	0.0	4.6	31
7	Sajas	17-013	52.0	5.5	3.5	0.5	0.1	4.5	31
8	Garnghuchai	17-026	189.6	17.3	9.4	2.8	0.5	18.1	28
9	Gerami	17-430	40.8	2.1	0.7	0.0	0.0	2.2	10
10	Sangur chai	17-031	50.4	4.9	3.2	1.4	0.2	4.9	9
11	Chamaghavis	17-001	173.7	18.1	8.3	2.4	0.9	17.4	26
12	Talvar	17-007	105.4	9.7	5.9	1.3	0.5	8.5	38

1.3.4 Discharge

The Ghezelozan and the Shahrud Rivers are the major tributaries which flow into Manjil Dam. A hydrograph (Figure 1.3.3) was constructed by using data collected at Gilvan and Loshan observatories located on the rivers. The UPSF is the gross total inflow volume to the dam which is calculated by adding the discharges recorded at Gilvan and Loshan observatories. The river discharge starts to increase in February and reaches its peak in April as shown in Figure 1.3.3.

Historical annual inflows into the Manjil reservoir, which is located at the outlet into the lowermost alluvial plains in the Gilan province, clearly decrease to 2,500 MCM for the recent nine years from 4,500 MCM for the entire period as shown in Figure 1.3.4. It might be due to a recent sequence of dry weather.

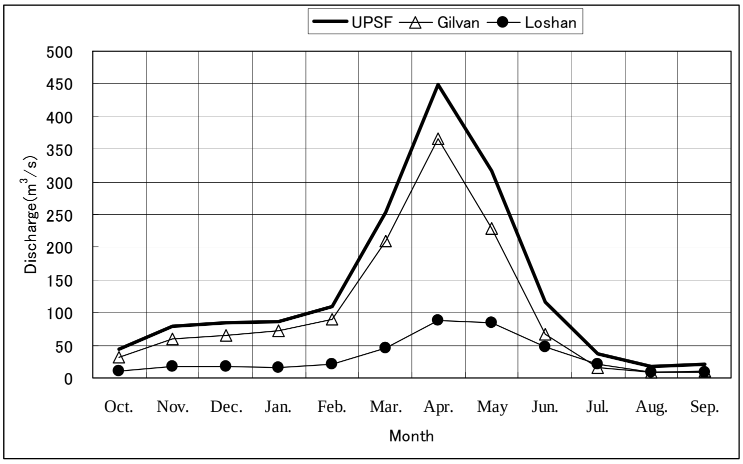


Figure 1.3.3 Variation of Annual Average of Daily Discharge (to Sefidrud Dam)

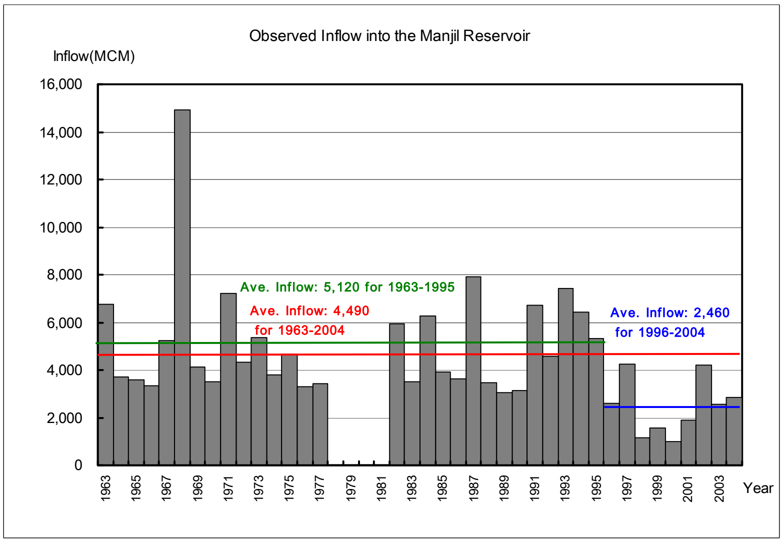


Figure 1.3.4 Historical Change of Inflow into Manjil Reservoir

1.3.5 Runoff-Ratio

Annual averaged runoff-ratio for the past 30 years is estimated at 0.22 as shown in Table R 3.5.1, while the ratio at the dry year between 1999 and 2001 is less than half of the annual averaged runoff ratio. The annual rainfall of whole basin upstream of Manjil dam, annual runoff volume and annual runoff ration is summarized in Table 1.3.3 in the Annex. According the table, it can be considered that the runoff ratio drop to a low value compared with the annual average when the annual rainfall is below 300 mm.

Table 1.3.3 Runoff Ratio (Upstream of Manjil Dam)

Period	Annual Average rainfall (mm)	Annual Average Runoff (MCM)	Average Runoff
1969～2005	375	4,158	0.22
Dry Year（From 1999 to 2001）	289	1,240	0.09

1.3.6 Probable Rainfall

1) Probable Minimum Rainfall

Annual probable minimum rainfall and the amount of rainfall in the rainy season are estimated at some of the rainfall observation stations in the Sefidrud River Basin. Stations with a long history of observation are selected in such way that there would be a uniform distribution of observation points throughout the Basin. The results are stated below and shown in Figure 1.3.5.

- The annual precipitation ranges from 230 mm to 530 mm in a 2-year return period, except for Gilan and Tehran provinces.
- The probable amount of precipitation in the rainy season was calculated to be larger than the annual rainfall for the Station 17-012 in Gito. This error was caused by using different calculation methods. If the same methods were used they could be almost an equal.
- At Station "17-002 Zafar Abad", the decrease in rainfall in accordance with the return periods is relatively large in comparison to the other stations. This means that the amount of rainfall widely varies depending on the year.
- Rasht, Gilan province predicted more than 1,000 mm of annual rainfall even in a 30- year return period. This means that the rainfall is relatively constant in this area.

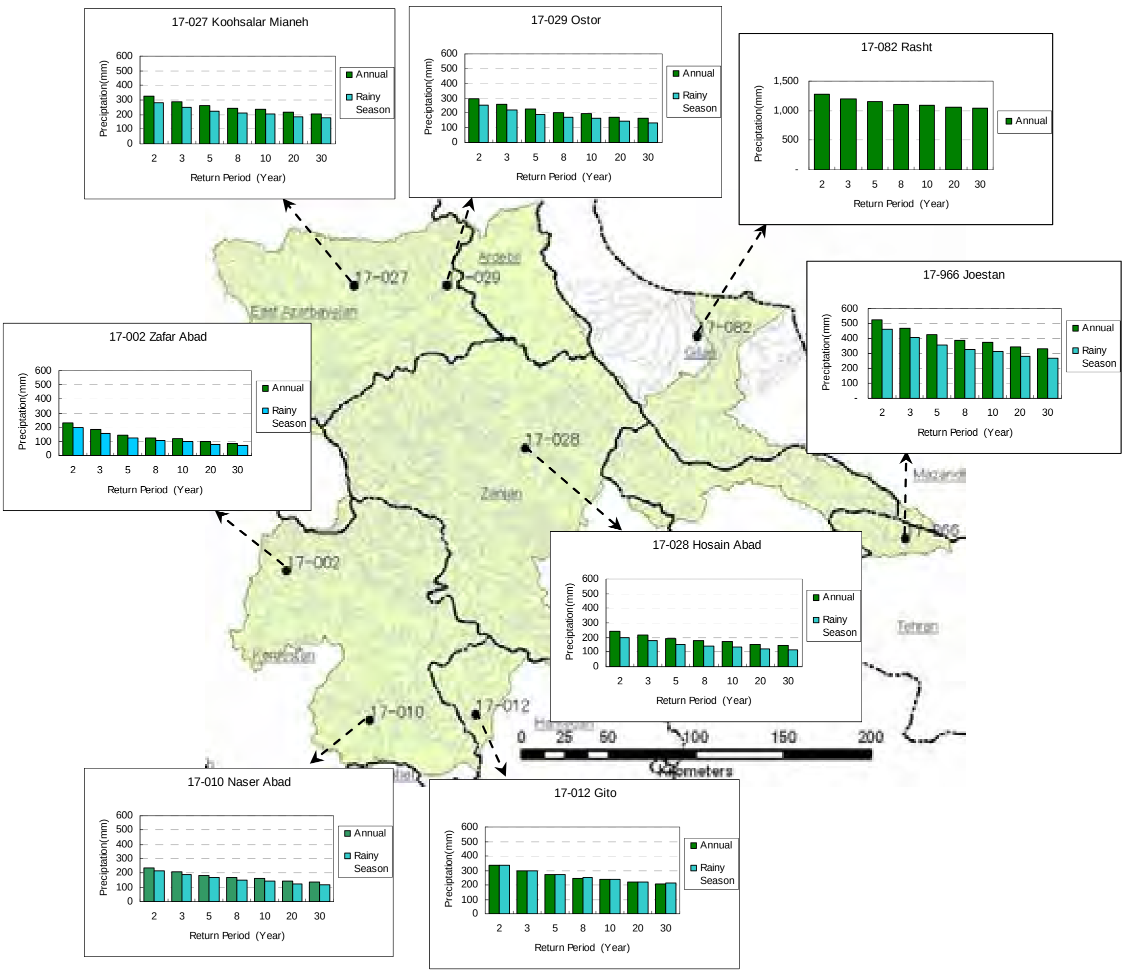


Figure 1.3.5 Probable Minimum Rainfall

2) Probable Maximum Rainfall

Probable Maximum 5-days Rainfall is estimated by assembling the collected daily rainfall data and making the probabilistic calculation. The result of the calculation is summarized in the Table 1.3.4.

Table 1.3.4 Results of Probable Maximum Rainfall

Return Period	17-002 Zafar Abad	17-010 Naser Abad	17-012 Gito	17-027 Koohsalar Mianeh	17-028 Hosain Abad	17-029 Ostor	17-082 Rasht	17-966 Joestan
2	64.7	39.5	56.9	49.6	38.4	42.9	154.2	64.7
5	83.6	52.6	75.1	66.0	52.3	57.1	186.4	83.6
10	96.2	58.9	87.4	75.1	60.0	67.3	205.0	96.2
20	108.2	63.6	99.4	82.9	66.4	77.7	221.4	108.2
30	115.2	65.8	106.5	87.0	69.7	84.0	230.3	115.2
50	123.8	68.1	115.3	91.7	73.5	92.1	241.0	123.8
100	135.5	70.7	127.4	97.7	78.2	103.7	254.8	135.5
Analysis Method	Log normal	Log Pearson	General-ized extreme value	Log Pearson	Log Pearson	Generalized extreme value	Ishihara-Takase	Gumbel

1.3.7 Probability of Discharge

The probable minimum discharge was analyzed by using minimum monthly flows in the dam sites. The results are shown in the Table below.

Table 1.3.5 Probable Minimum Monthly Discharge

Return Period	Talvar Dam	Ostor Dam	Taleghan Dam	Manjil Dam (inflow)	Manjil Dam (outflow)
2	0.0	1.6	3.0	12.6	17.1
3	-	0.0	2.7	9.2	10.2
5	-	-	2.4	6.8	6.2
8	-	-	2.2	5.4	4.3
10	-	-	2.1	5.0	3.7
20	-	-	1.9	3.8	2.4
30	-	-	1.8	2.8	1.9

CHAPTER 2. WATER BALANCE AND ALLOCATION SIMULATION

2.1 ESTABLISHMENT OF SIMULATION MODEL

The MIKE SHE and MIKE BASIN are employed to establish the water balance simulation model and the water allocation simulation model respectively. MIKE SHE, in its original formulation, could be characterized as a deterministic, physics-based, distributed model code. MIKE SHE covers the major processes in the hydrologic cycle and includes process models for evapotranspiration, overland flow, unsaturated flow, groundwater flow, and channel flow and their interactions. The result of the water balance simulation by MIKE SHE such as the time series of runoff water, recharge water as well as water demand are input into the water allocation model (MIKE BASIN) to examine the situation of the water distribution under the condition of various cases and to propose the appropriate water allocation plans. Outline of the Sefidrud Model is described below.

The water balance simulation model for Sefidrud River basin by MIKE SHE (hereinafter referred to as The Sefid-WBSM) is established to calculate the natural groundwater recharge and surface runoff to input into the MIKE BASIN allocation simulation model (hereinafter referred to as The Sefid-WASM). The groundwater recharge is equal to the amount of water percolating out through the bottom of the root zone. Runoff and infiltration are surface processes and as such require detailed information on the ground surface and root zone.

2.1.1 Outline of Simulation Models

The Sefid-WBSM domain is 210 grid cells East-to-West and 165 grid cells North-to-South. The grid cell size is 2040m. Normally, the smaller mesh size is better to increase the accuracy of simulation results. However, considering both the accuracy requirement and the practical use, the grid size is selected so that the model grid would correspond to the 60m DEM and the simulation time could be less than 6 hours. The model data is specified in a variety of formats independent of the model domain and grid, including native GIS formats. At run time, the spatial data is mapped onto the numerical grid, which makes it easy to change the spatial distribution.

The river network is arranged using the collected information such as DEM (ASTER) and topographic maps. In the coupled MIKE 11 river network model, the river discharges are calculated assuming there is no hydrograph transformation along the river network. In the Sefid-WBSM and WASM, the sub-catchments limit the lateral extent of interflow and overland flow. That is interflow and overland flow is only discharged to river links located within the sub-catchment.

Each of above-mentioned processes can be represented at different levels of spatial distribution and complexity, according to the goals of the modelling study, the availability of field data and the modeller's choices. There are, however, important limitations to the applicability of such physics-based models, primarily complexity and computational cost. Therefore, it is often practical to use simplified process descriptions. In case of Sefid-WBSM, it takes about 6 hours to simulate the water balance of the 62 Reaches for 30-year time series data.

As to the Sefid-WASM, the simulation result outputs in each Reach and the water transfers through the river channel in the same way as the Sefid-WBSM. The Sefid-WBSM can be visually established on the screen of a computer using the GIS software "Arc Map". Concretely, the visible figures of module for basins, river lines, dams and water users are pasted on GIS database screen and the data is input through the windows which appear when the modeler clicks the features. After the data input, the Sefid-WASM should be verified its tank parameters which express the conveyance from underground water (the recharge) to river flow.

2.1.2 Basic Conditions

The Sefid-WBSM and WASM is established based on the following basic conditions on which the both the Study Team and C/P agreed in the Phase I. The duration of water allocation simulation should be for 30 years, however, the data for 20 years is used in the current model due to the unsatisfactory calibration result about the first decade, that is from 1975 to 1984.

Table 2.1.1 Basic Condition for Model Construction

Model	Contents	Data Format	Duration of Simulation
Sefid-WBSM	The recharge and runoff are calculated. By the model using the hydro-meteorological data, land use, vegetation and so on.	Input and Output -Gregorian Calendar -Daily data -Start from March 21 (Far 1 in Iranian Calendar)	1) 20 Years for Calibration -1985/3/21-2005/3/21 -Duration during no dam at the upper basin of Manjil Dam 2) 30years for Simulation - Output data is to be inputted to Sefid-WASM
Sefid-WASM	The water allocation is considered by the model which are inputted the water demand, dam's information and the result of Sefid-WBSM.	Input (- ditto -) Output -Gregorian Calendar -Monthly Data -Start from March 21 (Far 1 in Iranian Calendar)	1) 30 years for Simulation -1975/3/21-2005/3/21

2.1.3 Flowchart of Model Establishment

The flowchart for the establishment of Sefid-models is shown in Figure 2.1.1.

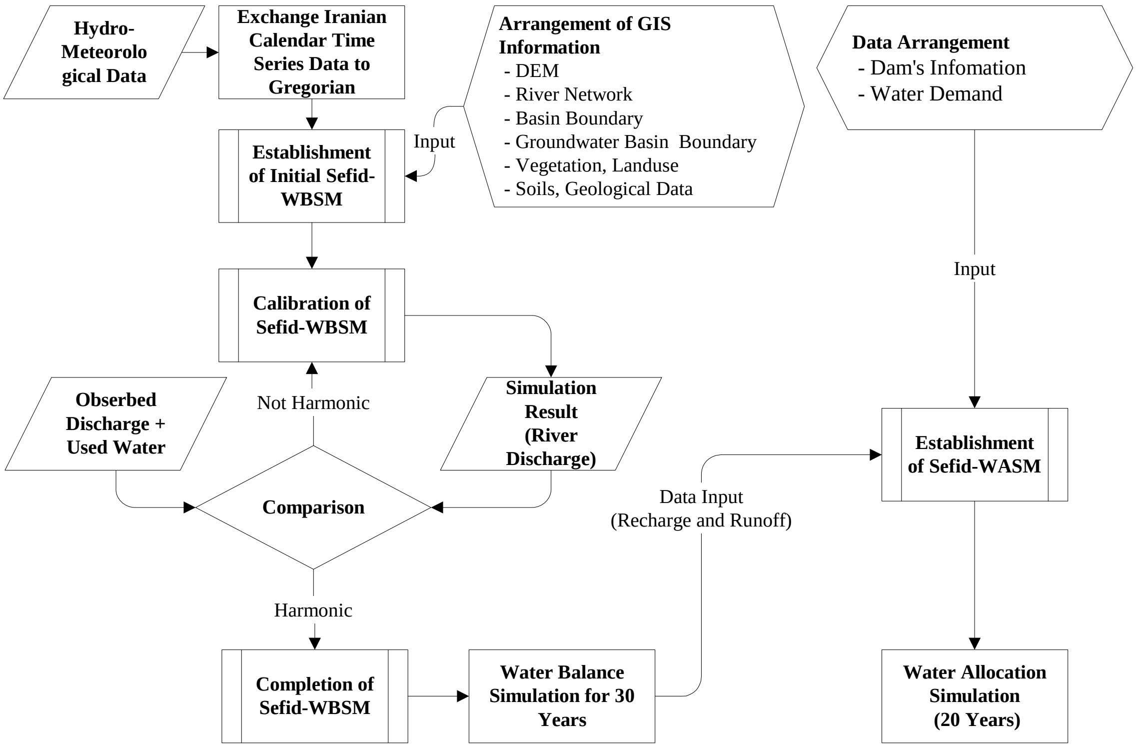


Figure 2.1.1 Flowchart of Model Establishment

2.2 ESTABLISHMENT OF WATER BALANCE SIMULATION MODEL

The Sefid-WBSM uses the simple, sub-catchment based method for calculating overland flow to the river, the gravity flow method with the Kristensen and Jensen ET method for calculating infiltration and root zone water contents, and the linear reservoir method for calculating groundwater interflow and baseflow to the river network. In the coupled MIKE 11 river network model, the river discharges are calculated assuming there is no hydrograph transformation along the river network.

Table 2.2.1 Numerical Method in Sefid-WBSM

Hydrologic Process	Numerical method used
Overland runoff	Sub-catchment based
River flow	Kinematic routing
Unsaturated flow	Gravity flow
Evapotranspiration	Kristensen and Jensen
Saturated flow	Linear reservoir routing

2.2.1 Boundary Condition for Sefid-WBSM

The time series data such as evaporation, temperature, used water and river discharge, and the land coverage information such as vegetation and geological information are collected to establish Initial Sefid-WBSM. These data are entered into database mounted on MIKE SHE software.

Table 2.2.2 Input Data into Sefid-WBSM

Item		Duration, Contents	Remarks
Observed Data	Precipitation (Daily)	1975 - 2005	Selected from 167 WRMC stations and 102 IRIMO stations
	Evaporation (Daily)	1975 - 2005	Selected from 47 WRMC stations
	Temperature (Daily)	1975 - 2005	Selected from IRIMO stations
Geographical Information	Land Use Map	2002	Obtained from MOJA
	Soil, Geological Map	2005	Obtained from MG
	DEM	2007	From ASTER Satellite (purchased by the Study Team)
	Basin Boundary	-	Generated using DEM
	Reach Boundary	Sub-basins based on dam construction plan	Upstream basin of existing, abuilding, planned dams
	Groundwater Aquifer Boundary	Delineated based on aquifer boundary	Re-defined during model calibration
	River Network	Major Rivers	Defined by topographic map and DEM
	Position of Observatories	Hydro-Meteorological Station	For making Thiessen polygon

1) Model Domain and Grid

The MIKE SHE model domain is delineated based on the Sefidrud River basin boundary and Gilan irrigation network drainage area. The model domain is 210 grid cells East-to-West and 165 grid cells North-to-South. The square grid cell size is 2040m. The grid size and grid origin were selected so that the model grid would correspond to the 60m DEM (Digital Elevation Model from Aster Satellite). That is each model cell contains exactly an even number of 60m DEM cells.

2) Delineation of Subcatchments (Reaches)

The subcatchments in the Sefidrud WBS model are defined based on the Reaches information supplied by WRMC. The subcatchments are identical to the catchments used in the Sefidrud WAS model (by MIKE BASIN software). In this model, the subcatchments limit the lateral extent of interflow and overland flow. That is interflow and overland flow is only discharged to river links located within the subcatchment. A MIKE 11 branch name and chainage range was specified for each subcatchment. This prevents any ambiguity with respect to the river links where the interflow and overland flow will discharge.

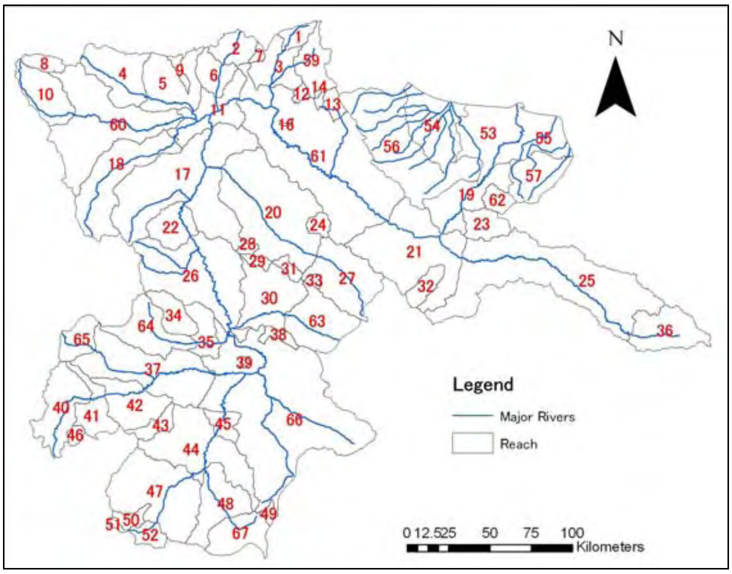


Figure 2.2.1 Delineation of Subcatchments (Reaches)

3) Topography (Elevation Distribution)

The model topography is based on the 60m DEM. The DEM raster data was converted to a dfs2 grid file using the built in tools in ArcMap to convert the raster to an ASCII grid. Following this, the Grid2dfs MIKE Zero tool was used to convert the ASCII grid to the dfs2 file format.

As mentioned in subsection 1.3.2. Since the topography data (60 m mesh) is much denser than the model grid (2,040m mesh), each model grid contains many topography data points. In this case, 34x34, or 1156 data points per grid cell. In the Sefidrud model, the model grid is aligned to the topography grid, which means that the model grid is defined by the topography data that is closest to the mid-point of the cell. The topography is used for calculation of the cell elevation for the temperature and precipitation elevation correction.

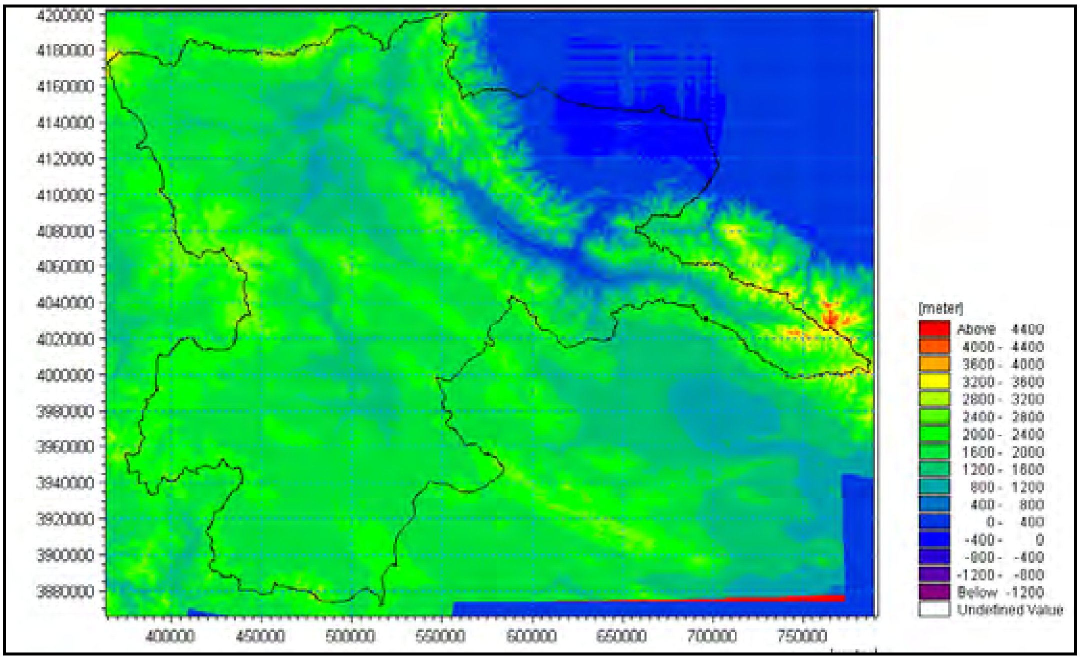


Figure 2.2.2 Topography

4) Climate

As a result of JICA Study, the available climate information consists of measured precipitation, evapotranspiration, and temperature in the view point of the situation of arrangement of the climatology data in the Sefidrud River Basin. Each of these data sets was analyzed to find the stations with long continuous data records (see JICA Report). These data stations were extracted and the remaining gaps were statistically filled from correlated stations, using MIKE Basin's Temporal Analyst tool in ArcMap. For each data set, a Thiessen polygon map was created based on the selected stations. The Thiessen polygon shape file was used to distribute the measured climate data at each station within its corresponding Thiessen polygon.

a) Precipitation

For precipitation, measurement data from WRMC was used. Thirty-nine measurement stations were selected with long, relatively continuous records. Gaps in the measurement records were filled based on the correlations to neighboring stations. A Thiessen polygon distribution was created based on these 39 stations (see Figure 2.2.3), which can significantly influence the distribution of rainfall relative to the station measurements.

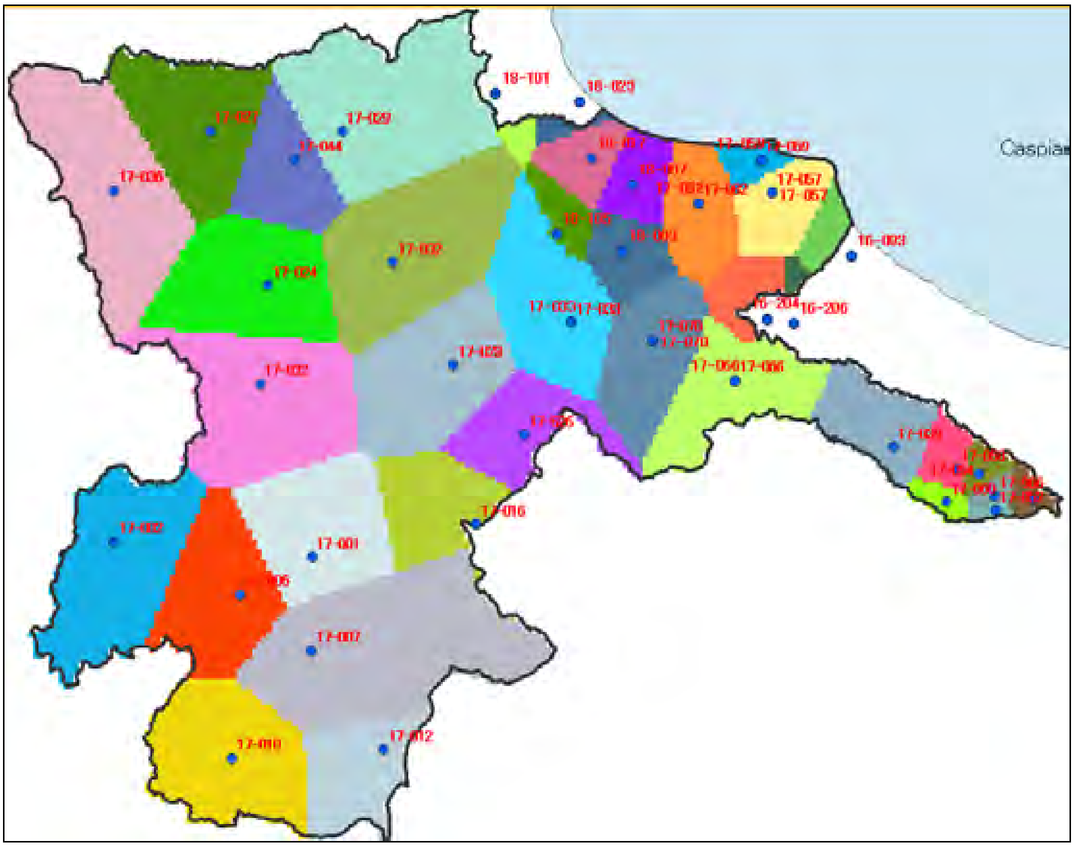


Figure 2.2.3 Precipitation Observatory and Thiessen Polygon

In mountainous areas like the Sefidrud basin, there is generally a noticeable elevation influence on actual precipitation. However, the correction factors depend on local effects, such as average wind direction and wind shadowing. Therefore, general correction factors are not available. In the Sefidrud basin, there is obvious elevation affects in some of the catchments based on additional station measurements that are located at high elevations. However, the record lengths for these stations were insufficient for them to be included in the model. Thus, during the calibration, precipitation correction factors were added in areas that were up slope from six stations (see Table 2.2.3). Stream flow in these catchments was significantly underestimated unless the corrections were included. The corrections used were between 2 and 4% per 100m elevation difference from the measurement station.

Table 2.2.3 Selected Rainfall Stations for Modeling

Code	Name	Location	Number of Year w/o deficit	Code	Name	Location	Number of Year w/o deficit
17-001	Bianloo	Kordestan	29	17-039*	Baghkolayeh	Qazvin	35
17-002	Zafar Abad	Kordestan	34	17-044	Sabzarbat-mianeh	East-Azarbaijan	36
17-006	Changiz Ghaleh	Kordestan	31	17-050	Ganeh deh	Tehran	37
17-007	Salamat Abat	Kordestan	40	17-052	Gelirod	Tehran	38
17-010	Naser Abad	Kordestan	30	17-054	Dizan	Tehran	37
17-012	Gito	Hamadan	32	17-057	Astaneh	Gilan	39
17-016	Ghidar Payghambar	Zanjan	35	17-058	Saghranchal	Tehran	37
17-022	Angooran(dandi)	Zanjan	32	17-059	Fakhr Abad-lastnesha	Gilan	59
17-024	Mashampa	Zanjan	32	17-060	Zidasht Taleghan	Gilan	27
17-027	Koohsalar Mianeh	East Azarbaijan	35	17-066*	Paroodbar	Gilan	38
17-028*	Hosain Aba	Zanjan	33	17-070	Manjil	Gilan	38
17-029*	Ostor	East Azarbaijan	39	17-082	Rasht	Gilan	38
17-032	Tokmeh Dash	Zanjan	30	17-526*	Soltanieh	Zanjan	40
17-033	Gilvan	Zanjan	37	17-966	Joestan	Joestan	37
17-036*	Khajeh Shahi	East Azarbaijan	30				

* elevation corrected

Figure 2.2.4 shows the distribution of elevation corrections for precipitation.

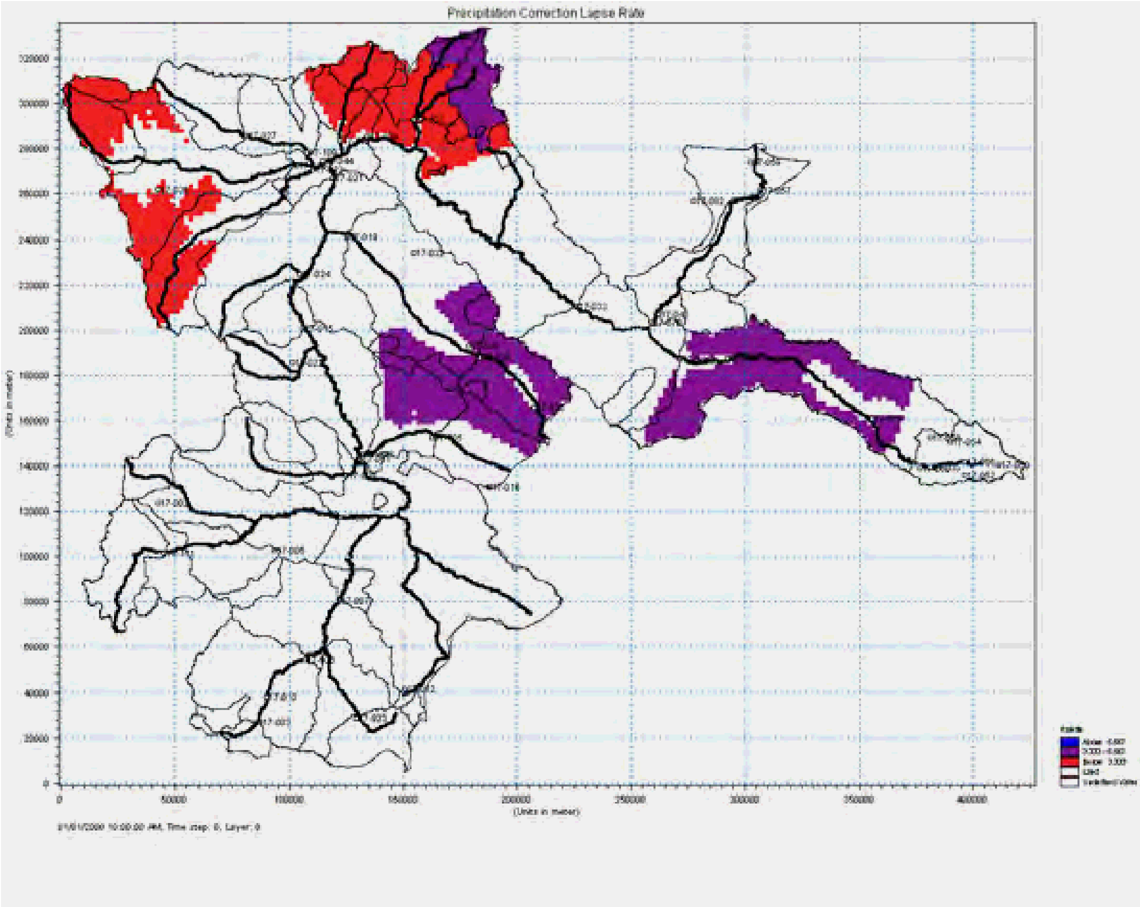


Figure 2.2.4 Precipitation Correction for Elevation

b) Evaporation

The evapotranspiration (ET) in the Sefidrud MIKE SHE model was based on daily measurements of pan evaporation at 31 stations from the WRMC (Figure 2.2.5). The 31 measurements were selected based on their length of record and continuity over time. Gaps in the measurement records were filled based on the correlations to neighboring stations.

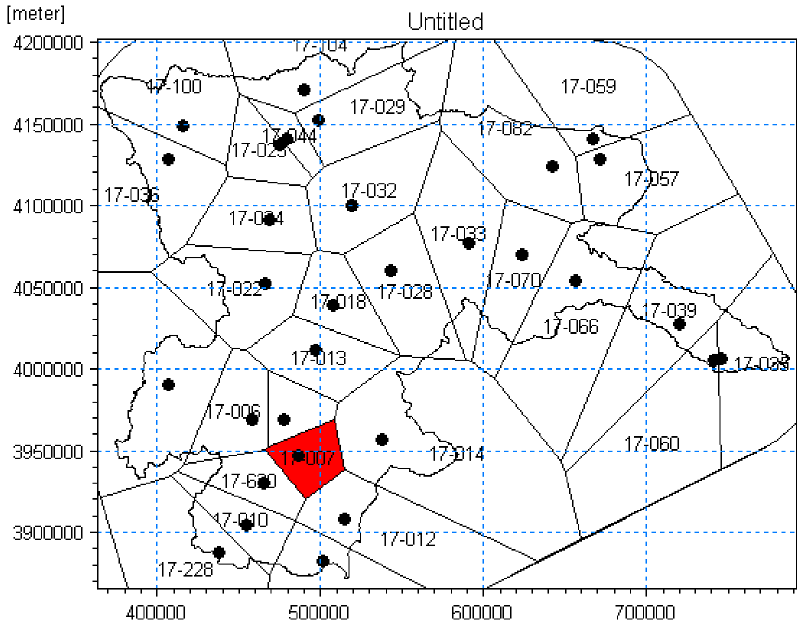


Figure 2.2.5 Polygon of Evaporation

MIKE SHE calculates actual ET from the available water. This requires crop reference ET as input, which is a standard amount ET expected from a standard reference crop (i.e. a well water grass of a specific species and height). Pan evaporation is, however, significantly greater than crop reference ET. Pan coefficients can be used to convert between pan evaporation and crop reference ET. However, these coefficients depend on the local weather and location of the pan (e.g. upwind vegetation, relative humidity, wind speed, etc). Pan coefficients for sites characteristic of the Sefidrud basin probably range between 0.5 and 0.9. For the Sefidrud MIKE SHE model, a pan coefficient of 0.7 was used. That is, all of the pan evaporation data was multiplied by 0.7.

Incidentally, actual values for crop reference ET can be calculated based climate data including wind speed, solar radiation, temperature, and humidity, using the Penman-Montieth (PM) method. The Iranian Meteorological Institute has such data at several synoptic stations in the Sefidrud basin up to four times per day, but these measurements were not available for this project. The existence of these measurements was confirmed during a meeting with Mahab Ghodss on June 23, 2008.

Table 2.2.4 Selected Climate Station for Modeling

Code	Name	Location	Number of Year w/o deficit	Code	Name	Location	Number of Year w/o deficit
17-002	Zafar Abad	Kordestan	10	17-036	Khajeh Shahi	East Azarbaijan	8
17-006	Changiz Ghaleh	Kordestan	10	17-039	Baghkolayeh	Qazvin	13
17-007	Salamat Abat	Kordestan	10	17-044	Sabzarbat-mianeh	Kordestan	12
17-010	Nasar Abad	Kordestan	10	17-057	Astaneh	Gilan	26
17-012	Gito	Hamadan	11	17-059	Fakhr Abad-lastnesha	Gilan	19
17-013	Yengi Kand	Zanjan	2	17-060	Zidasht Taleghan	Tehran	10
17-014	Ghareh Kahriz	Zanjan	12	17-066	Paroodbar	Gilan	26
17-018	Gholtoogh	Zanjan	11	17-070	Manjil	Gilan	31
17-022	Angooran(dandi)	Zanjan	11	17-082	Rasht	Gilan	31
17-023	Motorkhaneh	East Azarbaijan	2	17-100	Hashtrood saraskand	East Azarbaijan	8
17-024	Mashampa	Zanjan	11	17-104	Sarighamish	East Azarbaijan	6
17-028	Hosain Abad	Zanjan	11	17-150	Nesareh olya	Kordestan	10
17-029	Ostor	East Azarbaijan	9	17-222	Dosar Ghorveh	Kordestan	10
17-032	Tokmeh Dash	Zanjan	11	17-228	Bolbolan Abad	Kordestan	10
17-033	Gilvan	Zanjan	31	17-620	Khosro abad	Kordestan	8
17-035	Galinak	Tehran	1				

Gaps in the measurement records were filled based on the correlations to neighboring stations. Evaporation has a better spatial correlation than precipitation and the coefficients between nearby evaporation stations are generally good. For the selected stations, the correlations were generally greater than 0.7.

In addition to the uncertainty associated with a global pan coefficient of 0.7, a significant limitation of the current data is that evaporation pans cannot be used during the winter. Therefore, the measured evaporation is zero during the winter. In the model, this will lead to an overestimation of the snow depth during the winter. In the future, it is highly recommended that pan evaporation data be substituted with crop reference ET values. The crop reference ET can be calculated directly using the PM method. However, an easier method should be satisfactory, based on monthly correlations between crop reference ET and the pan measurements. This is attractive because the monthly crop reference ET values are already available from Mahab Ghodss.

c) Temperature

The temperature in the Sefidrud MIKE SHE model was based on daily measurements of temperature at 16 stations from the Iranian Meteorological Institute (IRIMO). The 18 measurements were selected based on their length of record and continuity over time. Gaps in the measurement records were filled based on the correlations to neighboring stations. Temperature has a better spatial correlation than precipitation and the coefficients between nearby temperature stations are generally good. For the selected stations, the correlations were generally greater than 0.7.

In mountainous areas like the Sefidrud basin, there is a significant and precise elevation influence on actual temperature. The correction factor, known as the lapse rate, used in the Sefidrud MIKE SHE model was -0.649 C per 100m of elevation change from the measurement station. In fact, the temperature lapse rate depends on humidity (wet lapse rate), but this effect has been ignored in this model. This is probably insignificant because the climate is generally dry. The temperature is only used for the snowmelt calculations.

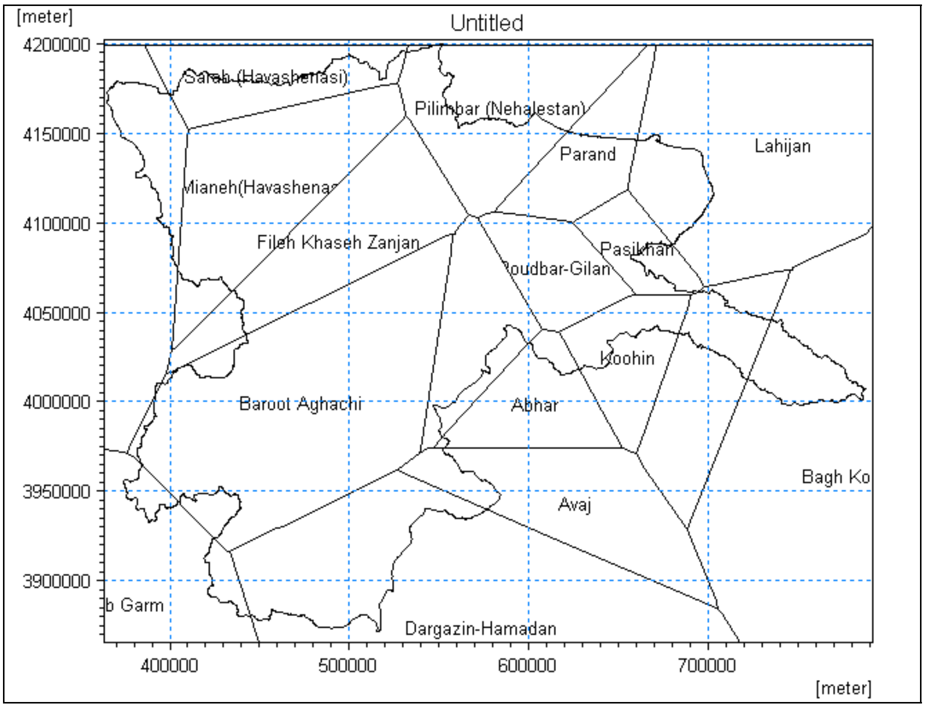


Figure 2.2.6 Polygon of Temperature

The spatial coverage of temperature across the Sefidrud basin was poor compared to precipitation and evaporation data. Further, the spatial correlation between separated valleys can be poor in some weather conditions, and micro climate effects of the Caspian mean that measurements along the coast are not representative inland. If additional temperature data from the WRMC is available, it is highly recommended that these additional measurements be incorporated into the model at a future time.

d) Snowmelt

The Sefidrud model considers the accumulation and melting of snow, as a function of air temperature. When the temperature is below 0C (Threshold melting temperature) precipitation accumulates as snow. When the temperature is above 0ºC, accumulated snow begins to melt at the rate of 2 mm/C/day (Degree-day melting coefficient).

Melted snow does not immediately add to runoff, but is adsorbed by the snow pack until the moisture content of the snow reaches 0.15 (Maximum wet snow fraction). Once this fraction is reached additional melting is added to ponded water, which is able to runoff, evaporate, or infiltrate. If the depth of snow is less than 50mm (Minimum snow depth for full area coverage) then the cell fraction covered by snow is linearly reduced as the snow depth decreases. All of these parameters were globally specified.

The snowmelt model in MIKE SHE also includes melting by shortwave radiation and by the heat capacity of rain on the snow pack when the air temperature is above zero, but snow storage exists. Solar radiation data was unavailable for this project, so this option was not included in the model. If melting due to shortwave radiation were added, the rate of melting in the spring would increase. Similarly, ignoring the heat capacity of rain on the snow pack would tend to underestimate the amount of melting.

Unfortunately, no precise measurements of snow storage in the Sefidrud basin are available, so calibration of the snow melt processes is not possible. Further, the uncertainty associated with the snow storage calculations is quite high given the lack of good rainfall measurements in the higher altitudes.

5) Vegetation

a) Land-Use Information

The distribution of vegetation in the Sefidrud BASIN was obtained as a polygon shape file from MOJA thorough WRMC. The shape file contained 76 unique vegetation classes; most of these being compounded mixed vegetation classes. These 76 classes were reduced to the following eight vegetation classes, based on the predominant class in mixed classes and lumping classes with similar characteristics.

Table 2.2.5 Dynamic Classification of Land-use

No.	Class	Description
1	Grass	"Grass" includes all of the good and moderate range areas, as well as fallow fields and areas classified as dry farming, which is assumed to be rain-fed grass-like crops
2	Scrub	"Scrub" is a lumping of all the areas that support limited or no vegetation, including all of the rock, bare land, poor range, floodplain and low forest classes
3	Urban	"Urban" includes the urban classes, as well as any other built up classifications, such as the airport class
4	Agriculture	"Agriculture" is the agriculture class, which is assumed to be irrigated crop areas
5	Water	"Water" includes areas of permanent surface water
6	Forest	"Forest" includes the modforest and woodland classes
7	Dense Forest	"Dense Forest" includes the dense forest class, which is predominantly on the coastal size of the mountains surrounding the Caspian Sea, where the precipitation rate is much higher than in the inland areas
8	Orchard	"Orchard" is assumed to be areas predominated by irrigated tree-based agriculture, such as fruit trees

The vegetation polygon shape file with these 8 classes was converted to a dfs2 file with 510 m-grid spacing. This means that each model domain grid (2040 m) includes 16 vegetation classes. The actual vegetation classes in the model are assigned to the model grids based on the dominant vegetation type in the cell, while accounting for the statistical variation of the distribution.

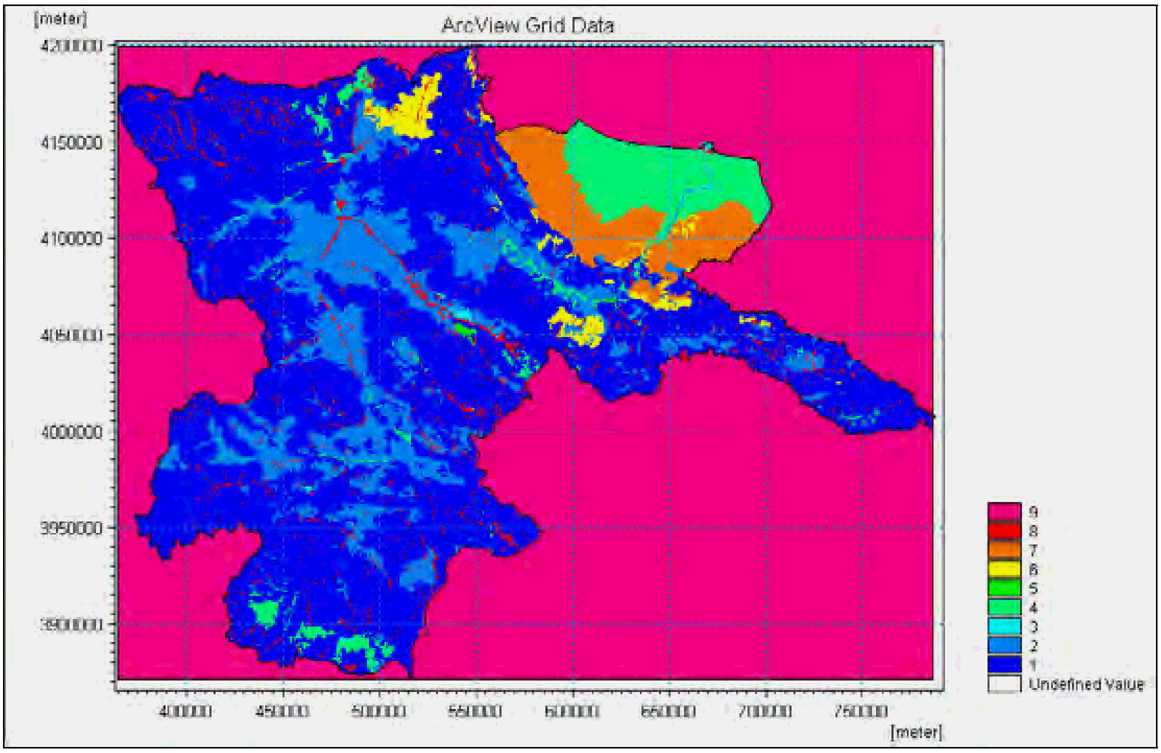


Figure 2.2.7 Land-Use Information

b) Leaf Area Index

Each vegetation class requires a Leaf Area Index (LAI), which is the area of leaves per m2 of ground surface, and a root depth. Both of these values can vary throughout the growing season depending on the plant and crop type. In the model, the LAI controls the actual amount of evapotranspiration, assuming that evapotranspiration is not limited by the available water. The root depth controls the depth to which water can be extracted from the unsaturated zone, and thus the unsaturated zone water deficit that must be filled before groundwater recharge can occur. Since the actual ET is largely limited by the available water due to the relatively dry climate, little effort was made to adjust these parameters during the calibration. More detailed evaluation of the LAI and root depths based on actual crops/plant types and growing seasons would likely improve the model, but only if better land-use and soils maps are also used.

Table 2.2.6 Summary of Leaf Area Index and Root depth values

Vegetation Class	LAI	Root depth [mm]
Grass	1	300
Scrub	0.5	600
Urban	0	0
Agriculture	4	1000
Water	0	0
Forest	5	1200
Dense Forest	6	2000
Orchard	5	2000

6) River Network

The main branches were selected from a detailed line shape file with all tertiary streams. The network was defined such that most of the large sub-catchments were connected to the river network. The stream nodes were imported to MIKE 11 from the shape file and a MIKE 11 network was routed through the points. The resulting MIKE 11 network consists of 37 branches that closely follow the actual meanderings of the river network. Since, there are no chainage data available for the river, calculated chainages based on the river nodes were used throughout the model. This is expected to be reasonably accurate given the scale of the basin and the detail of the original shape file.

In each river branch, three to six river cross-sections were defined depending on the length of the branch, with one cross-section at the upstream and downstream ends of the branch. To ensure that the river cross-sections intersected the lowest point of the river valley, 2km-wide cross-sections were used. The river cross-sections were interpolated to the 90m DEM from NASA using MIKE 11 GIS.

Since all the branches are defined without hydrograph transformation, the lateral inflows to MIKE 11 are simply summed and routed down the river network in each MIKE 11 time step. This is a reasonable assumption when we are calculating MIKE 11 with daily time steps. Some timing error is inevitable, since the travel time from the highest upstream areas to the outlet is probably a several days.

7) Over Flow Zone

The overland flow calculations in MIKE SHE are based on the simple, sub-catchment based method, where ponded water in the subcatchment is routed either to a lower overland flow zone or to the river. Typically, this involves routing overland flow from upland areas to the lowland areas and then to the river, within each subcatchment. However, in the Sefidrud basin, such topographic zones are not well defined everywhere at the scale of the model.

In the Sefidrud model, the 15 overland flow zones were defined the same as the baseflow zones, taking into account a regional catchment zone map that was available, as well as the need to calibrate the model to known discharge stations. The zone boundaries generally follow the reach boundaries used in the catchment definition, but consist of multiple catchments.

In the Extra parameters, the option to discharge simple overland flow directly to the rivers is activated (“no simple OL from ponded” = on). This prevents the overland flow from flowing to a lower overland flow zone that may exist in the subcatchment due to the mismatch between the overland flow zones and the Subcatchment boundaries.

Also in the extra parameters, the option to avoid redistribution of excess ponded water to the rest of the overland zone is activated (“only simple OL from ponded” = on). This option prevents locally ponded water from being redistributed across the entire overland flow zone at the end of the time step. Given the size of the overland flow zones, redistribution would result in a few millimeters of locally ponded water (e.g. due to a local rainfall event) becoming a very thin layer over the whole zone in the following time step, which would immediately be evaporated.

Each overland flow zone has five parameters: The slope (between 2 and 20 degrees), slope length (100m in all zones) and Mannings number (100 in all zones) together define how quickly water will flow to the river. The detention storage (0 mm in all zones) defines how much ponded water must build up before overland flow occurs. The initial depth is always zero. The average slope for each zone was roughly estimated based on a slope map for soil erosion analysis.

The actual runoff is not very sensitive to these parameters, because there is actually very little direct overland flow compared to the baseflow. The soil is primarily dry and the infiltration rate (saturated hydraulic conductivity) is much greater than the average daily rainfall rate. Runoff is generated whenever the top UZ layer becomes saturated. This occurs during heavy rainfall events that last more than one day. Reducing the time step tends to decrease the calculated runoff, because the unsaturated zone is able to drain. Shorter time steps should increase the accuracy of the runoff calculation, but only if more detailed temporal rainfall data were available. For this study, only daily rainfall data is available, thus limiting the amount of runoff that can be calculated. The primary source of rapid "runoff" in the Sefidrud basin is shallow discharge of groundwater (see Interflow section).

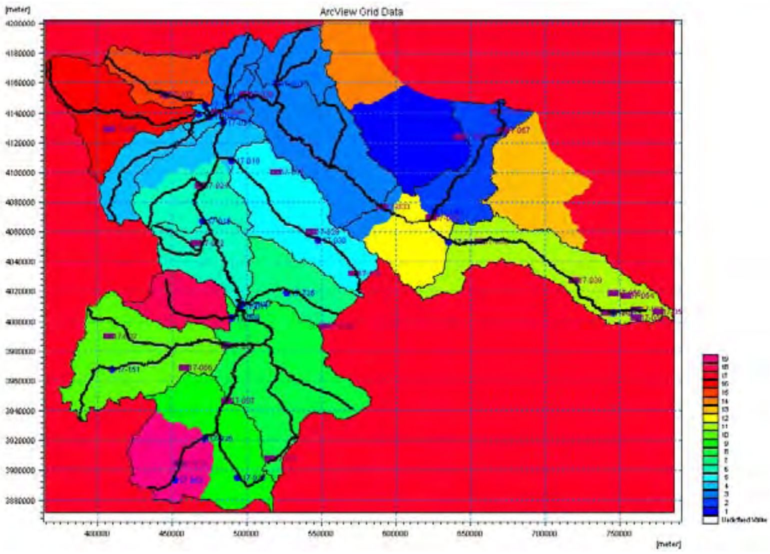


Figure 2.2.8 Overland flow zones

8) Unsaturated Flow Zone

Unsaturated flow is calculated using the gravity flow method. This method is more suitable than the two-layer water balance method when the soils are dry or the water table is deep. The Sefidrud basin has been divided into 10 soil classes based on the soils classification maps supplied by Mahab Ghodss. These soil classes refer to 3 different soil types defined in a soil database file: Alluvium, Loam and Rock. The Alluvium soil type was defined for the sand and gravel alluvial classes. The Loam soil type was used for all other areas except the Mountains, which were defined as rock. All soil profiles are assumed uniform in depth.

Soil characteristics, such as saturated water content, field capacity, and especially the parametric saturation and conductivity relationships represent microscopic phenomena. Given the size of the model grid cells, the parameter values used in the model must represent a broad average across the grid cell for the particular soil type. Thus, these parameters are calibration parameters, bounded by representative values for the particular soil class. All of the soil classes use the same vertical discretization. The top cell of the column is 10cm thick, which limits direct soil evaporation to the top 10cm. Beneath the top cell, the next two cells are 30cm and a 60cm thick, respectively. The remaining cells are 1m thick down to the bottom of the UZ column. The actual layer thicknesses used in the model are automatically slightly adjusted during the pre-processing phase to ensure a smooth transition between layer thicknesses.

The Green and Ampt infiltration model is used to increase the infiltration rate in dry soils beyond the saturated hydraulic conductivity, due to the presence of strong capillary forces in dry soils. Simple macropore flow is included to allow some of the infiltration to bypass the root zone and infiltrate directly to the groundwater. In large cells, such as those used in this model, it is expected that there will be lateral variability of the infiltration rate. There will be some areas with much higher infiltration rates that the average which will much very rapidly recharge to the groundwater. Also, macropores caused by shrinking soils, animal burrows etc, will also cause a fraction of the infiltration to rapidly bypass the root zone and recharge the groundwater directly. MIKE SHE calculates the actual amount of bypass flow based on the water content in the root zone, since dry soils will absorb some of the infiltrating water. Since ET is largely limited by the available water, decreasing the amount of bypass has the effect of making more water available for ET and thus increasing the actual ET at the expense of recharge. The bypass parameters were roughly calibrated to allow sufficient recharge, but there was no detailed calibration done.

Although a distributed soils map is used, as noted in the vegetation section, there is a lack of correlation between vegetation/land use and the soils map. This, along with the local variability of the soil parameters and their uncertainty, makes local calibration of the infiltration parameters difficult. Thus, each of the three soil classes were assigned the same soil parameter values, as summarized in Table 2.2.7. Generally, default values were used for medium grained sandy soils. The Green and Ampt suction parameter was taken from the literature for similar soils. The saturated hydraulic conductivity was a calibration parameter. The parameters set in the model are the default values for medium grained sandy soils

If the model is to be improved in subsequent phases, then some time should be spent on quality control of the soils map to ensure that there is a proper correlation between the soils and vegetation distributions. Further, the soil map is dominated by 2-3 soil classes, which could be each subdivided into 2-3 additional soil subclasses.

Table 2.2.7 Summary of soil parameters used in the model.

Parameter	Value
Saturated water content	0.3
Residual water content	0.01
pF at field capacity	2
pF at wilting point	4.2
Green and Ampt suction	-0.15 m
Van Genuchten – α	0.067
Van Genuchten - n	1.446
Van Genuchten - l	0.5
Saturated conductivity	$5(10^{-6})$ m/s
Max bypass fraction	0.3
Water content for reduced bypass	0.08
Water content for zero bypass	0.02

Groundwater Table for Lower UZ Boundary

In the Sefidrud model, the water table is not a calculated parameter because the linear reservoir method does not calculate a distributed water table. In the absence of a calculated water table, a static water table must be defined to represent the bottom of the UZ model. In the Sefid-WBSM, the groundwater table has been defined 3m below the ground surface everywhere. Three meters was chosen because it is greater than the root depth everywhere in the domain. Increasing the depth means more UZ cells and consequently longer simulation times.

The actual depth to groundwater is obviously variable across the basin. However, very little information exists on its depth, except in a few local areas. Further, the thickness of the UZ zone below the root zone does not affect the volume of recharge to the groundwater, but only the timing of its arrival at the groundwater table. Since the purpose of the model is to supply recharge to MIKE BASIN model for annual water allocation, the sensitivity of the model to this depth was not investigated.

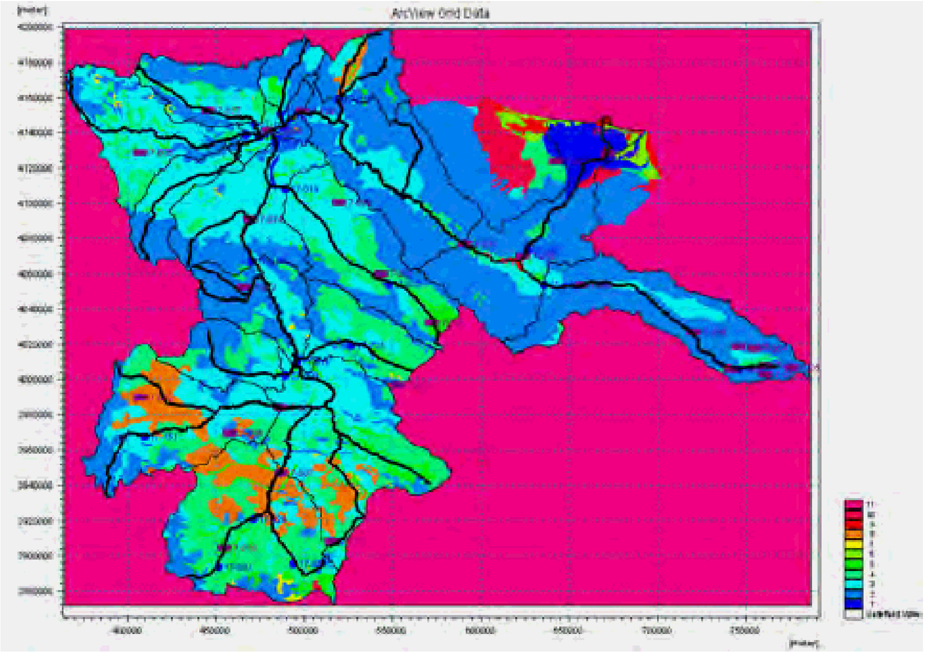


Figure 2.2.9 Soil distribution in the Sefidrud basin on a 510m grid resolution

9) Unsaturated Flow Zone

In the Sefidrud model, groundwater baseflow to streams is calculated using the linear reservoir method. This method uses a series of non-spatial “buckets” that collect infiltration from the unsaturated zone and discharge to the stream network. The time constants control the rate of outflow from the various reservoirs, and the specific yield determines the height of water in the reservoir and thus, the driving pressure for the outflow.

a) Interflow

The upper Interflow linear reservoirs represent the rapid discharge to streams that occurs after a rainfall event. This water infiltrates near small streams and drainage features where the water table is close to the surface and discharges over the following few days and weeks.

Recharge from the bottom of the unsaturated zone columns is added to the Interflow reservoir below the cell, where it either discharges to a lower interflow zone within the sub-catchment or directly to the stream network, if a lower zone does not exist. A portion of the infiltration percolates to the lower base flow reservoir.

The interflow reservoirs in the MIKE SHE model have been defined as one reservoir per catchment. This facilitates the cross calibration with MIKE BASIN, as both models then have the same structure. Also, it eliminates mass balance discrepancies associated with trying to calculate inflows and outflows on areas that do not correspond to the catchment boundaries.

Since the interflow reservoirs are limited to the catchment boundaries, it suffices to define a uniform interflow reservoir that will automatically be divided along the catchment boundaries. Calibration of the individual interflow reservoirs was beyond the scope of this model, given that the primary purpose of the model is to generate runoff and recharge for MIKE BASIN. A more detailed calibration of the interflow reservoirs would yield an improved recession curve after storm events at the various gauging stations, but would not affect the calculated runoff or recharge for MIKE BASIN.

Table 2.2.8 Interflow Parameters

Item	Value
Specific Yield	0.3
Initial depth	5
Bottom depth	5
Threshold depth	5
Interflow time constant	14 days
Percolation time constant	14 days

b) Baseflow

The Baseflow reservoirs represent the slower discharge from deep groundwater that sustains stream flow during dry periods. In MIKE SHE, the Baseflow reservoir is divided into two parallel reservoirs, to account for both the slow (months to years) and very slow (years to decades) baseflow components.

Since deep groundwater may discharge outside of the basin, a fraction of the percolation from the interflow reservoirs to the baseflow reservoirs can be diverted to Dead Zone Storage. In the Sefidrud model, the dead zone storage is assumed to be zero except in the Talvar and Shoor catchments. In these catchments, the dead zone storage is used to reduce the amount of baseflow to the streams to more closely reflect the measured flows in these catchments. See the Calibration section for more detail on this.

Not all discharge from the baseflow reservoirs is available to the river flow. Some water will discharge in any low lying areas near the rivers, where the water table is close to the ground surface. This outflow will be rapidly consumed by ET – especially in semi-arid climates such as in the Sefidrud basin. Further, in areas with shallow water tables, plant roots will extend to the water table and extract ET directly from the water table. These processes are accounted for in MIKE SHE by the UZ feedback fraction, which removes a fraction of the available discharge and makes it available to ET.

In the Sefidrud model the 15 baseflow reservoirs were defined the same as the overland flow zones, taking into account a regional catchment zone map that was available, as well as the need to calibrate the model to known discharge stations. The baseflow reservoir boundaries generally follow the reach boundaries used in the catchment definition, but consist of multiple catchments.

The baseflow reservoir parameters were defined consistently between the reservoirs. The only deviations are in the local specification of specific yield, dead zone storage and UZ feedback fraction. The dead zone storage and UZ feedback fraction were used to reduce the baseflow in two catchments (Talvar and Shoor) during the calibration. The specific yield was increased from 0.15 to 0.3 in the Zanjan and Ozundare catchments to reflect the higher availability of groundwater in these catchments.

Table 2.2.9 Summary of Baseflow Parameters

Parameter	Slow Baseflow	Very slow Baseflow
Specific yield	0.15	0.15
Time constant for baseflow	180 days	3600 days
Dead storage fraction	0	0
UZ feedback fraction	0.1	0.1
Initial depth	10	49
Threshold depth for baseflow	10	50
Threshold depth for pumping	10	50
Depth to the bottom of the reservoir	10	50

2.2.2 Calibration of Sefid-WBSM

1) Calibration to Annual Discharge

The model is calibrated focusing on the conformance of volume and wave shape between the simulation result and the observed discharge. Table 2.2.10 and Figure 2.2.11 are shown the calibration result at the major station of Ghezelozan River. The Sefid-WBSM model will only be used to supply groundwater recharge and surface runoff to MIKE BASIN; However, the only measurements available for calibration are river discharges.

Since the Sefidrud Sefid-WBSM model does not include any water consumption data (surface water or groundwater), the model calculates the natural catchment discharges. However, the measured discharges include the effect of groundwater abstractions, surface water diversions and surface water impoundments. Thus, the measured discharges are not representative of the natural discharges. The measured discharges must be adjusted to more closely reflect the natural discharges by adding the discharge values of extracted water.

In summary, the overall calibration is generally quite good with the individual catchments calibrated to within the margins of uncertainty in the estimated natural flows.

Table 2.2.10 Calibration Result

(Volume: MCM/year)

Station	Station No.	Simulation Result	Expected Discharge	Upstream Used Water	Observed Discharge	Observed Duration
Gilvan	17-033	4,759	4,414	1,147	3,267	20
Ostor	17-029	4,376	3,926	1,132	2,794	20
Pole. D.M.	17-021	2,877	2,705	956	1,749	20
Mah. N.	17-015	2,305	1,467	411	1,056	9
Ghare G.	17-011	1,680	1,282	139	1,143	19
Loshan	17-041	1,328	1,185	245	943	20

Figure 2.2.10 Major Stations of Ghezelozan River

2) Hydrograph Timing and Recession

The hydrograph recession is controlled by the time constants and the specific yield of the various reservoirs. The interflow time constant controls the short term recession of the quick peaks. However, since there are very few measured short term responses, it is difficult to calibrate the interflow time constant. A reasonable value of 14 days was used, but the affect of changing this value was not investigated in detail, as it does not affect the runoff or recharge to MIKE BASIN.

The baseflow time constant controls the long term recession after major events, such as the spring wet season. MIKE SHE includes two parallel baseflow reservoirs to simulate to more closely simulate the long and very long baseflow processes. Half of the percolation fraction was distributed to each of the parallel reservoirs.

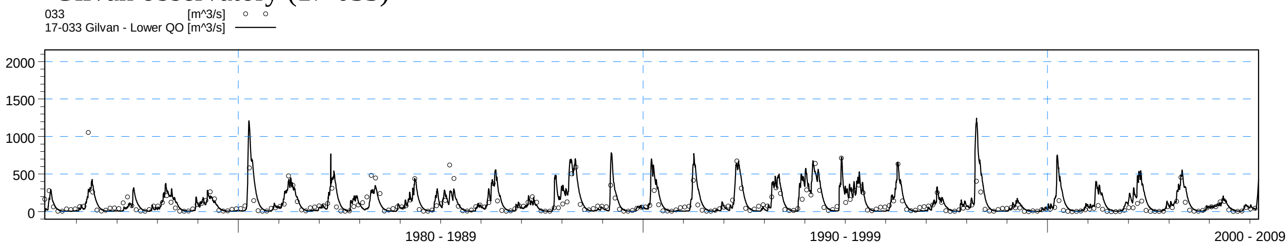
The groundwater reservoirs in the Sefidrud basin are relatively isolated and much of the baseflow discharge is probably originates from groundwater traveling in relatively thin unconsolidated deposits overlaying the bedrock – rather than deep, large-scale groundwater systems. A baseflow time constant of 180 days provides a reasonable recession shape for the medium term. The longer term recession was calibrated using a time constant of 3600 days (about 10 years).

3) Sensibility

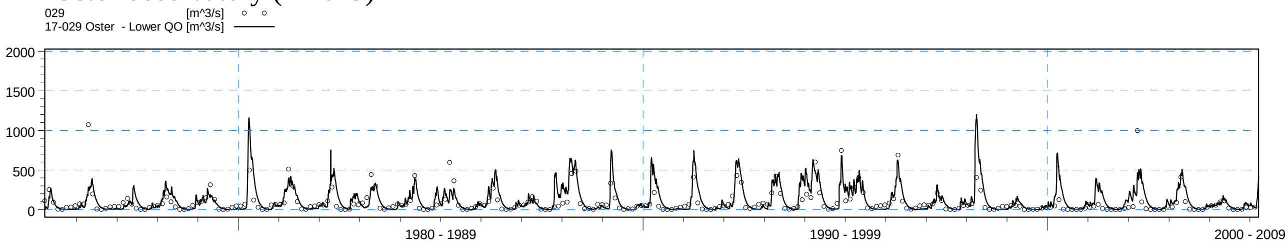
Probably the most sensitive parameter for the discharge calculation is the infiltration rate, which is currently set at 5e-6 m/s. This is a reasonable average value for medium loamy sand. A simple sensitivity analysis shows that a higher value leads to less runoff and more recharge, whereas a lower value leads to an increase in runoff at the expense of recharge. However, the relationship is not linear, because a lower value will increase ponding, which will also lead to an increase in evapotranspiration. So, the increased ponding does not lead to a similar total discharge. For example, if the infiltration rate is reduced by a factor of 10, then the total discharge is reduced by about 20%. Thus, the selected value appears to be a reasonable regional average that balances baseflow, runoff and evapotranspiration.

A more detailed investigation of the soils distribution could lead to local improvements in the runoff vs. baseflow vs evapotranspiration relationship. However, this should not be done in isolation, but must be done along with an improved vegetation distribution.

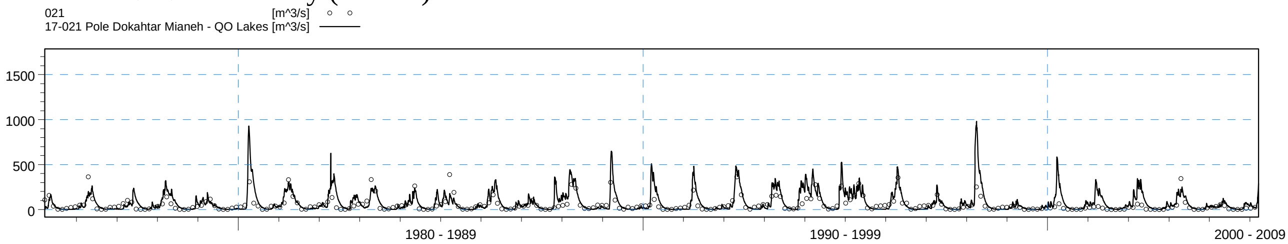
Gilvan observatory (17-033)



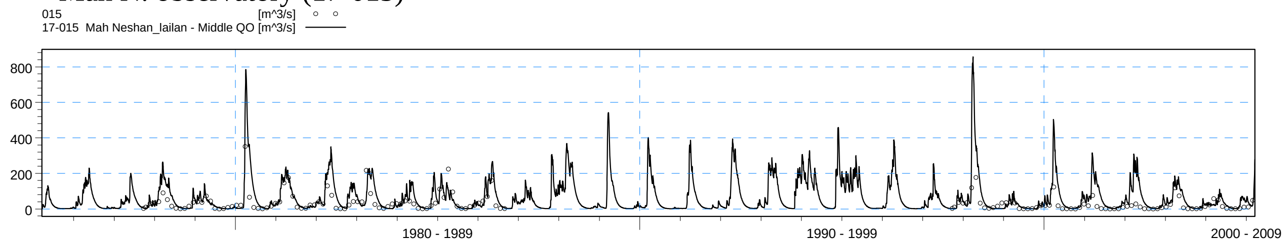
Ostor observatory (17-029)



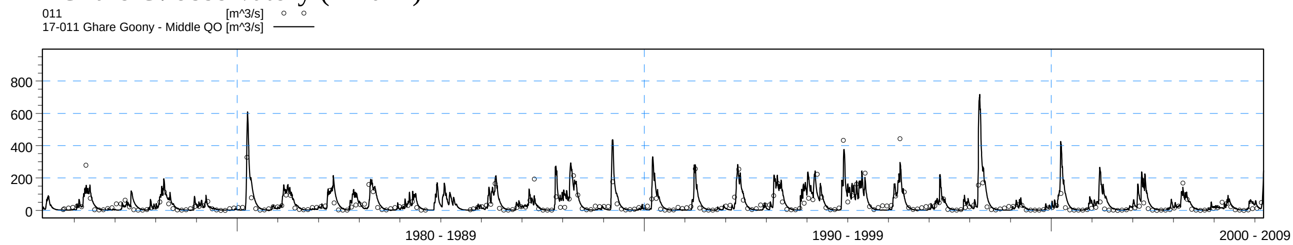
Pole D.M. observatory (17-021)



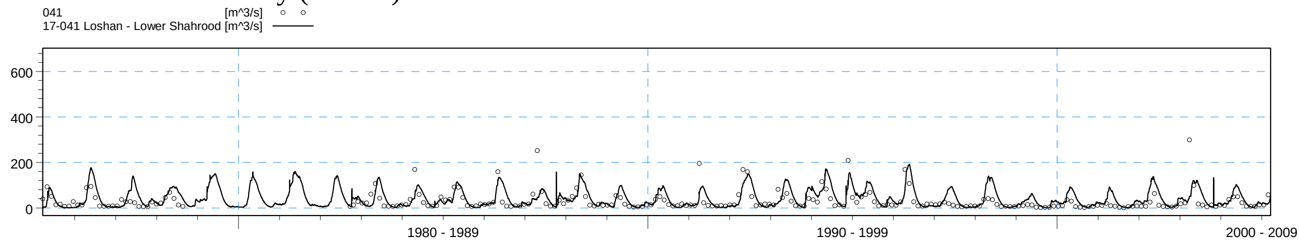
Mah N. observatory (17-015)



Ghare G. observatory (17-011)



Loshan observatory (17-041)



Source: JICA Study Team

Figure 2.2.11 Calibration Result (Wave Shape)

2.3 ESTABLISHMENT OF WATER ALLOCATION SIMULATION MODEL

2.3.1 Structure of MIKE-BASIN for Sefid-WASM

For addressing water allocation, conjunctive water use, reservoir operation, or water quality issues, MIKE BASIN couples the power of ArcGIS with comprehensive hydrologic modelling to provide BASIN-scale solutions. The MIKE BASIN philosophy is to keep modelling simple and intuitive, yet provide in-depth insight for planning and management. Being an ArcGIS extension, MIKE BASIN allows for seamless integration between model input/output and existing GIS data. Moreover, MIKE BASIN embeds DHI’s Temporal Analyst with its abundance of tools for spatial associations, analysis and presentation of time series data. MIKE BASIN operates on the basis of a digitized river network. Besides rivers, the MIKE BASIN model building blocks include:

- Water Users (inluding Irrigation Usage)
- Hydrologic Catchments, and
- Resercoirs (including Hydropower Plants).

The behavior of the individual building blocks, as well as the interactions between them, are defined using the built-in operation rules, or by creating customized macro rules. All information regarding the configuration of the model building blocks are defined by on-screen editing in ArcMap. River networks and catch¬ments can be imported from existing GIS maps, traced/delineated from a DEM, or represented schematically. The computational engine of MIKE BASIN solves the water balance and stores the stationary solution for each time step. The simulation time step can range from minutes to months. The time step of input data can be different from the simulation time step, and may even vary throughout a time series.

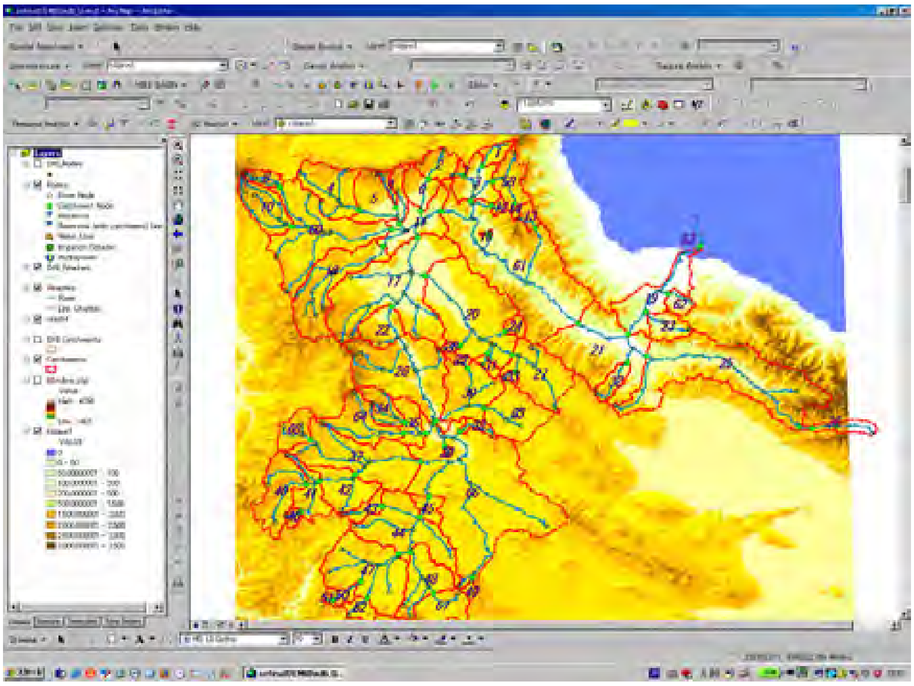


Figure 2.3.1 Display of MIKE-Basin

1) Water User Module

A Water User, including Irrigation demand users, represents any user that abstracts, consumes and returns surface and/or groundwater. Water demands are specified as time series, and water can be abstracted from river nodes, reservoirs or groundwater. Each user can have multiple sources, and a single source can provide water for multiple users. Return flow can be to any number of nodes along the river, or re-infiltrated to the groundwater.

In situations of water shortage, conflicts about the distribution of water will occur. For surface water, a strict priority ("riparian rights") or a shared priority ("fractional allocation"), or any combination thereof, can be enforced.

2) Hydrologic Catchment

A MIKE BASIN model can include any number of hydrological catchments. Optionally, groundwater processes can be included in the runoff description of a catchment. The underlying conceptual hydraulic model is the linear reservoir model with one or two aquifers (fast/slow response). Recharge to the groundwater has to be provided by the user, either as specific or absolute recharge. Groundwater interacts with the surface water via groundwater recharge, groundwater discharge and stream seepage, and can be pumped by the water users in the area, allowing for studies of conjunctive use of surface- and groundwater.

3) Reservoirs

MIKE BASIN has extensive reservoir modeling capabilities, and can accommodate everything from simple lakes to complex multi-purpose interconnected reservoir systems. All reservoir types are characterized by geometry (Level, area, volume relationship) and a spillway relation that defines the level and, optionally, the Q-h relation for the spillways. Losses and gains represented by precipitation, seepage and evaporation may also be included.

MIKE BASIN can perform advanced hydropower simulation – either for existing systems or to evaluate the feasibility of new developments. Hydropower is represented in MIKE BASIN as a node that extracts water from one or more reservoirs, produces power according to effective head difference and engine efficiencies, and returns water to one or more downstream locations. Optionally, conveyance losses, tail water level and backwater effects from cascading reservoirs can be included in the calculations.

2.3.2 MIKE Basin Calculations

The outflow from each MIKE BASIN catchment is calculated as the sum of overland flow (Qovl), outflow from shallow aquifers (Qshallow) and outflow from deep aquifers (Qdeep). In the Sefid-WASM, overland flow is calculated by MIKE SHE's (Sefid-WBSM) semi-distributed hydrological model. The overland flow is the so-called hortonian flow component, which occurs whenever the rainfall rate exceeds the infiltration capacity of the soil. The surface infiltration and evapotranspiration is calculated by Sefid-WBSM using a daily time-step and daily rainfall rates. The recharge (Qr) and the overland flow (Qovl) calculated by Sefid-WBSM is subsequently transferred to each Sefid-WASM (MIKE Basin) catchment as illustrated below.

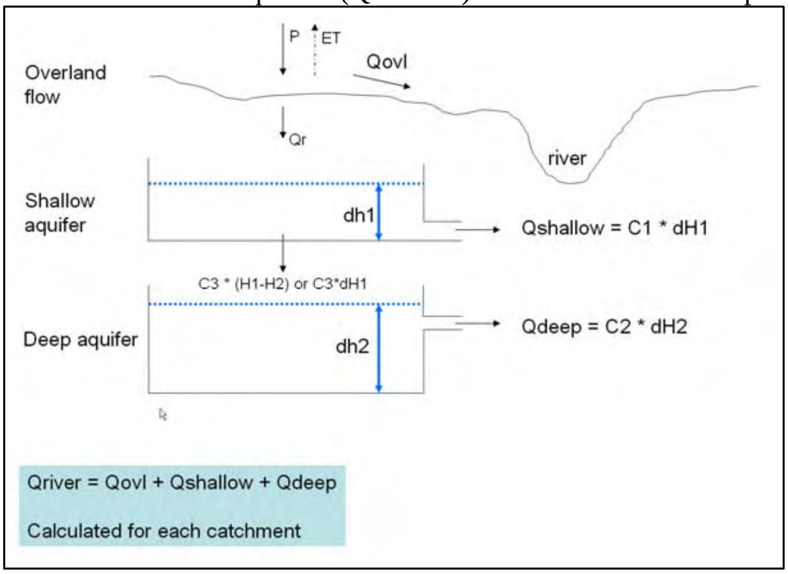


Figure 2.3.2 Display of MIKE-Basin

1) Shallow Aquifer

The shallow aquifer in MIKE BASIN is used to simulate the lateral groundwater flow and drainage of near surface aquifers. Drainage may be a combination of groundwater flow into streams and rivers or more diffuse artificial or natural drainage such as tile-drains, ditches or streams, creeks and rivers. Therefore the function and hydrological response of the near surface aquifers will vary greatly depending on landscape, geology and drainage conditions.

In nature, water that recharges the upper aquifer may either flow slowly in near-surface aquifers until it meets a drain (artificial or natural such as tile-drains, ditches, creeks and rivers). In low gradient systems with relatively low permeability – for instance some areas of the alluvial plains) the phreatic surface (upper groundwater) may be very shallow and those areas will often be artificially drained to keep the areas suitable for agriculture. In such areas the water will recharge the upper aquifer and relatively quickly water will be caught by drains and end up in surface water. The retention time in the upper aquifer under such condition will be low (e.g. 1-10 days). In other areas with higher permeabilities and higher slopes the upper groundwater will respond more as a “natural aquifer” where groundwater will flow downgradient until it meets a creek or a river. The retention times in such near surface systems may be in the order of 50-100 days or more. Thus the response of the near surface aquifer (shallow aquifer in MIKE BASIN) will strongly depend on the type of landscape and geology and in practice it encompasses a combination of what is normally called interflow and drainflow. The shallow aquifer is considered groundwater but some catchments may drain very quickly and thus, in some ways, respond almost as surface water. In mountainous catchments with permeable top-soils and impervious substrates, the shallow groundwater aquifer is used to simulate the lateral movement and drainage of the top soil. In such systems the retention time will typically also be very small (probably hours to a few days).

The most relevant MIKE BASIN result types related to the shallow aquifer are:

- Groundwater recharge (which is the recharge from MIKE SHE)
- Stream seepage (which is seepage from rivers which recharges the shallow aquifer)
- depth to shallow groundwater
- shallow discharge (which is the outflow of the river from the shallow aquifer , Qshallow)
- deep percolation (which is the amount of water the flows from the shallow to the deep aquifer).

The time-constant for the upper aquifer will rarely have a clear relation to the catchment area and shape since the shallow aquifers are typically drained by surface features (drains, ditches, creeks, streams, rivers) which tend to be distributed throughout the catchment so the distance from a certain point in the catchment to a drain will be a function of local drainage features rather than the size of the catchment. The time-constants are determined through model calibration. For ungauged catchments the best approach would be to transfer from similar catchment with calibration data or come up with reasonable estimates from other studies in similar catchments.

2) Deep Aquifer

The deep aquifer is used to simulate the slow groundwater outflows from deeper confined or unconfined aquifers. This flow is what provides inflows during the dry season (base flows). The retention time in these aquifers will depend on slopes, geology etc. The retention time in the deep aquifers will typically be in the order of months to years depending on slope and geology. As for the shallow aquifer the time-constants are calibrated by attempting to match an observed low flow during the dry season. The time-constants of the deep aquifer may have some relation to the size of the catchment (aquifers). For large aquifers (catchments) the flow path to the nearest drain may be long and for small aquifers the flow path will be short.

Table 2.3.1 Example of Time-Constants for Different Geology and Landscape Types

		Timeconstant (days)		
Geology/landscape type	category	C1 (shallow)	C3 (percolation)	C2 (deep)
Mountains - impermeable	1	5.00	500.00	1000.00
Mountains - limestone	2	5.00	2.00	200.00
Plain	3	40.00	60.00	400.00
Plain - drained	4	4.00	60.00	400.00
Low permeable	5	40.00	100.00	1000.00

Note:Based on DHI experiences from other studies

3) Deep Percolation

The deep percolation is the amount of water that flows vertically from the shallow aquifer to recharge the deep aquifer. The deep percolation is a function of the water level in the upper aquifer and the specified percolation time-constant (C3). If the water table of the deep aquifer is higher than the bottom of the shallow aquifer the head difference between the upper and the lower aquifer is used to calculate the deep percolation. In layered systems where the upper and lower aquifer are separated by a confining low permeable layer the movement from the upper to the lower aquifer will be very slow and may lead to time-constants in the order several days to years. In highly permeable areas (eg. sandy unconfined alluvial aquifers) then practically all recharge will enter the deep aquifer relatively fast and outflows from the shallow aquifer will be close to zero. For situations with only one unconfined aquifer, then you can decide to use either the upper or the lower aquifer. However, in MIKE BASIN pumping is only possible from the lower aquifer.

The approach will then be to use a small C3 so that all or almost all the recharge goes directly to the deep aquifer. The time-constant (C3) is obtained by calibration and by general knowledge about expected deep recharge in different landscape types and geological settings.

2.3.3 Coupling of MIKE SHE and Basin

The Sefidrud model includes MIKE SHE and MIKE BASIN as a linked model pair. MIKE SHE is the hydrological modeling system and creates the water balance for the MIKE BASIN water management model. The two modeling systems are linked by transferring simulated recharge and overland flow results from the hydrological model (MIKE SHE) to the management model (MIKE BASIN). To facilitate the transfer of data from MIKE SHE to MIKE BASIN, the “MIKE SHE – MIKE BASIN Data Exchange Utility Program” was developed. In the following the utility program is simply referred to as the “MSHE2MB Tool”. The transfer of overland flow and recharge from MIKE SHE to MIKE BASIN is illustrated in Figure 5.

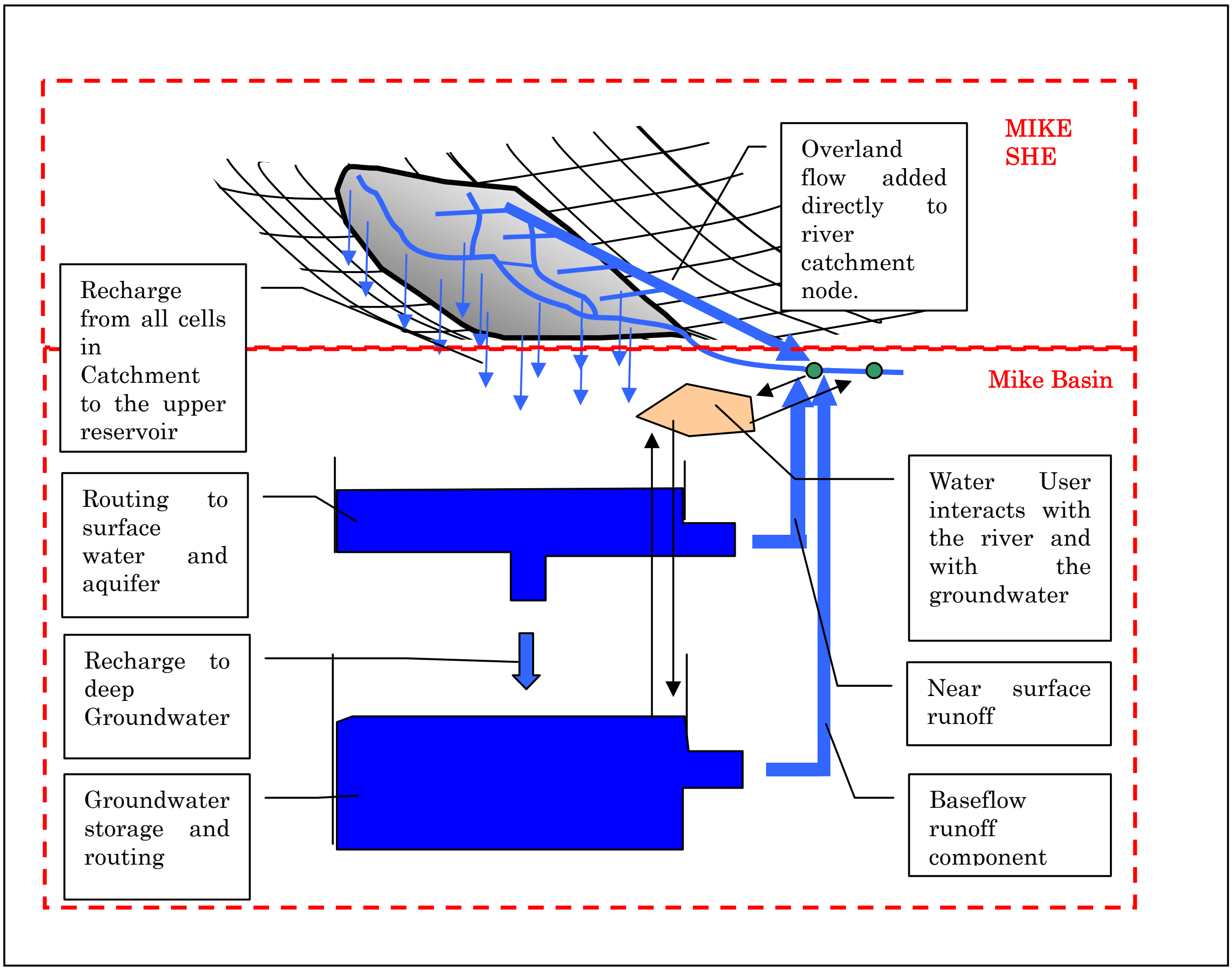


Figure 2.3.3 Data Flows between MIKE SHE and MIKE BASIN

2.3.4 Calibration of Water Allocation Simulation Model

1) Condition for Model Calibration

As a result of the consultation with the WRMC, the water allocation simulation model is calibrated on the condition as follows:

a) Duration of Simulation for Model Calibration

Duration of simulation for 20 years to calibrate the model is set from 1985 to 2005 as same period as the calibration for Sefid-WBSM. The discharge in this period is observed well compared with the period before 1985 year.

b) Minimum Unit of Simulation and Catchment

Minimum unit of the calculation is Reaches, the area and location of which are the same as Sefid-WBSM. In other words, the runoff and recharge data calculated by Sefid-WBSM are input to each Reach of Sefid-WASM. The location of Reaches and Zone is shown in Figure 2.3.4.

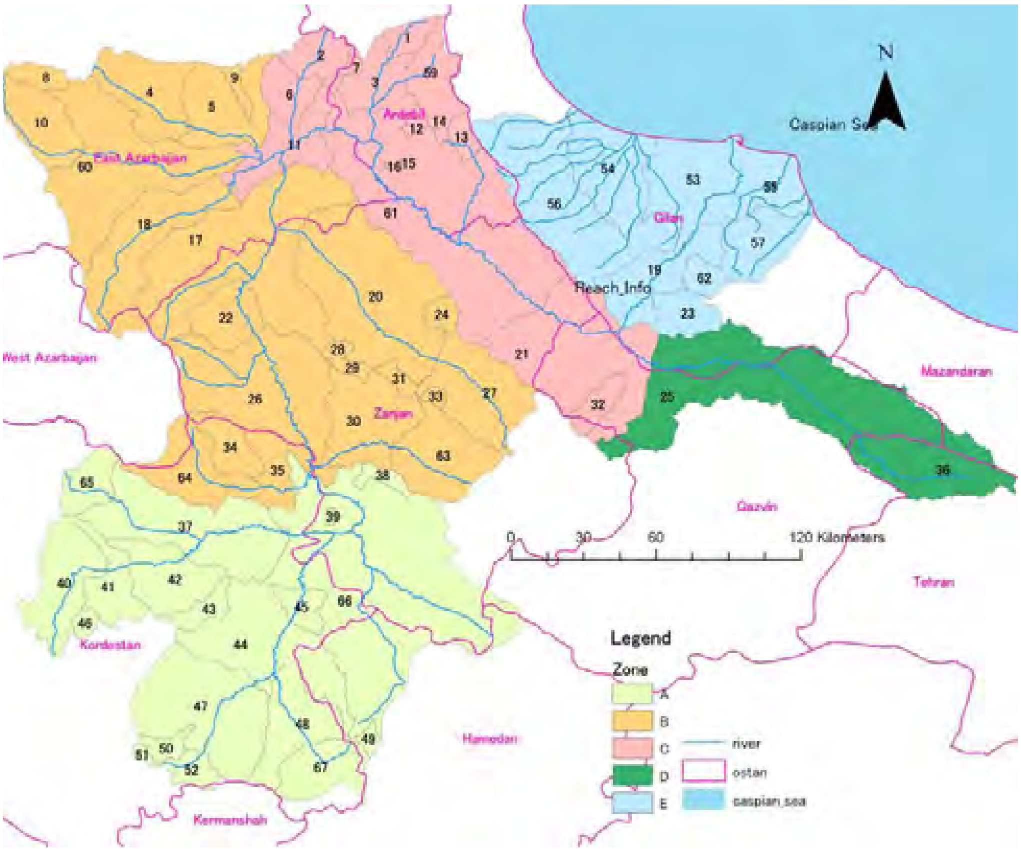


Figure 2.3.4 Reach and Zone

c) Quantity of Intake Water

Quantity of Intake water from river on the basis of Information from WRMC is entered into the model at the location of dams, weirs and Reaches. Incidentally, the quantity of intake water, which is separated into surface water and groundwater, is input as the water consumption of traditional irrigation area into water user modules. The quantity of intake water for each reach is summarized in Table 2.3.2 and Table 2.3.3.

Table 2.3.2 Quantity of Intake Water (Surface Water)

Reach	Meh. **Oct.**	Sha. **Nov.**	Mor. **Dec.**	Tir **Jan.**	Kho. **Feb.**	Ord. **Mar.**	Far. **Apr**	Esf. **May.**	Bah. **Jun.**	Dey **Jul.**	Aza. **Aug.**	Aba. **Sep.**	Total
R-01	31	22	0	0	0	0	33	63	103	94	88	66	500
R-02	841	127	0	0	0	0	308	1,131	2,597	3,112	3,047	2,118	13,281
R-03	157	161	0	0	0	0	234	429	736	674	608	379	3,378
R-04	838	115	0	0	0	0	514	1,291	2,307	2,513	2,484	1,556	11,618
R-05	3,686	496	0	0	0	0	2,820	7,540	12,078	14,501	14,281	6,642	62,044
R-06	512	469	0	0	0	0	623	1,614	2,975	3,339	3,115	1,679	14,326
R-07	9	2	0	0	0	0	5	12	26	31	30	21	136
R-08	0	0	0	0	0	0	0	0	0	0	0	0	0
R-09	655	89	0	0	0	0	645	1,373	2,141	2,174	1,869	849	9,795
R-10	1,339	294	0	0	0	0	793	1,760	3,135	3,943	3,975	2,709	17,948
R-11	2,009	925	0	0	0	0	2,446	4,804	9,527	9,139	8,544	4,939	42,333
R-12	15	4	0	0	0	0	9	20	41	48	47	34	218
R-13	110	25	0	0	0	0	69	140	278	327	320	238	1,507
R-14	12	5	0	0	0	0	9	18	32	35	34	25	170
R-15	0	0	0	0	0	0	0	0	0	0	0	0	0
R-16	0	0	0	0	0	0	0	0	0	0	0	0	0
R-17	8,978	2,243	0	0	0	0	8,360	15,597	24,593	20,480	18,735	14,156	113,142
R-18	2,099	374	0	0	0	0	1,730	3,372	4,987	4,125	3,909	2,577	23,173
R-20	31,359	4,505	0	0	0	0	27,776	38,722	73,414	58,468	46,383	32,598	313,225
R-21	5,102	2,580	0	0	0	0	3,794	7,382	15,478	16,375	15,274	10,732	76,717
R-22	3,317	1,072	0	0	0	0	3,347	6,221	8,243	6,434	5,859	4,623	39,116
R-24	950	173	0	0	0	0	728	988	1,928	1,591	1,481	1,119	8,958
R-25	17,474	1,137	0	0	0	0	16,254	27,417	62,317	61,936	50,892	34,831	272,258
R-26	4,450	1,450	0	0	0	0	3,750	10,694	14,873	17,967	17,657	11,019	81,860
R-27	6,773	1,137	0	0	0	0	6,406	7,344	16,651	15,518	11,779	7,687	73,295
R-28	462	126	0	0	0	0	275	397	1,044	1,267	1,225	921	5,717
R-29	3,465	312	0	0	0	0	1,940	4,277	7,311	6,930	6,435	5,081	35,751
R-30	6,561	591	0	0	0	0	3,624	8,355	14,178	14,063	13,633	10,298	71,303
R-31	978	189	0	0	0	0	787	1,103	2,005	1,775	1,649	1,198	9,684
R-32	2,068	1,835	0	0	0	0	2,700	4,812	7,251	5,423	4,008	3,166	31,263
R-33	957	240	0	0	0	0	612	877	2,125	2,337	2,277	1,715	11,140
R-34	68	29	0	0	0	0	49	98	146	158	153	128	829
R-35	76	29	0	0	0	0	71	137	184	162	155	120	934
R-36	0	0	0	0	0	0	0	0	0	0	0	0	0
R-37	732	304	0	0	0	178	772	1,307	1,637	1,592	1,459	905	8,886
R-38	949	236	0	0	0	0	755	1,140	2,098	2,132	2,004	1,446	10,760
R-39	0	0	0	0	0	0	0	0	0	0	0	0	0
R-40	1,155	462	0	0	0	0	1,022	1,933	2,627	2,371	2,216	1,859	13,645
R-41	509	215	0	0	0	0	444	818	1,103	1,033	976	820	5,918
R-42	4,733	2,008	0	0	0	0	3,830	7,251	10,224	10,272	9,799	8,179	56,296
R-43	262	98	0	0	0	0	196	370	501	463	458	376	2,724
R-44	337	120	0	0	0	0	256	499	690	644	638	517	3,701
R-45	17	5	0	0	0	0	16	31	40	31	30	20	190
R-46	22	8	0	0	0	0	22	38	50	40	36	32	248
R-47	88	23	0	0	0	0	78	157	201	164	158	120	989
R-48	325	75	0	0	0	0	307	609	794	574	533	399	3,616
R-49	0	0	0	0	0	0	0	0	0	0	0	0	0
R-50	1	0	0	0	0	0	1	1	2	2	2	1	10
R-51	0	0	0	0	0	0	0	0	0	0	0	0	0
R-52	0	0	0	0	0	0	0	0	0	0	0	0	0
R-59	846	247	0	0	0	0	566	1,206	2,319	2,669	2,569	1,868	12,290
R-60	1,538	319	0	0	0	0	1,101	2,262	3,653	3,839	3,800	2,559	19,071
R-61	1,088	519	0	0	0	0	1,282	2,148	4,827	5,632	5,346	3,316	24,158
R-63	6,315	531	0	0	0	0	3,709	7,874	13,724	13,452	12,510	9,309	67,424
R-64	72	28	0	0	0	0	56	110	160	156	148	124	854
R-65	550	253	0	0	0	0	421	792	1,136	1,220	1,174	997	6,543
R-66	3,539	748	0	0	0	0	3,146	4,964	8,250	6,926	6,503	4,562	38,638
R-67	15	2	0	0	0	0	16	32	39	23	20	13	160
Total	128,444	26,957	0	0	0	178	108,707	191,530	346,779	328,174	290,325	200,646	1,621,740

Table 2.3.3 Quantity of Intake Water (Ground Water)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
R-01	171	146	118	162	124	271	366	539	549	403	333	285	3,467
R-02	447	375	335	460	354	772	985	1,442	1,430	1,047	858	739	9,244
R-03	552	498	366	503	387	843	1,199	1,786	1,903	1,435	1,192	960	11,624
R-04	611	261	195	258	207	414	744	1,306	1,730	1,622	1,512	1,047	9,907
R-05	1,845	931	753	978	797	1,533	2,618	4,599	5,663	5,574	5,162	3,000	33,453
R-06	1,098	1,006	520	655	550	989	1,814	3,241	4,509	4,432	3,990	2,455	25,259
R-07	55	48	44	60	46	100	127	183	177	125	101	89	1,155
R-08	0	0	0	0	0	0	0	0	0	0	0	0	0
R-09	333	166	138	171	146	253	480	787	977	878	740	432	5,501
R-10	126	95	83	111	88	180	240	354	366	291	250	205	2,389
R-11	2,379	1,200	202	248	213	362	3,057	5,737	10,778	10,212	9,494	5,582	49,464
R-12	84	73	66	91	70	153	193	279	270	191	154	136	1,760
R-13	135	118	107	146	113	245	310	449	432	306	246	216	2,823
R-14	1	1	0	1	1	1	1	2	2	1	1	1	13
R-15	0	0	0	0	0	0	0	0	0	0	0	0	0
R-16	5	4	4	5	4	9	11	16	15	11	9	8	101
R-17	3,881	2,636	2,162	2,796	2,288	4,361	6,609	9,823	10,846	8,209	6,941	5,736	66,288
R-18	436	317	272	374	288	627	868	1,293	1,321	961	800	666	8,223
R-20	2,567	2,431	2,412	2,872	2,553	3,994	4,665	6,104	5,778	4,273	3,437	2,962	44,048
R-21	5,268	3,627	2,053	2,785	2,171	4,604	7,806	12,240	16,224	14,379	12,683	9,719	93,559
R-22	891	728	630	860	666	1,430	1,905	2,786	2,750	1,968	1,605	1,396	17,615
R-24	87	81	78	96	83	141	168	227	216	157	127	110	1,571
R-25	14,605	12,836	11,618	15,890	12,286	26,503	33,451	48,231	46,416	32,886	26,462	23,284	304,468
R-26	2,924	2,266	1,919	2,516	2,030	3,994	5,476	8,487	8,791	7,327	6,349	4,931	57,010
R-27	11,410	3,785	2,312	2,625	2,450	3,370	12,376	14,519	26,710	24,145	18,479	12,586	134,767
R-28	1	1	1	1	1	1	2	3	3	2	1	1	17
R-29	192	172	159	211	168	340	423	600	577	411	330	291	3,874
R-30	3,946	3,416	3,453	3,914	3,659	5,011	5,877	7,524	7,513	5,964	4,970	4,128	59,375
R-31	222	187	176	215	186	311	393	528	531	398	326	276	3,749
R-32	411	360	325	447	344	749	947	1,369	1,318	933	750	661	8,614
R-33	80	70	63	87	67	146	185	267	257	182	147	129	1,680
R-34	448	399	367	489	388	790	985	1,402	1,346	960	772	678	9,024
R-35	399	351	322	423	340	673	847	1,201	1,161	836	676	591	7,820
R-36	5,697	4,998	4,485	6,191	4,773	10,361	13,094	18,908	18,205	12,893	10,376	9,132	119,113
R-37	587	479	407	535	431	851	1,138	1,648	1,652	1,241	1,031	895	10,895
R-38	452	391	353	480	373	795	1,010	1,453	1,409	1,007	814	711	9,248
R-39	1	0	0	0	0	0	2	4	12	19	15	7	60
R-40	256	225	202	277	213	465	589	852	821	582	468	412	5,362
R-41	336	296	269	363	285	597	753	1,081	1,042	741	598	525	6,886
R-42	268	219	186	245	197	392	522	756	755	567	471	409	4,987
R-43	287	121	22	29	24	43	248	442	569	511	497	410	3,203
R-44	1,769	779	246	261	261	292	1,472	2,603	3,451	3,183	3,110	2,519	19,946
R-45	171	59	15	18	15	27	180	329	410	316	296	210	2,046
R-46	17	15	13	18	14	30	38	55	53	38	30	27	348
R-47	11,445	4,140	1,619	1,715	1,716	1,925	10,850	19,812	24,499	20,026	18,999	14,586	131,332
R-48	1,868	555	157	198	167	200	1,957	3,662	4,607	3,334	3,048	2,317	22,070
R-49	809	624	582	719	616	1,056	1,425	1,946	1,993	1,411	1,144	960	13,285
R-50	1,746	625	145	183	154	277	1,706	3,102	3,883	3,211	3,051	2,396	20,479
R-51	271	109	22	29	24	43	262	468	611	531	477	356	3,203
R-52	2,309	765	186	234	197	354	2,312	4,164	5,106	3,940	3,720	2,890	26,177
R-59	516	316	223	307	236	515	808	1,275	1,548	1,380	1,227	971	9,322
R-60	1,072	493	320	440	339	738	1,411	2,329	2,883	2,584	2,388	1,761	16,758
R-61	2,737	2,194	1,759	2,417	1,860	4,052	5,730	8,420	9,409	7,675	6,586	5,141	57,980
R-63	8,601	4,951	4,553	5,522	4,820	7,891	11,477	16,981	19,732	16,431	14,193	11,404	126,556
R-64	112	100	94	119	99	184	227	317	305	222	179	157	2,115
R-65	489	434	399	527	422	844	1,054	1,495	1,440	1,033	834	730	9,701
R-66	10,889	5,956	4,608	5,636	4,879	8,149	14,872	21,173	25,941	20,440	17,977	13,810	154,330
R-67	4,323	980	370	467	392	705	5,348	10,130	11,801	7,267	6,237	4,156	52,176
Total	112,637	68,409	52,488	67,380	55,575	103,957	173,613	260,729	302,696	241,102	206,663	160,192	1,805,440

d) Initial Condition of Dams

Only the Manjil dam and the Golboragh dam are set as dam modules for the initial model because these dams had been constructed in the simulation period for calibration (before 2005). The initial water level of dam lake is set the value corresponding to the 70% storage volume of the lake. In addition, the surplus water shall be released from the spill way on the condition that the inflow volume equals to the outflow, when the water level rise up over the flood control level. The initial condition and dimension of dams is described in. In addition, the evaporation data also set to calculate the amount of evaporation from the dam storage volume.

Table 2.3.4 Initial and Physical Condition of Dams

Dam	Reach	Cachement Area (km2)	Bottom Level (m)	Low Water Level (m)	Flood ontrol Level (m)	Initial Water Level (m)	Effective Storage Vollume (MCM)
Manjir	R53	56,019	191	259	272	271.7	1,150
Golbolagh	R43	250	1,793	1,808	1,814	1768	6

2) Model Calibration

When a certain quantity of the water demand on the ground water and the surface water was drawn form the underground tank and river module in the Sefid-WASM, the water balance is calculated between runoff and recharge in each Reach. Thus, in the Sefid-WASM, the parameters for tanks should be confirmed comparing the hydrograph in shape and quantity between the calculation result and the measured discharge.

The inflow into the Manjil dam is the clue to improve the model accuracy because the surface water in Sefidrud River Basin is finally aggregated at this site. At the upstream of the Manjil dam, the annual average total inflow is calculated as 4,000 mil. m^3 by Sefid-WASM on the present condition, which is highly consistent with the actual flow amount into the Manjil dam. Furthermore, the shape of simulated hydrograph at the Loshan and the Gilvan observatory are corresponding to the actual that.

At the observatory No.17-015 in the middle of Gezelozen River, the reduction of total runoff occurs due to the diverse factors such as geomorphologic features, the high quantity of demand or measurement error. Concretely, the feature of this area shows the wider flood plane with the paddy field on the either side of the river. Therefore, either the infiltration of widely and shallowly spread surface water or the highly demand on the paddy field is considered as a dominating factor of the reduction. Then, the simulation result also expresses the reduction even though not clear appearance of that.

The study team concludes that the Sefid-WASM can be applied for the water allocation simulation in Sefidrud River Basin because of the reasonable accuracy of the model as mentioned above.

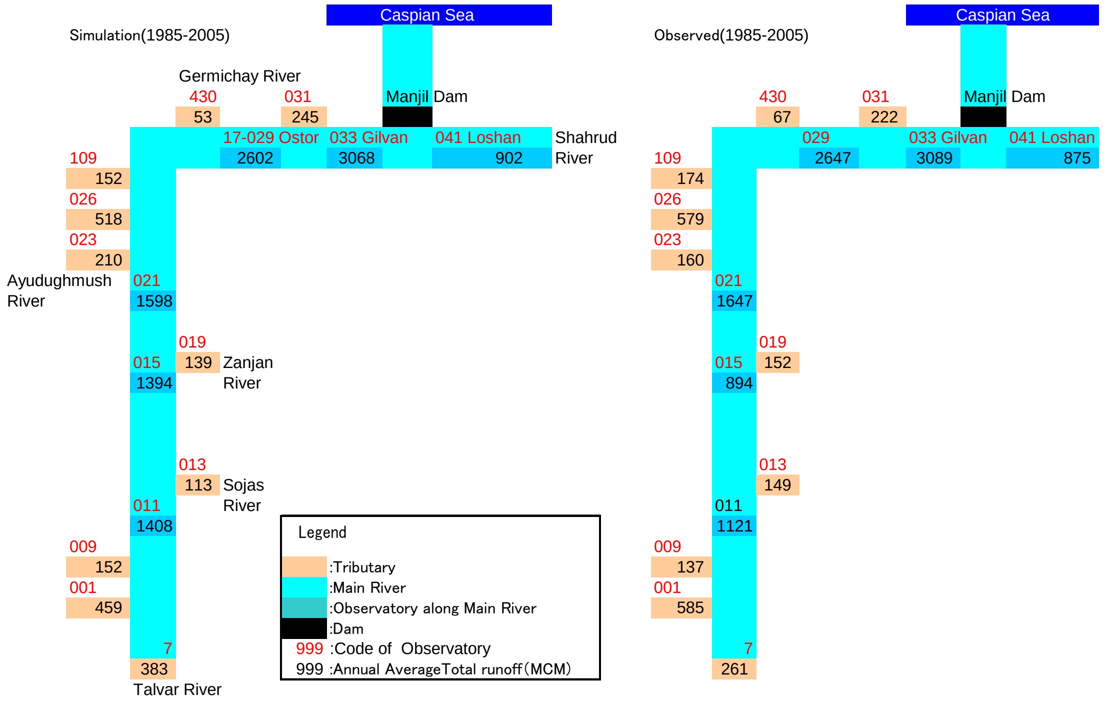


Figure 2.3.5 Comparison of Total Runoff between Simulation and Observation

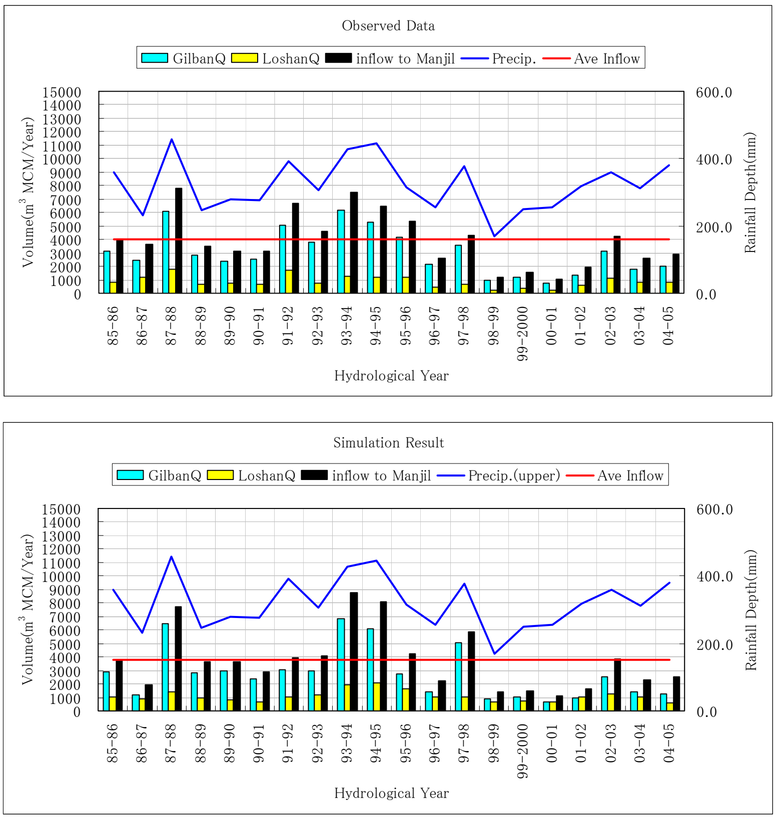


Figure 2.3.6 Comparison of Inflow Volume between Simulation and Observation at Manjil

2.3.5 Establishment of Simulation Model for Gilan SIDN

Because of the complexiaty of water usage of Gilan SIDN area, the additional survey and data collection were carried out to establish the detailed model in the area. Subsequently, SIDN was expressed on Sefid-WBSM (MIKE SHE) and WASM (MIKE Basin) to examine the water balance of the area which is located on both side of Sefidrud River. The boundary conditions and calibration result of the model for SIDN is explained in this section.

1) Added Reaches and Local Rivers

Three new Reaches are added in the model for the analysis of SIDN, namely, Reach 54, 56, and 57 at downstream of Manjil Dam, changing the shape of Reach 53 and 19. The boundary of these Reaches is shown in Figure 2.3.7. Concurrently, the thirteen local rivers of SIDN, which are expected to affect the water balance, are embedded as the river modules to grasp the amount of surface flow. The name and location of river streams are also presented in Figure 2.3.7.

Figure 2.3.7 Reaches and Rivers for SIDN

2) Data Collection

The information regarding to hydrology, geology, geography and land use data are especially essential to run the simulation model. Among of these information and data, the rainfall data, flow discharge data and landuse information are collected this time while the geology, DEM and a part of hydrological data (Evaporation depth and Air temperature data) had already collected in the last phase. The contents of additional information are described in the items below.

a) Rainfall Data

There are 40 rainfall observation stations under the jurisdiction of WRMC around SIDN. Among these stations, the 15 key stations were selected to input the data into the simulation model based on the condition that the long-term rainfall observation is carried out and number of missing data is small during the simulation period (1975 to 2005). The location and the code of rainfall observation stations are presented in Figure 2.3.8.

In addition, the influence zone of the selected rainfall stations are determined by using the Thiessen Polygon method to dispose the input data into each grid (2km by 2km) of the Sefid-WBSM model (distribution type physical model). On the basis of collected 30 years rainfall time series data, the annual average rainfall depth in SIDN was estimated to about 1,050 mm by this model.

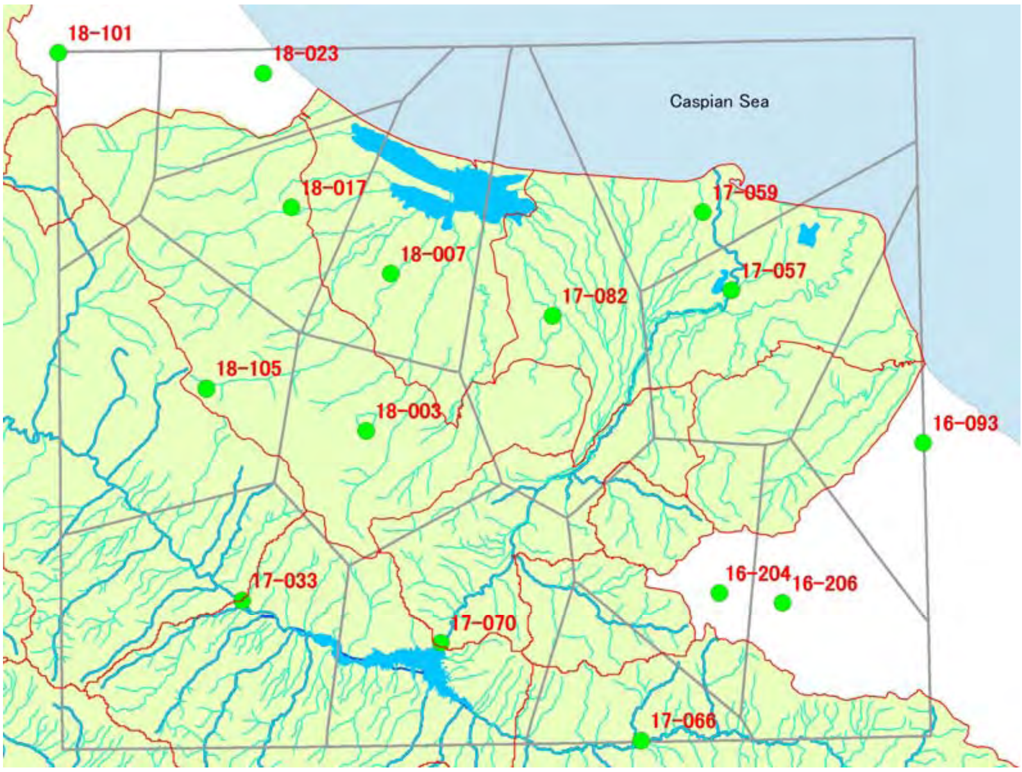


Figure 2.3.8 Selected Rainfall Observation Station and Thiessen Polygon

b) Flow Discharge

The flow discharge of local thirteen rivers was observed at the stations listed in Table 2.3.5, which are used for the calibration of the simulation model comparing with the calculated discharge by the model.

Table 2.3.5 Discharge Observation Station

Area	Code	River	Station Name	Catchment Area (km^2)
Left Side of Sefidrud River	18-083	Shakhraz	Laskar	429.3
	18-081	Pasikhan	Nokhaleh	751.2
	18-021	Shafarood	Ponel	344.3
	18-019	Chafroud	Rudbarsara	131.7
	18-095	Bahmber	Aghamahaleh	150.6
	18-067	Morghak	Imamzadeh Shafi	235.7
	18-065	Khalkai	Toskooh	215.9
	18-089	Palangvar	Kalsar	227.0
	18-063	Masulehroudkhan	Kamadol	223.7
	17-053	Siahroud	Behdan	147.2
Right Side of Sefidrud River	17-055	Nisam/Disam	Pashaky	143.3
	16-063	Shamrud	Golnaran	162.5
	16-099	Langarrudkhan	Anzalimahale	254.0

Based on the observed discharge data, the annual total runoff amount of the SIDN Area located on the left and right side of Sefidrud River are estimated 1,850 MCM and 520 MCM respectively as illustrated in Figure 2.3.9.

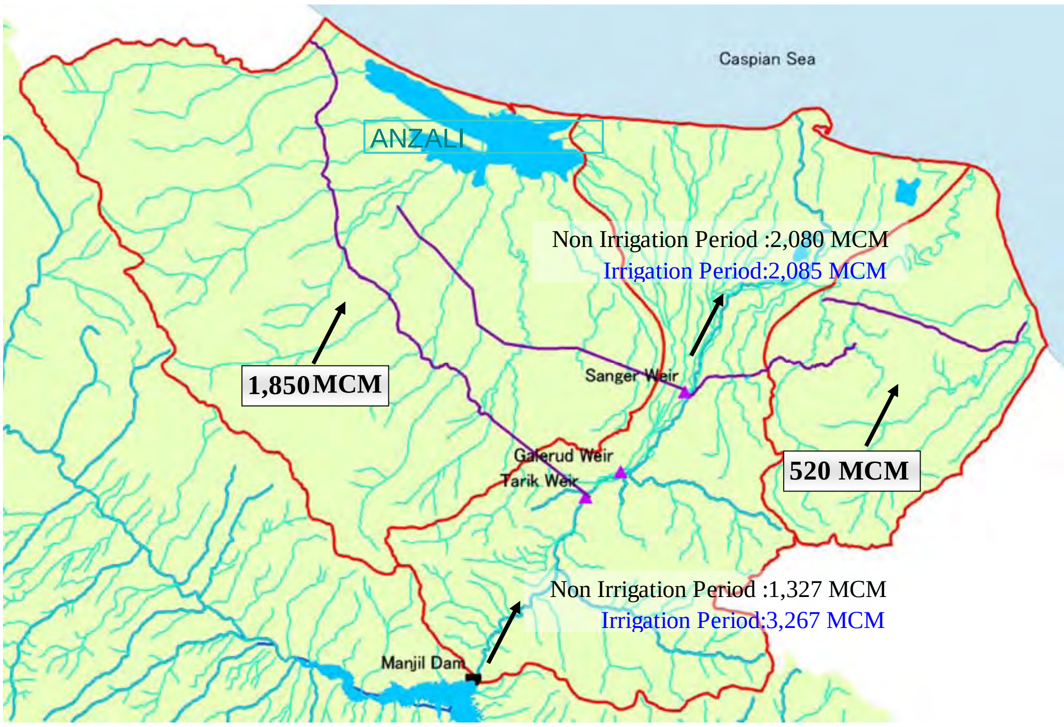


Figure 2.3.9 Annual Runoff Volume of SIDN

c) Land Use Information

Through WRMC, MOJA provided the Study Team with the land use map of SIDN on GIS database that is the same accuracy as the information of upper basin. The extended area for the analysis of SIDN is delineated by the red colored line in Figure 2.3.10.

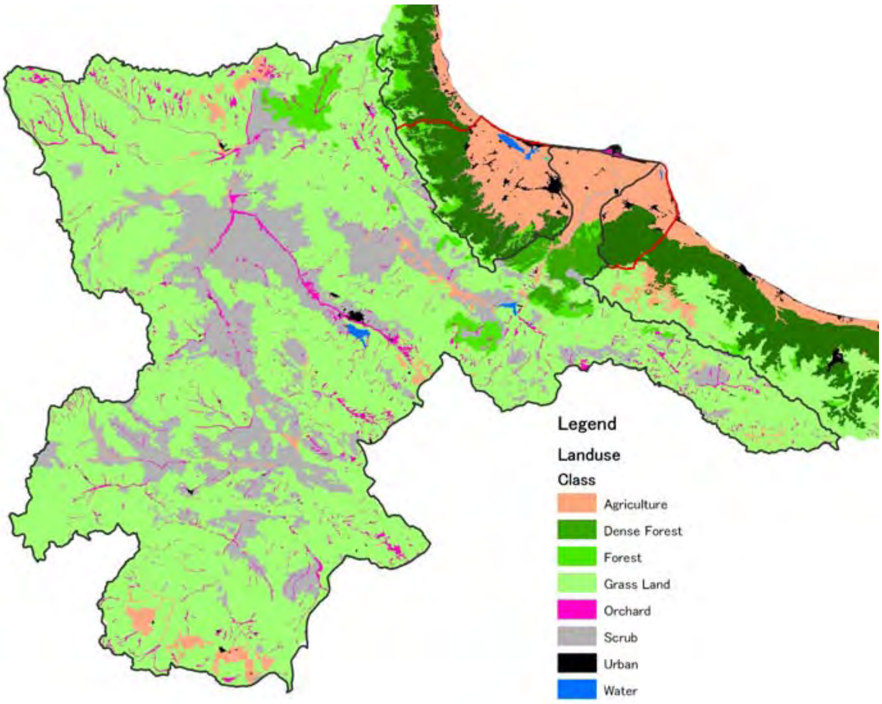
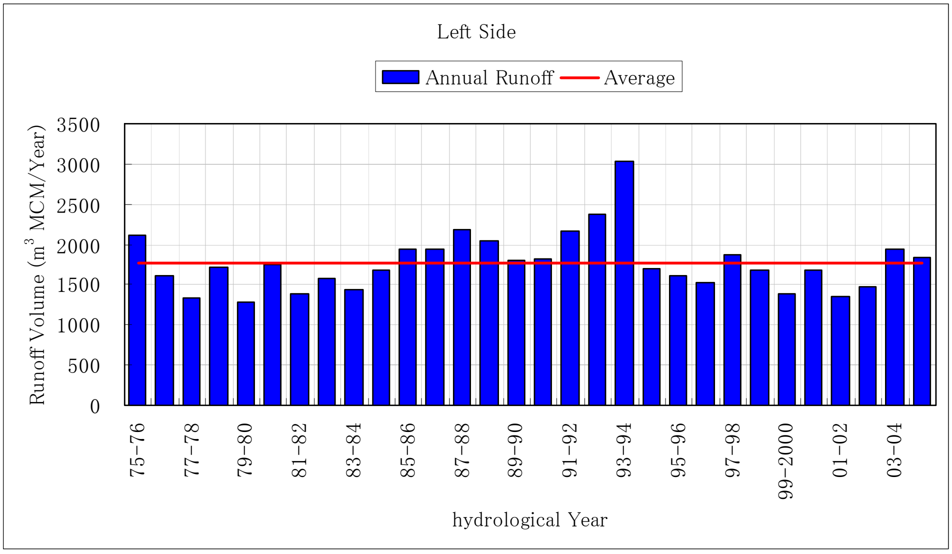


Figure 2.3.10 Land Use Map of SIDN

3) Model Calibration

Based on the conditions described in foregoing section, the time series data of runoff and recharge calculated by Sefid-WBSM(MIKE SHE) was input to Sefid-WASM (MIKE BASIN) by which the annual average total runoff of SIDN are estimated matching up to the observed that as shown in Figure 2.3.11. Although the observed flow discharge time series data is such patchy information that the observed secular change can not compare with the simulation result, the model of SIN area also keep the equivalent accuracy with the upper basin model because of the high distribution density of rainfall station and small number of missing data compared with the condition of the upper basin.



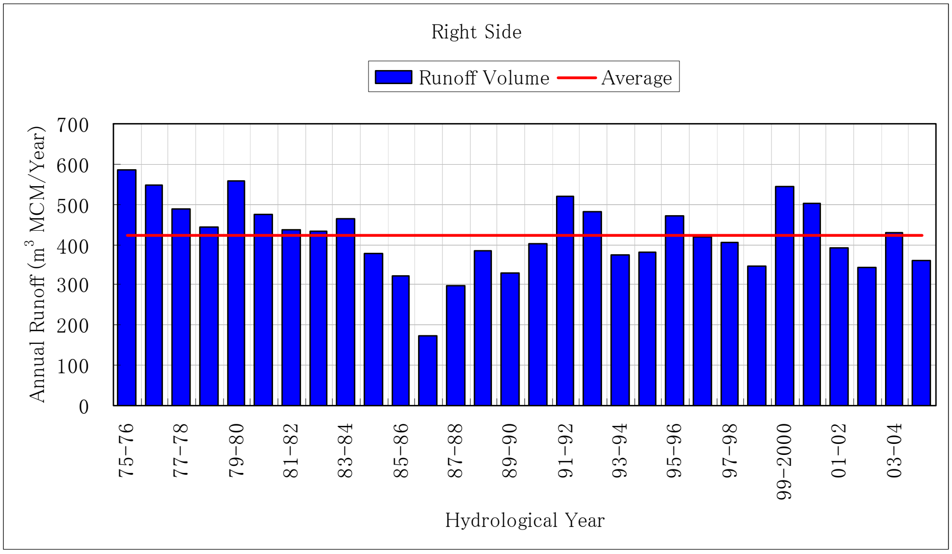


Figure 2.3.11 Calibration Result

In addition, the simulation result of right side of SIDN is rather smaller than the observed annual average total runoff, which is caused by the complex boundary condition of a hydrological aspect between Gilan alluvial fan and Caspian Sea. To improve of the accuracy of model, the runoff characteristic of surface and ground water condition should be grasped for the arranging the model parameters based on the long term observation at the top and edge of the alluvial fan.

2.3.6 Simulation Case

The water alocation simulation is carried out in accordance with the condition of simulation cases which are explaned in Table below. Incidentially, Case 5 is carried out for the additional study in case of using the water demand based on the result of sutellite image analysis, and Case 4 is carried out for confirming the effect by Aldebil Interbasin Transfer.

Table 2.3.6 Condition of Simulation Cases

Target year	Case No.	Dams into Model	Irrigation Efficiency	Water Demand	Interbasin Transfer
Natural Condition	0	Nothing	Nothing	Nothing	Nothing
Present (2006)	1	3 dams (Manjil, Taleghan, Golblakh)	Present Condition TAA=0.33 SIDN=0.42	Present Conditiom	-Teheran and Qazvin from Taleghan Dam
Mid-Term (2016)	2-1	1.Manjil, 2.Taleghan, 3.Golblakh, 4.Taham, 5.Talvar, 6.Siazakh, 7.Sural, 8.Ostor, 9.Sahand, 10.Kalghan, 11.Aydughmush, 12.Garmichay, 13.Golabar, 14.Sange siah, 15. Givi, 16. Shahreh bijar	Present Condition TAA=0.33 SIDN=0.42	Present ondition	-Teheran and Qazvin from Taleghan Dam
	2-2	16 dams	Intermidiate TAA=0.37 SIDN=0.45	Mid-Term Condition	-Teheran and Qazvin from Taleghan Dan
	2-3	16 dams	WRMC Proposed TAA=0.40 SIDN=0.48	Long-Term Condition	-Teheran and Qazvin from Taleghan Dam
Long-Term (2031)	3-1	16 dams in middle-term 21 dams under planning	Present Condition TAA=0.33 SIDN=0.42	Present ondition	-Teheran and Quazvin from Taleghan Dam -Qazvin Transfer with Almout Project
	3-2	16 dams in middle-term 21 dams under planning	Intermidiate TAA=0.37 SIDN=0.45	Mid-Term Condition	-Teheran and Quazvin from Taleghan -Qazvin Transfer with Almout Project
	3-3	16 dams in middle-term 21 dams under planning	WRMC Proposed TAA=0.40 SIDN=0.48	Long-Term Condition	-Teheran and Quazvin from Taleghan -Qazvin Transfer with Almout Project
Long-Term (2031)	4-1	-16 dams in middle-term -21 dams under planning -3 Hydropower Dam	Intermidiate TAA=0.37 SIDN=0.45	Long-Term Condition	-Teheran and Quazvin from Taleghan -Qazvin Transfer with Almout Project
	4-2	-16 dams in middle-term -21 dams under planning - Hydropower Dam	Intermidiate TAA=0.37 SIDN=0.45	Long-Term Condition	-Teheran and Quazvin from Taleghan -Qazvin Transfer with Almout Project -Aldebil Interbasin Transfer
Present (2006)	5	3 dams (Manjil, Taleghan, Golblakh)	Present Condition TAA=0.33 SIDN=0.42	Present Condition (by Satellite Image Analysis)	-Teheran and Qazvin from Taleghan Dam

Note1:TAA=Traditional Agricultural Area, SIDN=Sefidrud Irrigation Drainage Area in Gilan

2.3.7 Simulation Result for Master Plan

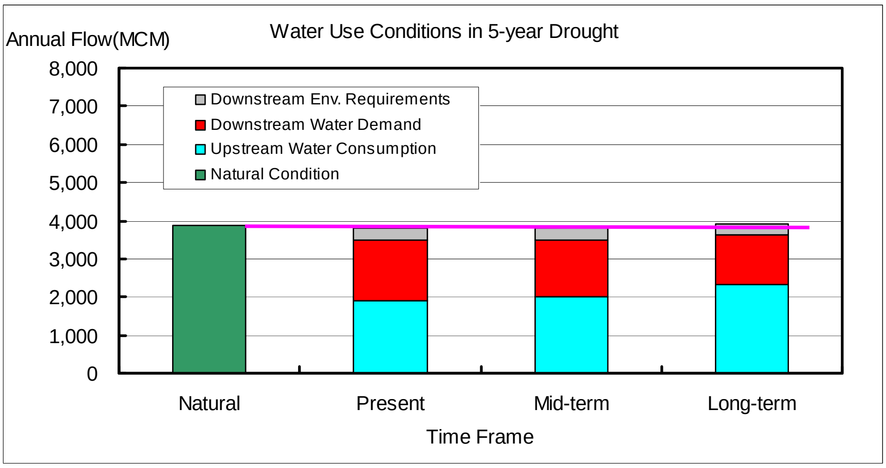
The result of execution of simulation cases above mentioned is organised coresponding to scenarios as shown in Table 2.3.6. In this subsection, the simulation result is explained in acordance with the senarios.

Table 2.3.7 Condition of Simulation Cases

Scenario	Contents
1	Irrigation efficiency in the traditional irrigation areas and SIDN areas will not be improved, and water resources development plan proposed by the provinces will be implemented.
2	Irrigation efficiency in the traditional irrigation areas and SIDN areas will be improved as WRMC proposed, and water resources development plan proposed by the provinces will be implemented.
3	Irrigation efficiency in the traditional irrigation areas and SIDN areas will be improved in an intermediate manner between scenarios 1 and 3, and water resources development plan proposed by the provinces will be implemented.

1) Water Resource Potential and Water Consumption

Natural water resources potential of the Manjil inflow without any water uses and related facilities could be computed at 3,892 MCM in 5-year drought and at 6,865 MCM in an average year, while water demands in the areas upstream of the Manjil could be simply summed up at 4,712 MCM in 2006, at 5,097 MCM in 2016 and at 5,354 MCM in 2031. Even at present the total water demands exceed the water resources potential in 5-year drought.



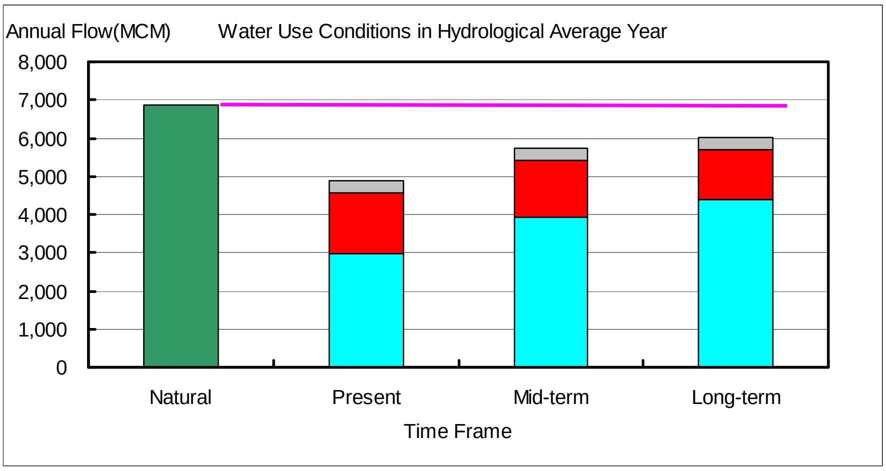


Figure 2.3.12 Water Resources Potential and Water Consumption/Demand up- and down-stream of the Manjil Reservoir

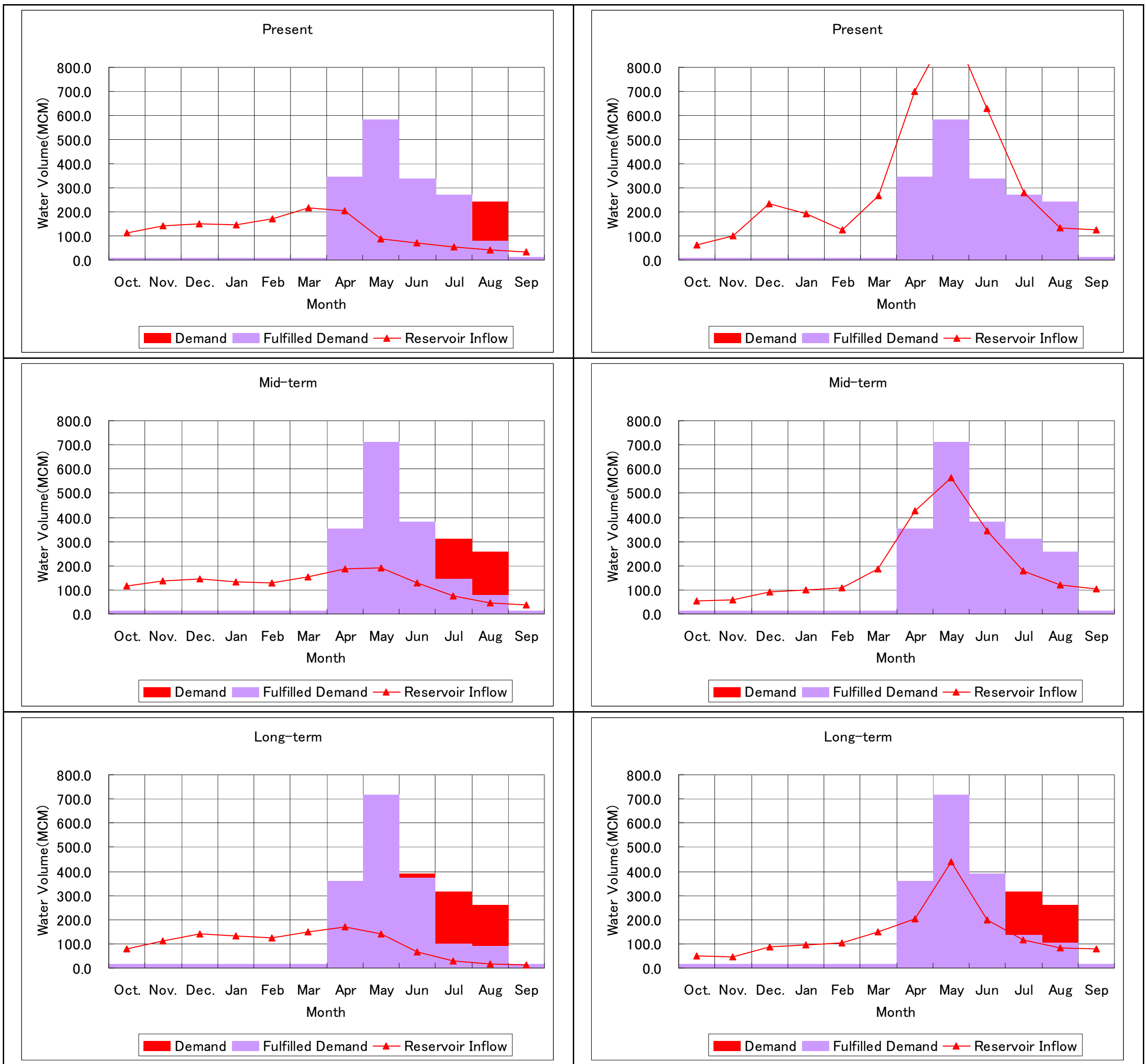
2) Scenario 1

a) SIDN

The first step is to clarify: if planning dams proposed by the provinces are operated to supply water to their command areas as planned without improvement in the traditional irrigation areas, how the water release of the Manjil will be affected by the upstream developments. Table 2.3.8 and Figure 2.3.13 shows the simulation results.

Table 2.3.8 Sufficiency Rate to the downstream Demand of the Manjil

Time Frame	5-year Drought	Average Year
Present	90.9 %	100 %
Mid-term	83.0 %	100 %
Long-term	80.3 %	83.3 %



5-year Drought (1998/99)	Average Year (1991/92)

Figure 2.3.13 Evaluation of Development Scenario without Improvement of Irrigation Efficiency

b) Traditional Agricultural Area upstream of the Manjil Dam

Table 2.3.9 and Figure 2.3.14 present sufficiency rates for the traditional irrigation areas located in the upstream areas of the Manjil dam.

Table 2.3.9 Sufficiency Rate for the Traditional Irrigation Areas upstream of the Manjil

Zone	Sub-zone	5-year Drought			Average Year		
		Present	Mid-term	Long-term	Present	Mid-term	Long-term
A	A-1	57.1	72.4	72.4	74.4	79.3	79.3
	A-2	31.7	76.6	85.3	92.6	93.9	94.2
	A-3	80.7	80.7	80.7	92.2	92.2	92.2
	Sub-total	57.8	76.4	79.0	85.8	88.0	88.0
B	B-1	91.9	91.9	91.9	100.0	100.0	100.0
	B-2	28.4	60.6	64.2	80.9	94.5	94.6
	B-3	37.0	35.1	37.1	67.9	66.5	66.2
	B-4	59.2	47.3	64.8	99.0	100.0	99.2
	B-5	73.7	89.6	95.5	100.0	100.0	100.0
	B-6	73.0	87.5	87.1	100.0	100.0	100.0
	B-7	47.1	47.1	47.1	61.5	61.5	61.5
	Sub-total	56.1	59.1	65.3	87.5	89.0	88.7
C	C-1	52.6	74.7	77.4	93.7	90.9	91.1
	C-2	49.4	59.8	60.5	97.3	97.3	97.7
	C-3	56.5	75.5	74.6	94.1	94.1	94.1
	C-4	69.9	90.3	75.2	100.0	100.0	79.8
	Sub-total	58.0	76.4	72.9	96.0	95.6	90.7
D	D-1	100.0	100.0	100.0	100.0	100.0	100.0
	D-2	100.0	100.0	100.0	100.0	100.0	100.0
	Sub-total	100.0	100.0	100.0	100.0	100.0	100.0
Average		60.8	71.5	74.1	89.7	90.9	89.9

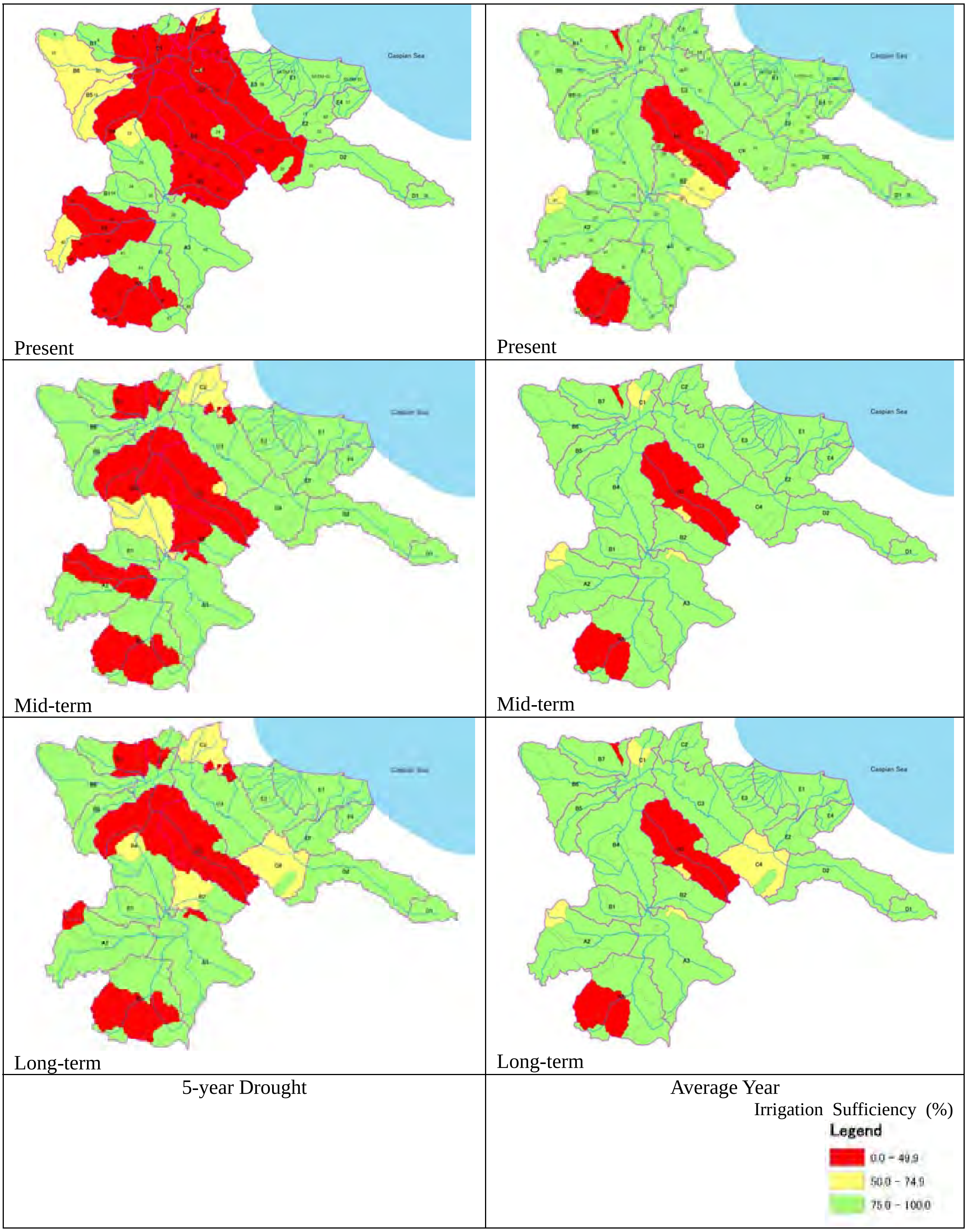


Figure 2.3.14 Future Changes of Water Demand Sufficiency in the Traditional Irrigation Area (without improvement of irrigation efficiency)

3) Scenario 2

a) SIDN

Scenario 2 follows the improvement of irrigation efficiency proposed by the WRMC. The simulation results are presented in Table 2.3.10 and Figure 2.3.15.

Table 2.3.10 Sufficiency Rate to the downstream Demand of the Manjil

Time Frame	5-year Drought	Average Year
Present	90.9 %	100 %
Mid-term	95.6 %	100 %
Long-term	99.4 %	100 %

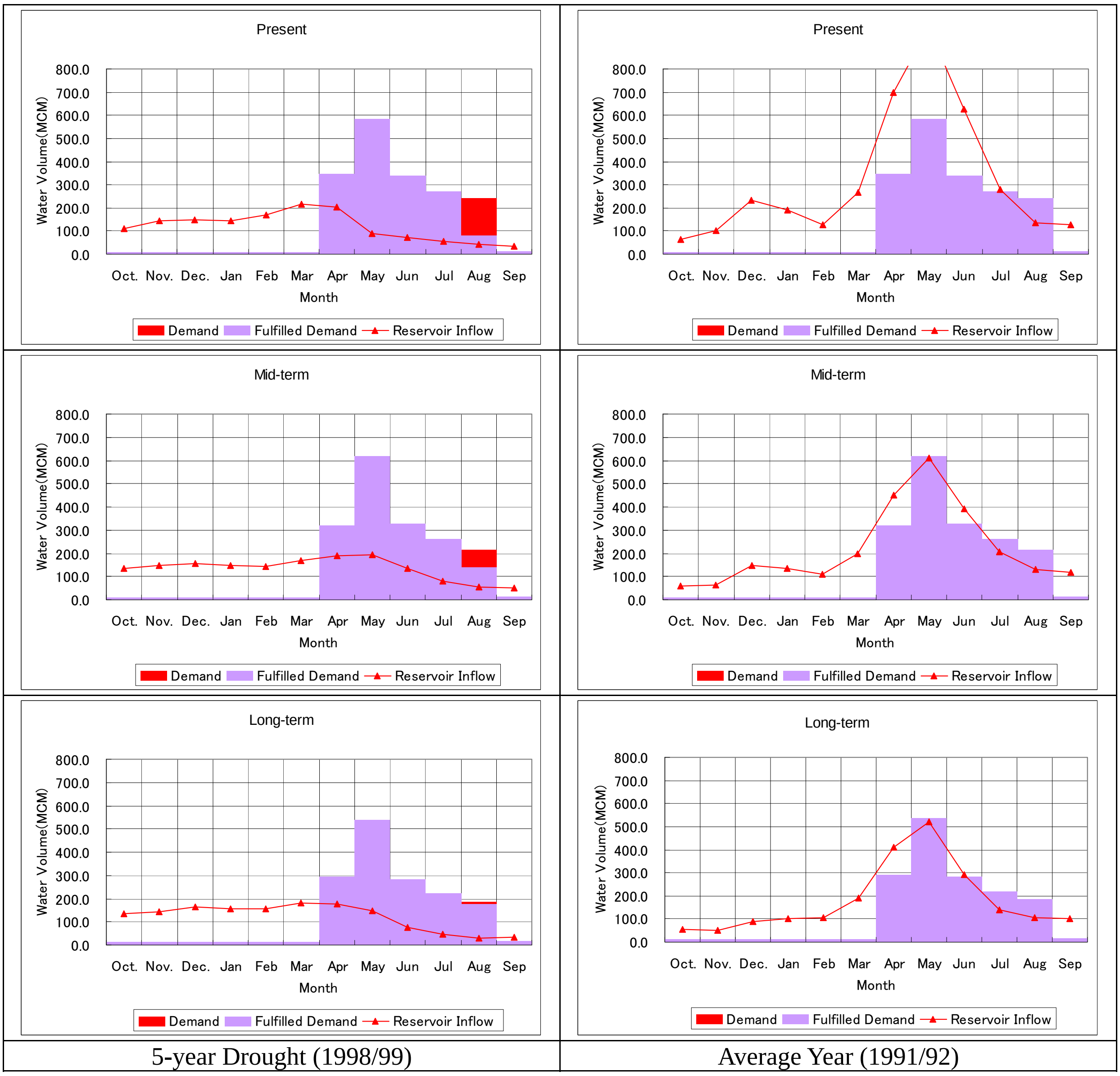


Figure 2.3.15 Evaluation of Development Scenario with Improvement of Irrigation Efficiency Proposed by WRMC

b) Traditional Agricultural Area

Table 2.3.11 and Figure 2.3.16 present sufficiency rates for the traditional irrigation areas located in the upstream areas of the Manjil dam.

Table 2.3.11 Sufficiency Rate for the Traditional Irrigation Areas upstream of the Manjil

Zone	Sub-zone	5-year Drought			Average Year		
		Present	Mid-term	Long-term	Present	Mid-term	Long-term
A	A-1	57.1	78.3	78.9	74.4	81.6	84.4
	A-2	31.7	77.6	85.9	92.6	94.5	95.5
	A-3	80.7	81.4	82.2	92.2	94.2	94.5
	Sub-total	57.8	79.2	82.1	85.8	89.7	91.1
B	B-1	91.9	95.7	99.2	100.0	100.0	100.0
	B-2	28.4	72.5	84.0	80.9	99.1	100.0
	B-3	37.0	50.5	58.6	67.9	91.4	95.2
	B-4	59.2	62.7	89.7	99.0	100.0	100.0
	B-5	73.7	97.2	100.0	100.0	100.0	100.0
	B-6	73.0	96.3	98.8	100.0	100.0	100.0
	B-7	47.1	52.1	57.9	61.5	67.1	73.0
	Sub-total	56.1	70.6	82.7	87.5	95.0	96.5
C	C-1	52.6	97.1	100.0	93.7	100.0	100.0
	C-2	49.4	70.6	77.4	97.3	99.4	100.0
	C-3	56.5	78.1	82.1	94.1	94.8	95.6
	C-4	69.9	100.0	100.0	100.0	100.0	100.0
	Sub-total	58.0	85.2	88.5	96.0	97.6	98.1
D	D-1	100.0	100.0	100.0	100.0	100.0	100.0
	D-2	100.0	100.0	100.0	100.0	100.0	100.0
	Sub-total	100.0	100.0	100.0	100.0	100.0	100.0
Average		60.8	78.7	85.2	89.7	94.3	95.4

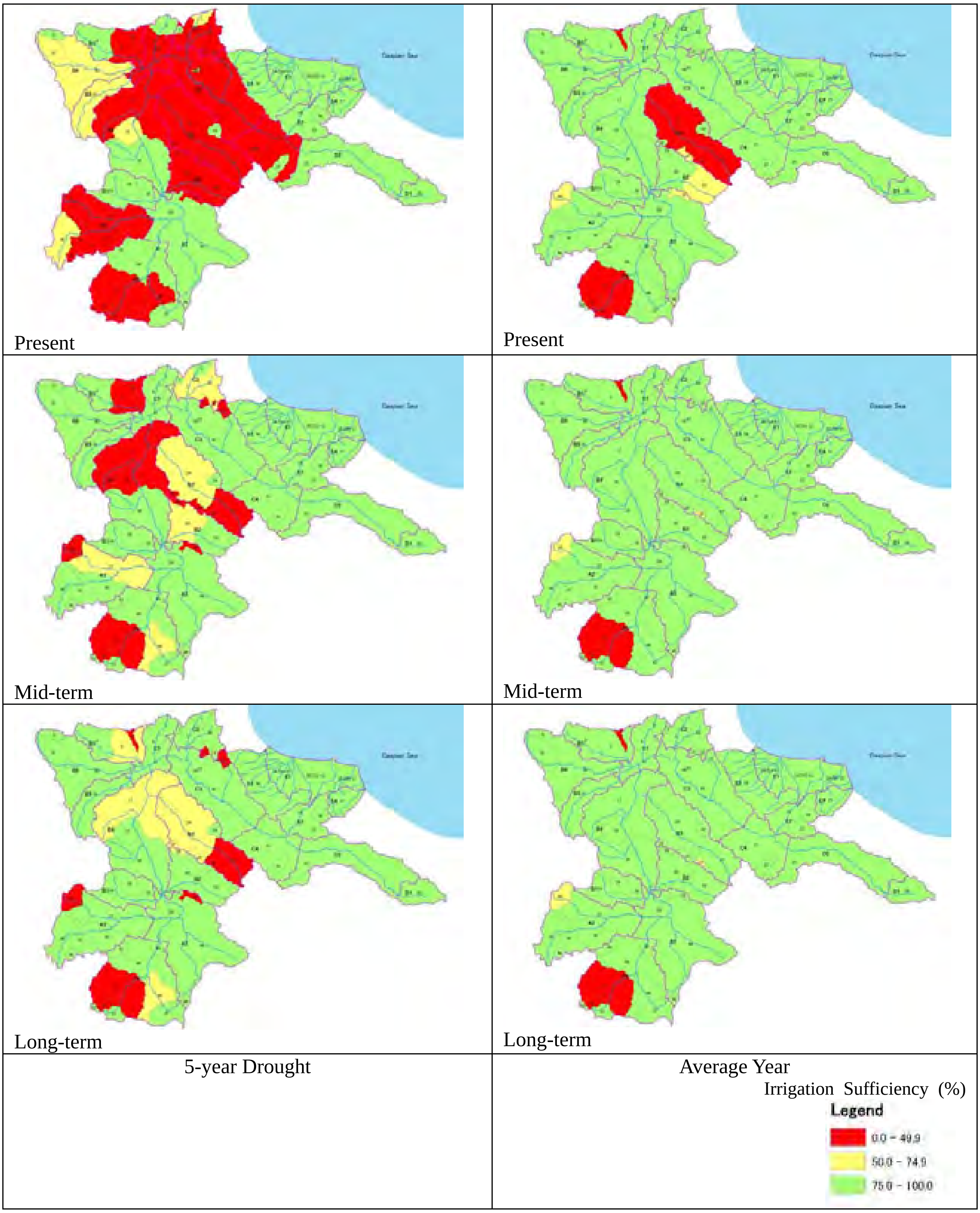


Figure 2.3.16 Future Changes of Water Demand Sufficiency in the Traditional Irrigation Area (with improvement of irrigation efficiency proposed by WRMC)

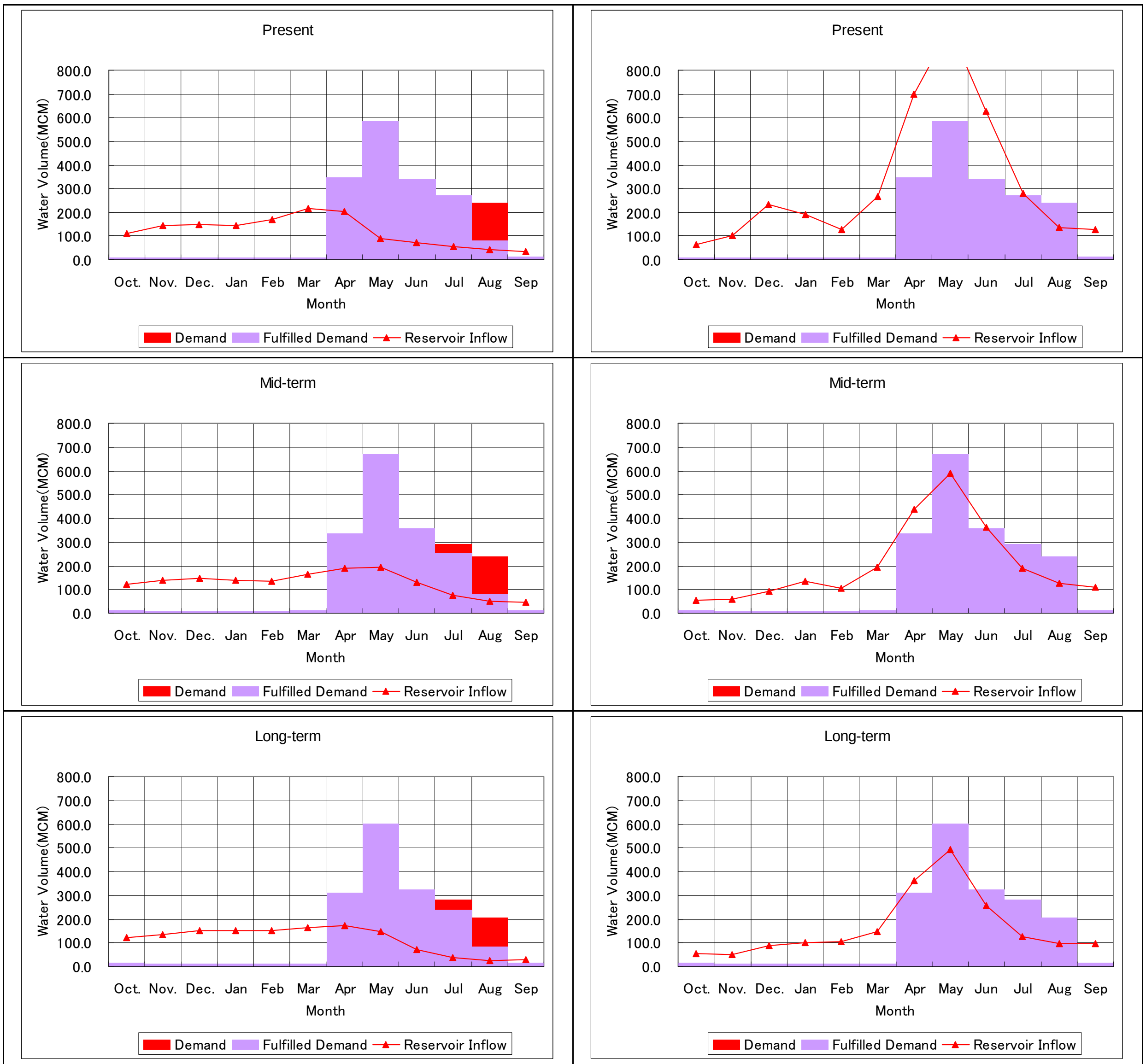
4) Scenario 3

a) SIDN

Scenario 3 follows the intermediate level between present and WRMC proposition on improvement of irrigation efficiency. The simulation results are presented in Table 2.3.12 and Figure 2.3.17.

Table 2.3.12 Sufficiency Rate to the downstream Demand of the Manjil

Time Frame	5-year Drought	Average Year
Present	90.9 %	100 %
Mid-term	89.4 %	100 %
Long-term	90.5 %	100 %



5-year Drought (1998/99)	Average Year (1991/92)

Figure 2.3.17 Evaluation of Development Scenario with Intermediate Improvement of Irrigation Efficiency

b) Traditional Agricultural Area

Table 2.3.13 and Figure 2.3.18 present sufficiency rates for the traditional irrigation areas located in the upstream areas of the Manjil dam.

Table 2.3.13 Sufficiency Rate in Scenario 3 for the Traditional Irrigation Areas upstream of the Manjil

Zone	Sub-zone	5-year Drought			Average Year		
		Present	Mid-term	Long-term	Present	Mid-term	Long-term
A	A-1	57.1	72.1	73.1	74.4	79.1	81.6
	A-2	31.7	75.2	85.5	92.6	93.6	95.0
	A-3	80.7	81.0	81.6	92.2	93.0	94.2
	Sub-total	57.8	76.0	79.6	85.8	88.0	89.8
B	B-1	91.9	94.1	97.3	100.0	100.0	100.0
	B-2	28.4	64.7	75.0	80.9	97.1	97.2
	B-3	37.0	38.7	43.5	67.9	71.0	74.9
	B-4	59.2	52.9	72.9	99.0	100.0	100.0
	B-5	73.7	96.5	100.0	100.0	100.0	100.0
	B-6	73.0	92.7	97.2	100.0	100.0	100.0
	B-7	47.1	50.0	54.3	61.5	64.4	69.8
	Sub-total	56.1	63.6	73.1	87.5	90.4	91.8
C	C-1	52.6	75.4	88.8	93.7	91.4	97.7
	C-2	49.4	61.9	69.8	97.3	97.4	99.6
	C-3	56.5	75.0	81.2	94.1	94.1	94.9
	C-4	69.9	79.8	79.8	100.0	100.0	100.0
	Sub-total	58.0	74.0	80.1	96.0	95.7	97.4
D	D-1	100.0	100.0	100.0	100.0	100.0	100.0
	D-2	100.0	100.0	100.0	100.0	100.0	100.0
	Sub-total	100.0	100.0	100.0	100.0	100.0	100.0
Average		60.8	72.7	78.9	89.7	91.6	93.0

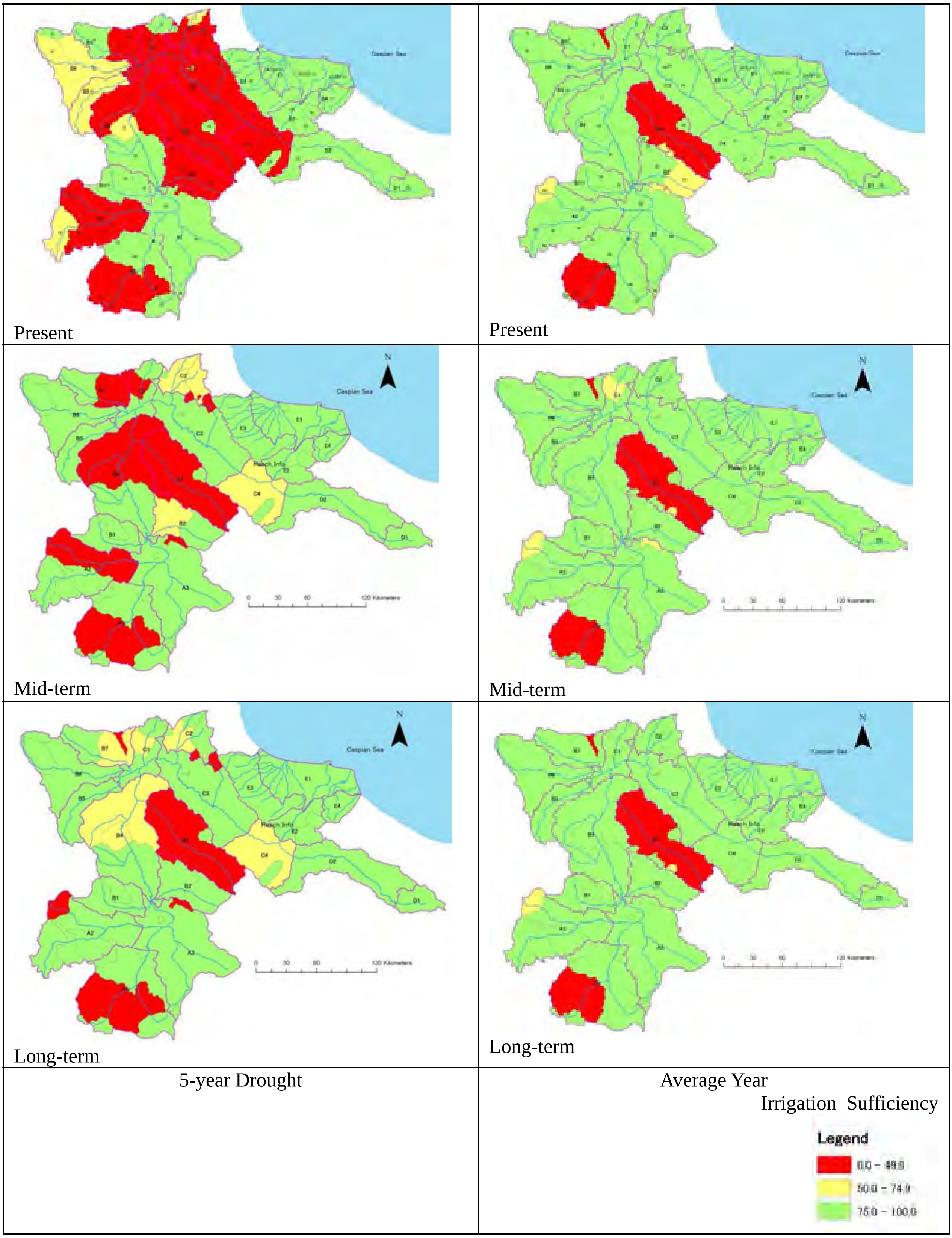


Figure 2.3.18 Future Changes of Water Demand Sufficiency in the Traditional Irrigation Area (with intermediate improvement of irrigation efficiency)

2.3.8 Simulation Result for Supplemental Study

Presently, the effect of three hydroelectric dams, which is planned between Manjil dam and Ostor dam by Water and Power Resources Development Company and Ardebil Interbasin Transfer Project (carrying water outside of the basin from Ostor dam) on Sefidrud River is the issues in terms of water resource management at the stakeholder meeting. These projects are still in the stage of completion of the concepts. The determination of target completion years of construction and detail designs are not yet started so that these projects are not considered in the master plan described in Chapter 9. However, considering that the effects of those two projects are large and the intense request made by the stakeholders, the supplemental study was done under insufficient information. This supplemental study evaluated the effect of those two projects to the water resource management in the Long-Term (2031). This Evaluation was performed revising the water balance simulation made during the Study.

1) General Information on Projects

a) Hydroelectric Dams

i) Location

Paverud dam, Gizvan dam and Pirtaghi dam are presently planned to be located in Ghezelozan river between Manjil dam and Ostor dam by Water and Power Resources Development Company. The location of those dams is shown in Figure 2.3.19.

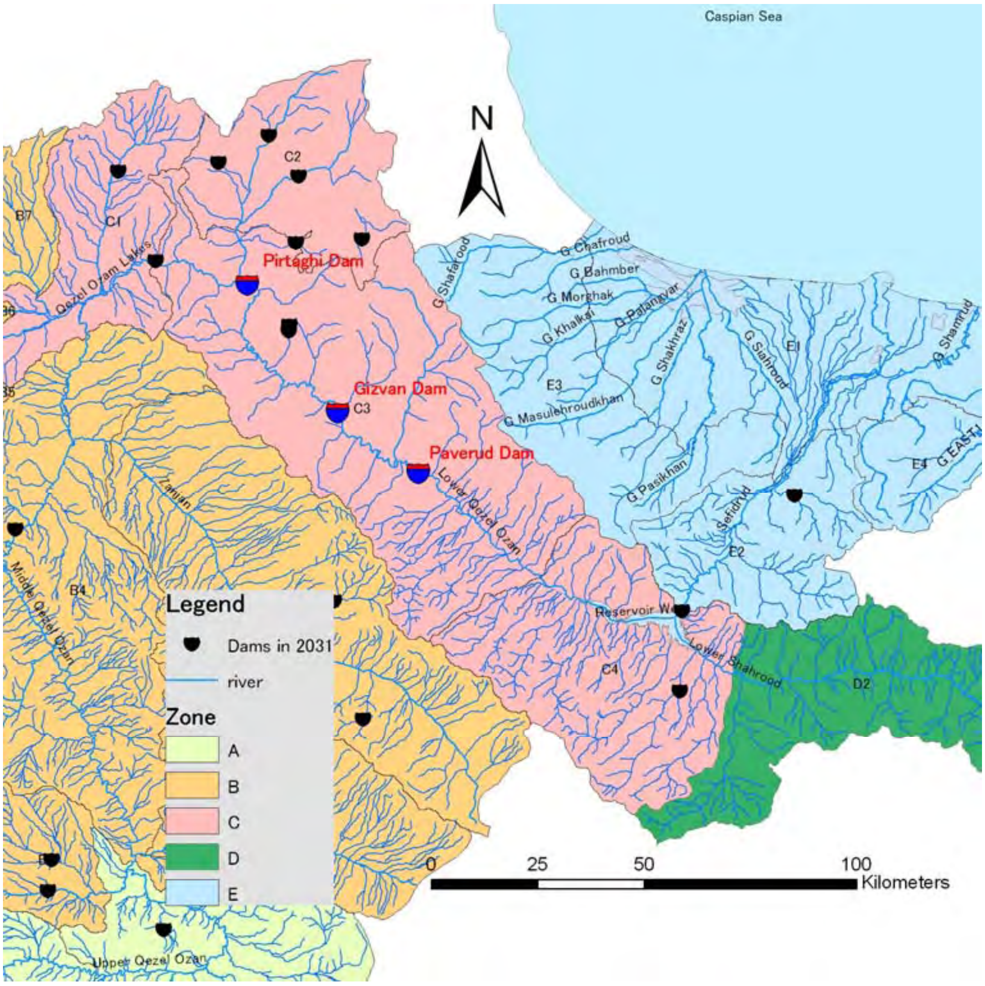


Figure 2.3.19 Location of Hydroelectric Dams

ii) Specification of Dam and Standard Water Levels

The relation between the water level, area of the reservoir and the water volume is shown in Table 2.3.14. The total storage volume of Gizvan dam and Paverud dam is approximately same with or larger than the one of Manjil dam. Pirtaghi dam also possess the total storage volume comes with the ones of Osor dam. In Table 2.3.14, orange-hatched, green-hatched and blue-hatched values show the low water level (the top of inactive storage capacity), the normal water level and the surcharge water level respectively. The normal water level and the surcharge water level for Gizvan dam and Paverud dam is not found out.

Table 2.3.14 Water Level – Area- Storage Volume Relation

Pirtaghi Dam			Gizvan Dam			Paverud Dam		
Level (MSL)	Area (ha)	Volume (MCM)	Level (MSL)	Area (ha)	Volume (MCM)	Level (MSL)	Area (ha)	Volume (MCM)
856	0.0	0.0	615	0.0	0.0	468	0.0	0.0
860	8.6	0.1	620	16.5	0.3	480	150.0	6.0
880	76.3	7.5	660	369.5	63.2	500	301.7	50.3
890	121.7	19.4	700	1229.1	363.6	520	727.1	150.1
900	167.1	31.2	740	2076.8	1001.6	540	1017.2	323.7
920	301.4	77.4	780	3440.0	2092.0	560	1346.0	559.3
940	498.4	156.6	820	5449.5	3859.6	580	1696.5	862.8
960	873.0	292.0	840	6136.1	5017.5	600	2166.0	1248.1
966	986.2	357.2	871	7196.9	6806.4	600.4	2175.3	1256.9
970	1055.3	397.0	890	7852.6	7912.3	620	2674.0	1731.3
980	1237.5	502.0						

b) Ardebil Interbasin Transfer

The project of Ardebil Interbasin Transfer is to carry 538MCM/year to the outside of the Sefidrud river basin, which consists of irrigation water, domestic water and industrial water. This amount is about one third of the average inflow at Ostor dam in Long-Term (2031) and equivalent to the effective storage volume of Ostor dam. The detail information such as the target completion year is not clear in the present situation. According to Ardebil RWC, the amount of transfer water is as shown in Table 2.3.15.

Table 2.3.15 Amount of Ardebil Transfer ('000m^3)

Month	Irrigation	Domestic	Industrial	合計
Oct.	20,339	5,247	13,080	38,667
Nov.	26,115	6,736	16,795	49,647
Dec.	26,952	6,952	17,338	51,238
Jan.	27,371	7,060	17,602	52,034
Feb.	27,371	7,060	17,602	52,034
Mar.	26,115	6,736	16,795	49,647
Apr.	27,622	7,125	17,763	52,511
May	24,190	6,240	15,557	45,987
Jun	22,097	5,700	14,211	42,009
July	20,339	5,246	13,080	38,667
Aug.	18,225	4,707	11,734	34,689
Sep.	16,238	4,189	10,443	30,870
合計	283,000	73,000	182,000	538,000

2) Execution of Simulation

a) Conditions

i) Basic Conditions

Since the target completion year is not defined yet, the three hydroelectric dams were modeled in the water balance simulation with MIKE-BASIN as a Long-Term model. This model includes the dams and Almout Transfer whose completion years are set by 2031.

ii) Duration of Model Simulation and Natural Flow

Water allocation simulation was executed using natural flow obtained with MIKE SHE model for 20 years from 1985 to 2005 in hydrological year.

iii) Water Demand and Irrigation Efficiency

Irrigation efficiency in the traditional irrigation area in each Reach and irrigation area located at the lower stream of Manjil Dam was set as shown in Table 2.3.16. Irrigation efficiency was used for the calculation of water demand and the intermediate value between present condition and WRMC target values were applied.

Table 2.3.16 Irrigation Efficiency in the Simulation

Irrigation Efficieny Variations	Irrigation Area at Lower Stream of Manjil dam			Traditional Irrigation Area in Each Reach		
	Present	Middle-Term	Long-Term	Present	Middle-Term	Long-Term
Present	0.42	0.42	0.42	0.33	0.33	0.33
Intermediate	0.42	0.45	***0.51***	0.33	0.37	***0.44***
WRMC Target	0.42	0.48	0.55	0.33	0.40	0.50

iv) Initial Condition of Dams

In the model, the initial water level at each dam was set at a certain height with witch the storage volume of a dam can be 70% of its effective storage volume. In case the water level reached at the surcharge water level and above, the amount of discharge was set at the same amount of the inflow. Since the surcharge water levels of Gizvan dam and Paverud dam were not clear, those were set by 5m higher than the normal water level in order to avoid complexity of the modeling. The inactive storage capacity of three dams was estimated by reference of the ratio between the total capacity and the inactive capacity of Manjil dam.

v) Discharge for Electrical Power Generation

Discharge for electrical power generation of new three dams is not clear presently. Hence, it was set at the same discharge of Ostor dam. Discharge for other purposes was not set in the model.

Table 2.3.17 Discharge for Electrical Power Generation ('000m^3)

Month	Discharge	Month	Discharge
Oct.	23,872	Apr.	111,314
Nov.	32,841	May	113,966
Dec.	47,226	Jun	83,191
Jan.	59,512	July	41,354
Feb.	70,036	Aug.	26,945
Mar.	94,261	Sep.	26,945
Total			731,463

vi) Priority of Intake from Ostor Dam

Ostor dam provides electricity, irrigation water and domestic water in the basin. In the simulation, continuously utilized water until 2031 was prioritized and intake for Ardebil Transfer was set at lower. Simply saying, in the algorithm of the simulation, irrigation water, domestic water and hydroelectric discharge were subtracted from the flow at first, then the residual amount of water flow is applied for Ardebil Transfer.

b) Simulation Cases

Simulation cases are shown in Table 2.3.18. Comparing these results, the effect of the hydroelectric dam and Ardebil Transfer was evaluated in terms of water resource management.

Table 2.3.18 Simulation Cases

Cases	Conditions
1	Neither Hydroelectric Dam nor Aldebil Transfer
2	Construct Hydroelectric Dams only
3	Construct Both Hydroelectric Dam and Aldebil Transfer

c) Result of Evaluation for Hydropower Dams

i) Effect on Flow

Table 2.3.16 shows the relation between the discharge at Ostor dam and the flow at the lower stream point of a group of the hydroelectric dams, or the discharge at Pirtaghi dam. This figure tells that there is a positive effect of the flow recovery at the lower stream with interannual storage of the hydroelectric dams even in the sever drought years from 2000 to 2003. In other words, the discharge for hydroelectric generation contributed to stabilization of maintenance flow. As a conclusion, this result indicates that establishment of a discharge rule of the hydroelectric dams which has a large amount of storage capacity has a high potential of improving maintenance flow.

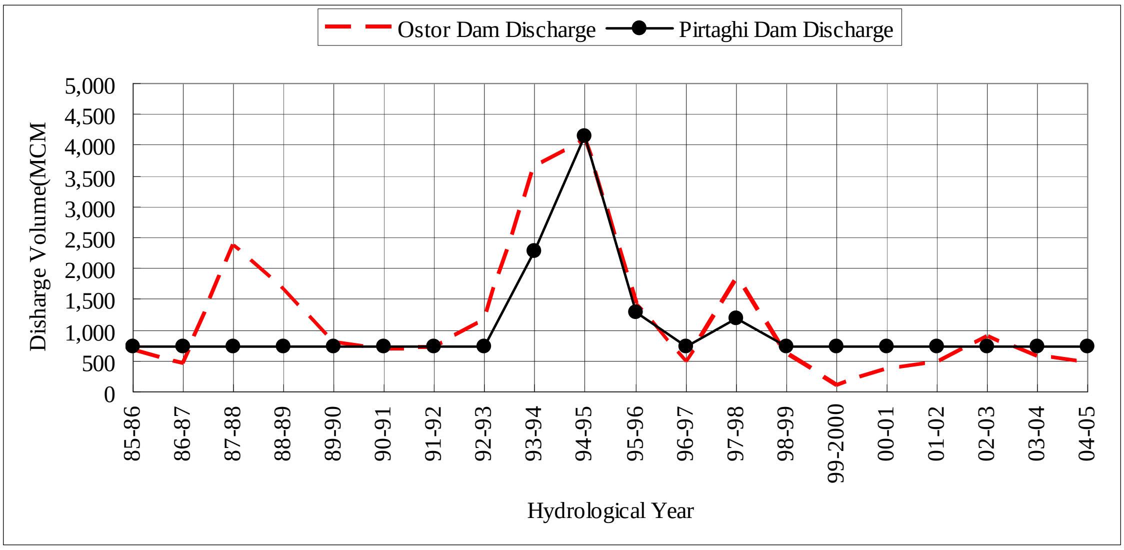


Figure 2.3.20 Comparison of Discharge at Ostor Dam and Pirtaghi Dam

Table 2.3.19 shows the annual inflow and discharge between Ostor dam and Pirtaghi dam. Considering the average of these inflow and discharge, the discharge at Ostor dam was reduced by only 1% in comparison to the outlet flow of the Gizvan dam which has the largest storage capacity among three dams. In addition, no lack of discharge for hydroelectric generation can be seen in any year.

Table 2.3.19 Annual Inflow and Discharge at Ostor・Pirtaghi・Gizvan・Paverud Dams

No.	Hydraulic Year	Ostor		Pirtaghi		Gizvan		Paverud	
		In	Out	In	Out	In	Out	In	Out
1	85-86	1,024	835	931	905	905	735	740	735
2	86-87	543	787	836	818	818	735	737	735
3	87-88	3,378	2,935	3,027	2,991	2,991	2,630	2,633	2,630
4	88-89	1,907	2,061	2,140	2,119	2,119	2,064	2,066	2,064
5	89-90	1,364	1,149	1,180	1,151	1,152	965	965	965
6	90-91	1,125	1,091	1,123	1,094	1,094	931	931	931
7	91-92	1,396	1,267	1,323	1,296	1,296	1,124	1,125	1,124
8	92-93	1,734	1,734	1,841	1,822	1,822	1,684	1,687	1,684
9	93-94	4,400	4,269	4,484	4,458	4,459	4,238	4,244	4,238
10	94-95	4,625	4,583	4,821	4,800	4,800	4,722	4,729	4,722
11	95-96	1,812	1,895	1,951	1,927	1,927	1,815	1,818	1,815
12	96-97	516	743	767	746	746	737	738	737
13	97-98	2,630	2,110	2,166	2,134	2,134	1,776	1,779	1,776
14	98-99	619	967	1,003	984	984	905	907	905
15	99-2000	131	121	149	610	610	732	732	732
16	00-01	448	435	445	443	443	737	737	737
17	01-02	605	543	571	566	566	735	735	735
18	02-03	1,732	1,229	1,273	772	772	735	736	735
19	03-04	607	886	962	929	930	732	733	732
20	04-05	635	683	739	768	768	737	738	737
Average		1,562	1,516	1,587	1,567	1,567	1,473	1,475	1,473

ii) Effect on Water Demand at Lower Stream

The effect in terms of reduction of water demand of SIDN was approximately 3% by the hydroelectric dams. Since these dams don’t possess any water demand which consumes water flow, this negative impact can be fully covered by establishing an operation rule of hydroelectric dams. The management rules such as more water flow to Manjil dam before and during an agricultural season will be recommended.

d) Effect of Ardebil Transfer

Assuming the hydroelectric dams would be constructed, the water demand for Ardebil Interbasin Transfer at Ostor dam was taken into account in the water allocation simulation. The effect of the transfer is discussed below.

i) Effect on Stream Regime

Table 2.3.20 shows the annual inflow and discharge between Ostor dam and Pirtaghi dam. Due to Ardebil Interbasin Transfer, the average of the discharge at Ostor dam and the one at Pirtaghi dam was reduced by approximately 22% and 30% respectively.

Table 2.3.20 Effect of Ardebil Transfer on Annual Inflow and Discharge at Ostor・Pirtaghi・Gizvan・Paverud Dams on Flow Regime

No.	Hydraulic Year	Ostor		Pirtaghi		Gizvan		Pirtaghi	
		In	Out	In	Out	In	Out	In	Out
1	85-86	1,024	671	767	735	735	735	740	735
2	86-87	543	449	499	735	735	735	737	735
3	87-88	3,378	2,381	2,474	2,111	2,111	735	737	735
4	88-89	1,907	1,665	1,744	1,722	1,723	735	737	735
5	89-90	1,364	796	828	799	799	735	735	735
6	90-91	1,125	703	735	735	735	735	735	735
7	91-92	1,396	719	775	735	735	735	736	735
8	92-93	1,734	1,167	1,274	1,242	1,242	735	737	735
9	93-94	4,400	3,644	3,859	3,833	3,834	3,406	3,412	2,289
10	94-95	4,625	4,088	4,326	4,305	4,305	4,194	4,201	4,155
11	95-96	1,812	1,437	1,493	1,469	1,470	1,342	1,345	1,295
12	96-97	516	488	512	737	737	737	738	737
13	97-98	2,630	1,840	1,895	1,628	1,628	1,297	1,301	1,191
14	98-99	619	611	647	757	757	735	737	735
15	99-2000	131	100	127	461	461	732	732	732
16	00-01	448	386	396	394	394	737	737	737
17	01-02	605	474	503	498	498	735	735	735
18	02-03	1,732	892	936	732	732	735	736	735
19	03-04	607	568	644	732	732	732	733	732
20	04-05	635	468	524	607	607	737	738	737
Average w/ Transfer		1,562	1,177	1,248	1,248	1,248	1,100	1,102	1,034
Average w/o Transfer		1,587	1,516	1,587	1,567	1,567	1,473	1,475	1,473

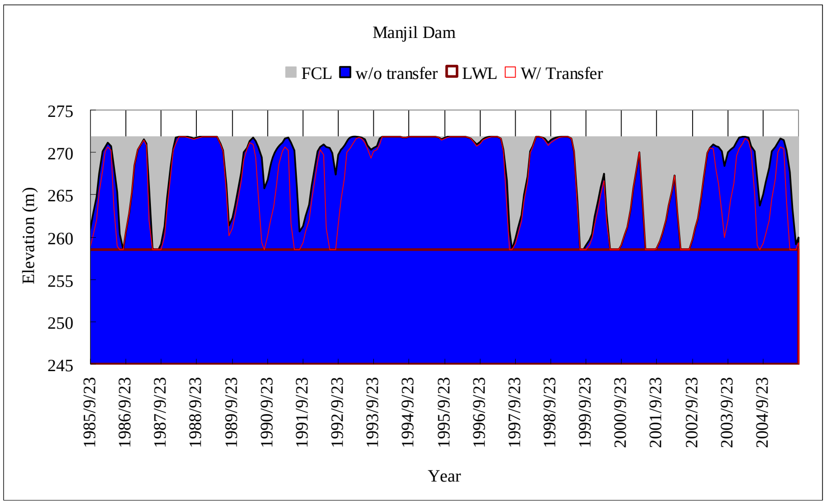
w/: with w/o: without

ii) Effect on Ostor Dam and Manjil Dam

As shown in Table 2.3.21, after the completion of Ardebil Interbasin Transfer, the frequency of emptying Ostor dam and Manjil dam are 15 years (times) and 12 times in 20 years. This means the frequency becomes 2.5 times and 1.7 times as large as the one before completion in Ostor dam and Manjil dam, respectively. In the actual dam management, it is hardly possible to predict the inflow in the following year. Hence, this result is undesirable.

Table 2.3.21 Frequency of Emptying Dams

Condition	Ostor Dam	Manjil Dam
Witout Transfer	6 years (6 times)	7 years (7 times)
With Transfer	15 years (15 times)	12 years (12 times)



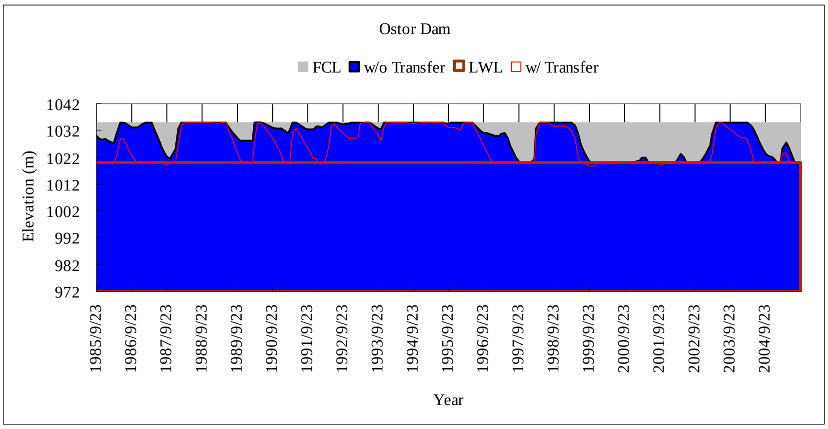


Figure 2.3.21 Interannual Change of Water Level at Manjil Dam and Ostor Dam

iii) Sufficiency of Ardebil Transfer

The sufficiency of Ardebil Interbasin Transfer is at 64.2% and it is not considered as high. In 20 years, the year when the transfer can carry 100% of design discharge is only 4 years. It is required for the stakeholders to discuss and study how to solve this problem, and then find an adequate water demand allocation.

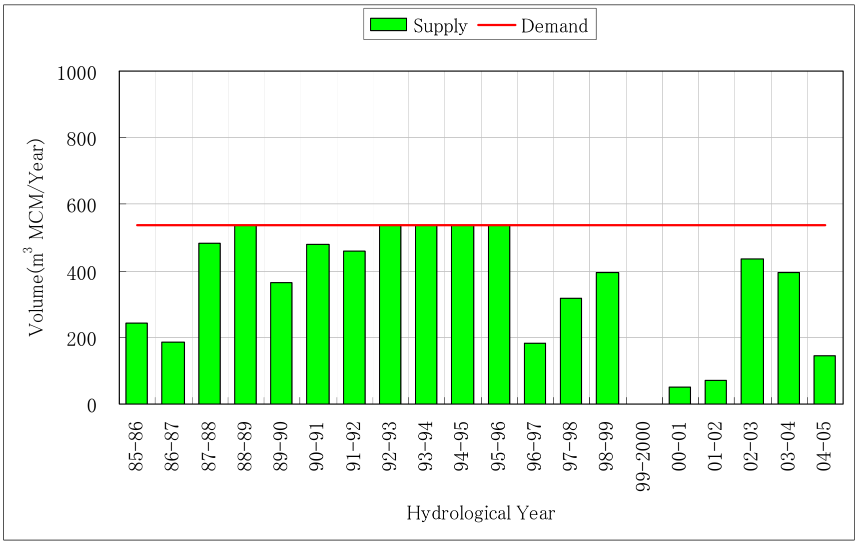


Figure 2.3.22 Water Supply and Demand Set at Ardebil Transfer

iv) Sufficiency at lower Stream

The sufficiency of water demands in Long-Term at the lower stream of Manjil dam in the drought year is reduced from 90.5% to 75.7% by Ardebil Transfer. Comparing to the case without any improvement in the traditional irrigation area, in which the sufficient was 80.3%, it is clear that Ardebil Transfer is carrying water more than the improvement can save.

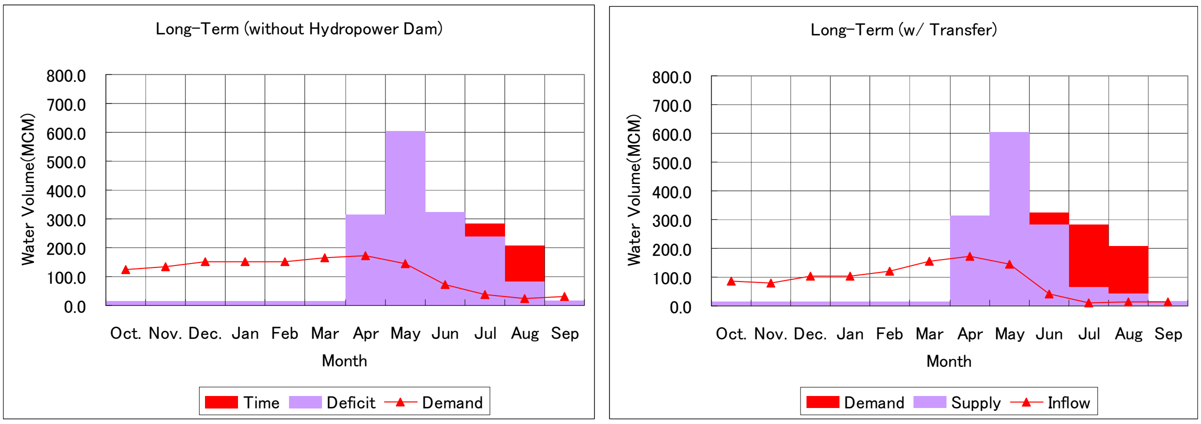


Figure 2.3.23 Monthly Sufficient at Lower Stream of Manjil Dam

3) Conclusion

Conclusion of the simulation above is summarized in Table 2.3.22. The hydroelectric dams can provide positive effect to beneficiaries with appropriate discharge control at the dams. However, since Ardebil Interbasin Transfer Project carries away water outside the basin, the negative effect to the beneficiaries is considerably large. Regarding this issue, WRMC should discuss with the stakeholders and set the adequate timing and amount of water discharge.

Table 2.3.22 Evaluation of Projects

Evaluation Item	Hydroelectric Dam Project	Aldebil Interbasin Transfer Project
Change of Flow	No significant change in the lower stream Group of dams can cover the change during the draught years.	Discharge to the lower stream is reduced to approximately 1/3.
Effect on Surrounding Dams	As long as the hydroelectric dams release the same amount of discharge at Ostor dam, the effect is negligible.	The possibilities of emptying Ostor dan and Manjil dam become about twice as large as the case without the project.
Sufficiency in Project	No ristriction on releasing hydroelectric discharge as much as the one at Ostor dam. Discussion with water user in the lower stream will be required for additional discharge.	In average, approximately 64% of the desig discharge can be transferred.
Effect on the Lower Stream	It is possible to have flexible action for the water demand in the lower stream with integrated management of lower dams.	Reducing the sufficiency in the lower stream by approximately 15% More than seved water with improvement of traditional irrigation area in Long-Term (2031) are carried away.

Appendix Tables

Appendix Table 1 Quantity of Intake Water (Surface Water, 2006, Scenario-1)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	294	213	0	0	0	0	315	603	974	896	839	629	4,763
2	2,056	310	0	0	0	0	753	2,764	6,348	7,608	7,448	5,178	32,465
3	1,059	1,087	0	0	0	0	1,573	2,890	4,954	4,540	4,096	2,550	22,749
4	2,503	343	0	0	0	0	1,536	3,853	6,889	7,502	7,416	4,645	34,687
5	9,148	1,231	0	0	0	0	6,998	18,714	29,976	35,988	35,442	16,483	153,980
6	1,182	1,085	0	0	0	0	1,441	3,731	6,877	7,718	7,201	3,881	33,116
7	109	20	0	0	0	0	56	143	305	362	353	253	1,601
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,768	376	0	0	0	0	2,726	5,805	9,052	9,194	7,904	3,591	41,416
10	6,417	1,411	0	0	0	0	3,800	8,435	15,026	18,895	19,050	12,986	86,020
11	3,175	1,462	0	0	0	0	3,866	7,592	15,057	14,443	13,504	7,805	66,904
12	396	96	0	0	0	0	234	542	1,085	1,263	1,230	896	5,742
13	279	62	0	0	0	0	172	349	694	819	801	598	3,774
14	105	41	0	0	0	0	82	160	288	310	298	221	1,505
15	9	4	0	0	0	0	10	26	55	70	58	28	260
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	14,980	3,743	0	0	0	0	13,948	26,022	41,032	34,170	31,259	23,620	188,774
18	7,938	1,416	0	0	0	0	6,542	12,753	18,862	15,599	14,785	9,747	87,642
19	113	48	0	0	1	6	20,531	52,903	29,300	29,291	24,647	163	157,003
20	12,317	1,770	0	0	0	0	10,910	15,210	28,836	22,965	18,218	12,804	123,030
21	3,796	1,919	0	0	0	0	2,823	5,492	11,514	12,183	11,363	7,985	57,075
22	3,461	1,118	0	0	0	0	3,492	6,490	8,601	6,713	6,112	4,824	40,811
23	27	15	0	0	0	1	523	1,348	874	794	662	46	4,290
24	1,336	243	0	0	0	0	1,024	1,391	2,713	2,239	2,085	1,576	12,607
25	532	35	0	0	0	0	495	834	1,897	1,885	1,549	1,060	8,287
26	1,846	601	0	0	0	0	1,556	4,436	6,169	7,452	7,324	4,570	33,954
27	12,421	2,085	0	0	0	0	11,749	13,469	30,536	28,458	21,602	14,096	134,416
28	415	114	0	0	0	0	248	357	940	1,140	1,102	829	5,145
29	945	85	0	0	0	0	529	1,166	1,993	1,889	1,754	1,385	9,746
30	7,420	668	0	0	0	0	4,099	9,449	16,035	15,905	15,419	11,646	80,641
31	1,354	261	0	0	0	0	1,090	1,527	2,776	2,456	2,282	1,659	13,405
32	63	56	0	0	0	0	81	146	220	165	121	96	948
33	873	218	0	0	0	0	558	800	1,938	2,131	2,076	1,564	10,158
34	1,242	533	0	0	0	0	906	1,796	2,688	2,901	2,816	2,345	15,227
35	967	362	0	0	0	0	902	1,739	2,335	2,056	1,971	1,528	11,860
36	1,047	137	0	0	0	0	437	1,070	2,814	3,216	3,062	2,474	14,257
37	1,556	646	0	0	0	0	1,292	2,481	3,496	3,436	3,260	2,721	18,888
38	530	132	0	0	0	0	422	637	1,173	1,191	1,120	808	6,013
39	3	1	0	0	0	0	4	9	29	43	34	15	138
40	1,382	554	0	0	0	0	1,224	2,314	3,145	2,839	2,653	2,226	16,337
41	1,907	807	0	0	0	0	1,666	3,066	4,133	3,875	3,663	3,077	22,194
42	900	382	0	0	0	0	729	1,379	1,945	1,954	1,864	1,556	10,709
43	351	131	0	0	0	0	264	498	673	621	615	505	3,658
44	1,917	683	0	0	0	0	1,454	2,833	3,923	3,658	3,625	2,933	21,026
45	53	15	0	0	0	0	50	97	125	97	93	64	594
46	98	38	0	0	0	0	95	172	224	181	165	140	1,113
47	6,619	1,746	0	0	0	0	5,892	11,751	14,996	12,258	11,783	8,999	74,044
48	2,033	469	0	0	0	0	1,920	3,808	4,972	3,599	3,335	2,499	22,635
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1,070	320	0	0	0	0	928	1,789	2,331	1,958	1,893	1,472	11,761
51	305	106	0	0	0	0	261	493	675	599	544	400	3,383
52	421	115	0	0	0	0	378	717	912	709	681	523	4,456
53	0	0	0	0	0	0	2,581	6,658	3,666	3,666	3,067	0	19,637
54	0	0	0	0	0	0	7,863	20,266	11,019	11,179	8,728	0	59,055
55	0	0	0	0	0	0	5,355	13,810	7,604	7,604	6,361	0	40,734
56	0	0	0	0	0	0	21,660	55,980	30,510	30,860	22,350	0	161,360
57	0	0	0	0	0	0	2,340	6,020	3,280	3,320	2,400	0	17,360
59	3,477	1,016	0	0	0	0	2,325	4,957	9,525	10,966	10,555	7,675	50,496
60	13,555	2,812	0	0	0	0	9,705	19,931	32,198	33,830	33,495	22,552	168,078
61	8,044	3,840	0	0	0	0	9,482	15,886	35,703	41,946	39,535	24,522	178,958
62	0	0	0	0	0	0	480	1,239	686	685	580	0	3,670
63	5,263	442	0	0	0	0	3,091	6,563	11,438	11,211	10,426	7,758	56,192
64	1,240	481	0	0	0	0	968	1,896	2,748	2,673	2,549	2,127	14,682
65	612	282	0	0	0	0	470	882	1,266	1,358	1,307	1,110	7,287
66	330	70	0	0	0	0	294	463	770	647	607	426	3,607
67	18	3	0	0	0	0	21	42	50	30	26	17	207
Total	154,277	38,259	0	0	1	7	189,219	400,641	502,868	500,209	453,163	257,886	2,496,530

Appendix Table 2 Quantity of Intake Water (Ground Water, 2006, Scenario-1)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	993	720	0	0	0	0	1,063	2,033	3,288	3,023	2,830	2,123	16,073
2	1,223	185	0	0	0	0	448	1,643	3,776	4,524	4,430	3,080	19,309
3	1,744	1,791	0	0	0	0	2,593	4,763	8,162	7,480	6,748	4,201	37,482
4	1,254	172	0	0	0	0	770	1,931	3,452	3,760	3,717	2,328	17,384
5	1,605	216	0	0	0	0	1,228	3,283	5,258	6,313	6,217	2,891	27,011
6	1,614	1,480	0	0	0	0	1,966	5,092	9,384	10,532	9,828	5,296	45,192
7	126	23	0	0	0	0	64	165	351	417	407	292	1,845
8	2,625	514	30	0	0	122	1,631	3,556	6,029	7,451	7,273	4,828	34,059
9	561	76	0	0	0	0	552	1,176	1,833	1,862	1,601	727	8,388
10	38	8	0	0	0	0	23	50	89	112	113	77	510
11	2,367	1,090	0	0	0	0	2,882	5,660	11,226	10,768	10,068	5,819	49,880
12	263	64	0	0	0	0	156	359	720	838	817	595	3,812
13	185	41	0	0	0	0	114	232	461	543	532	397	2,505
14	2	1	0	0	0	0	2	4	6	7	7	5	34
15	1	0	0	0	0	0	1	3	6	8	6	3	28
16	13	19	0	0	0	0	12	21	21	20	13	0	119
17	5,875	1,468	0	0	0	0	5,470	10,206	16,092	13,401	12,259	9,263	74,034
18	214	38	0	0	0	0	176	344	509	421	399	263	2,364
19	6	3	0	0	0	0	1,065	2,745	1,520	1,520	1,279	8	8,146
20	15,717	2,258	0	0	0	0	13,921	19,407	36,794	29,304	23,247	16,337	156,985
21	2,609	1,320	0	0	0	0	1,941	3,775	7,916	8,375	7,812	5,489	39,237
22	3,146	1,016	0	0	0	0	3,174	5,899	7,817	6,101	5,555	4,384	37,092
23	16	9	0	0	0	1	323	834	541	491	410	28	2,653
24	121	22	0	0	0	0	92	125	245	202	188	142	1,137
25	6,121	398	0	0	0	0	5,693	9,604	21,829	21,695	17,827	12,201	95,368
26	5,808	1,892	0	0	0	0	4,895	13,957	19,410	23,449	23,044	14,381	106,836
27	15,882	2,665	0	0	0	0	15,022	17,223	39,046	36,389	27,622	18,025	171,874
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	211	19	0	0	0	0	118	261	446	422	392	310	2,179
30	2,057	185	0	0	0	0	1,136	2,619	4,445	4,409	4,274	3,229	22,354
31	132	26	0	0	0	0	106	149	271	240	223	162	1,309
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	60	15	0	0	0	0	38	55	134	147	143	108	700
34	35	15	0	0	0	0	25	50	75	81	79	66	426
35	11	4	0	0	0	0	10	19	25	22	21	17	129
36	2,145	281	0	0	0	0	895	2,192	5,766	6,589	6,273	5,069	29,210
37	2,359	979	0	0	0	0	1,958	3,761	5,299	5,208	4,941	4,123	28,628
38	403	100	0	0	0	0	321	485	891	905	852	614	4,571
39	1	0	0	0	0	0	2	4	10	15	12	5	49
40	967	387	0	0	0	0	856	1,618	2,200	1,986	1,856	1,557	11,427
41	2,378	1,006	0	0	0	0	2,078	3,824	5,155	4,833	4,568	3,837	27,679
42	1,950	827	0	0	0	0	1,578	2,987	4,212	4,232	4,037	3,370	23,193
43	350	130	0	0	0	0	263	496	671	619	613	504	3,646
44	1,816	647	0	0	0	0	1,378	2,685	3,718	3,466	3,435	2,779	19,924
45	398	114	0	0	0	0	378	731	944	731	699	482	4,477
46	140	54	0	0	0	0	136	246	320	258	236	201	1,591
47	19,526	5,151	0	0	0	0	17,380	34,664	44,234	36,160	34,756	26,546	218,417
48	2,809	648	0	0	0	0	2,653	5,261	6,869	4,972	4,608	3,453	31,273
49	711	102	0	0	0	0	706	1,025	1,594	981	833	575	6,527
50	3,122	934	0	0	0	0	2,708	5,218	6,801	5,714	5,522	4,294	34,313
51	281	98	0	0	0	0	241	455	623	552	502	369	3,121
52	5,151	1,402	0	0	0	0	4,623	8,777	11,156	8,674	8,328	6,397	54,508
53	0	0	0	0	0	0	939	2,421	1,333	1,333	1,115	0	7,141
54	0	0	0	0	0	0	3,300	8,507	4,625	4,693	3,664	0	24,788
55	0	0	0	0	0	0	325	837	461	461	386	0	2,469
56	0	0	0	0	0	0	7,550	19,512	10,635	10,757	7,790	0	56,244
57	0	0	0	0	0	0	22,152	56,988	31,050	31,429	22,720	0	164,338
59	1,233	360	0	0	0	0	825	1,758	3,379	3,890	3,744	2,723	17,912
60	2,218	460	0	0	0	0	1,588	3,261	5,268	5,535	5,480	3,690	27,500
61	3,086	1,474	0	0	0	0	3,638	6,096	13,700	16,096	15,170	9,410	68,670
62	0	0	0	0	0	0	51	132	73	73	62	0	391
63	7,492	630	0	0	0	0	4,400	9,343	16,284	15,961	14,843	11,045	79,998
64	13	5	0	0	0	0	10	20	29	28	27	22	154
65	1,267	583	0	0	0	0	972	1,825	2,619	2,811	2,704	2,298	15,079
66	15,017	3,171	0	0	0	0	13,347	21,060	35,005	29,389	27,595	19,359	163,943
67	10,978	1,668	0	0	0	0	12,643	25,202	30,053	18,166	15,715	10,095	124,520
Total	158,446	38,964	30	0	0	123	176,603	348,634	466,154	430,843	382,466	239,892	2,242,155

Appendix Table 3 Quantity of Intake Water (Surface Water, 2016, Scenario-1)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	294	213	0	0	0	0	315	603	974	896	839	629	4,763
2	2,056	310	0	0	0	0	753	2,764	6,348	7,608	7,448	5,178	32,465
3	492	505	0	0	0	0	731	1,343	2,303	2,110	1,904	1,185	10,573
4	2,503	343	0	0	0	0	1,536	3,853	6,889	7,502	7,416	4,645	34,687
5	9,148	1,231	0	0	0	0	6,998	18,714	29,976	35,988	35,442	16,483	153,980
6	598	549	0	0	0	0	729	1,888	3,480	3,905	3,643	1,964	16,756
7	109	20	0	0	0	0	56	143	305	362	353	253	1,601
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,768	376	0	0	0	0	2,726	5,805	9,052	9,194	7,904	3,591	41,416
10	6,417	1,411	0	0	0	0	3,800	8,435	15,026	18,895	19,050	12,986	86,020
11	2,128	980	0	0	0	0	2,591	5,088	10,090	9,679	9,049	5,230	44,835
12	396	96	0	0	0	0	234	542	1,085	1,263	1,230	896	5,742
13	279	62	0	0	0	0	172	349	694	819	801	598	3,774
14	105	41	0	0	0	0	82	160	288	310	298	221	1,505
15	9	4	0	0	0	0	10	26	55	70	58	28	260
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	14,980	3,743	0	0	0	0	13,948	26,022	41,032	34,170	31,259	23,620	188,774
18	7,938	1,416	0	0	0	0	6,542	12,753	18,862	15,599	14,785	9,747	87,642
19	113	48	0	0	1	6	20,531	52,903	29,300	29,291	24,647	163	157,003
20	11,710	1,683	0	0	0	0	10,373	14,461	27,416	21,834	17,321	12,173	116,971
21	3,796	1,919	0	0	0	0	2,823	5,492	11,514	12,183	11,363	7,985	57,075
22	3,461	1,118	0	0	0	0	3,492	6,490	8,601	6,713	6,112	4,824	40,811
23	27	15	0	0	0	1	523	1,348	874	794	662	46	4,290
24	1,336	243	0	0	0	0	1,024	1,391	2,713	2,239	2,085	1,576	12,607
25	532	35	0	0	0	0	495	834	1,897	1,885	1,549	1,060	8,287
26	1,846	601	0	0	0	0	1,556	4,436	6,169	7,452	7,324	4,570	33,954
27	12,421	2,085	0	0	0	0	11,749	13,469	30,536	28,458	21,602	14,096	134,416
28	415	114	0	0	0	0	248	357	940	1,140	1,102	829	5,145
29	945	85	0	0	0	0	529	1,166	1,993	1,889	1,754	1,385	9,746
30	5,077	457	0	0	0	0	2,804	6,465	10,971	10,882	10,549	7,968	55,173
31	1,354	261	0	0	0	0	1,090	1,527	2,776	2,456	2,282	1,659	13,405
32	63	56	0	0	0	0	81	146	220	165	121	96	948
33	873	218	0	0	0	0	558	800	1,938	2,131	2,076	1,564	10,158
34	1,242	533	0	0	0	0	906	1,796	2,688	2,901	2,816	2,345	15,227
35	967	362	0	0	0	0	902	1,739	2,335	2,056	1,971	1,528	11,860
36	1,047	137	0	0	0	0	437	1,070	2,814	3,216	3,062	2,474	14,257
37	1,556	646	0	0	0	0	1,292	2,481	3,496	3,436	3,260	2,721	18,888
38	530	132	0	0	0	0	422	637	1,173	1,191	1,120	808	6,013
39	3	1	0	0	0	0	4	9	29	43	34	15	138
40	1,382	554	0	0	0	0	1,224	2,314	3,145	2,839	2,653	2,226	16,337
41	659	279	0	0	0	0	576	1,059	1,428	1,339	1,266	1,063	7,669
42	900	382	0	0	0	0	729	1,379	1,945	1,954	1,864	1,556	10,709
43	351	131	0	0	0	0	264	498	673	621	615	505	3,658
44	1,917	683	0	0	0	0	1,454	2,833	3,923	3,658	3,625	2,933	21,026
45	53	15	0	0	0	0	50	97	125	97	93	64	594
46	98	38	0	0	0	0	95	172	224	181	165	140	1,113
47	6,295	1,661	0	0	0	0	5,603	11,176	14,262	11,658	11,206	8,558	70,419
48	2,033	469	0	0	0	0	1,920	3,808	4,972	3,599	3,335	2,499	22,635
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1,070	320	0	0	0	0	928	1,789	2,331	1,958	1,893	1,472	11,761
51	305	106	0	0	0	0	261	493	675	599	544	400	3,383
52	421	115	0	0	0	0	378	717	912	709	681	523	4,456
53	0	0	0	0	0	0	2,581	6,658	3,666	3,666	3,067	0	19,637
54	0	0	0	0	0	0	7,863	20,266	11,019	11,179	8,728	0	59,055
55	0	0	0	0	0	0	5,355	13,810	7,604	7,604	6,361	0	40,734
56	0	0	0	0	0	0	21,660	55,980	30,510	30,860	22,350	0	161,360
57	0	0	0	0	0	0	2,340	6,020	3,280	3,320	2,400	0	17,360
59	3,477	1,016	0	0	0	0	2,325	4,957	9,525	10,966	10,555	7,675	50,496
60	10,998	2,281	0	0	0	0	7,874	16,171	26,124	27,448	27,176	18,297	136,369
61	8,044	3,840	0	0	0	0	9,482	15,886	35,703	41,946	39,535	24,522	178,958
62	0	0	0	0	0	0	480	1,239	686	685	580	0	3,670
63	5,263	442	0	0	0	0	3,091	6,563	11,438	11,211	10,426	7,758	56,192
64	1,240	481	0	0	0	0	968	1,896	2,748	2,673	2,549	2,127	14,682
65	612	282	0	0	0	0	470	882	1,266	1,358	1,307	1,110	7,287
66	330	70	0	0	0	0	294	463	770	647	607	426	3,607
67	18	3	0	0	0	0	21	42	50	30	26	17	207
Total	145,000	35,217	0	0	1	7	181,348	384,672	475,856	473,530	427,898	241,010	2,364,539

Appendix Table 4 Quantity of Intake Water (Ground Water, 2016, Scenario-1)

Reach	Meh. Oct.	Sha. Nov.	Mor. Dec.	Tir Jan.	Kho. Feb.	Ord. Mar.	Far. Apr	Esf. May.	Bah. Jun.	Dey Jul.	Aza. Aug.	Aba. Sep.	Total
1	993	720	0	0	0	0	1,063	2,033	3,288	3,023	2,830	2,123	16,073
2	1,223	185	0	0	0	0	448	1,643	3,776	4,524	4,430	3,080	19,309
3	1,744	1,791	0	0	0	0	2,593	4,763	8,162	7,480	6,748	4,201	37,482
4	1,254	172	0	0	0	0	770	1,931	3,452	3,760	3,717	2,328	17,384
5	1,605	216	0	0	0	0	1,228	3,283	5,258	6,313	6,217	2,891	27,011
6	1,614	1,480	0	0	0	0	1,966	5,092	9,384	10,532	9,828	5,296	45,192
7	126	23	0	0	0	0	64	165	351	417	407	292	1,845
8	2,625	514	30	0	0	122	1,631	3,556	6,029	7,451	7,273	4,828	34,059
9	561	76	0	0	0	0	552	1,176	1,833	1,862	1,601	727	8,388
10	38	8	0	0	0	0	23	50	89	112	113	77	510
11	2,367	1,090	0	0	0	0	2,882	5,660	11,226	10,768	10,068	5,819	49,880
12	263	64	0	0	0	0	156	359	720	838	817	595	3,812
13	185	41	0	0	0	0	114	232	461	543	532	397	2,505
14	2	1	0	0	0	0	2	4	6	7	7	5	34
15	1	0	0	0	0	0	1	3	6	8	6	3	28
16	13	19	0	0	0	0	12	21	21	20	13	0	119
17	5,875	1,468	0	0	0	0	5,470	10,206	16,092	13,401	12,259	9,263	74,034
18	214	38	0	0	0	0	176	344	509	421	399	263	2,364
19	6	3	0	0	0	0	1,065	2,745	1,520	1,520	1,279	8	8,146
20	15,717	2,258	0	0	0	0	13,921	19,407	36,794	29,304	23,247	16,337	156,985
21	2,609	1,320	0	0	0	0	1,941	3,775	7,916	8,375	7,812	5,489	39,237
22	3,146	1,016	0	0	0	0	3,174	5,899	7,817	6,101	5,555	4,384	37,092
23	16	9	0	0	0	1	323	834	541	491	410	28	2,653
24	121	22	0	0	0	0	92	125	245	202	188	142	1,137
25	6,121	398	0	0	0	0	5,693	9,604	21,829	21,695	17,827	12,201	95,368
26	5,808	1,892	0	0	0	0	4,895	13,957	19,410	23,449	23,044	14,381	106,836
27	15,882	2,665	0	0	0	0	15,022	17,223	39,046	36,389	27,622	18,025	171,874
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	211	19	0	0	0	0	118	261	446	422	392	310	2,179
30	2,057	185	0	0	0	0	1,136	2,619	4,445	4,409	4,274	3,229	22,354
31	132	26	0	0	0	0	106	149	271	240	223	162	1,309
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	60	15	0	0	0	0	38	55	134	147	143	108	700
34	35	15	0	0	0	0	25	50	75	81	79	66	426
35	11	4	0	0	0	0	10	19	25	22	21	17	129
36	2,145	281	0	0	0	0	895	2,192	5,766	6,589	6,273	5,069	29,210
37	2,359	979	0	0	0	0	1,958	3,761	5,299	5,208	4,941	4,123	28,628
38	403	100	0	0	0	0	321	485	891	905	852	614	4,571
39	1	0	0	0	0	0	2	4	10	15	12	5	49
40	967	387	0	0	0	0	856	1,618	2,200	1,986	1,856	1,557	11,427
41	2,378	1,006	0	0	0	0	2,078	3,824	5,155	4,833	4,568	3,837	27,679
42	1,950	827	0	0	0	0	1,578	2,987	4,212	4,232	4,037	3,370	23,193
43	350	130	0	0	0	0	263	496	671	619	613	504	3,646
44	1,816	647	0	0	0	0	1,378	2,685	3,718	3,466	3,435	2,779	19,924
45	398	114	0	0	0	0	378	731	944	731	699	482	4,477
46	140	54	0	0	0	0	136	246	320	258	236	201	1,591
47	19,526	5,151	0	0	0	0	17,380	34,664	44,234	36,160	34,756	26,546	218,417
48	2,809	648	0	0	0	0	2,653	5,261	6,869	4,972	4,608	3,453	31,273
49	711	102	0	0	0	0	706	1,025	1,594	981	833	575	6,527
50	3,122	934	0	0	0	0	2,708	5,218	6,801	5,714	5,522	4,294	34,313
51	281	98	0	0	0	0	241	455	623	552	502	369	3,121
52	5,151	1,402	0	0	0	0	4,623	8,777	11,156	8,674	8,328	6,397	54,508
53	0	0	0	0	0	0	939	2,421	1,333	1,333	1,115	0	7,141
54	0	0	0	0	0	0	3,300	8,507	4,625	4,693	3,664	0	24,788
55	0	0	0	0	0	0	325	837	461	461	386	0	2,469
56	0	0	0	0	0	0	7,550	19,512	10,635	10,757	7,790	0	56,244
57	0	0	0	0	0	0	22,152	56,988	31,050	31,429	22,720	0	164,338
59	1,233	360	0	0	0	0	825	1,758	3,379	3,890	3,744	2,723	17,912
60	2,218	460	0	0	0	0	1,588	3,261	5,268	5,535	5,480	3,690	27,500
61	3,086	1,474	0	0	0	0	3,638	6,096	13,700	16,096	15,170	9,410	68,670
62	0	0	0	0	0	0	51	132	73	73	62	0	391
63	7,492	630	0	0	0	0	4,400	9,343	16,284	15,961	14,843	11,045	79,998
64	13	5	0	0	0	0	10	20	29	28	27	22	154
65	1,267	583	0	0	0	0	972	1,825	2,619	2,811	2,704	2,298	15,079
66	15,017	3,171	0	0	0	0	13,347	21,060	35,005	29,389	27,595	19,359	163,943
67	10,978	1,668	0	0	0	0	12,643	25,202	30,053	18,166	15,715	10,095	124,520
Total	158,446	38,964	30	0	0	123	176,603	348,634	466,154	430,843	382,466	239,892	2,242,155

Appendix Table 5 Quantity of Intake Water (Surface Water, 2031, Scenario-1)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	294	213	0	0	0	0	315	603	974	896	839	629	4,763
2	2,056	310	0	0	0	0	753	2,764	6,348	7,608	7,448	5,178	32,465
3	34	35	0	0	0	0	50	92	157	144	130	81	723
4	2,503	343	0	0	0	0	1,536	3,853	6,889	7,502	7,416	4,645	34,687
5	9,148	1,231	0	0	0	0	6,998	18,714	29,976	35,988	35,442	16,483	153,980
6	598	549	0	0	0	0	729	1,888	3,480	3,905	3,643	1,964	16,756
7	109	20	0	0	0	0	56	143	305	362	353	253	1,601
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,768	376	0	0	0	0	2,726	5,805	9,052	9,194	7,904	3,591	41,416
10	6,417	1,411	0	0	0	0	3,800	8,435	15,026	18,895	19,050	12,986	86,020
11	2,128	980	0	0	0	0	2,591	5,088	10,090	9,679	9,049	5,230	44,835
12	396	96	0	0	0	0	234	542	1,085	1,263	1,230	896	5,742
13	279	62	0	0	0	0	172	349	694	819	801	598	3,774
14	105	41	0	0	0	0	82	160	288	310	298	221	1,505
15	9	4	0	0	0	0	10	26	55	70	58	28	260
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	9,122	2,279	0	0	0	0	8,494	15,846	24,987	20,808	19,035	14,384	114,955
18	7,938	1,416	0	0	0	0	6,542	12,753	18,862	15,599	14,785	9,747	87,642
19	113	48	0	0	1	6	20,531	52,903	29,300	29,291	24,647	163	157,003
20	11,395	1,638	0	0	0	0	10,093	14,072	26,678	21,246	16,854	11,846	113,822
21	2,862	1,447	0	0	0	0	2,128	4,140	8,680	9,185	8,566	6,020	43,028
22	3,461	1,118	0	0	0	0	3,492	6,490	8,601	6,713	6,112	4,824	40,811
23	27	15	0	0	0	1	523	1,348	874	794	662	46	4,290
24	1,336	243	0	0	0	0	1,024	1,391	2,713	2,239	2,085	1,576	12,607
25	532	35	0	0	0	0	495	834	1,897	1,885	1,549	1,060	8,287
26	1,846	601	0	0	0	0	1,556	4,436	6,169	7,452	7,324	4,570	33,954
27	12,128	2,036	0	0	0	0	11,472	13,151	29,815	27,786	21,092	13,763	131,243
28	415	114	0	0	0	0	248	357	940	1,140	1,102	829	5,145
29	945	85	0	0	0	0	529	1,166	1,993	1,889	1,754	1,385	9,746
30	3,570	321	0	0	0	0	1,972	4,547	7,715	7,653	7,419	5,604	38,801
31	1,354	261	0	0	0	0	1,090	1,527	2,776	2,456	2,282	1,659	13,405
32	63	56	0	0	0	0	81	146	220	165	121	96	948
33	873	218	0	0	0	0	558	800	1,938	2,131	2,076	1,564	10,158
34	1,242	533	0	0	0	0	906	1,796	2,688	2,901	2,816	2,345	15,227
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	1,047	137	0	0	0	0	437	1,070	2,814	3,216	3,062	2,474	14,257
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	530	132	0	0	0	0	422	637	1,173	1,191	1,120	808	6,013
39	3	1	0	0	0	0	4	9	29	43	34	15	138
40	1,382	554	0	0	0	0	1,224	2,314	3,145	2,839	2,653	2,226	16,337
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	900	382	0	0	0	0	729	1,379	1,945	1,954	1,864	1,556	10,709
43	351	131	0	0	0	0	264	498	673	621	615	505	3,658
44	1,917	683	0	0	0	0	1,454	2,833	3,923	3,658	3,625	2,933	21,026
45	53	15	0	0	0	0	50	97	125	97	93	64	594
46	98	38	0	0	0	0	95	172	224	181	165	140	1,113
47	6,295	1,661	0	0	0	0	5,603	11,176	14,262	11,658	11,206	8,558	70,419
48	2,033	469	0	0	0	0	1,920	3,808	4,972	3,599	3,335	2,499	22,635
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1,070	320	0	0	0	0	928	1,789	2,331	1,958	1,893	1,472	11,761
51	305	106	0	0	0	0	261	493	675	599	544	400	3,383
52	421	115	0	0	0	0	378	717	912	709	681	523	4,456
53	0	0	0	0	0	0	2,581	6,658	3,666	3,666	3,067	0	19,637
54	0	0	0	0	0	0	7,863	20,266	11,019	11,179	8,728	0	59,055
55	0	0	0	0	0	0	5,355	13,810	7,604	7,604	6,361	0	40,734
56	0	0	0	0	0	0	21,660	55,980	30,510	30,860	22,350	0	161,360
57	0	0	0	0	0	0	2,340	6,020	3,280	3,320	2,400	0	17,360
59	3,477	1,016	0	0	0	0	2,325	4,957	9,525	10,966	10,555	7,675	50,496
60	10,998	2,281	0	0	0	0	7,874	16,171	26,124	27,448	27,176	18,297	136,369
61	7,804	3,725	0	0	0	0	9,199	15,412	34,638	40,695	38,356	23,790	173,619
62	0	0	0	0	0	0	480	1,239	686	685	580	0	3,670
63	5,263	442	0	0	0	0	3,091	6,563	11,438	11,211	10,426	7,758	56,192
64	1,240	481	0	0	0	0	968	1,896	2,748	2,673	2,549	2,127	14,682
65	612	282	0	0	0	0	470	882	1,266	1,358	1,307	1,110	7,287
66	0	0	0	0	0	0	0	0	0	0	0	0	0
67	18	3	0	0	0	0	21	42	50	30	26	17	207
Total	131,883	31,109	0	0	1	7	169,782	363,052	441,022	441,986	398,713	219,211	2,196,766

Appendix Table 6 Quantity of Intake Water (Ground Water, 2031, Scenario-1)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	993	720	0	0	0	0	1,063	2,033	3,288	3,023	2,830	2,123	16,073
2	1,223	185	0	0	0	0	448	1,643	3,776	4,524	4,430	3,080	19,309
3	1,744	1,791	0	0	0	0	2,593	4,763	8,162	7,480	6,748	4,201	37,482
4	1,254	172	0	0	0	0	770	1,931	3,452	3,760	3,717	2,328	17,384
5	1,605	216	0	0	0	0	1,228	3,283	5,258	6,313	6,217	2,891	27,011
6	1,614	1,480	0	0	0	0	1,966	5,092	9,384	10,532	9,828	5,296	45,192
7	126	23	0	0	0	0	64	165	351	417	407	292	1,845
8	2,625	514	30	0	0	122	1,631	3,556	6,029	7,451	7,273	4,828	34,059
9	561	76	0	0	0	0	552	1,176	1,833	1,862	1,601	727	8,388
10	38	8	0	0	0	0	23	50	89	112	113	77	510
11	2,367	1,090	0	0	0	0	2,882	5,660	11,226	10,768	10,068	5,819	49,880
12	263	64	0	0	0	0	156	359	720	838	817	595	3,812
13	185	41	0	0	0	0	114	232	461	543	532	397	2,505
14	2	1	0	0	0	0	2	4	6	7	7	5	34
15	1	0	0	0	0	0	1	3	6	8	6	3	28
16	13	19	0	0	0	0	12	21	21	20	13	0	119
17	5,875	1,468	0	0	0	0	5,470	10,206	16,092	13,401	12,259	9,263	74,034
18	214	38	0	0	0	0	176	344	509	421	399	263	2,364
19	6	3	0	0	0	0	1,065	2,745	1,520	1,520	1,279	8	8,146
20	15,717	2,258	0	0	0	0	13,921	19,407	36,794	29,304	23,247	16,337	156,985
21	2,609	1,320	0	0	0	0	1,941	3,775	7,916	8,375	7,812	5,489	39,237
22	3,146	1,016	0	0	0	0	3,174	5,899	7,817	6,101	5,555	4,384	37,092
23	16	9	0	0	0	1	323	834	541	491	410	28	2,653
24	121	22	0	0	0	0	92	125	245	202	188	142	1,137
25	6,121	398	0	0	0	0	5,693	9,604	21,829	21,695	17,827	12,201	95,368
26	5,808	1,892	0	0	0	0	4,895	13,957	19,410	23,449	23,044	14,381	106,836
27	15,882	2,665	0	0	0	0	15,022	17,223	39,046	36,389	27,622	18,025	171,874
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	211	19	0	0	0	0	118	261	446	422	392	310	2,179
30	2,057	185	0	0	0	0	1,136	2,619	4,445	4,409	4,274	3,229	22,354
31	132	26	0	0	0	0	106	149	271	240	223	162	1,309
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	60	15	0	0	0	0	38	55	134	147	143	108	700
34	35	15	0	0	0	0	25	50	75	81	79	66	426
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	2,145	281	0	0	0	0	895	2,192	5,766	6,589	6,273	5,069	29,210
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	403	100	0	0	0	0	321	485	891	905	852	614	4,571
39	1	0	0	0	0	0	2	4	10	15	12	5	49
40	967	387	0	0	0	0	856	1,618	2,200	1,986	1,856	1,557	11,427
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	1,950	827	0	0	0	0	1,578	2,987	4,212	4,232	4,037	3,370	23,193
43	350	130	0	0	0	0	263	496	671	619	613	504	3,646
44	1,816	647	0	0	0	0	1,378	2,685	3,718	3,466	3,435	2,779	19,924
45	398	114	0	0	0	0	378	731	944	731	699	482	4,477
46	140	54	0	0	0	0	136	246	320	258	236	201	1,591
47	19,526	5,151	0	0	0	0	17,380	34,664	44,234	36,160	34,756	26,546	218,417
48	2,809	648	0	0	0	0	2,653	5,261	6,869	4,972	4,608	3,453	31,273
49	711	102	0	0	0	0	706	1,025	1,594	981	833	575	6,527
50	3,122	934	0	0	0	0	2,708	5,218	6,801	5,714	5,522	4,294	34,313
51	281	98	0	0	0	0	241	455	623	552	502	369	3,121
52	5,151	1,402	0	0	0	0	4,623	8,777	11,156	8,674	8,328	6,397	54,508
53	0	0	0	0	0	0	939	2,421	1,333	1,333	1,115	0	7,141
54	0	0	0	0	0	0	3,300	8,507	4,625	4,693	3,664	0	24,788
55	0	0	0	0	0	0	325	837	461	461	386	0	2,469
56	0	0	0	0	0	0	7,550	19,512	10,635	10,757	7,790	0	56,244
57	0	0	0	0	0	0	22,152	56,988	31,050	31,429	22,720	0	164,338
59	1,233	360	0	0	0	0	825	1,758	3,379	3,890	3,744	2,723	17,912
60	2,218	460	0	0	0	0	1,588	3,261	5,268	5,535	5,480	3,690	27,500
61	3,086	1,474	0	0	0	0	3,638	6,096	13,700	16,096	15,170	9,410	68,670
62	0	0	0	0	0	0	51	132	73	73	62	0	391
63	7,492	630	0	0	0	0	4,400	9,343	16,284	15,961	14,843	11,045	79,998
64	13	5	0	0	0	0	10	20	29	28	27	22	154
65	1,267	583	0	0	0	0	972	1,825	2,619	2,811	2,704	2,298	15,079
66	14,340	3,028	0	0	0	0	12,745	20,111	33,427	28,064	26,351	18,486	156,552
67	10,978	1,668	0	0	0	0	12,643	25,202	30,053	18,166	15,715	10,095	124,520
Total	153,021	36,832	30	0	0	123	171,955	340,081	454,097	419,455	371,692	231,042	2,178,328

Appendix Table 7 Quantity of Intake Water (Surface Water, 2006, Scenario-2)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	294	213	0	0	0	0	315	603	974	896	839	629	4,763
2	2,056	310	0	0	0	0	753	2,764	6,348	7,608	7,448	5,178	32,465
3	1,059	1,087	0	0	0	0	1,573	2,890	4,954	4,540	4,096	2,550	22,749
4	2,503	343	0	0	0	0	1,536	3,853	6,889	7,502	7,416	4,645	34,687
5	9,148	1,231	0	0	0	0	6,998	18,714	29,976	35,988	35,442	16,483	153,980
6	1,182	1,085	0	0	0	0	1,441	3,731	6,877	7,718	7,201	3,881	33,116
7	109	20	0	0	0	0	56	143	305	362	353	253	1,601
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,768	376	0	0	0	0	2,726	5,805	9,052	9,194	7,904	3,591	41,416
10	6,417	1,411	0	0	0	0	3,800	8,435	15,026	18,895	19,050	12,986	86,020
11	3,175	1,462	0	0	0	0	3,866	7,592	15,057	14,443	13,504	7,805	66,904
12	396	96	0	0	0	0	234	542	1,085	1,263	1,230	896	5,742
13	279	62	0	0	0	0	172	349	694	819	801	598	3,774
14	105	41	0	0	0	0	82	160	288	310	298	221	1,505
15	9	4	0	0	0	0	10	26	55	70	58	28	260
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	14,980	3,743	0	0	0	0	13,948	26,022	41,032	34,170	31,259	23,620	188,774
18	7,938	1,416	0	0	0	0	6,542	12,753	18,862	15,599	14,785	9,747	87,642
19	113	48	0	0	1	6	20,531	52,903	29,300	29,291	24,647	163	157,003
20	12,317	1,770	0	0	0	0	10,910	15,210	28,836	22,965	18,218	12,804	123,030
21	3,796	1,919	0	0	0	0	2,823	5,492	11,514	12,183	11,363	7,985	57,075
22	3,461	1,118	0	0	0	0	3,492	6,490	8,601	6,713	6,112	4,824	40,811
23	27	15	0	0	0	1	523	1,348	874	794	662	46	4,290
24	1,336	243	0	0	0	0	1,024	1,391	2,713	2,239	2,085	1,576	12,607
25	532	35	0	0	0	0	495	834	1,897	1,885	1,549	1,060	8,287
26	1,846	601	0	0	0	0	1,556	4,436	6,169	7,452	7,324	4,570	33,954
27	12,421	2,085	0	0	0	0	11,749	13,469	30,536	28,458	21,602	14,096	134,416
28	415	114	0	0	0	0	248	357	940	1,140	1,102	829	5,145
29	945	85	0	0	0	0	529	1,166	1,993	1,889	1,754	1,385	9,746
30	7,420	668	0	0	0	0	4,099	9,449	16,035	15,905	15,419	11,646	80,641
31	1,354	261	0	0	0	0	1,090	1,527	2,776	2,456	2,282	1,659	13,405
32	63	56	0	0	0	0	81	146	220	165	121	96	948
33	873	218	0	0	0	0	558	800	1,938	2,131	2,076	1,564	10,158
34	1,242	533	0	0	0	0	906	1,796	2,688	2,901	2,816	2,345	15,227
35	967	362	0	0	0	0	902	1,739	2,335	2,056	1,971	1,528	11,860
36	1,047	137	0	0	0	0	437	1,070	2,814	3,216	3,062	2,474	14,257
37	1,556	646	0	0	0	0	1,292	2,481	3,496	3,436	3,260	2,721	18,888
38	530	132	0	0	0	0	422	637	1,173	1,191	1,120	808	6,013
39	3	1	0	0	0	0	4	9	29	43	34	15	138
40	1,382	554	0	0	0	0	1,224	2,314	3,145	2,839	2,653	2,226	16,337
41	1,907	807	0	0	0	0	1,666	3,066	4,133	3,875	3,663	3,077	22,194
42	900	382	0	0	0	0	729	1,379	1,945	1,954	1,864	1,556	10,709
43	351	131	0	0	0	0	264	498	673	621	615	505	3,658
44	1,917	683	0	0	0	0	1,454	2,833	3,923	3,658	3,625	2,933	21,026
45	53	15	0	0	0	0	50	97	125	97	93	64	594
46	98	38	0	0	0	0	95	172	224	181	165	140	1,113
47	6,619	1,746	0	0	0	0	5,892	11,751	14,996	12,258	11,783	8,999	74,044
48	2,033	469	0	0	0	0	1,920	3,808	4,972	3,599	3,335	2,499	22,635
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1,070	320	0	0	0	0	928	1,789	2,331	1,958	1,893	1,472	11,761
51	305	106	0	0	0	0	261	493	675	599	544	400	3,383
52	421	115	0	0	0	0	378	717	912	709	681	523	4,456
53	0	0	0	0	0	0	2,581	6,658	3,666	3,666	3,067	0	19,637
54	0	0	0	0	0	0	7,863	20,266	11,019	11,179	8,728	0	59,055
55	0	0	0	0	0	0	5,355	13,810	7,604	7,604	6,361	0	40,734
56	0	0	0	0	0	0	21,660	55,980	30,510	30,860	22,350	0	161,360
57	0	0	0	0	0	0	2,340	6,020	3,280	3,320	2,400	0	17,360
59	3,477	1,016	0	0	0	0	2,325	4,957	9,525	10,966	10,555	7,675	50,496
60	13,555	2,812	0	0	0	0	9,705	19,931	32,198	33,830	33,495	22,552	168,078
61	8,044	3,840	0	0	0	0	9,482	15,886	35,703	41,946	39,535	24,522	178,958
62	0	0	0	0	0	0	480	1,239	686	685	580	0	3,670
63	5,263	442	0	0	0	0	3,091	6,563	11,438	11,211	10,426	7,758	56,192
64	1,240	481	0	0	0	0	968	1,896	2,748	2,673	2,549	2,127	14,682
65	612	282	0	0	0	0	470	882	1,266	1,358	1,307	1,110	7,287
66	330	70	0	0	0	0	294	463	770	647	607	426	3,607
67	18	3	0	0	0	0	21	42	50	30	26	17	207
Total	154,277	38,259	0	0	1	7	189,219	400,641	502,868	500,209	453,163	257,886	2,496,530

Appendix Table 8 Quantity of Intake Water (Ground Water, 2006, Scenario-2)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	993	720	0	0	0	0	1,063	2,033	3,288	3,023	2,830	2,123	16,073
2	1,223	185	0	0	0	0	448	1,643	3,776	4,524	4,430	3,080	19,309
3	1,744	1,791	0	0	0	0	2,593	4,763	8,162	7,480	6,748	4,201	37,482
4	1,254	172	0	0	0	0	770	1,931	3,452	3,760	3,717	2,328	17,384
5	1,605	216	0	0	0	0	1,228	3,283	5,258	6,313	6,217	2,891	27,011
6	1,614	1,480	0	0	0	0	1,966	5,092	9,384	10,532	9,828	5,296	45,192
7	126	23	0	0	0	0	64	165	351	417	407	292	1,845
8	2,625	514	30	0	0	122	1,631	3,556	6,029	7,451	7,273	4,828	34,059
9	561	76	0	0	0	0	552	1,176	1,833	1,862	1,601	727	8,388
10	38	8	0	0	0	0	23	50	89	112	113	77	510
11	2,367	1,090	0	0	0	0	2,882	5,660	11,226	10,768	10,068	5,819	49,880
12	263	64	0	0	0	0	156	359	720	838	817	595	3,812
13	185	41	0	0	0	0	114	232	461	543	532	397	2,505
14	2	1	0	0	0	0	2	4	6	7	7	5	34
15	1	0	0	0	0	0	1	3	6	8	6	3	28
16	13	19	0	0	0	0	12	21	21	20	13	0	119
17	5,875	1,468	0	0	0	0	5,470	10,206	16,092	13,401	12,259	9,263	74,034
18	214	38	0	0	0	0	176	344	509	421	399	263	2,364
19	6	3	0	0	0	0	1,065	2,745	1,520	1,520	1,279	8	8,146
20	15,717	2,258	0	0	0	0	13,921	19,407	36,794	29,304	23,247	16,337	156,985
21	2,609	1,320	0	0	0	0	1,941	3,775	7,916	8,375	7,812	5,489	39,237
22	3,146	1,016	0	0	0	0	3,174	5,899	7,817	6,101	5,555	4,384	37,092
23	16	9	0	0	0	1	323	834	541	491	410	28	2,653
24	121	22	0	0	0	0	92	125	245	202	188	142	1,137
25	6,121	398	0	0	0	0	5,693	9,604	21,829	21,695	17,827	12,201	95,368
26	5,808	1,892	0	0	0	0	4,895	13,957	19,410	23,449	23,044	14,381	106,836
27	15,882	2,665	0	0	0	0	15,022	17,223	39,046	36,389	27,622	18,025	171,874
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	211	19	0	0	0	0	118	261	446	422	392	310	2,179
30	2,057	185	0	0	0	0	1,136	2,619	4,445	4,409	4,274	3,229	22,354
31	132	26	0	0	0	0	106	149	271	240	223	162	1,309
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	60	15	0	0	0	0	38	55	134	147	143	108	700
34	35	15	0	0	0	0	25	50	75	81	79	66	426
35	11	4	0	0	0	0	10	19	25	22	21	17	129
36	2,145	281	0	0	0	0	895	2,192	5,766	6,589	6,273	5,069	29,210
37	2,359	979	0	0	0	0	1,958	3,761	5,299	5,208	4,941	4,123	28,628
38	403	100	0	0	0	0	321	485	891	905	852	614	4,571
39	1	0	0	0	0	0	2	4	10	15	12	5	49
40	967	387	0	0	0	0	856	1,618	2,200	1,986	1,856	1,557	11,427
41	2,378	1,006	0	0	0	0	2,078	3,824	5,155	4,833	4,568	3,837	27,679
42	1,950	827	0	0	0	0	1,578	2,987	4,212	4,232	4,037	3,370	23,193
43	350	130	0	0	0	0	263	496	671	619	613	504	3,646
44	1,816	647	0	0	0	0	1,378	2,685	3,718	3,466	3,435	2,779	19,924
45	398	114	0	0	0	0	378	731	944	731	699	482	4,477
46	140	54	0	0	0	0	136	246	320	258	236	201	1,591
47	19,526	5,151	0	0	0	0	17,380	34,664	44,234	36,160	34,756	26,546	218,417
48	2,809	648	0	0	0	0	2,653	5,261	6,869	4,972	4,608	3,453	31,273
49	711	102	0	0	0	0	706	1,025	1,594	981	833	575	6,527
50	3,122	934	0	0	0	0	2,708	5,218	6,801	5,714	5,522	4,294	34,313
51	281	98	0	0	0	0	241	455	623	552	502	369	3,121
52	5,151	1,402	0	0	0	0	4,623	8,777	11,156	8,674	8,328	6,397	54,508
53	0	0	0	0	0	0	939	2,421	1,333	1,333	1,115	0	7,141
54	0	0	0	0	0	0	3,300	8,507	4,625	4,693	3,664	0	24,788
55	0	0	0	0	0	0	325	837	461	461	386	0	2,469
56	0	0	0	0	0	0	7,550	19,512	10,635	10,757	7,790	0	56,244
57	0	0	0	0	0	0	22,152	56,988	31,050	31,429	22,720	0	164,338
59	1,233	360	0	0	0	0	825	1,758	3,379	3,890	3,744	2,723	17,912
60	2,218	460	0	0	0	0	1,588	3,261	5,268	5,535	5,480	3,690	27,500
61	3,086	1,474	0	0	0	0	3,638	6,096	13,700	16,096	15,170	9,410	68,670
62	0	0	0	0	0	0	51	132	73	73	62	0	391
63	7,492	630	0	0	0	0	4,400	9,343	16,284	15,961	14,843	11,045	79,998
64	13	5	0	0	0	0	10	20	29	28	27	22	154
65	1,267	583	0	0	0	0	972	1,825	2,619	2,811	2,704	2,298	15,079
66	15,017	3,171	0	0	0	0	13,347	21,060	35,005	29,389	27,595	19,359	163,943
67	10,978	1,668	0	0	0	0	12,643	25,202	30,053	18,166	15,715	10,095	124,520
Total	158,446	38,964	30	0	0	123	176,603	348,634	466,154	430,843	382,466	239,892	2,242,155

Appendix Table 9 Quantity of Intake Water (Surface Water, 2016, Scenario-2)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	244	176	0	0	0	0	260	499	809	746	699	523	3,956
2	1,773	256	0	0	0	0	622	2,383	5,516	6,625	6,488	4,499	28,162
3	412	417	0	0	0	0	604	1,119	1,927	1,775	1,604	1,000	8,858
4	2,063	274	0	0	0	0	1,231	3,153	5,716	6,282	6,219	3,899	28,837
5	7,438	985	0	0	0	0	5,601	15,116	24,447	29,427	29,005	13,577	125,596
6	513	453	0	0	0	0	602	1,585	2,945	3,314	3,097	1,680	14,189
7	92	17	0	0	0	0	46	122	261	310	302	216	1,366
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,234	300	0	0	0	0	2,182	4,668	7,307	7,444	6,415	2,934	33,484
10	5,204	1,129	0	0	0	0	3,041	6,816	12,234	15,410	15,539	10,589	69,962
11	1,707	784	0	0	0	0	2,073	4,081	8,104	7,786	7,283	4,208	36,026
12	331	79	0	0	0	0	194	455	916	1,068	1,041	756	4,840
13	232	52	0	0	0	0	142	291	581	686	671	500	3,155
14	86	34	0	0	0	0	68	133	239	259	248	184	1,251
15	7	3	0	0	0	0	9	22	47	60	49	24	221
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	12,043	2,995	0	0	0	0	11,163	20,897	33,024	27,568	25,235	19,072	151,997
18	6,383	1,133	0	0	0	0	5,235	10,246	15,226	12,664	12,017	7,909	70,813
19	105	43	0	0	1	5	16,945	43,657	24,195	24,189	20,355	150	129,645
20	8,894	1,262	0	0	0	0	7,786	10,954	21,042	16,948	13,551	9,513	89,950
21	3,297	1,578	0	0	0	0	2,339	4,602	9,750	10,415	9,744	6,876	48,601
22	2,782	895	0	0	0	0	2,795	5,221	6,952	5,451	4,968	3,909	32,973
23	23	13	0	0	0	1	431	1,113	722	657	547	39	3,546
24	1,016	182	0	0	0	0	769	1,056	2,092	1,747	1,630	1,227	9,719
25	421	27	0	0	0	0	385	661	1,508	1,506	1,243	850	6,601
26	1,496	481	0	0	0	0	1,247	3,588	5,026	6,065	5,959	3,726	27,588
27	9,372	1,564	0	0	0	0	8,816	10,160	23,155	21,645	16,496	10,771	101,979
28	317	85	0	0	0	0	186	273	727	882	853	639	3,962
29	713	64	0	0	0	0	397	882	1,518	1,443	1,343	1,057	7,417
30	3,836	343	0	0	0	0	2,106	4,901	8,392	8,344	8,097	6,102	42,121
31	1,026	196	0	0	0	0	817	1,156	2,128	1,898	1,766	1,281	10,268
32	50	45	0	0	0	0	66	117	176	132	98	77	761
33	667	164	0	0	0	0	420	613	1,506	1,661	1,619	1,214	7,864
34	1,000	426	0	0	0	0	725	1,446	2,176	2,350	2,281	1,896	12,300
35	775	290	0	0	0	0	721	1,400	1,896	1,677	1,607	1,239	9,605
36	850	106	0	0	0	0	342	871	2,318	2,653	2,528	2,043	11,711
37	1,454	597	0	0	0	0	1,195	2,313	3,288	3,245	3,079	2,565	17,736
38	415	102	0	0	0	0	327	502	938	959	904	646	4,793
39	2	0	0	0	0	0	3	7	22	33	26	11	104
40	1,291	512	0	0	0	0	1,132	2,156	2,953	2,678	2,504	2,097	15,323
41	612	258	0	0	0	0	533	984	1,333	1,252	1,184	993	7,149
42	840	353	0	0	0	0	674	1,285	1,825	1,839	1,754	1,462	10,032
43	328	121	0	0	0	0	244	463	631	585	580	475	3,427
44	1,796	631	0	0	0	0	1,346	2,657	3,734	3,519	3,493	2,818	19,994
45	50	14	0	0	0	0	46	91	119	93	89	62	564
46	91	35	0	0	0	0	88	160	209	169	155	132	1,039
47	5,843	1,536	0	0	0	0	5,185	10,360	13,252	10,860	10,442	7,975	65,453
48	1,921	434	0	0	0	0	1,778	3,578	4,756	3,531	3,293	2,469	21,760
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	992	296	0	0	0	0	858	1,657	2,165	1,823	1,762	1,370	10,923
51	285	98	0	0	0	0	242	459	631	562	511	376	3,164
52	393	106	0	0	0	0	351	669	856	671	645	495	4,186
53	0	0	0	0	0	0	2,258	5,825	3,207	3,207	2,684	0	17,183
54	0	0	0	0	0	0	6,880	17,733	9,642	9,782	7,637	0	51,673
55	0	0	0	0	0	0	4,686	12,084	6,654	6,654	5,566	0	35,642
56	0	0	0	0	0	0	18,953	48,983	26,696	27,003	19,556	0	141,190
57	0	0	0	0	0	0	2,048	5,268	2,870	2,905	2,100	0	15,190
59	2,893	838	0	0	0	0	1,918	4,134	7,979	9,196	8,853	6,425	42,236
60	8,876	1,825	0	0	0	0	6,301	13,027	21,179	22,341	22,131	14,884	110,564
61	6,967	3,189	0	0	0	0	7,891	13,442	30,344	35,763	33,760	21,041	152,397
62	0	0	0	0	0	0	395	1,020	564	564	477	0	3,020
63	3,970	332	0	0	0	0	2,319	4,964	8,711	8,557	7,970	5,920	42,743
64	1,000	385	0	0	0	0	774	1,528	2,228	2,172	2,072	1,726	11,885
65	569	261	0	0	0	0	434	818	1,179	1,267	1,219	1,035	6,782
66	267	56	0	0	0	0	235	376	639	546	515	357	2,991
67	18	3	0	0	0	0	20	41	49	30	26	17	204
Total	118,275	28,833	0	0	1	6	149,479	320,840	393,231	392,892	355,584	199,530	1,958,671

Appendix Table 10 Quantity of Intake Water (Ground Water, 2016, Scenario-2)

Reach	Meh. Oct.	Sha. Nov.	Mor. Dec.	Tir Jan.	Kho. Feb.	Ord. Mar.	Far. Apr	Esf. May.	Bah. Jun.	Dey Jul.	Aza. Aug.	Aba. Sep.	Total
1	823	594	0	0	0	0	877	1,686	2,735	2,522	2,361	1,768	13,366
2	1,055	153	0	0	0	0	370	1,418	3,283	3,942	3,861	2,677	16,759
3	1,462	1,478	0	0	0	0	2,140	3,966	6,833	6,294	5,687	3,544	31,404
4	1,033	137	0	0	0	0	617	1,579	2,863	3,146	3,114	1,953	14,442
5	1,305	173	0	0	0	0	982	2,651	4,288	5,161	5,087	2,381	22,028
6	1,383	1,221	0	0	0	0	1,622	4,275	7,941	8,937	8,351	4,530	38,260
7	105	19	0	0	0	0	53	139	298	354	346	247	1,561
8	2,102	411	24	0	0	97	1,305	2,847	4,831	5,971	5,829	3,870	27,287
9	453	61	0	0	0	0	443	947	1,482	1,510	1,301	595	6,792
10	30	7	0	0	0	0	18	40	71	90	91	62	409
11	1,900	872	0	0	0	0	2,306	4,542	9,018	8,664	8,104	4,682	40,088
12	221	53	0	0	0	0	129	303	610	711	693	503	3,223
13	153	34	0	0	0	0	94	192	384	453	443	330	2,083
14	2	1	0	0	0	0	1	3	5	5	5	4	26
15	1	0	0	0	0	0	1	3	5	7	6	3	26
16	11	16	0	0	0	0	10	18	19	18	11	0	103
17	4,722	1,174	0	0	0	0	4,377	8,194	12,949	10,810	9,895	7,478	59,599
18	172	31	0	0	0	0	141	277	411	342	324	213	1,911
19	5	2	0	0	0	0	878	2,263	1,254	1,254	1,055	8	6,719
20	11,937	1,693	0	0	0	0	10,450	14,701	28,240	22,746	18,186	12,767	120,720
21	2,266	1,085	0	0	0	0	1,607	3,163	6,701	7,158	6,697	4,726	33,403
22	2,528	813	0	0	0	0	2,540	4,743	6,316	4,952	4,514	3,552	29,958
23	14	8	0	0	0	1	267	689	447	407	339	24	2,196
24	92	16	0	0	0	0	70	96	189	158	148	111	880
25	4,849	309	0	0	0	0	4,440	7,614	17,368	17,341	14,311	9,789	76,021
26	4,708	1,514	0	0	0	0	3,923	11,289	15,815	19,083	18,750	11,723	86,805
27	11,983	1,999	0	0	0	0	11,272	12,990	29,605	27,675	21,091	13,771	130,386
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	160	14	0	0	0	0	89	198	340	323	301	237	1,662
30	1,554	139	0	0	0	0	853	1,986	3,400	3,381	3,281	2,472	17,066
31	101	19	0	0	0	0	80	113	209	186	173	126	1,007
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	45	11	0	0	0	0	29	42	103	113	110	83	536
34	28	12	0	0	0	0	20	40	60	65	63	52	340
35	9	3	0	0	0	0	8	16	22	19	19	14	110
36	1,743	218	0	0	0	0	702	1,785	4,754	5,440	5,183	4,189	24,014
37	2,205	905	0	0	0	0	1,812	3,509	4,987	4,922	4,671	3,891	26,902
38	315	78	0	0	0	0	249	382	714	730	688	492	3,648
39	1	0	0	0	0	0	1	3	9	14	11	5	44
40	903	358	0	0	0	0	792	1,508	2,066	1,873	1,752	1,467	10,719
41	2,211	931	0	0	0	0	1,924	3,554	4,813	4,522	4,275	3,587	25,817
42	1,822	765	0	0	0	0	1,461	2,785	3,956	3,987	3,803	3,170	21,749
43	328	121	0	0	0	0	244	463	631	585	580	475	3,427
44	1,701	598	0	0	0	0	1,276	2,518	3,538	3,334	3,309	2,670	18,944
45	373	106	0	0	0	0	350	684	894	703	674	466	4,250
46	131	50	0	0	0	0	126	229	299	242	222	188	1,487
47	18,122	4,764	0	0	0	0	16,080	32,130	41,099	33,679	32,385	24,733	202,992
48	2,652	600	0	0	0	0	2,455	4,941	6,568	4,876	4,547	3,409	30,048
49	555	79	0	0	0	0	547	805	1,274	808	693	471	5,232
50	2,898	865	0	0	0	0	2,506	4,839	6,321	5,323	5,146	4,001	31,899
51	262	90	0	0	0	0	223	422	580	517	471	346	2,911
52	4,799	1,296	0	0	0	0	4,280	8,166	10,446	8,187	7,870	6,041	51,085
53	0	0	0	0	0	0	821	2,118	1,166	1,166	976	0	6,248
54	0	0	0	0	0	0	2,888	7,443	4,047	4,106	3,206	0	21,690
55	0	0	0	0	0	0	284	732	403	403	337	0	2,160
56	0	0	0	0	0	0	6,606	17,073	9,305	9,412	6,817	0	49,213
57	0	0	0	0	0	0	19,383	49,865	27,169	27,500	19,880	0	143,796
59	1,026	297	0	0	0	0	681	1,467	2,831	3,263	3,141	2,279	14,985
60	1,790	368	0	0	0	0	1,271	2,628	4,272	4,506	4,464	3,002	22,301
61	2,673	1,223	0	0	0	0	3,027	5,157	11,642	13,721	12,952	8,073	58,468
62	0	0	0	0	0	0	43	111	62	62	52	0	330
63	5,654	472	0	0	0	0	3,303	7,069	12,405	12,185	11,350	8,431	60,869
64	11	4	0	0	0	0	8	16	24	23	22	18	126
65	1,179	540	0	0	0	0	899	1,696	2,444	2,626	2,527	2,145	14,056
66	12,142	2,537	0	0	0	0	10,685	17,130	29,110	24,886	23,452	16,242	136,184
67	10,208	1,543	0	0	0	0	11,697	23,381	27,992	17,054	14,793	9,530	116,198
Total	132,916	32,880	24	0	0	98	148,636	297,633	393,917	364,454	324,795	203,616	1,898,968

Appendix Table 11 Quantity of Intake Water (Surface Water, 2031, Scenario-2)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr	May.	Jun.	Jul.	Aug.	Sep.	
1	195	141	0	0	0	0	208	399	647	597	559	418	3,164
2	1,418	205	0	0	0	0	497	1,906	4,413	5,300	5,191	3,599	22,529
3	23	23	0	0	0	0	33	61	105	97	88	55	485
4	1,650	219	0	0	0	0	985	2,522	4,573	5,025	4,975	3,119	23,068
5	5,950	788	0	0	0	0	4,480	12,092	19,558	23,542	23,204	10,862	100,476
6	410	362	0	0	0	0	481	1,268	2,356	2,651	2,478	1,344	11,350
7	74	13	0	0	0	0	37	97	209	248	242	173	1,093
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1,787	240	0	0	0	0	1,746	3,735	5,845	5,955	5,132	2,347	26,787
10	4,163	903	0	0	0	0	2,433	5,453	9,787	12,328	12,431	8,471	55,969
11	1,366	627	0	0	0	0	1,658	3,265	6,483	6,229	5,826	3,366	28,820
12	265	64	0	0	0	0	155	364	733	855	833	604	3,873
13	185	41	0	0	0	0	114	233	465	548	536	400	2,522
14	69	27	0	0	0	0	54	107	191	207	199	147	1,001
15	6	2	0	0	0	0	7	18	37	48	39	20	177
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	5,867	1,459	0	0	0	0	5,438	10,180	16,088	13,430	12,293	9,291	74,046
18	5,106	906	0	0	0	0	4,188	8,196	12,180	10,132	9,613	6,327	56,648
19	84	34	0	0	0	4	13,556	34,926	19,356	19,351	16,284	120	103,715
20	6,924	982	0	0	0	0	6,061	8,527	16,380	13,193	10,548	7,405	70,020
21	1,988	952	0	0	0	0	1,411	2,775	5,880	6,281	5,877	4,147	29,311
22	2,225	716	0	0	0	0	2,236	4,176	5,561	4,360	3,974	3,127	26,375
23	18	10	0	0	0	1	345	890	578	525	438	31	2,836
24	813	146	0	0	0	0	615	844	1,673	1,398	1,304	982	7,775
25	337	21	0	0	0	0	308	529	1,206	1,204	994	680	5,279
26	1,197	385	0	0	0	0	997	2,870	4,021	4,852	4,767	2,980	22,069
27	7,321	1,221	0	0	0	0	6,886	7,936	18,087	16,908	12,886	8,414	79,659
28	253	68	0	0	0	0	149	218	582	706	682	511	3,169
29	570	51	0	0	0	0	317	705	1,215	1,155	1,074	846	5,933
30	2,158	193	0	0	0	0	1,185	2,757	4,721	4,695	4,556	3,433	23,698
31	821	157	0	0	0	0	654	925	1,703	1,518	1,413	1,024	8,215
32	40	36	0	0	0	0	52	93	141	106	78	62	608
33	533	131	0	0	0	0	336	490	1,205	1,329	1,295	971	6,290
34	800	341	0	0	0	0	580	1,157	1,741	1,880	1,825	1,517	9,841
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	680	85	0	0	0	0	274	697	1,855	2,122	2,022	1,634	9,369
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	332	82	0	0	0	0	262	401	750	768	723	517	3,835
39	1	0	0	0	0	0	2	5	17	26	21	9	81
40	1,032	410	0	0	0	0	906	1,725	2,363	2,143	2,003	1,678	12,260
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	672	282	0	0	0	0	539	1,028	1,460	1,471	1,403	1,170	8,025
43	262	97	0	0	0	0	195	371	505	468	464	380	2,742
44	1,436	505	0	0	0	0	1,077	2,126	2,987	2,815	2,794	2,254	15,994
45	40	11	0	0	0	0	37	73	95	75	72	49	452
46	73	28	0	0	0	0	70	128	167	135	124	105	830
47	4,675	1,229	0	0	0	0	4,148	8,288	10,601	8,688	8,354	6,380	52,363
48	1,537	347	0	0	0	0	1,422	2,863	3,805	2,825	2,634	1,975	17,408
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	794	237	0	0	0	0	687	1,326	1,732	1,458	1,410	1,096	8,740
51	228	78	0	0	0	0	194	367	505	450	409	301	2,532
52	314	85	0	0	0	0	280	535	684	536	516	396	3,346
53	0	0	0	0	0	0	1,971	5,084	2,799	2,799	2,342	0	14,996
54	0	0	0	0	0	0	6,004	15,476	8,414	8,537	6,665	0	45,096
55	0	0	0	0	0	0	4,089	10,546	5,807	5,807	4,857	0	31,106
56	0	0	0	0	0	0	16,540	42,748	23,299	23,566	17,067	0	123,220
57	0	0	0	0	0	0	1,787	4,597	2,505	2,535	1,833	0	13,257
59	2,314	670	0	0	0	0	1,535	3,307	6,383	7,357	7,082	5,140	33,788
60	7,101	1,460	0	0	0	0	5,041	10,422	16,943	17,873	17,705	11,907	88,452
61	5,407	2,475	0	0	0	0	6,125	10,433	23,551	27,757	26,202	16,331	118,281
62	0	0	0	0	0	0	316	816	451	451	382	0	2,416
63	3,176	265	0	0	0	0	1,856	3,971	6,969	6,846	6,376	4,736	34,195
64	800	308	0	0	0	0	619	1,222	1,783	1,738	1,658	1,380	9,508
65	455	208	0	0	0	0	347	655	944	1,014	976	828	5,427
66	0	0	0	0	0	0	0	0	0	0	0	0	0
67	14	2	0	0	0	0	16	32	39	24	21	13	161
Total	85,959	20,328	0	0	0	5	114,542	248,956	295,133	296,937	267,750	145,072	1,474,681

Appendix Table 12 Quantity of Intake Water (Ground Water, 2031, Scenario-2)

Reach	Meh. **Oct.**	Sha. **Nov.**	Mor. **Dec.**	Tir **Jan.**	Kho. **Feb.**	Ord. **Mar.**	Far. **Apr**	Esf. **May.**	Bah. **Jun.**	Dey **Jul.**	Aza. **Aug.**	Aba. **Sep.**	Total
1	659	475	0	0	0	0	702	1,349	2,188	2,017	1,889	1,414	10,693
2	844	122	0	0	0	0	296	1,135	2,626	3,154	3,089	2,142	13,408
3	1,170	1,182	0	0	0	0	1,712	3,173	5,466	5,035	4,550	2,835	25,123
4	826	110	0	0	0	0	493	1,263	2,290	2,517	2,491	1,562	11,552
5	1,044	138	0	0	0	0	786	2,121	3,430	4,129	4,070	1,905	17,623
6	1,107	977	0	0	0	0	1,298	3,420	6,353	7,150	6,681	3,624	30,610
7	84	15	0	0	0	0	42	111	239	283	277	198	1,249
8	1,681	329	20	0	0	78	1,044	2,278	3,864	4,777	4,663	3,096	21,830
9	362	49	0	0	0	0	354	757	1,185	1,208	1,041	476	5,432
10	24	5	0	0	0	0	14	32	57	72	73	49	326
11	1,520	698	0	0	0	0	1,845	3,633	7,215	6,931	6,483	3,746	32,071
12	176	42	0	0	0	0	103	242	488	569	554	402	2,576
13	122	27	0	0	0	0	75	154	307	362	354	264	1,665
14	1	1	0	0	0	0	1	2	4	4	4	3	20
15	1	0	0	0	0	0	1	2	4	6	5	2	21
16	9	13	0	0	0	0	8	15	15	14	9	0	83
17	3,778	939	0	0	0	0	3,502	6,555	10,360	8,648	7,916	5,983	47,681
18	138	24	0	0	0	0	113	221	329	273	259	171	1,528
19	4	2	0	0	0	0	703	1,810	1,003	1,003	844	6	5,375
20	9,549	1,355	0	0	0	0	8,360	11,761	22,592	18,197	14,549	10,213	96,576
21	1,813	868	0	0	0	0	1,286	2,530	5,361	5,726	5,358	3,781	26,723
22	2,022	650	0	0	0	0	2,032	3,795	5,053	3,962	3,611	2,841	23,966
23	11	6	0	0	0	1	214	551	358	325	271	19	1,756
24	74	13	0	0	0	0	56	76	152	127	118	89	705
25	3,880	247	0	0	0	0	3,552	6,091	13,894	13,872	11,449	7,831	60,816
26	3,766	1,211	0	0	0	0	3,138	9,031	12,652	15,267	15,000	9,378	69,443
27	9,586	1,599	0	0	0	0	9,017	10,392	23,684	22,140	16,873	11,017	104,308
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	128	11	0	0	0	0	71	158	272	259	241	190	1,330
30	1,244	111	0	0	0	0	683	1,589	2,720	2,705	2,625	1,978	13,655
31	80	15	0	0	0	0	64	91	167	149	139	100	805
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	36	9	0	0	0	0	23	33	82	91	88	66	428
34	22	9	0	0	0	0	16	32	48	52	50	42	271
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	1,394	174	0	0	0	0	561	1,428	3,803	4,352	4,146	3,351	19,209
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	252	62	0	0	0	0	199	305	571	584	551	393	2,917
39	1	0	0	0	0	0	1	2	7	11	9	4	35
40	722	287	0	0	0	0	634	1,207	1,653	1,499	1,401	1,174	8,577
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	1,458	612	0	0	0	0	1,169	2,228	3,165	3,189	3,043	2,536	17,400
43	262	97	0	0	0	0	195	371	505	468	464	380	2,742
44	1,361	479	0	0	0	0	1,021	2,014	2,830	2,667	2,647	2,136	15,155
45	298	84	0	0	0	0	280	547	715	562	539	372	3,397
46	104	40	0	0	0	0	101	183	239	194	178	151	1,190
47	14,498	3,811	0	0	0	0	12,864	25,704	32,879	26,943	25,908	19,786	162,393
48	2,122	480	0	0	0	0	1,964	3,953	5,254	3,901	3,637	2,727	24,038
49	444	63	0	0	0	0	438	644	1,019	646	554	377	4,185
50	2,318	692	0	0	0	0	2,005	3,871	5,057	4,258	4,117	3,201	25,519
51	209	72	0	0	0	0	178	338	464	414	376	277	2,328
52	3,839	1,037	0	0	0	0	3,424	6,533	8,357	6,550	6,296	4,833	40,869
53	0	0	0	0	0	0	717	1,849	1,018	1,018	852	0	5,453
54	0	0	0	0	0	0	2,520	6,496	3,532	3,583	2,798	0	18,929
55	0	0	0	0	0	0	248	639	352	352	294	0	1,885
56	0	0	0	0	0	0	5,765	14,900	8,121	8,214	5,949	0	42,950
57	0	0	0	0	0	0	16,916	43,518	23,711	24,000	17,349	0	125,494
59	821	238	0	0	0	0	544	1,173	2,264	2,610	2,512	1,824	11,986
60	1,432	294	0	0	0	0	1,017	2,102	3,418	3,605	3,571	2,402	17,841
61	2,138	979	0	0	0	0	2,422	4,126	9,314	10,977	10,362	6,458	46,776
62	0	0	0	0	0	0	35	89	49	49	42	0	264
63	4,523	378	0	0	0	0	2,642	5,655	9,924	9,748	9,080	6,745	48,695
64	9	3	0	0	0	0	7	13	19	19	18	15	103
65	943	432	0	0	0	0	719	1,357	1,955	2,101	2,021	1,716	11,244
66	9,276	1,938	0	0	0	0	8,163	13,086	22,238	19,011	17,916	12,408	104,036
67	8,167	1,235	0	0	0	0	9,358	18,705	22,394	13,643	11,834	7,624	92,960
Total	102,352	24,739	20	0	0	79	117,711	237,439	309,285	286,192	254,088	156,313	1,488,219

Appendix Table 13 Quantity of Intake Water (Surface Water, 2006, Scenario-3)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	294	213	0	0	0	0	315	603	974	896	839	629	4,763
2	2,056	310	0	0	0	0	753	2,764	6,348	7,608	7,448	5,178	32,465
3	1,059	1,087	0	0	0	0	1,573	2,890	4,954	4,540	4,096	2,550	22,749
4	2,503	343	0	0	0	0	1,536	3,853	6,889	7,502	7,416	4,645	34,687
5	9,148	1,231	0	0	0	0	6,998	18,714	29,976	35,988	35,442	16,483	153,980
6	1,182	1,085	0	0	0	0	1,441	3,731	6,877	7,718	7,201	3,881	33,116
7	109	20	0	0	0	0	56	143	305	362	353	253	1,601
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,768	376	0	0	0	0	2,726	5,805	9,052	9,194	7,904	3,591	41,416
10	6,417	1,411	0	0	0	0	3,800	8,435	15,026	18,895	19,050	12,986	86,020
11	3,175	1,462	0	0	0	0	3,866	7,592	15,057	14,443	13,504	7,805	66,904
12	396	96	0	0	0	0	234	542	1,085	1,263	1,230	896	5,742
13	279	62	0	0	0	0	172	349	694	819	801	598	3,774
14	105	41	0	0	0	0	82	160	288	310	298	221	1,505
15	9	4	0	0	0	0	10	26	55	70	58	28	260
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	14,980	3,743	0	0	0	0	13,948	26,022	41,032	34,170	31,259	23,620	188,774
18	7,938	1,416	0	0	0	0	6,542	12,753	18,862	15,599	14,785	9,747	87,642
19	113	48	0	0	1	6	20,531	52,903	29,300	29,291	24,647	163	157,003
20	12,317	1,770	0	0	0	0	10,910	15,210	28,836	22,965	18,218	12,804	123,030
21	3,796	1,919	0	0	0	0	2,823	5,492	11,514	12,183	11,363	7,985	57,075
22	3,461	1,118	0	0	0	0	3,492	6,490	8,601	6,713	6,112	4,824	40,811
23	27	15	0	0	0	1	523	1,348	874	794	662	46	4,290
24	1,336	243	0	0	0	0	1,024	1,391	2,713	2,239	2,085	1,576	12,607
25	532	35	0	0	0	0	495	834	1,897	1,885	1,549	1,060	8,287
26	1,846	601	0	0	0	0	1,556	4,436	6,169	7,452	7,324	4,570	33,954
27	12,421	2,085	0	0	0	0	11,749	13,469	30,536	28,458	21,602	14,096	134,416
28	415	114	0	0	0	0	248	357	940	1,140	1,102	829	5,145
29	945	85	0	0	0	0	529	1,166	1,993	1,889	1,754	1,385	9,746
30	7,420	668	0	0	0	0	4,099	9,449	16,035	15,905	15,419	11,646	80,641
31	1,354	261	0	0	0	0	1,090	1,527	2,776	2,456	2,282	1,659	13,405
32	63	56	0	0	0	0	81	146	220	165	121	96	948
33	873	218	0	0	0	0	558	800	1,938	2,131	2,076	1,564	10,158
34	1,242	533	0	0	0	0	906	1,796	2,688	2,901	2,816	2,345	15,227
35	967	362	0	0	0	0	902	1,739	2,335	2,056	1,971	1,528	11,860
36	1,047	137	0	0	0	0	437	1,070	2,814	3,216	3,062	2,474	14,257
37	1,556	646	0	0	0	0	1,292	2,481	3,496	3,436	3,260	2,721	18,888
38	530	132	0	0	0	0	422	637	1,173	1,191	1,120	808	6,013
39	3	1	0	0	0	0	4	9	29	43	34	15	138
40	1,382	554	0	0	0	0	1,224	2,314	3,145	2,839	2,653	2,226	16,337
41	1,907	807	0	0	0	0	1,666	3,066	4,133	3,875	3,663	3,077	22,194
42	900	382	0	0	0	0	729	1,379	1,945	1,954	1,864	1,556	10,709
43	351	131	0	0	0	0	264	498	673	621	615	505	3,658
44	1,917	683	0	0	0	0	1,454	2,833	3,923	3,658	3,625	2,933	21,026
45	53	15	0	0	0	0	50	97	125	97	93	64	594
46	98	38	0	0	0	0	95	172	224	181	165	140	1,113
47	6,619	1,746	0	0	0	0	5,892	11,751	14,996	12,258	11,783	8,999	74,044
48	2,033	469	0	0	0	0	1,920	3,808	4,972	3,599	3,335	2,499	22,635
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1,070	320	0	0	0	0	928	1,789	2,331	1,958	1,893	1,472	11,761
51	305	106	0	0	0	0	261	493	675	599	544	400	3,383
52	421	115	0	0	0	0	378	717	912	709	681	523	4,456
53	0	0	0	0	0	0	2,581	6,658	3,666	3,666	3,067	0	19,637
54	0	0	0	0	0	0	7,863	20,266	11,019	11,179	8,728	0	59,055
55	0	0	0	0	0	0	5,355	13,810	7,604	7,604	6,361	0	40,734
56	0	0	0	0	0	0	21,660	55,980	30,510	30,860	22,350	0	161,360
57	0	0	0	0	0	0	2,340	6,020	3,280	3,320	2,400	0	17,360
59	3,477	1,016	0	0	0	0	2,325	4,957	9,525	10,966	10,555	7,675	50,496
60	13,555	2,812	0	0	0	0	9,705	19,931	32,198	33,830	33,495	22,552	168,078
61	8,044	3,840	0	0	0	0	9,482	15,886	35,703	41,946	39,535	24,522	178,958
62	0	0	0	0	0	0	480	1,239	686	685	580	0	3,670
63	5,263	442	0	0	0	0	3,091	6,563	11,438	11,211	10,426	7,758	56,192
64	1,240	481	0	0	0	0	968	1,896	2,748	2,673	2,549	2,127	14,682
65	612	282	0	0	0	0	470	882	1,266	1,358	1,307	1,110	7,287
66	330	70	0	0	0	0	294	463	770	647	607	426	3,607
67	18	3	0	0	0	0	21	42	50	30	26	17	207
Total	154,277	38,259	0	0	1	7	189,219	400,641	502,868	500,209	453,163	257,886	2,496,530

Appendix Table 14 Quantity of Intake Water (Ground Water, 2006, Scenario-3)

Reach	Meh.	Sha.	Mor.	Tir	Kho.	Ord.	Far.	Esf.	Bah.	Dey	Aza.	Aba.	Total
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	
1	993	720	0	0	0	0	1,063	2,033	3,288	3,023	2,830	2,123	16,073
2	1,223	185	0	0	0	0	448	1,643	3,776	4,524	4,430	3,080	19,309
3	1,744	1,791	0	0	0	0	2,593	4,763	8,162	7,480	6,748	4,201	37,482
4	1,254	172	0	0	0	0	770	1,931	3,452	3,760	3,717	2,328	17,384
5	1,605	216	0	0	0	0	1,228	3,283	5,258	6,313	6,217	2,891	27,011
6	1,614	1,480	0	0	0	0	1,966	5,092	9,384	10,532	9,828	5,296	45,192
7	126	23	0	0	0	0	64	165	351	417	407	292	1,845
8	2,625	514	30	0	0	122	1,631	3,556	6,029	7,451	7,273	4,828	34,059
9	561	76	0	0	0	0	552	1,176	1,833	1,862	1,601	727	8,388
10	38	8	0	0	0	0	23	50	89	112	113	77	510
11	2,367	1,090	0	0	0	0	2,882	5,660	11,226	10,768	10,068	5,819	49,880
12	263	64	0	0	0	0	156	359	720	838	817	595	3,812
13	185	41	0	0	0	0	114	232	461	543	532	397	2,505
14	2	1	0	0	0	0	2	4	6	7	7	5	34
15	1	0	0	0	0	0	1	3	6	8	6	3	28
16	13	19	0	0	0	0	12	21	21	20	13	0	119
17	5,875	1,468	0	0	0	0	5,470	10,206	16,092	13,401	12,259	9,263	74,034
18	214	38	0	0	0	0	176	344	509	421	399	263	2,364
19	6	3	0	0	0	0	1,065	2,745	1,520	1,520	1,279	8	8,146
20	15,717	2,258	0	0	0	0	13,921	19,407	36,794	29,304	23,247	16,337	156,985
21	2,609	1,320	0	0	0	0	1,941	3,775	7,916	8,375	7,812	5,489	39,237
22	3,146	1,016	0	0	0	0	3,174	5,899	7,817	6,101	5,555	4,384	37,092
23	16	9	0	0	0	1	323	834	541	491	410	28	2,653
24	121	22	0	0	0	0	92	125	245	202	188	142	1,137
25	6,121	398	0	0	0	0	5,693	9,604	21,829	21,695	17,827	12,201	95,368
26	5,808	1,892	0	0	0	0	4,895	13,957	19,410	23,449	23,044	14,381	106,836
27	15,882	2,665	0	0	0	0	15,022	17,223	39,046	36,389	27,622	18,025	171,874
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	211	19	0	0	0	0	118	261	446	422	392	310	2,179
30	2,057	185	0	0	0	0	1,136	2,619	4,445	4,409	4,274	3,229	22,354
31	132	26	0	0	0	0	106	149	271	240	223	162	1,309
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	60	15	0	0	0	0	38	55	134	147	143	108	700
34	35	15	0	0	0	0	25	50	75	81	79	66	426
35	11	4	0	0	0	0	10	19	25	22	21	17	129
36	2,145	281	0	0	0	0	895	2,192	5,766	6,589	6,273	5,069	29,210
37	2,359	979	0	0	0	0	1,958	3,761	5,299	5,208	4,941	4,123	28,628
38	403	100	0	0	0	0	321	485	891	905	852	614	4,571
39	1	0	0	0	0	0	2	4	10	15	12	5	49
40	967	387	0	0	0	0	856	1,618	2,200	1,986	1,856	1,557	11,427
41	2,378	1,006	0	0	0	0	2,078	3,824	5,155	4,833	4,568	3,837	27,679
42	1,950	827	0	0	0	0	1,578	2,987	4,212	4,232	4,037	3,370	23,193
43	350	130	0	0	0	0	263	496	671	619	613	504	3,646
44	1,816	647	0	0	0	0	1,378	2,685	3,718	3,466	3,435	2,779	19,924
45	398	114	0	0	0	0	378	731	944	731	699	482	4,477
46	140	54	0	0	0	0	136	246	320	258	236	201	1,591
47	19,526	5,151	0	0	0	0	17,380	34,664	44,234	36,160	34,756	26,546	218,417
48	2,809	648	0	0	0	0	2,653	5,261	6,869	4,972	4,608	3,453	31,273
49	711	102	0	0	0	0	706	1,025	1,594	981	833	575	6,527
50	3,122	934	0	0	0	0	2,708	5,218	6,801	5,714	5,522	4,294	34,313
51	281	98	0	0	0	0	241	455	623	552	502	369	3,121
52	5,151	1,402	0	0	0	0	4,623	8,777	11,156	8,674	8,328	6,397	54,508
53	0	0	0	0	0	0	939	2,421	1,333	1,333	1,115	0	7,141
54	0	0	0	0	0	0	3,300	8,507	4,625	4,693	3,664	0	24,788
55	0	0	0	0	0	0	325	837	461	461	386	0	2,469
56	0	0	0	0	0	0	7,550	19,512	10,635	10,757	7,790	0	56,244
57	0	0	0	0	0	0	22,152	56,988	31,050	31,429	22,720	0	164,338
59	1,233	360	0	0	0	0	825	1,758	3,379	3,890	3,744	2,723	17,912
60	2,218	460	0	0	0	0	1,588	3,261	5,268	5,535	5,480	3,690	27,500
61	3,086	1,474	0	0	0	0	3,638	6,096	13,700	16,096	15,170	9,410	68,670
62	0	0	0	0	0	0	51	132	73	73	62	0	391
63	7,492	630	0	0	0	0	4,400	9,343	16,284	15,961	14,843	11,045	79,998
64	13	5	0	0	0	0	10	20	29	28	27	22	154
65	1,267	583	0	0	0	0	972	1,825	2,619	2,811	2,704	2,298	15,079
66	15,017	3,171	0	0	0	0	13,347	21,060	35,005	29,389	27,595	19,359	163,943
67	10,978	1,668	0	0	0	0	12,643	25,202	30,053	18,166	15,715	10,095	124,520
Total	158,446	38,964	30	0	0	123	176,603	348,634	466,154	430,843	382,466	239,892	2,242,155

Appendix Table 15 Quantity of Intake Water (Surface Water, 2016, Scenario-3)

Reach	Meh. Oct.	Sha. Nov.	Mor. Dec.	Tir Jan.	Kho. Feb.	Ord. Mar.	Far. Apr	Esf. May.	Bah. Jun.	Dey Jul.	Aza. Aug.	Aba. Sep.	Total
1	264	191	0	0	0	0	283	542	875	805	754	565	4,279
2	1,932	291	0	0	0	0	708	2,598	5,966	7,150	7,000	4,866	30,511
3	445	457	0	0	0	0	661	1,214	2,081	1,907	1,720	1,071	9,556
4	2,242	307	0	0	0	0	1,376	3,451	6,171	6,720	6,643	4,161	31,071
5	8,049	1,083	0	0	0	0	6,157	16,466	26,376	31,665	31,185	14,503	135,484
6	546	501	0	0	0	0	666	1,723	3,176	3,565	3,326	1,793	15,296
7	100	18	0	0	0	0	52	132	281	333	325	233	1,474
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,414	328	0	0	0	0	2,378	5,063	7,895	8,019	6,894	3,132	36,123
10	5,647	1,242	0	0	0	0	3,344	7,423	13,224	16,629	16,765	11,428	75,702
11	1,847	851	0	0	0	0	2,249	4,417	8,761	8,404	7,857	4,541	38,927
12	362	88	0	0	0	0	214	495	991	1,154	1,124	819	5,247
13	252	56	0	0	0	0	155	315	626	739	723	539	3,405
14	94	37	0	0	0	0	74	144	259	279	268	199	1,354
15	8	4	0	0	0	0	9	24	51	64	53	26	239
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	13,026	3,255	0	0	0	0	12,128	22,627	35,679	29,712	27,181	20,539	164,147
18	6,931	1,236	0	0	0	0	5,712	11,136	16,470	13,621	12,910	8,511	76,527
19	101	43	0	0	1	5	18,371	47,336	26,217	26,209	22,053	146	140,482
20	9,713	1,396	0	0	0	0	8,603	11,994	22,739	18,109	14,366	10,097	97,017
21	3,487	1,763	0	0	0	0	2,594	5,046	10,578	11,193	10,439	7,336	52,436
22	3,021	976	0	0	0	0	3,048	5,665	7,508	5,860	5,335	4,211	35,624
23	24	13	0	0	0	1	470	1,210	785	713	594	41	3,851
24	1,113	202	0	0	0	0	853	1,159	2,260	1,865	1,737	1,313	10,502
25	457	30	0	0	0	0	425	716	1,628	1,618	1,330	910	7,114
26	1,619	527	0	0	0	0	1,365	3,892	5,412	6,538	6,425	4,009	29,787
27	10,182	1,709	0	0	0	0	9,632	11,042	25,033	23,329	17,709	11,556	110,192
28	347	95	0	0	0	0	207	298	786	953	921	693	4,300
29	778	70	0	0	0	0	435	960	1,640	1,555	1,443	1,140	8,021
30	4,187	377	0	0	0	0	2,313	5,332	9,048	8,975	8,701	6,572	45,505
31	1,120	216	0	0	0	0	902	1,263	2,297	2,032	1,888	1,373	11,091
32	55	49	0	0	0	0	70	127	191	143	105	83	823
33	732	183	0	0	0	0	468	671	1,625	1,786	1,740	1,311	8,516
34	1,086	466	0	0	0	0	792	1,570	2,350	2,537	2,462	2,050	13,313
35	848	318	0	0	0	0	791	1,526	2,048	1,804	1,729	1,340	10,404
36	930	122	0	0	0	0	388	950	2,498	2,855	2,719	2,197	12,659
37	1,587	659	0	0	0	0	1,317	2,530	3,565	3,503	3,324	2,774	19,259
38	458	114	0	0	0	0	365	551	1,014	1,030	969	699	5,200
39	3	1	0	0	0	0	4	8	26	38	30	13	123
40	1,406	564	0	0	0	0	1,245	2,354	3,200	2,889	2,699	2,265	16,622
41	666	282	0	0	0	0	581	1,070	1,443	1,353	1,279	1,074	7,748
42	915	389	0	0	0	0	742	1,403	1,978	1,988	1,896	1,583	10,894
43	357	133	0	0	0	0	269	507	685	632	626	514	3,723
44	1,990	709	0	0	0	0	1,509	2,941	4,072	3,797	3,763	3,045	21,826
45	54	15	0	0	0	0	51	100	128	100	96	66	610
46	99	38	0	0	0	0	96	174	227	183	167	142	1,126
47	6,327	1,669	0	0	0	0	5,632	11,233	14,335	11,717	11,263	8,602	70,778
48	2,120	489	0	0	0	0	2,002	3,970	5,184	3,752	3,477	2,605	23,599
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1,075	322	0	0	0	0	933	1,798	2,343	1,968	1,903	1,480	11,822
51	308	107	0	0	0	0	264	498	682	605	550	404	3,418
52	427	117	0	0	0	0	383	727	925	719	691	530	4,519
53	0	0	0	0	0	0	2,409	6,214	3,421	3,421	2,863	0	18,328
54	0	0	0	0	0	0	7,338	18,915	10,284	10,434	8,146	0	55,118
55	0	0	0	0	0	0	4,998	12,889	7,097	7,097	5,937	0	38,018
56	0	0	0	0	0	0	20,489	52,954	28,861	29,192	21,142	0	152,638
57	0	0	0	0	0	0	2,214	5,695	3,103	3,141	2,270	0	16,422
59	3,147	920	0	0	0	0	2,105	4,487	8,622	9,926	9,554	6,947	45,708
60	9,641	2,000	0	0	0	0	6,903	14,176	22,900	24,061	23,823	16,040	119,544
61	7,403	3,534	0	0	0	0	8,726	14,620	32,857	38,602	36,383	22,567	164,692
62	0	0	0	0	0	0	428	1,105	612	611	517	0	3,273
63	4,326	363	0	0	0	0	2,541	5,395	9,402	9,216	8,570	6,377	46,190
64	1,086	421	0	0	0	0	848	1,661	2,408	2,342	2,233	1,863	12,862
65	618	285	0	0	0	0	475	891	1,279	1,372	1,320	1,121	7,361
66	297	63	0	0	0	0	265	417	693	582	546	383	3,246
67	18	3	0	0	0	0	21	42	50	30	26	17	207
Total	128,287	31,697	0	0	1	6	163,046	347,852	424,921	423,141	382,487	214,415	2,115,853

Appendix Table 16 Quantity of Intake Water (Ground Water, 2016, Scenario-3)

Reach	Meh. Oct.	Sha. Nov.	Mor. Dec.	Tir Jan.	Kho. Feb.	Ord. Mar.	Far. Apr	Esf. May.	Bah. Jun.	Dey Jul.	Aza. Aug.	Aba. Sep.	Total
1	892	647	0	0	0	0	955	1,826	2,954	2,716	2,542	1,907	14,439
2	1,149	174	0	0	0	0	421	1,544	3,549	4,252	4,163	2,895	18,147
3	1,576	1,618	0	0	0	0	2,343	4,304	7,376	6,760	6,098	3,796	33,871
4	1,123	154	0	0	0	0	690	1,730	3,092	3,368	3,330	2,085	15,572
5	1,412	190	0	0	0	0	1,081	2,889	4,626	5,555	5,470	2,544	23,767
6	1,473	1,351	0	0	0	0	1,795	4,648	8,566	9,614	8,972	4,835	41,254
7	116	21	0	0	0	0	59	152	323	384	375	269	1,699
8	2,274	445	26	0	0	106	1,413	3,080	5,222	6,454	6,299	4,182	29,501
9	489	66	0	0	0	0	481	1,026	1,599	1,624	1,396	634	7,315
10	33	7	0	0	0	0	20	44	78	99	99	68	448
11	2,055	946	0	0	0	0	2,502	4,914	9,747	9,349	8,742	5,052	43,307
12	240	58	0	0	0	0	143	328	658	766	747	544	3,484
13	167	37	0	0	0	0	103	209	416	490	480	358	2,260
14	2	1	0	0	0	0	2	4	5	6	6	4	30
15	1	0	0	0	0	0	1	3	6	7	6	3	27
16	12	17	0	0	0	0	11	19	19	18	12	0	108
17	5,109	1,276	0	0	0	0	4,756	8,875	13,993	11,653	10,660	8,055	64,377
18	187	33	0	0	0	0	154	300	444	368	348	230	2,064
19	5	3	0	0	0	0	953	2,456	1,360	1,360	1,144	7	7,288
20	13,036	1,873	0	0	0	0	11,546	16,096	30,517	24,305	19,281	13,550	130,204
21	2,397	1,213	0	0	0	0	1,783	3,468	7,273	7,694	7,177	5,043	36,048
22	2,746	887	0	0	0	0	2,771	5,149	6,824	5,326	4,849	3,827	32,379
23	14	8	0	0	0	1	290	749	486	441	368	25	2,382
24	101	18	0	0	0	0	77	104	204	168	157	118	947
25	5,254	342	0	0	0	0	4,887	8,244	18,738	18,623	15,303	10,474	81,865
26	5,095	1,660	0	0	0	0	4,294	12,244	17,028	20,572	20,216	12,616	93,725
27	13,020	2,185	0	0	0	0	12,315	14,119	32,009	29,831	22,644	14,777	140,900
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	174	16	0	0	0	0	97	215	367	347	323	255	1,794
30	1,697	153	0	0	0	0	937	2,160	3,666	3,636	3,525	2,663	18,437
31	109	22	0	0	0	0	88	123	224	199	185	134	1,084
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	50	13	0	0	0	0	32	46	112	123	120	91	587
34	31	13	0	0	0	0	22	44	66	71	69	58	374
35	10	4	0	0	0	0	9	17	22	19	18	15	114
36	1,904	249	0	0	0	0	795	1,946	5,119	5,850	5,569	4,500	25,932
37	2,405	998	0	0	0	0	1,996	3,835	5,403	5,310	5,038	4,204	29,189
38	349	86	0	0	0	0	278	419	771	783	737	531	3,954
39	1	0	0	0	0	0	2	4	9	13	11	4	44
40	984	394	0	0	0	0	871	1,646	2,238	2,021	1,888	1,584	11,626
41	2,402	1,016	0	0	0	0	2,099	3,863	5,208	4,883	4,615	3,876	27,962
42	1,983	841	0	0	0	0	1,605	3,038	4,284	4,305	4,106	3,428	23,590
43	356	132	0	0	0	0	268	505	683	630	624	513	3,711
44	1,885	672	0	0	0	0	1,431	2,787	3,860	3,598	3,566	2,885	20,684
45	409	117	0	0	0	0	388	751	970	751	718	495	4,599
46	142	55	0	0	0	0	138	249	324	261	239	203	1,611
47	19,626	5,177	0	0	0	0	17,469	34,841	44,460	36,345	34,934	26,682	219,534
48	2,929	676	0	0	0	0	2,766	5,485	7,161	5,184	4,804	3,600	32,605
49	616	88	0	0	0	0	611	887	1,380	849	721	498	5,650
50	3,138	939	0	0	0	0	2,722	5,245	6,836	5,743	5,550	4,316	34,489
51	284	99	0	0	0	0	243	460	629	558	507	373	3,153
52	5,223	1,422	0	0	0	0	4,688	8,900	11,313	8,796	8,445	6,487	55,274
53	0	0	0	0	0	0	876	2,260	1,244	1,244	1,041	0	6,665
54	0	0	0	0	0	0	3,080	7,940	4,317	4,380	3,419	0	23,136
55	0	0	0	0	0	0	303	781	430	430	360	0	2,304
56	0	0	0	0	0	0	7,142	18,458	10,060	10,175	7,369	0	53,203
57	0	0	0	0	0	0	20,954	53,908	29,372	29,730	21,491	0	155,455
59	1,116	326	0	0	0	0	747	1,591	3,059	3,521	3,389	2,465	16,214
60	1,944	403	0	0	0	0	1,392	2,859	4,618	4,852	4,804	3,235	24,107
61	2,840	1,356	0	0	0	0	3,348	5,610	12,608	14,813	13,961	8,660	63,196
62	0	0	0	0	0	0	45	118	65	65	55	0	348
63	6,159	518	0	0	0	0	3,617	7,680	13,386	13,120	12,201	9,079	65,760
64	11	4	0	0	0	0	9	18	25	25	24	19	135
65	1,280	589	0	0	0	0	982	1,844	2,646	2,840	2,732	2,322	15,235
66	13,518	2,854	0	0	0	0	12,015	18,957	31,510	26,455	24,840	17,426	147,575
67	11,067	1,681	0	0	0	0	12,745	25,406	30,296	18,313	15,842	10,177	125,527
Total	144,620	36,143	26	0	0	107	162,656	323,419	425,852	392,041	348,725	218,676	2,052,265

Appendix Table 17 Quantity of Intake Water (Surface Water, 2031, Scenario-3)

Reach	Meh. Oct.	Sha. Nov.	Mor. Dec.	Tir Jan.	Kho. Feb.	Ord. Mar.	Far. Apr	Esf. May.	Bah. Jun.	Dey Jul.	Aza. Aug.	Aba. Sep.	Total
1	222	161	0	0	0	0	238	456	736	677	634	475	3,599
2	1,625	245	0	0	0	0	595	2,184	5,017	6,012	5,886	4,092	25,656
3	26	26	0	0	0	0	38	70	120	110	99	62	551
4	1,885	258	0	0	0	0	1,157	2,902	5,189	5,651	5,586	3,499	26,127
5	6,769	911	0	0	0	0	5,178	13,847	22,179	26,628	26,224	12,196	113,932
6	459	421	0	0	0	0	560	1,449	2,671	2,998	2,797	1,507	12,862
7	84	15	0	0	0	0	43	111	236	280	273	196	1,238
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2,030	276	0	0	0	0	1,999	4,258	6,639	6,743	5,797	2,634	30,376
10	4,749	1,044	0	0	0	0	2,812	6,242	11,120	13,983	14,098	9,610	63,658
11	1,553	715	0	0	0	0	1,892	3,715	7,367	7,067	6,607	3,819	32,735
12	304	74	0	0	0	0	180	416	834	970	945	688	4,411
13	212	47	0	0	0	0	130	265	527	621	608	454	2,864
14	79	31	0	0	0	0	62	121	218	234	225	167	1,137
15	7	3	0	0	0	0	8	20	43	54	45	22	202
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	6,670	1,667	0	0	0	0	6,211	11,587	18,270	15,215	13,919	10,517	84,056
18	5,829	1,040	0	0	0	0	4,804	9,364	13,850	11,454	10,856	7,157	64,354
19	85	36	0	0	1	5	15,448	39,805	22,046	22,039	18,545	123	118,133
20	7,948	1,142	0	0	0	0	7,040	9,814	18,607	14,818	11,755	8,262	79,386
21	2,211	1,118	0	0	0	0	1,644	3,199	6,706	7,096	6,618	4,651	33,243
22	2,541	821	0	0	0	0	2,563	4,764	6,314	4,928	4,487	3,541	29,959
23	20	11	0	0	0	1	395	1,018	660	599	500	35	3,239
24	936	170	0	0	0	0	717	974	1,900	1,568	1,460	1,104	8,829
25	384	25	0	0	0	0	357	602	1,369	1,361	1,118	765	5,981
26	1,362	443	0	0	0	0	1,148	3,273	4,551	5,498	5,403	3,371	25,049
27	8,360	1,403	0	0	0	0	7,908	9,066	20,553	19,155	14,540	9,488	90,473
28	292	80	0	0	0	0	174	251	661	801	775	583	3,617
29	654	59	0	0	0	0	366	807	1,379	1,307	1,214	958	6,744
30	2,476	223	0	0	0	0	1,368	3,153	5,351	5,308	5,145	3,886	26,910
31	942	182	0	0	0	0	758	1,062	1,931	1,709	1,588	1,154	9,326
32	46	41	0	0	0	0	59	107	161	120	88	70	692
33	615	154	0	0	0	0	393	564	1,366	1,502	1,463	1,102	7,159
34	913	392	0	0	0	0	666	1,321	1,976	2,133	2,071	1,724	11,196
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	782	102	0	0	0	0	326	799	2,101	2,401	2,286	1,847	10,644
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	385	96	0	0	0	0	307	463	853	866	814	588	4,372
39	2	1	0	0	0	0	3	7	22	32	25	11	103
40	1,182	474	0	0	0	0	1,047	1,980	2,691	2,429	2,270	1,905	13,978
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	770	327	0	0	0	0	624	1,180	1,664	1,671	1,594	1,331	9,161
43	300	112	0	0	0	0	226	426	576	532	526	432	3,130
44	1,669	595	0	0	0	0	1,266	2,466	3,415	3,185	3,156	2,553	18,305
45	46	13	0	0	0	0	43	84	108	84	80	55	513
46	83	32	0	0	0	0	81	146	191	154	140	119	946
47	5,320	1,403	0	0	0	0	4,736	9,446	12,054	9,853	9,471	7,234	59,517
48	1,778	410	0	0	0	0	1,679	3,329	4,347	3,147	2,916	2,185	19,791
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	904	270	0	0	0	0	784	1,512	1,970	1,655	1,600	1,244	9,939
51	259	90	0	0	0	0	222	419	573	509	462	340	2,874
52	359	98	0	0	0	0	322	611	778	605	581	446	3,800
53	0	0	0	0	0	0	2,126	5,483	3,019	3,019	2,526	0	16,172
54	0	0	0	0	0	0	6,475	16,690	9,074	9,207	7,188	0	48,633
55	0	0	0	0	0	0	4,410	11,373	6,262	6,262	5,238	0	33,546
56	0	0	0	0	0	0	18,796	48,578	26,476	26,779	19,395	0	140,023
57	0	0	0	0	0	0	2,031	5,224	2,846	2,881	2,083	0	15,064
59	2,647	773	0	0	0	0	1,770	3,773	7,250	8,347	8,034	5,842	38,436
60	8,107	1,682	0	0	0	0	5,804	11,920	19,257	20,233	20,033	13,488	100,524
61	6,039	2,883	0	0	0	0	7,119	11,927	26,805	31,493	29,682	18,411	134,359
62	0	0	0	0	0	0	360	929	515	514	435	0	2,753
63	3,638	306	0	0	0	0	2,137	4,537	7,906	7,750	7,207	5,363	38,844
64	914	354	0	0	0	0	713	1,397	2,024	1,969	1,878	1,567	10,816
65	520	240	0	0	0	0	399	749	1,076	1,154	1,110	943	6,191
66	0	0	0	0	0	0	0	0	0	0	0	0	0
67	15	3	0	0	0	0	18	36	42	25	22	14	175
Total	98,007	23,498	0	0	1	6	130,734	282,270	334,442	335,395	302,120	163,830	1,670,303

Appendix Table 18 Quantity of Intake Water (Ground Water, 2031, Scenario-3)

Reach	Meh. **Oct.**	Sha. **Nov.**	Mor. **Dec.**	Tir **Jan.**	Kho. **Feb.**	Ord. **Mar.**	Far. **Apr**	Esf. **May.**	Bah. **Jun.**	Dey **Jul.**	Aza. **Aug.**	Aba. **Sep.**	Total
1	750	544	0	0	0	0	803	1,536	2,484	2,284	2,138	1,604	12,143
2	967	146	0	0	0	0	354	1,298	2,984	3,575	3,501	2,434	15,259
3	1,325	1,361	0	0	0	0	1,970	3,619	6,202	5,684	5,128	3,192	28,481
4	945	130	0	0	0	0	580	1,455	2,600	2,832	2,800	1,754	13,096
5	1,188	160	0	0	0	0	909	2,429	3,890	4,671	4,600	2,139	19,986
6	1,239	1,136	0	0	0	0	1,509	3,909	7,204	8,085	7,544	4,065	34,691
7	98	18	0	0	0	0	50	128	272	323	315	226	1,430
8	1,912	374	22	0	0	89	1,188	2,590	4,391	5,427	5,297	3,516	24,806
9	411	56	0	0	0	0	405	863	1,344	1,366	1,174	533	6,152
10	28	6	0	0	0	0	17	37	66	83	84	57	378
11	1,728	796	0	0	0	0	2,104	4,133	8,196	7,862	7,351	4,249	36,419
12	202	49	0	0	0	0	120	276	553	644	628	457	2,929
13	140	31	0	0	0	0	86	176	350	412	404	301	1,900
14	2	1	0	0	0	0	2	3	5	5	5	4	27
15	1	0	0	0	0	0	1	2	5	6	5	2	22
16	10	15	0	0	0	0	9	16	16	15	10	0	91
17	4,296	1,073	0	0	0	0	4,000	7,463	11,767	9,799	8,964	6,773	54,135
18	157	28	0	0	0	0	129	253	374	309	293	193	1,736
19	5	2	0	0	0	0	801	2,065	1,144	1,144	962	6	6,129
20	10,962	1,575	0	0	0	0	9,709	13,536	25,662	20,438	16,214	11,394	109,490
21	2,016	1,020	0	0	0	0	1,500	2,916	6,116	6,470	6,035	4,241	30,314
22	2,309	746	0	0	0	0	2,330	4,330	5,738	4,478	4,078	3,218	27,227
23	12	7	0	0	0	1	244	630	408	371	310	21	2,004
24	85	15	0	0	0	0	64	88	172	141	132	99	796
25	4,418	287	0	0	0	0	4,109	6,933	15,757	15,661	12,868	8,807	68,840
26	4,285	1,396	0	0	0	0	3,611	10,296	14,319	17,299	17,000	10,609	78,815
27	10,948	1,837	0	0	0	0	10,356	11,873	26,917	25,085	19,042	12,426	118,484
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	146	13	0	0	0	0	82	181	309	292	271	215	1,509
30	1,427	128	0	0	0	0	788	1,816	3,083	3,058	2,964	2,239	15,503
31	92	18	0	0	0	0	74	104	189	167	155	113	912
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	42	11	0	0	0	0	27	39	94	104	101	76	494
34	26	11	0	0	0	0	18	37	55	60	58	49	314
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	1,601	210	0	0	0	0	668	1,637	4,305	4,919	4,683	3,785	21,808
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	293	73	0	0	0	0	233	353	648	658	620	446	3,324
39	1	0	0	0	0	0	1	3	7	11	9	4	36
40	827	331	0	0	0	0	732	1,384	1,882	1,699	1,588	1,332	9,775
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	1,668	707	0	0	0	0	1,350	2,555	3,603	3,620	3,453	2,882	19,838
43	300	111	0	0	0	0	225	425	574	530	525	431	3,121
44	1,581	563	0	0	0	0	1,200	2,338	3,237	3,017	2,990	2,419	17,345
45	344	99	0	0	0	0	327	632	816	632	604	417	3,871
46	119	46	0	0	0	0	116	209	272	219	201	171	1,353
47	16,503	4,354	0	0	0	0	14,690	29,298	37,387	30,563	29,376	22,437	184,608
48	2,456	567	0	0	0	0	2,320	4,600	6,006	4,347	4,029	3,019	27,344
49	518	74	0	0	0	0	514	746	1,161	714	606	419	4,752
50	2,639	789	0	0	0	0	2,289	4,410	5,748	4,830	4,667	3,629	29,001
51	239	83	0	0	0	0	205	387	529	469	426	313	2,651
52	4,392	1,196	0	0	0	0	3,942	7,484	9,513	7,397	7,102	5,455	46,481
53	0	0	0	0	0	0	773	1,994	1,098	1,098	919	0	5,881
54	0	0	0	0	0	0	2,718	7,005	3,809	3,864	3,017	0	20,414
55	0	0	0	0	0	0	267	689	380	380	317	0	2,033
56	0	0	0	0	0	0	6,551	16,932	9,228	9,334	6,760	0	48,806
57	0	0	0	0	0	0	19,222	49,453	26,944	27,273	19,715	0	142,607
59	939	274	0	0	0	0	628	1,338	2,572	2,961	2,850	2,073	13,635
60	1,635	339	0	0	0	0	1,171	2,404	3,883	4,080	4,040	2,720	20,272
61	2,388	1,141	0	0	0	0	2,815	4,718	10,602	12,456	11,740	7,282	53,142
62	0	0	0	0	0	0	38	99	55	55	47	0	294
63	5,179	435	0	0	0	0	3,041	6,458	11,256	11,033	10,260	7,635	55,297
64	10	4	0	0	0	0	7	15	21	21	20	16	114
65	1,076	495	0	0	0	0	826	1,550	2,225	2,388	2,297	1,952	12,809
66	10,855	2,292	0	0	0	0	9,648	15,223	25,303	21,244	19,947	13,993	118,505
67	9,306	1,414	0	0	0	0	10,718	21,364	25,476	15,399	13,322	8,558	105,557
Total	117,041	28,587	22	0	0	90	135,185	270,733	351,206	323,361	286,562	176,400	1,689,187

Annex – 1

DESCRIPTION OF SEFIDRUD-WBSM

Annex - 1

DESCRIPTION OF SEFIDRUD-WBSM

Table of Contents

Page

List of Tables

List of Figures

CHAPTER 1. WATER BALANCE SIMULATION MODEL

1.1 OUTLINE OF SIMULATION MODEL

The water balance simulation model for Sefidrud River basin by MIKE SHE (hereinafter referred to as The Sefid-WBSM) is established to calculate the natural groundwater recharge and surface runoff to input into the MIKE BASIN allocation simulation model (hereinafter referred to as The Sefid-WASM). The groundwater recharge is equal to the amount of water percolating out through the bottom of the root zone. Runoff and infiltration are surface processes and as such require detailed information on the ground surface and root zone.

The Sefid-WBSM domain is 210 grid cells East-to-West and 165 grid cells North-to-South. The grid cell size is 2040m. Normally, the smaller mesh size is better to increase the accuracy of simulation results. However, considering both the accuracy requirement and the practical use, the grid size is selected so that the model grid would correspond to the 60m DEM and the simulation time could be less than 6 hours. The model data is specified in a variety of formats independent of the model domain and grid, including native GIS formats. At run time, the spatial data is mapped onto the numerical grid, which makes it easy to change the spatial distribution.

The river network is arranged using the collected information such as DEM (ASTER) and topographic maps. In the coupled MIKE 11 river network model, the river discharges are calculated assuming there is no hydrograph transformation along the river network. In the Sefid-WBSM and WASM, the sub-catchments limit the lateral extent of interflow and overland flow. That is interflow and overland flow is only discharged to river links located within the sub-catchment.

Each of above-mentioned processes can be represented at different levels of spatial distribution and complexity, according to the goals of the modeling study, the availability of field data and the modeler’s choices. There are, however, important limitations to the applicability of such physics-based models, primarily complexity and computational cost. Therefore, it is often practical to use simplified process descriptions. In case of Sefid-WBSM, it takes about 6 hours to simulate the water balance of the 62 Reaches for 30-year time series data.

1.2 DATABASE OF SEFIDRUD BASIN MODEL

When a user click the SHE file the user can browse the data base of Sefid-WBSM Model via MIKE ZERO Project Explorer as follows:

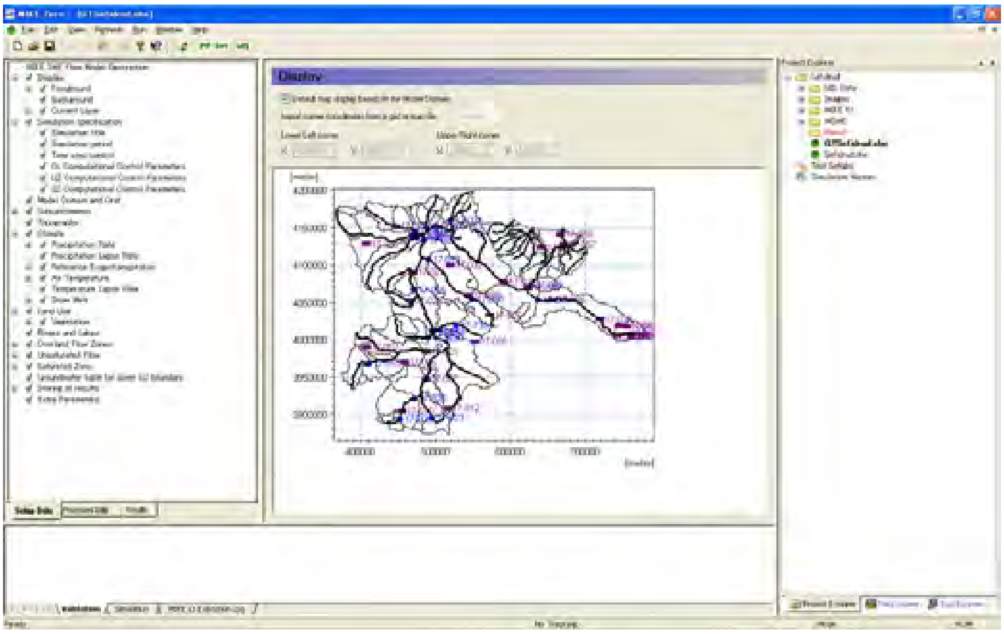


Figure 1.2.1 Structure of Database of Sefid-WBSM

In accordance to the MIKE ZERO Project Explorer, the MIKE SHE document consists of 4 parts:
• Along the top - the Tool bar and drop-down Menus
• On the left - the dynamic Data tree and tab control
• On the right - the context sensitive Dialog area
• Along the bottom - the Validation area and Mouse-over data area

Tool bar - contains icon short cuts for many MIKE SHE operations that can be accessed via the Menus. Also, it changes depending on the tools that are currently in use.
Data tree - displays the data items required to run the model as it is currently defined. If you add or subtract hydrologic processes or change numeric engines, the make up of the data tree will change.
Dialog Area - is different for each item in the data tree.
Validation area - displays information on missing data or invalid data items. Any items displayed here are hot linked to the dialog in which the error has occurred.
Mouse-over area - displays dynamic coordinate and value information related to the mouse position in the map area of any of the spatial dialogs.

(Reference: MIKE SHE Basic Exercise)

1.3 INPUT DATA

The time series data such as evaporation, temperature, used water and river discharge, and the land coverage information such as vegetation and geological information are collected to establish Initial Sefid-WBSM. These data are entered into database mounted on MIKE SHE software.

Table 1.3.1 Input Data into Sefid-WBSM

Item		Duration, Contents
Observed Data	Precipitation (Daily)	1975 - 2005
	Evaporation (Daily)	1975 - 2005
	Temperature (Daily)	1975 - 2005
Geographical Information	Land Use Map	2002
	Soil, Geological Map	2005
	DEM	2007
	Basin Boundary	-
	Reach Boundary	Sub-basins based on dam construction plan
	Groundwater Basin Boundary	Delineated based on basin boundary
	River Network	Major Rivers
	Position of Observatories	Hydro-Meteorological Station

1.3.1 Model Domain and Grid

The MIKE SHE model domain is delineated based on the Sefidrud River basin boundary and Gilan irrigation network drainage area. The model domain is 210 grid cells East-to-West and 165 grid cells North-to-South. The square grid cell size is 2040m. The grid size and grid origin were selected so that the model grid would correspond to the 60m DEM (Digital Elevation Map from Aster Satellite). That is each model cell contains exactly an even number of 60m DEM cells.

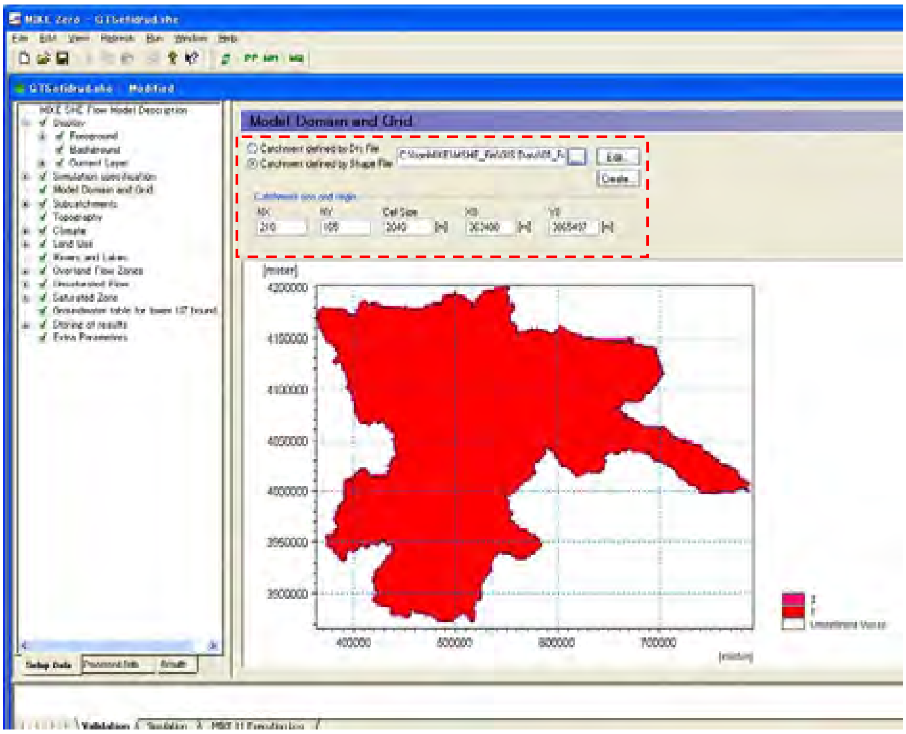


Figure 1.3.1 Model Domain and Grid

Note: when you change model domain, please click [...] button and select new shp file. In addition it is better not to change the "Catchment size and origin" (if change, other related information also should be changed reviewing model accuracy and simulation run time.

After inputting model domain information, users can edit the model domain range by clicking [Edit...] button. The button will open the ".shp file utility", where users can add, move and delete on a shp file polygon (For details, please refer to MIKE SHE Manual and Exercise books).

1.3.2 Subcatchments

The subcatchments in the Sefidrud WBS model are defined based on the Reaches information supplied by WRMC. The subcatchments are identical to the catchments used in the Sefidrud WAS model (by MIKE BASIN software). In this model, the subcatchments limit the lateral extent of interflow and overland flow. That is interflow and overland flow is only discharged to river links located within the subcatchment. A MIKE 11 branch name and chainage range was specified for each subcatchment. This prevents any ambiguity with respect to the river links where the interflow and overland flow will discharge.

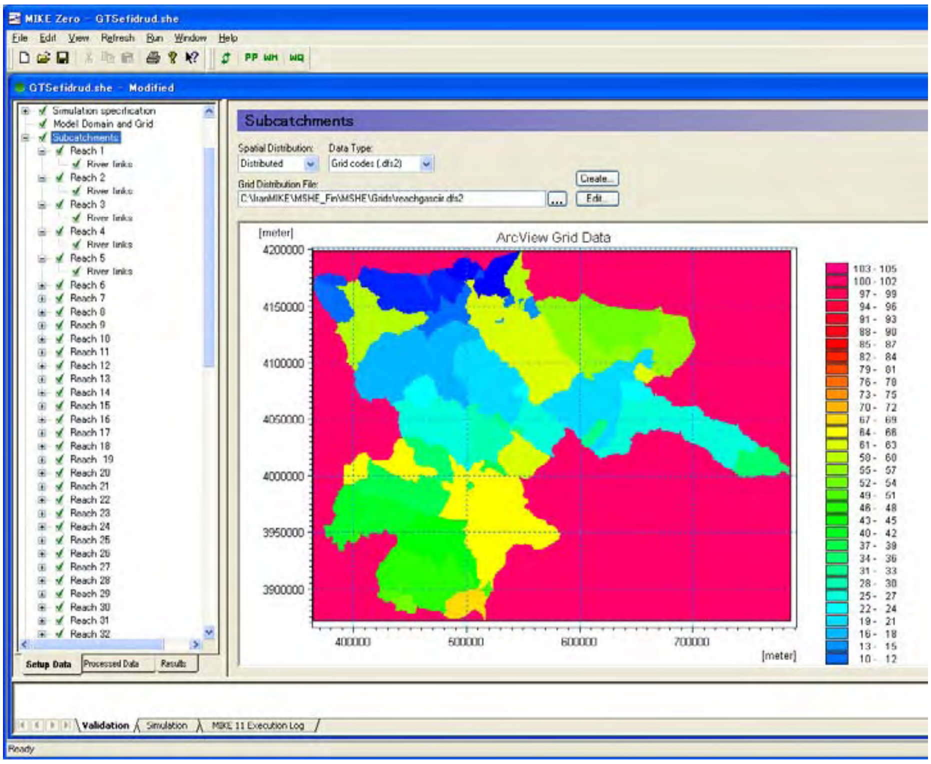


Figure 1.3.2 Subcatchment

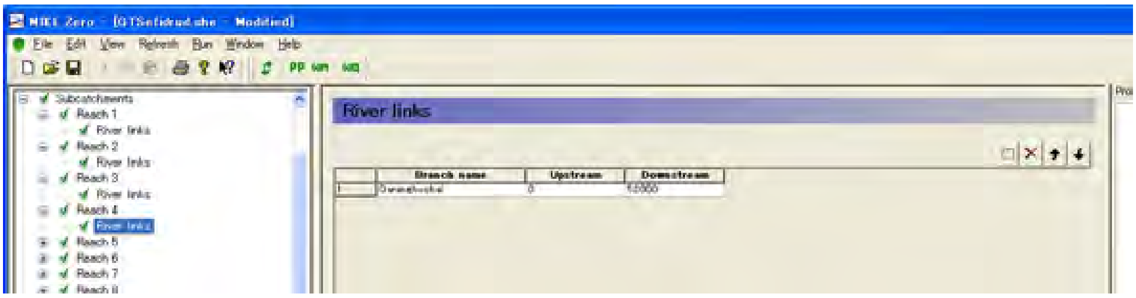
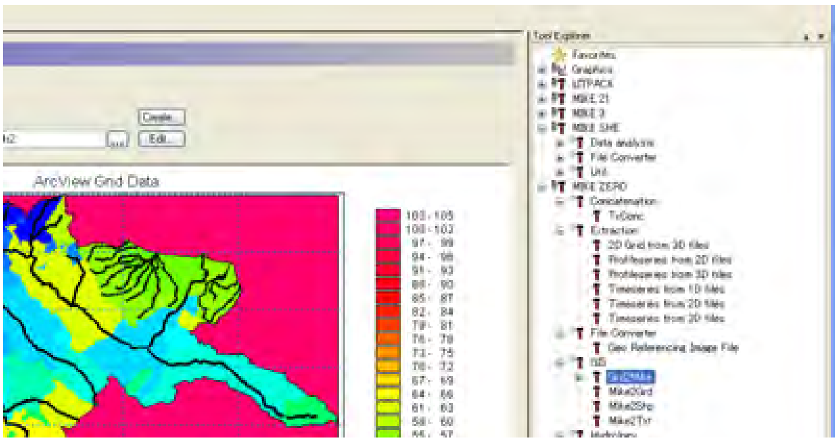


Figure 1.3.3 River Links

Note 1:

If you click [...] button, you can select new shp file or dfs2 grid file. The dfs2 file, is a specialized format for MIKE software series, can be made out the "Tool explorer:/MIKE ZERO/GIS/Grd2MIKE " based on ASCII file which can be generated from shp file by using ArcMAP tools.



Note 2:

Users can edit the dfs2 grid file by clicking [Edit...] button. The button will open the "Grid Editor Window". The grid editor is a split window that can be dragged rightwards to make the map larger. As shown above figure, the table of values on the right side reflects highlighted grid shown on the left-hand map. Ranges of values can be searched for, selected and changed using the select and unselect tools, [tool icons], plus the Tools/Set Value dialog.

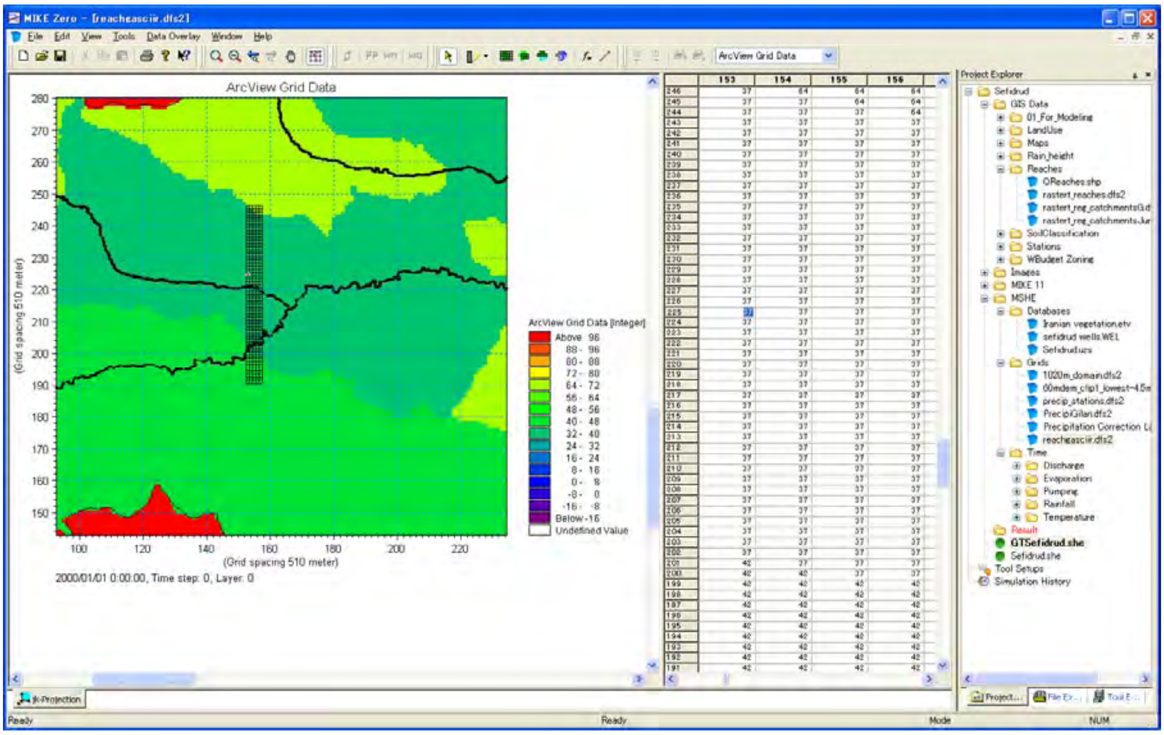


Figure 1.3.4 River Links

1.3.3 Topography

The model topography is based on the 60m DEM. As mentioned in subsection 1.3.2. Since the topography data (60 m mesh) is much denser than the model grid (2,040m mesh), each model grid contains many topography data points. In this case, 34x34, or 1156 data points per grid cell. In the Sefidrud model, the model grid is aligned to the topography grid, which means that the model grid is defined by the topography data that is closest to the mid-point of the cell. The topography is used for calculation of the cell elevation for the temperature and precipitation elevation correction.

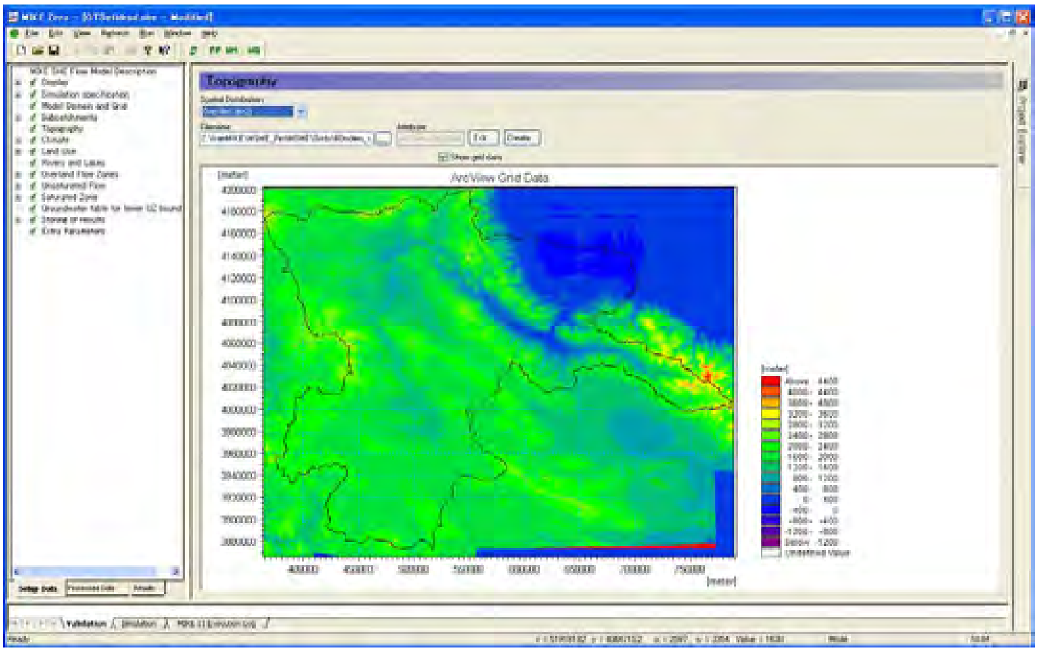


Figure 1.3.5 Topography

Note 1:
The DEM raster data was also converted to a dfs2 grid file using the "built in tools" in ArcMap to convert the raster to an ASCII grid. Following this, the "Grid2dfs MIKE Zero" tool was used to convert the ASCII grid to the dfs2 file format.

Note 2:
As mentioned in subsection 1.3.2, Note 2, Users can edit the dfs2 grid file by clicking [Edit...] button. The button will open the "Grid Editor Window". The grid editor is a split window that can be dragged rightwards to make the map larger. As shown Fig 1.3.5, the table of values on the right side reflects highlighted grid shown on the left-hand map. Ranges of values can be searched for, selected and changed using the select and unselect tools, , plus the Tools/Set Value dialog.

1.3.4 Climate

As a result of JICA Study, the available climate information consists of measured precipitation, evapotranspiration, and temperature in the view point of the situation of arrangement of the climatology data in the Sefidrud River Basin. Each of these data sets was analyzed to find the stations with long continuous data records (See JICA Report). These data stations were extracted and the remaining gaps were statistically filled from correlated stations, using MIKE Basin's Temporal Analyst tool in ArcMap. For each data set, a Thiessen polygon map was created based on the selected stations. The Thiessen polygon shape file was used to distribute the measured climate data at each station within its corresponding Thiessen polygon.

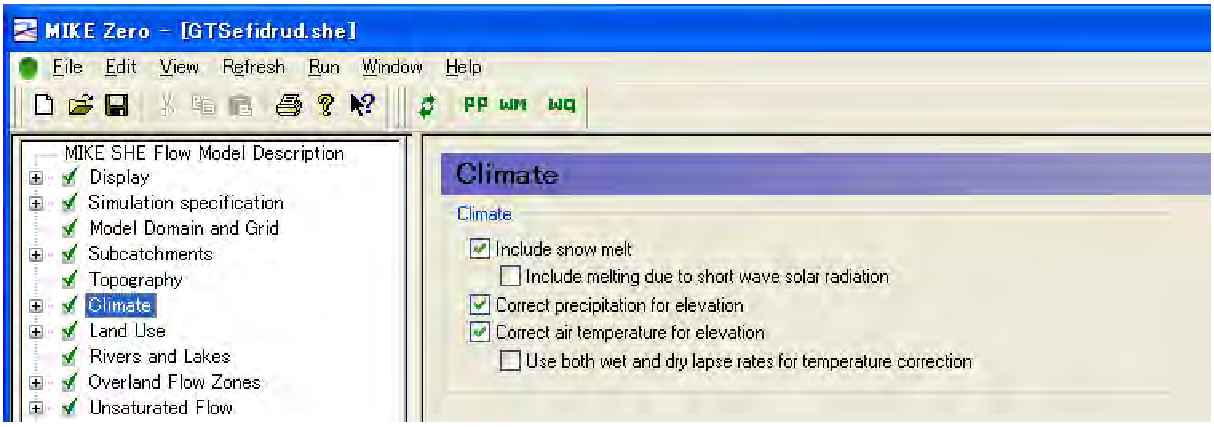


Figure 1.3.6 Set of Climate Basic Data Condition

1) Precipitation

For precipitation, measurement data from WRMC was used. Thirty-nine measurement stations were selected with long, relatively continuous records. Gaps in the measurement records were filled based on the correlations to neighboring stations. A Thiessen polygon distribution was created based on these 39 stations (see Figure 1.3.7), which can significantly influence the distribution of rainfall relative to the station measurements.

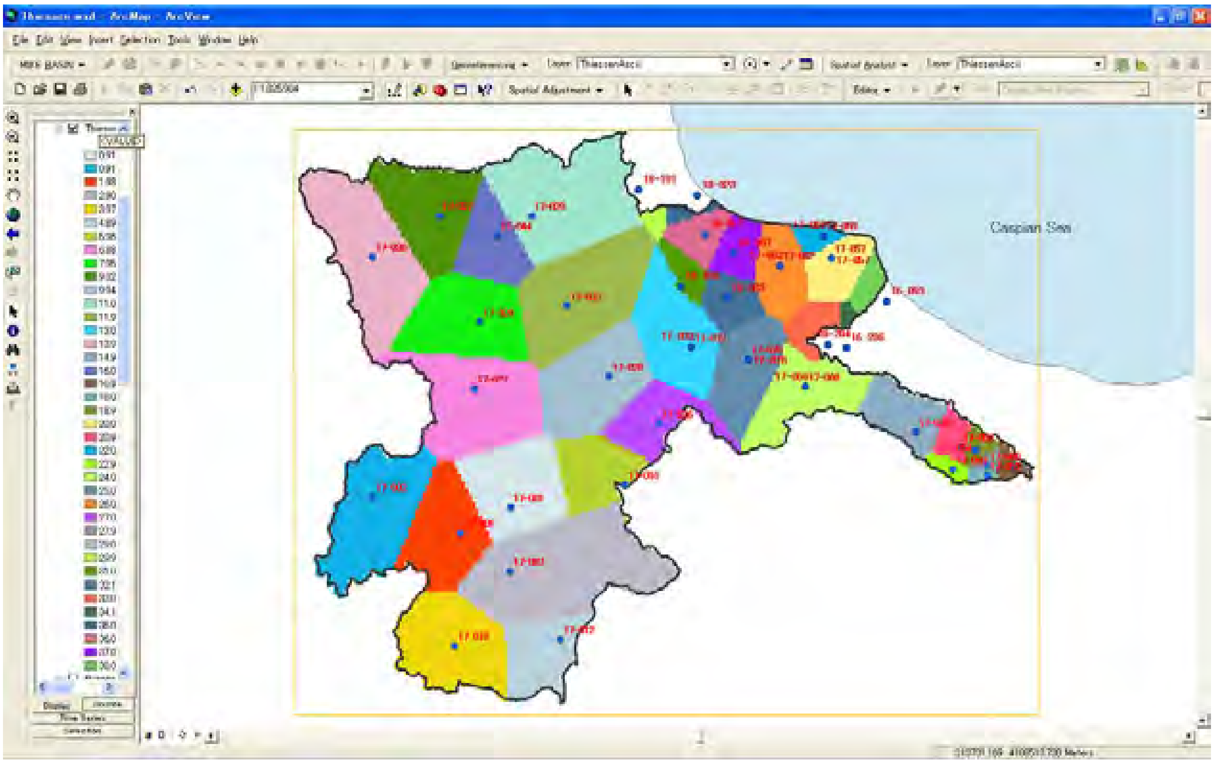


Figure 1.3.7 Precipitation Observatory and Thiessen Polygon (ArcMap)

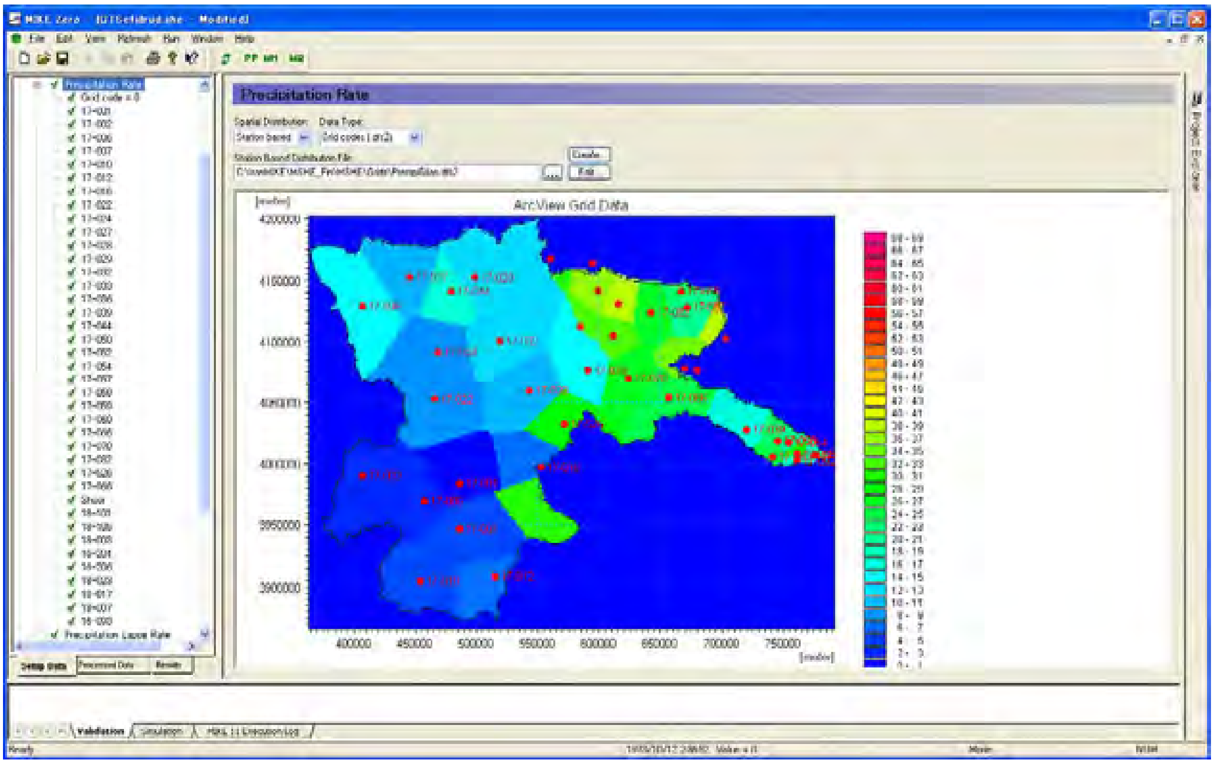


Figure 1.3.8 Precipitation Observatory and Thiessen Polygon(MIKE SHE)

Note 1: If you click [...] button, you can select new shp file or dfs2 grid file which indicated the influence range of the precipitation measured in each observatory. The dfs2 file, is a specialized format for MIKE software series, can be made out the "Tool explorer:/MIKE ZERO/GIS/Grd2MIKE " based on ASCII file which can be generated from shp file by using ArcMAP tools.

Adjusting Influence Area

When you make the Thiessen polygon and input as explained in Note 1, the precipitation time series data should be attribute to each polygon or area as follows:

1. Select the polygon by clicking the range name in dynamic data tree as shown in Fig 1.3.9. You can see the selected range in the main window. If you have already set the data, the bar chart of rainfall data will be appeared at the top of main window.
2. Click button and choose the rainfall time series data (dfs0 file) from the list of pop-up window as shown in Fig 1.3.10.

Note 1: The dfs0 file, is one of the specialized format for MIKE software series, can be easily made out by using MIKE zero which is basic software.

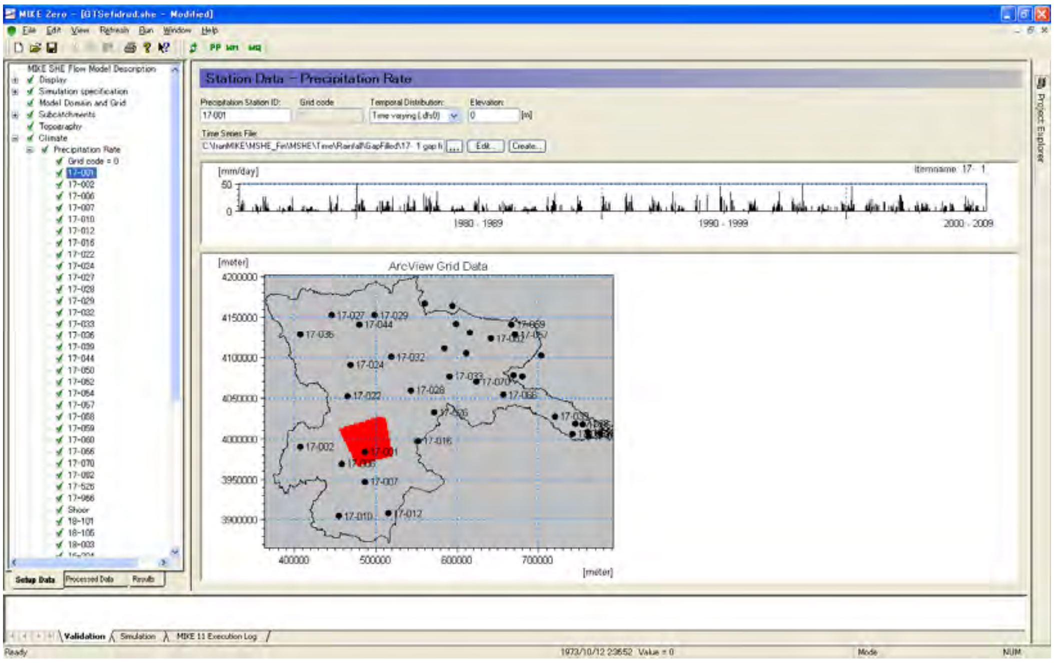


Figure 1.3.9 Set of Precipitation Time Series Data 1

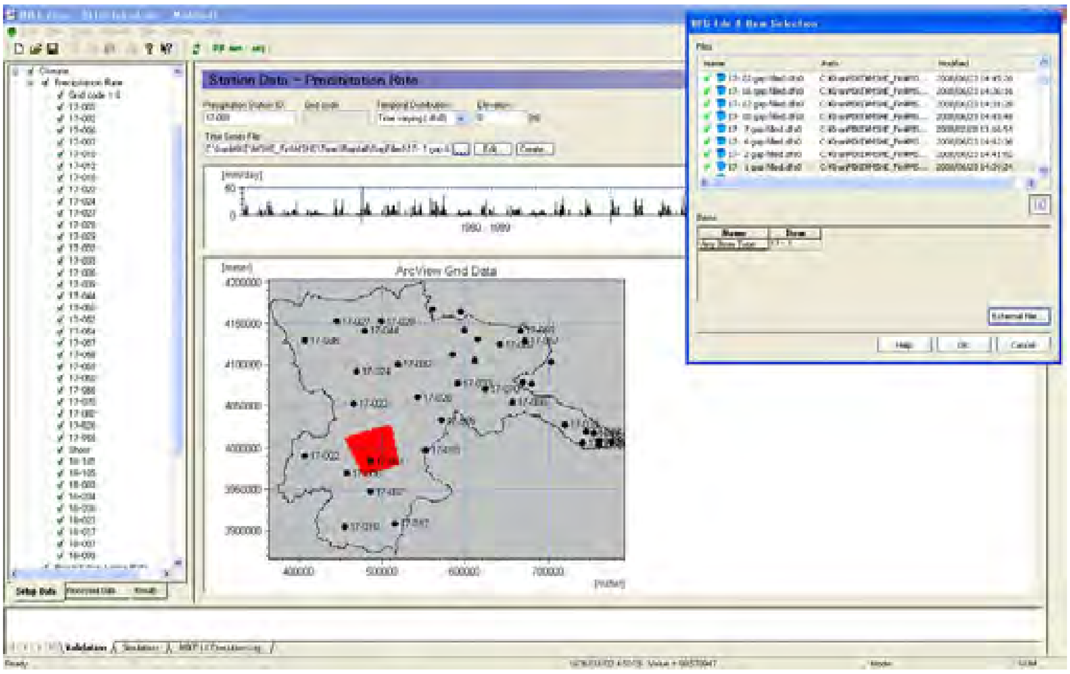


Figure 1.3.10 Set of Precipitation Time Series Data 2

In mountainous areas like the Sefidrud basin, there is generally a noticeable elevation influence on actual precipitation. However, the correction factors depend on local effects, such as average wind direction and wind shadowing. Therefore, general correction factors are not available. In the Sefidrud basin, there is obvious elevation affects in some of the catchments based on additional station measurements that are located at high elevations. However, the record lengths for these stations were insufficient for them to be included in the model. Thus, during the calibration, precipitation correction factors were added in areas that were up slope from six stations. Stream flow in these catchments was significantly underestimated unless the corrections were included. The corrections used were between 2 and 4% per 100m elevation difference from the measurement station. Figure 1.3.11 shows the distribution of elevation corrections for precipitation.

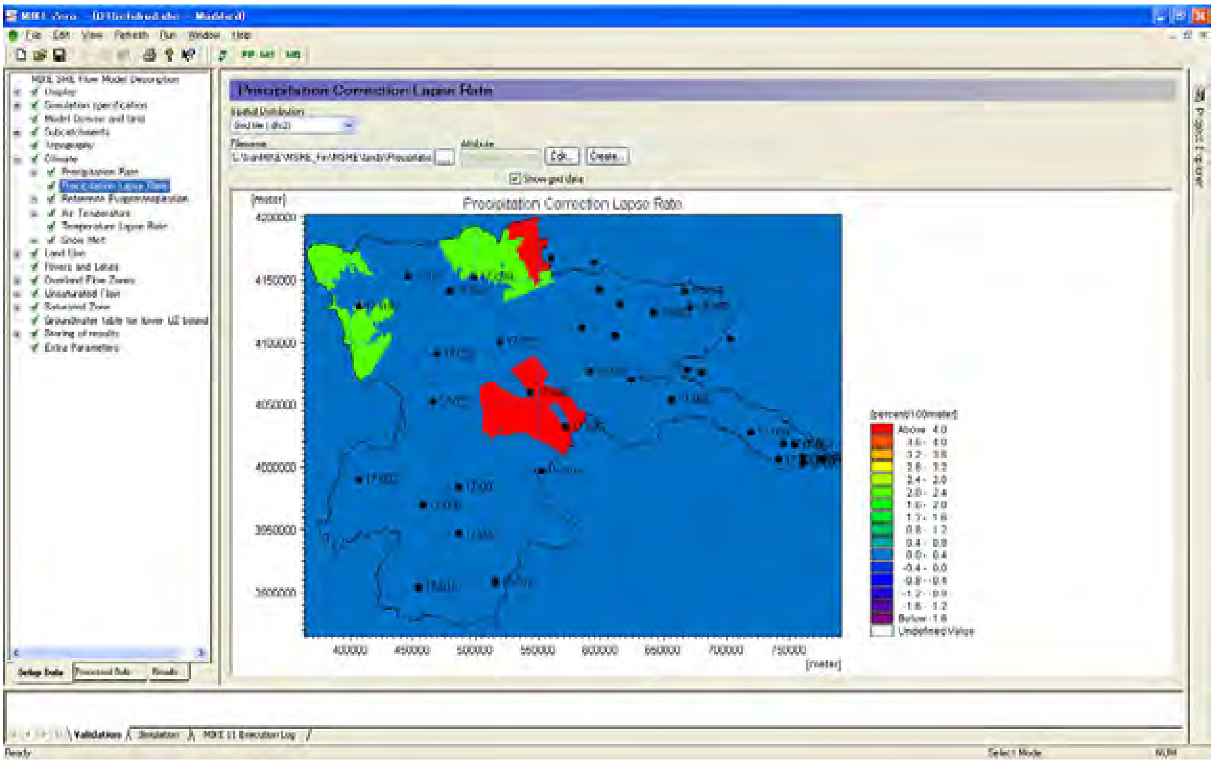


Figure 1.3.11 Precipitation Correction Lapse Rate

2) Evaporation

The evapotranspiration (ET) in the Sefidrud MIKE SHE model was based on daily measurements of pan evaporation at 31 stations from the RWMC (Figure 1.3.12). The 31 measurements were selected based on their length of record and continuity over time. Gaps in the measurement records were filled based on the correlations to neighboring stations.

Note 1: The evaporation time series data (dfs0 file) and Thiessen polygon can be change as same way as the information regarding precipitation as explained in item 1).

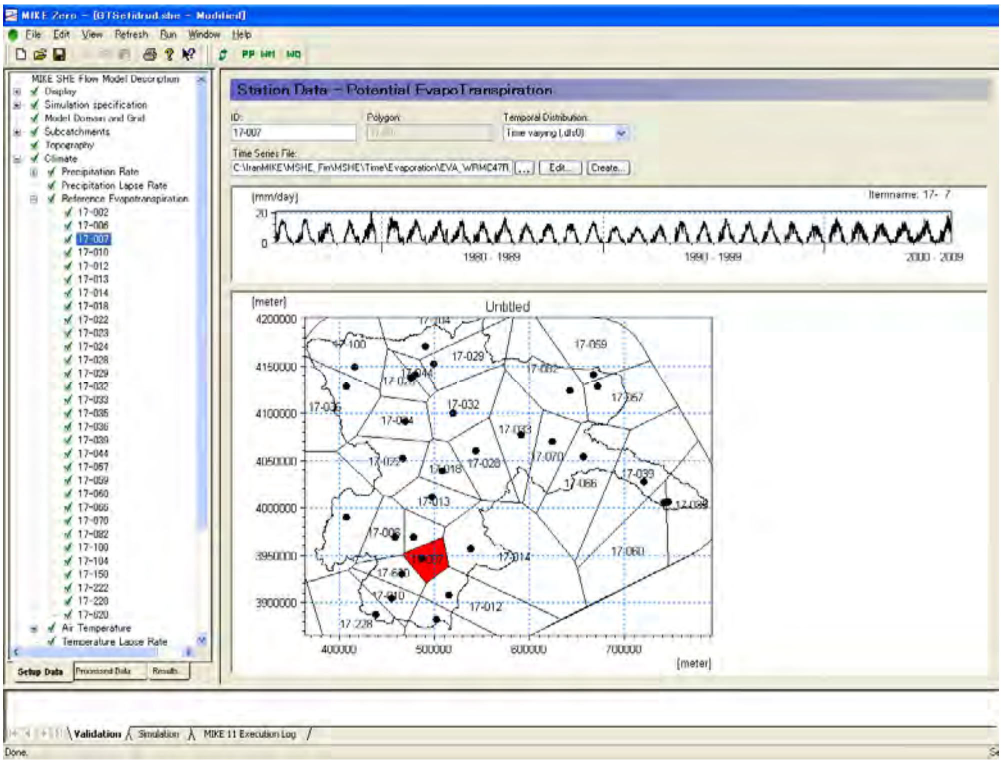


Figure 1.3.12 Polygon of Evaporation

MEMO

MIKE SHE calculates actual ET from the available water. This requires crop reference ET as input, which is a standard amount ET expected from a standard reference crop (i.e. a well water grass of a specific species and height). Pan evaporation is, however, significantly greater than crop reference ET. Pan coefficients can be used to convert between pan evaporation and crop reference ET. However, these coefficients depend on the local weather and location of the pan (e.g. upwind vegetation, relative humidity, wind speed, etc). Pan coefficients for sites characteristic of the Sefidrud basin probably range between 0.5 and 0.9. For the Sefidrud MIKE SHE model, a pan coefficient of 0.7 was used. That is, all of the pan evaporation data was multiplied by 0.7.

Actual values for crop reference ET can be calculated based climate data including wind speed, solar radiation, temperature, and humidity, using the Penman-Montieth (PM) method. The Iranian Meteorological Institute has such data at several synoptic stations in the Sefidrud basin up to four times per day, but these measurements were not available for this project. The existence of these measurements was confirmed during a meeting with WRMC (& Mahab Ghodss) on June 23, 2008.

In addition to the uncertainty associated with a global pan coefficient of 0.7, a significant limitation of the current data is that evaporation pans cannot be used during the winter. Therefore, the measured evaporation is zero during the winter. In the model, this will lead to an overestimation of the snow depth during the winter. In the future, it is highly recommended that pan evaporation data be substituted with crop reference ET values. The crop reference ET can be calculated directly using the PM method. However, an easier method should be satisfactory, based on monthly correlations between crop reference ET and the pan measurements. This is attractive because the monthly crop reference ET values are already available from Mahab Ghodss.

3) Temperature

The temperature in the Sefidrud MIKE SHE model was based on daily measurements of temperature at 16 stations from the Iranian Meteorological Institute (MOM). The 18 measurements were selected based on their length of record and continuity over time. Gaps in the measurement records were filled based on the correlations to neighboring stations.

Note 1: The temperature time series data (dfs0 file) and Thiessen polygon can be change as same way as the information regarding precipitation as explained in item 1).

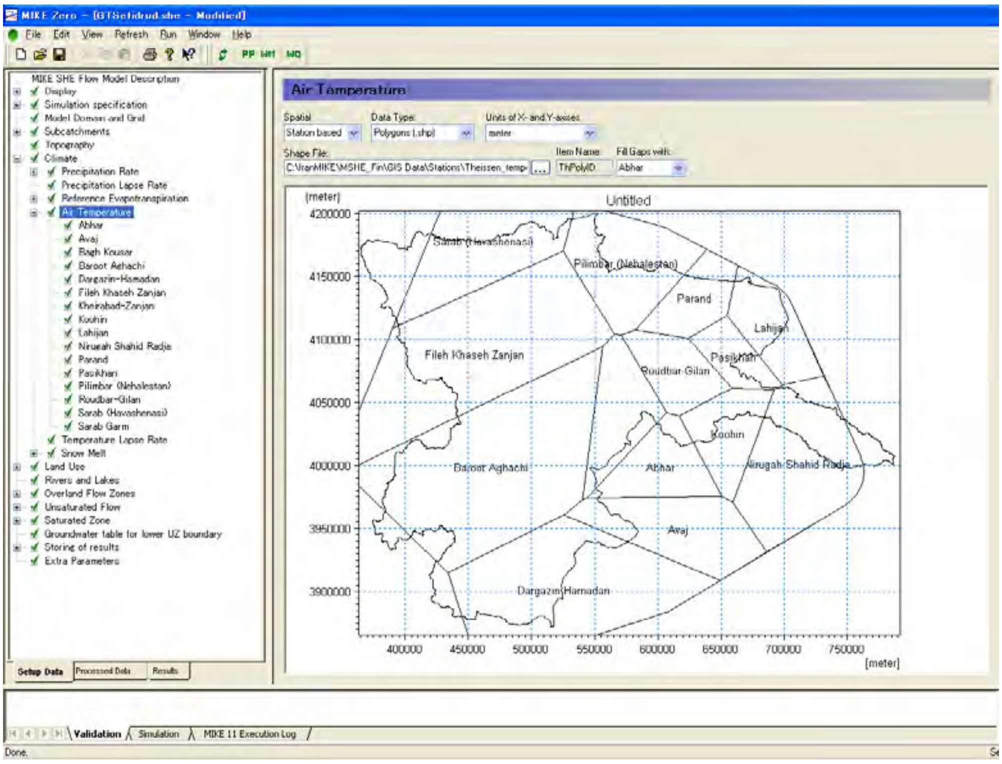


Figure 1.3.13 Polygon of Temperature

MEMO

In mountainous areas like the Sefidrud basin, there is a significant and precise elevation influence on actual temperature. The correction factor, known as the lapse rate, used in the Sefidrud MIKE SHE model was -0.649 C per 100m of elevation change from the measurement station. In fact, the temperature lapse rate depends on humidity (wet lapse rate), but this effect has been ignored in this model. This is probably insignificant because the climate is generally dry. The temperature is only used for the snowmelt calculations.

4) Snowmelt

The Sefidrud model considers the accumulation and melting of snow, as a function of air temperature. When the temperature is below 0C (Threshold melting temperature) precipitation accumulates as snow. When the temperature is above 0C, accumulated snow begins to melt at the rate of 2 mm/C/day (Degree-day melting coefficient).

MEMO

Melted snow does not immediately add to runoff, but is adsorbed by the snow pack until the moisture content of the snow reaches 0.15 (Maximum wet snow fraction). Once this fraction is reached, additional melting is added to ponded water, which is able to runoff, evaporate, or infiltrate. If the depth of snow is less than 50mm (Minimum snow depth for full area coverage) then the cell fraction covered by snow is linearly reduced as the snow depth decreases. All of these parameters were globally specified.

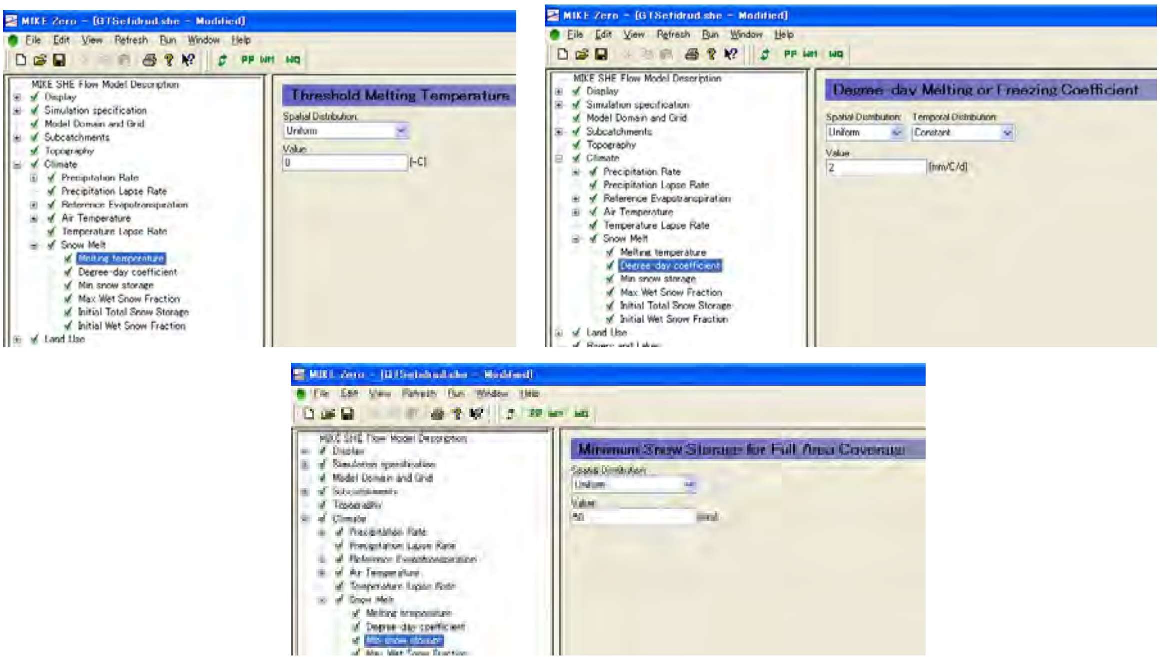


Figure 1.3.14 Parameter Set for Snow Melt

1.3.5 Vegetation

1) Land-Use Information

The distribution of vegetation in the Sefidrud BASIN was obtained as a polygon shape file from MOJA thorough WRMC. The shape file contained 76 unique vegetation classes; most of these being compounded mixed vegetation classes. These 76 classes were reduced to the following eight vegetation classes, based on the predominant class in mixed classes and lumping classes with similar characteristics.

Table 1.3.2 Dynamic Classification of Land-use

No.	Class	Description
1	Grass	“Grass” includes all of the good and moderate range areas, as well as fallow fields and areas classified as dry farming, which is assumed to be rain-fed grass-like crops
2	Scrub	“Scrub” is a lumping of all the areas that support limited or no vegetation, including all of the rock, bare land, poor range, floodplain and low forest classes
3	Urban	“Urban” includes the urban classes, as well as any other built up classifications, such as the airport class
4	Agriculture	“Agriculture” is the agriculture class, which is assumed to be irrigated crop areas
5	Water	“Water” includes areas of permanent surface water
6	Forest	“Forest” includes the modforest and woodland classes
7	Dense Forest	“Dense Forest” includes the dense forest class, which is predominantly on the coastal size of the mountains surrounding the Caspian Sea, where the precipitation rate is much higher than in the inland areas
8	Orchard	“Orchard” is assumed to be areas predominated by irrigated tree-based agriculture, such as fruit trees

The vegetation polygon shape file with these 8 classes was converted to a dfs2 file with 510 m-grid spacing. This means that each model domain grid (2040 m) includes 16 vegetation classes. The actual vegetation classes in the model are assigned to the model grids based on the dominant vegetation type in the cell, while accounting for the statistical variation of the distribution.

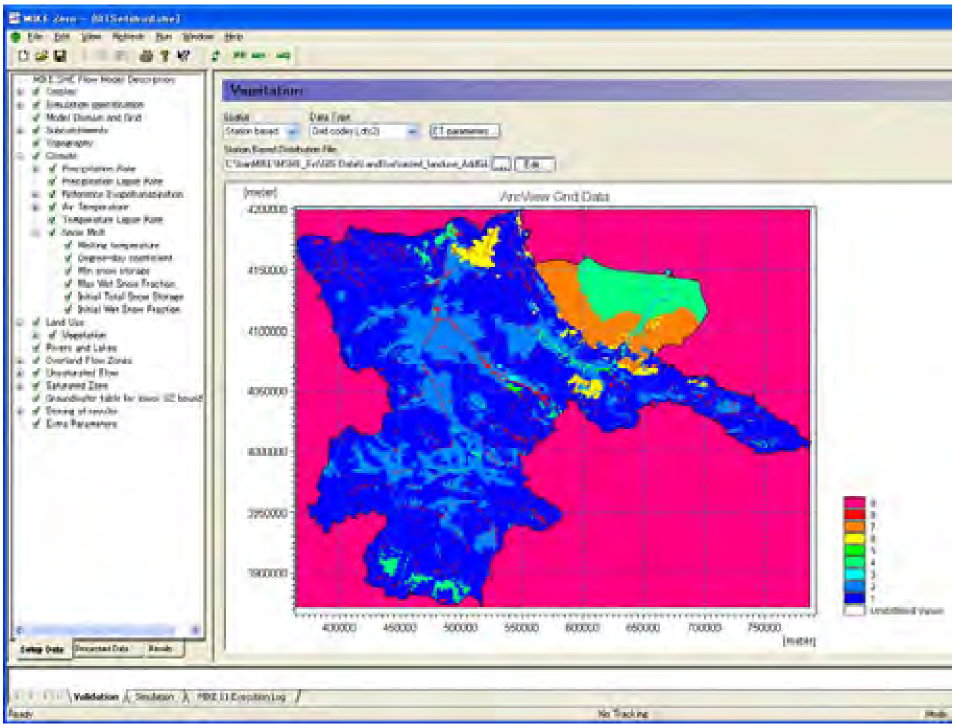


Figure 1.3.15 Land-Use Information

2) LAI for Vegetation

Each vegetation class requires a Leaf Area Index (LAI), which is the area of leaves per m2 of ground surface, and a root depth. Both of these values can vary throughout the growing season depending on the plant and crop type. In MIKE SHE, the LAI controls the actual amount of evapotranspiration, assuming that evapotranspiration is not limited by the available water. The root depth controls the depth to which water can be extracted from the unsaturated zone, and thus the unsaturated zone water deficit that must be filled before groundwater recharge can occur.

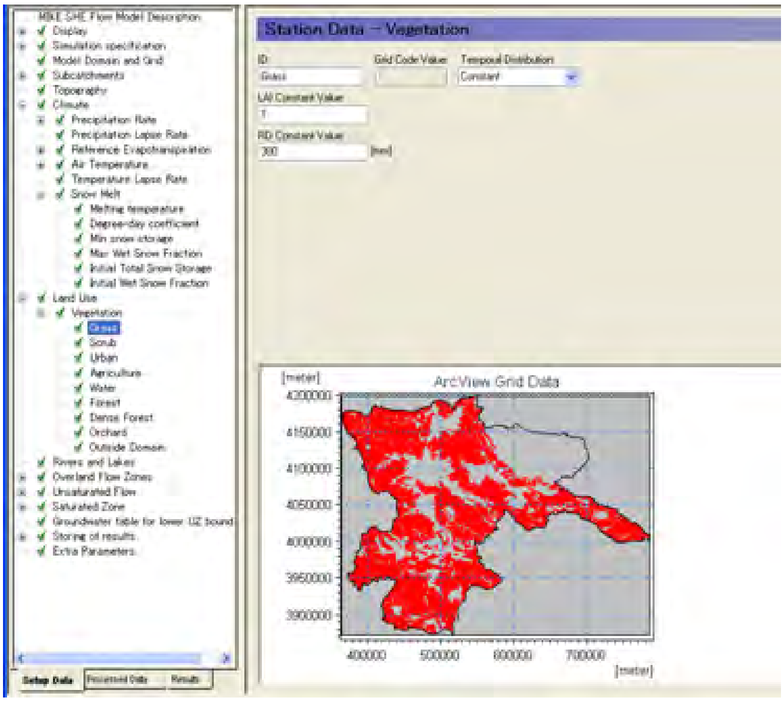


Figure 1.3.16 LAI for Land-Use

In the Sefidrud model, there is very little information available on the actual plant types in the study area. Thus, reasonable LAI and Root Depth values were assumed based on the expected dominant plant type.

Table 1.3.3 Summary of Leaf Area Index and Root depth values

Vegetation Class	LAI	Root depth [mm]
Grass	1	300
Scrub	0.5	600
Urban	0	0
Agriculture	4	1000
Water	0	0
Forest	5	1200
Dense Forest	6	2000
Orchard	5	2000

MEMO

Since the actual ET is largely limited by the available water due to the relatively dry climate, little effort was made to adjust these parameters during the calibration. More detailed evaluation of the LAI and root depths based on actual crops/plant types and growing seasons would likely improve the model, but only if better land-use and soils maps are also used.

1.3.6 River Network

The main branches were selected from a detailed line shape file with all tertiary streams. The network was defined such that most of the large sub-catchments were connected to the river network. The stream nodes were imported to MIKE 11 from the shape file and a MIKE 11 network was routed through the points. The resulting MIKE 11 network consists of 27 branches (excluding Gilan local rivers) that closely follow the actual meanderings of the river network.

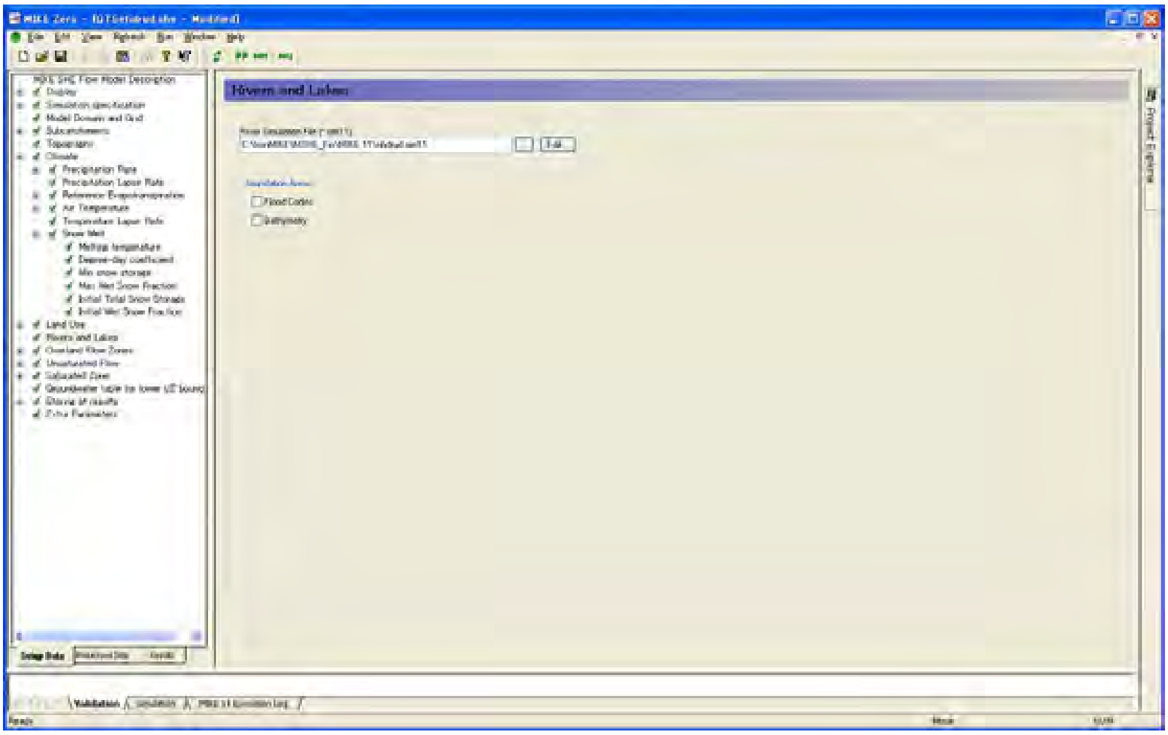


Figure 1.3.17 River and Lakes Main Window

When you click [...] button on main window of “River and Lakes”, the MIKE 11 database window will appear as shown in Fig 1.3.18. Then, you can see the river network if you select the “Input Tab” and click [Edit...] button at the line of “Network” as shown Fig. 1.3.19.

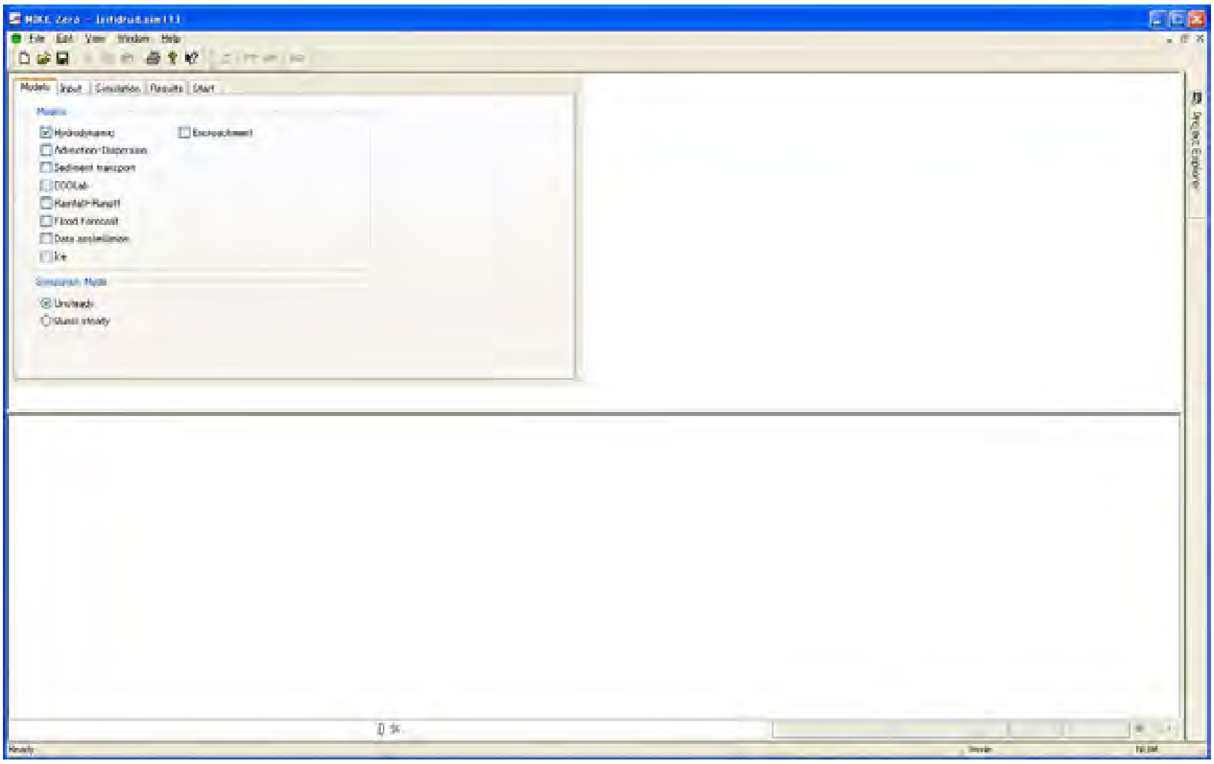


Figure 1.3.18 MIKE 11 Simulation Data Window (1)

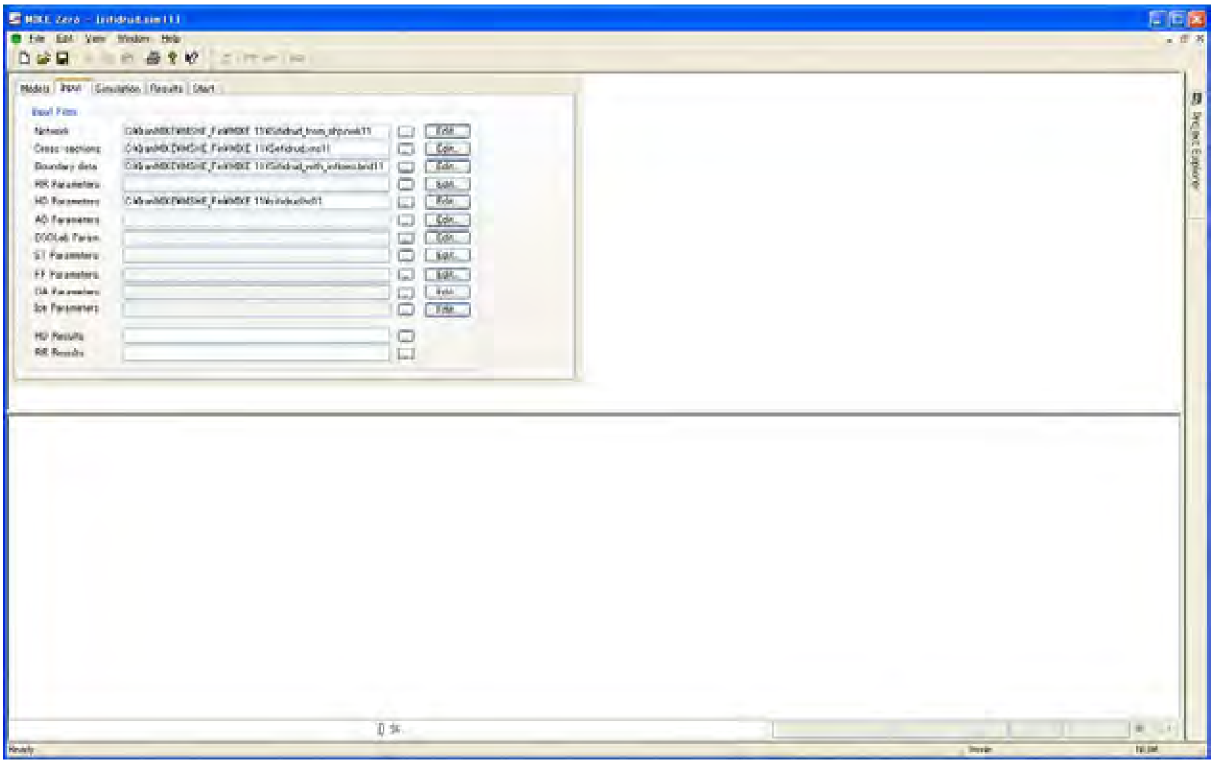


Figure 1.3.19 MIKE 11 Simulation Data Window (2)

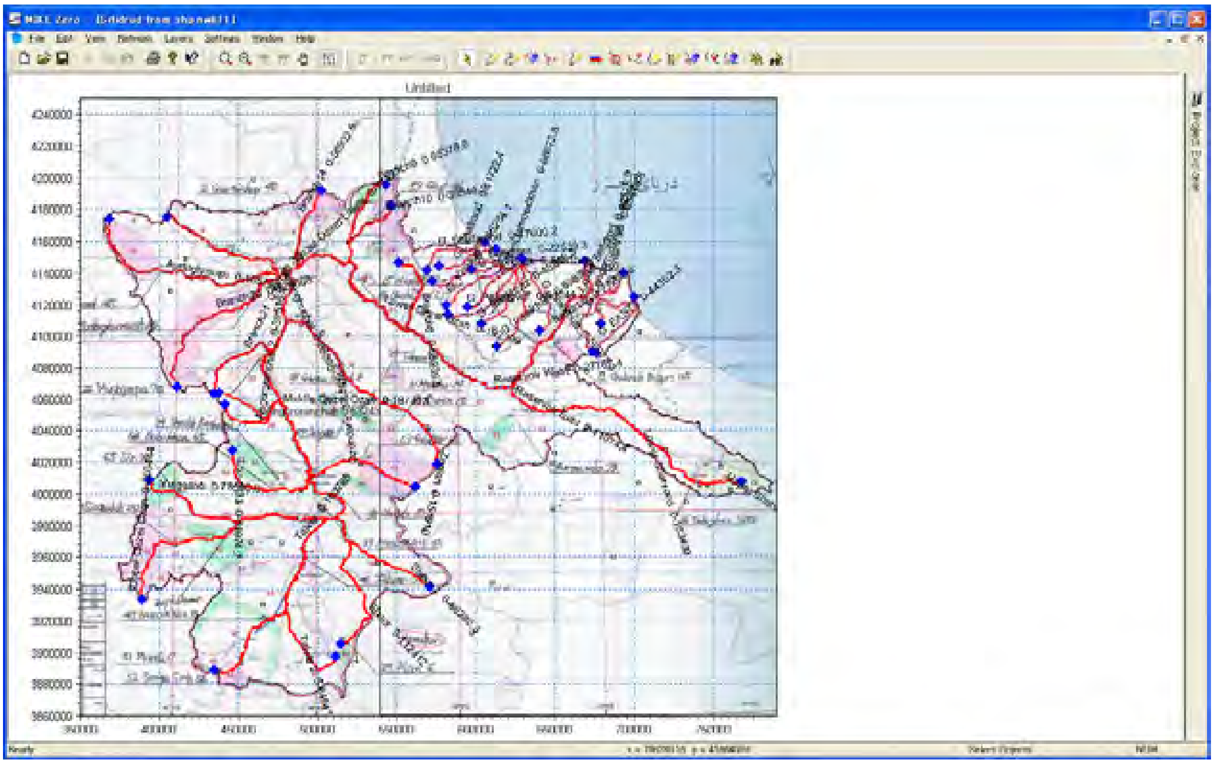


Figure 1.3.20 River Network

In each river branch, three to six river cross-sections were defined depending on the length of the branch, with one cross-section at the upstream and downstream ends of the branch. To ensure that the river cross-sections intersected the lowest point of the river valley, 2km-wide cross-sections were used. The river cross-sections were interpolated to the 90m DEM from NASA using MIKE 11 GIS.

<u>MEMO</u>

Since all the branches are defined without hydrograph transformation, the lateral inflows to MIKE 11 are simply summed and routed down the river network in each MIKE 11 time step. This is a reasonable assumption when we are calculating MIKE 11 with daily time steps. Some timing error is inevitable, since the travel time from the highest upstream areas to the outlet is probably a several days, especially during low flow periods. However, the timing error will not change the calculated recharge or infiltration used by MIKE BASIN. It also means that more accurate cross-sections will not affect the calibration or the resulting runoff and recharge calculations.

1.3.7 Overland flow

The overland flow calculations in MIKE SHE are based on the simple, sub-catchment based method, where ponded water in the subcatchment is routed either to a lower overland flow zone or to the river. Typically, this involves routing overland flow from upland areas to the lowland areas and then to the river, within each subcatchment.

In the Sefidrud model, the 15 overland flow zones were defined the same as the baseflow zones, taking into account a regional catchment zone, as well as the need to calibrate the model to known discharge stations. The zone boundaries generally follow the reach boundaries used in the catchment definition.

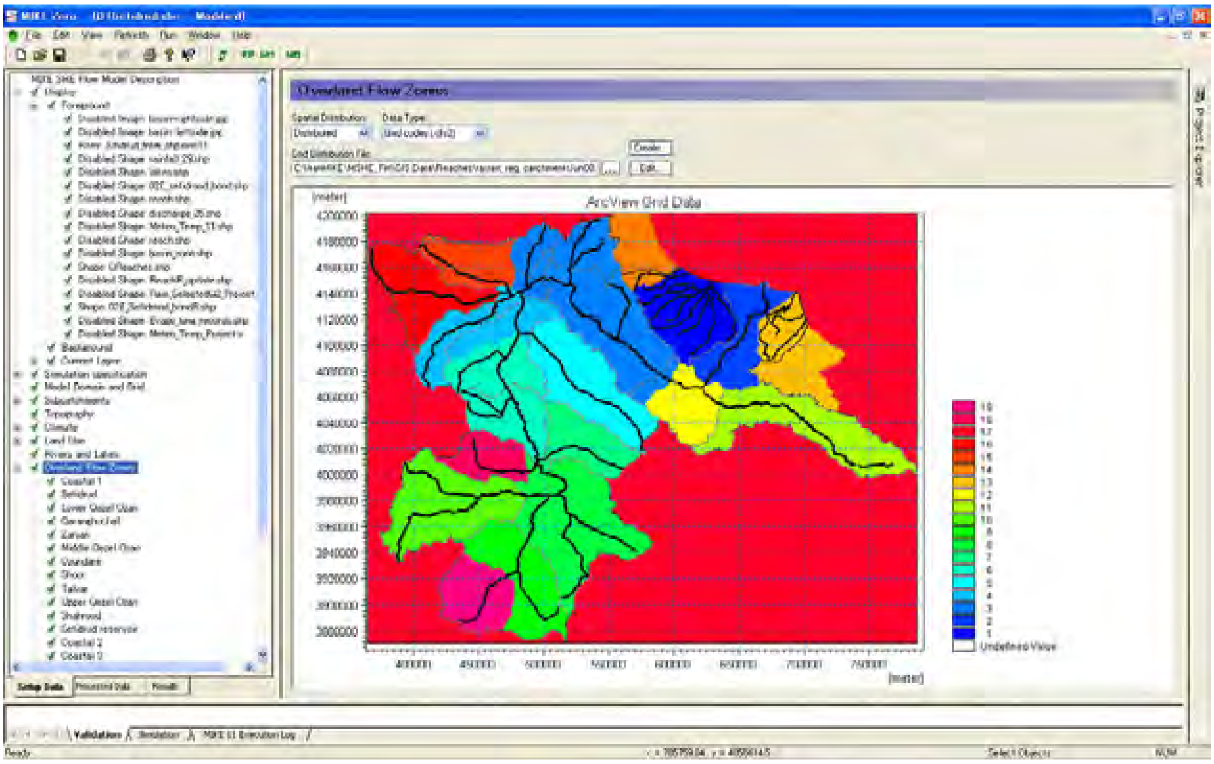


Figure 1.3.21 Over Land Flow Zone (1)

Each overland flow zone has five parameters: The slope (between 2 and 20 degrees), slope length (100m in all zones) and Mannings number (100 in all zones) together define how quickly water will flow to the river. The detention storage (0 mm in all zones) defines how much ponded water must build up before overland flow occurs. The initial depth is always zero. The average slope for each zone was roughly estimated based on a slope map for soil erosion analysis

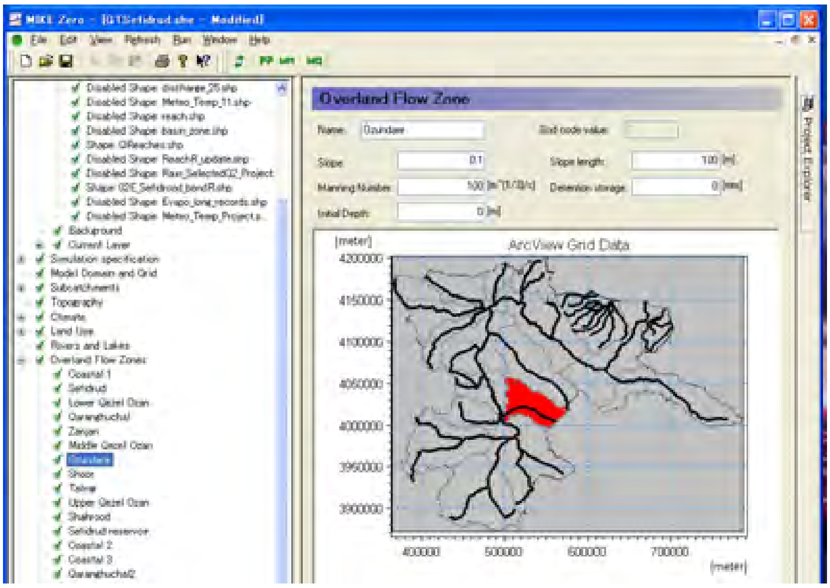


Figure 1.3.22 Over Land Flow Zone (2)

1.3.8 Unsaturated flow zone

Unsaturated flow is calculated using the gravity flow method. This method is more suitable than the two-layer water balance method when the soils are dry or the water table is deep.

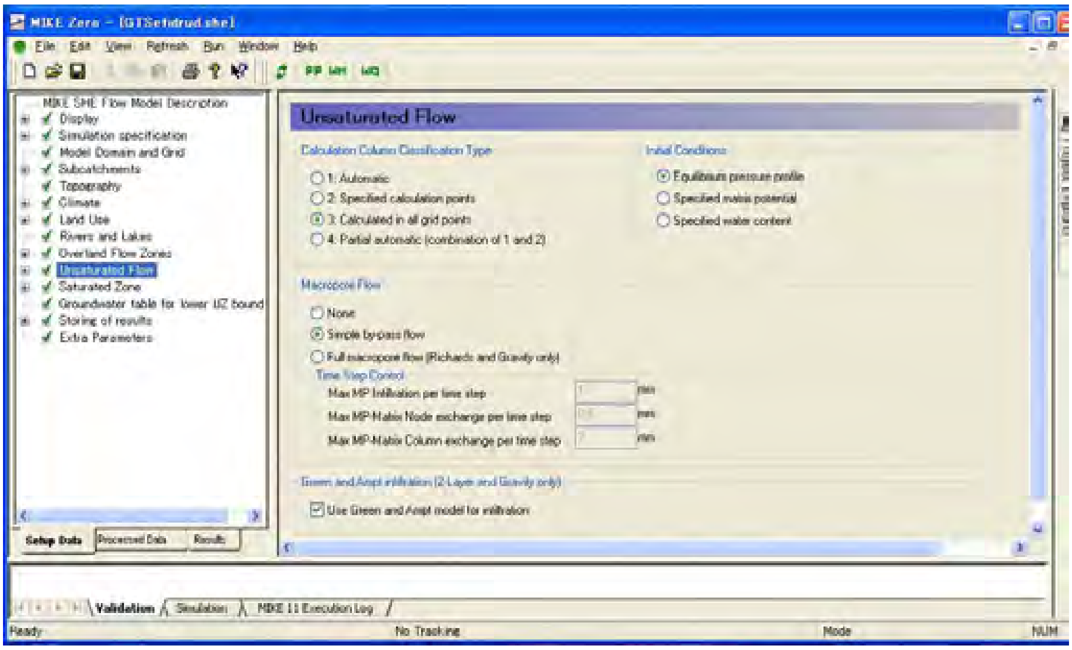


Figure 1.3.23 Main Window of unsaturated Zone

The Sefidrud basin has been divided into 10 soil classes based on the soils classification maps supplied by WRMC. These soil classes refer to 3 different soil types defined in a soil database file: Alluvium, Loam and Rock. The Alluvium soil type was defined for the sand and gravel alluvial classes. The Loam soil type was used for all other areas except the Mountains, which were defined as rock. All soil profiles are assumed uniform in depth.

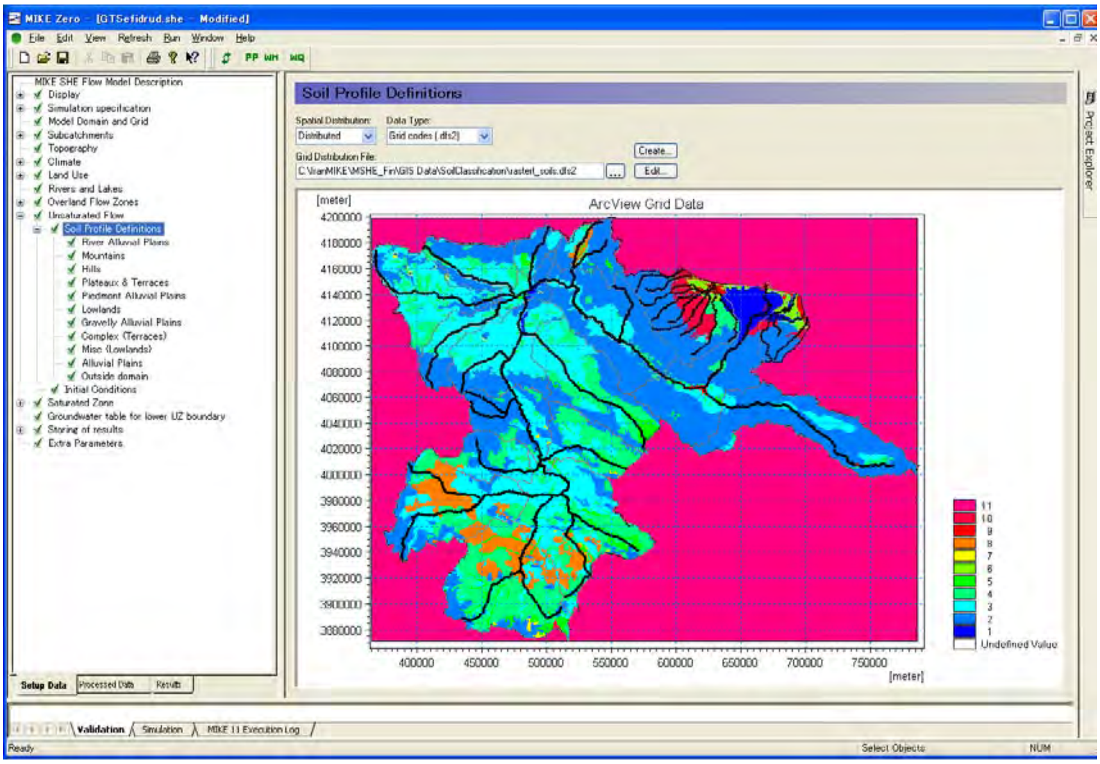


Figure 1.3.24 Soil Map

Soil characteristics, such as saturated water content, field capacity, and especially the parametric saturation and conductivity relationships represent microscopic phenomena. Given the size of the model grid cells, the parameter values used in the model must represent a broad average across the grid cell for the particular soil type. Thus, these parameters are calibration parameters, bounded by representative values for the particular soil class.

All of the soil classes use the same vertical discretization. The top cell of the column is 10cm thick, which limits direct soil evaporation to the top 10cm. Beneath the top cell, the next two cells are 30cm and a 60cm thick, respectively. The remaining cells are 1m thick down to the bottom of the UZ column. The actual layer thicknesses used in the model are automatically slightly adjusted during the pre-processing phase to ensure a smooth transition between layer thicknesses.

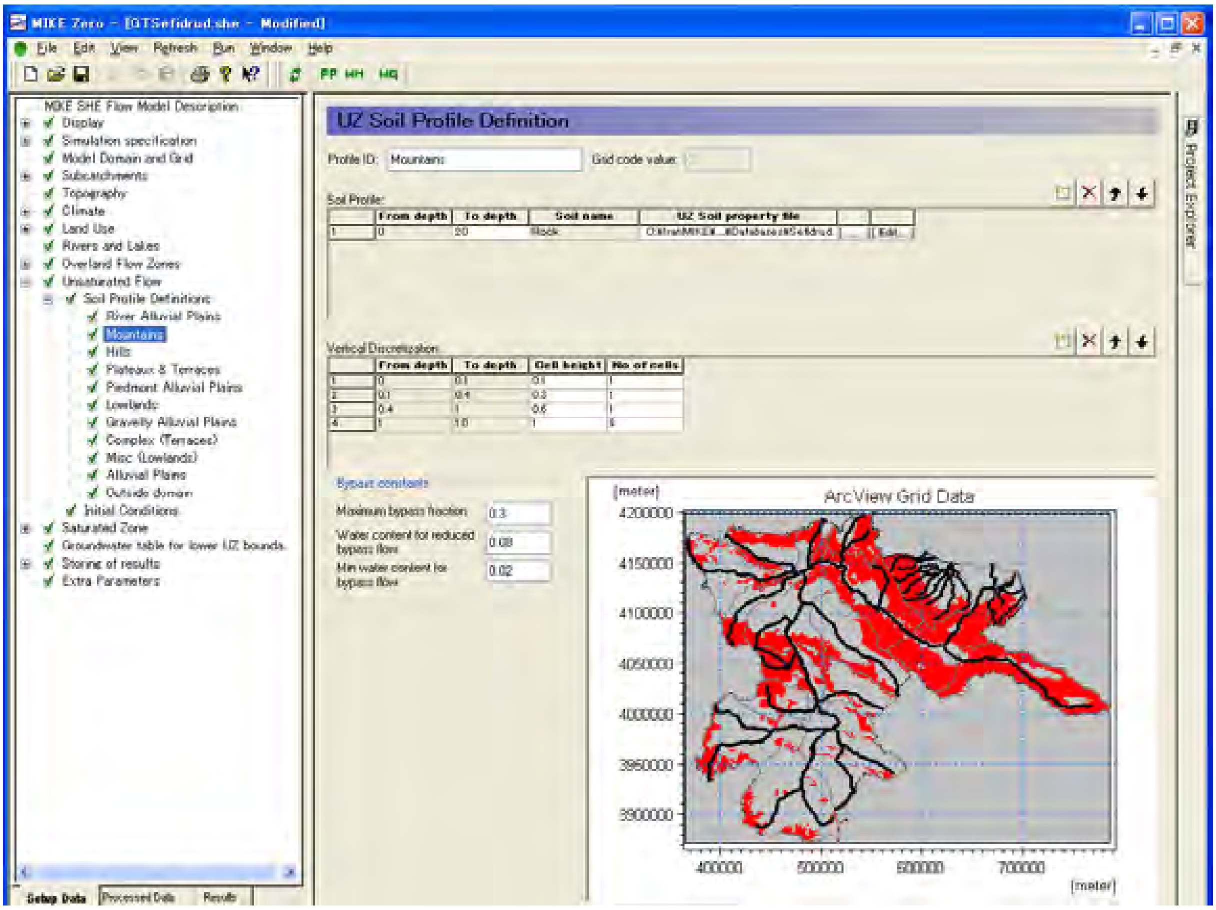


Figure 1.3.25 Soil Profile Definition

<u>Bypass Parameter</u>

Simple macro-pore flow is included to allow some of the infiltration to bypass the root zone and infiltrate directly to the groundwater. In large cells, such as those used in this model, it is expected that there will be lateral variability of the infiltration rate. There will be some areas with much higher infiltration rates that the average which will much very rapidly recharge to the groundwater. Also, macro-pores caused by shrinking soils, animal burrows etc, will also cause a fraction of the infiltration to rapidly bypass the root zone and recharge the groundwater directly. MIKE SHE calculates the actual amount of bypass flow based on the water content in the root zone, since dry soils will absorb some of the infiltrating water. Since ET is largely limited by the available water, decreasing the amount of bypass has the effect of making more water available for ET and thus increasing the actual ET at the expense of recharge. The bypass parameters were roughly calibrated to allow sufficient recharge.

Table 4 Summary of soil parameters

Parameter	Value
Max bypass fraction	0.3
Water content for reduced bypass	0.08
Water content for zero bypass	0.02

Groundwater table for lower UZ boundary

In the Sefidrud model, the water table is not a calculated parameter because the linear reservoir method does not calculate a distributed water table. In the absence of a calculated water table, a static water table must be defined to represent the bottom of the UZ model. In the Sefidrud model, the groundwater table has been defined 3m below the ground surface everywhere. Three meters was chosen because it is greater than the root depth everywhere in the domain.

The actual depth to groundwater is obviously variable across the basin. However, very little information exists on its depth, except in a few local areas. Further, the thickness of the UZ zone below the root zone does not affect the volume of recharge to the groundwater, but only the timing of its arrival at the groundwater table. Since the purpose of the model is to supply recharge to MIKE BASIN model for annual water allocation, the sensitivity of the model to this depth was not investigated.

1.3.9 Groundwater

In the Sefidrud model, groundwater baseflow to streams is calculated using the linear reservoir method. This method uses a series of non-spatial “buckets” that collect infiltration from the unsaturated zone and discharge to the stream network. The time constants control the rate of outflow from the various reservoirs, and the specific yield determines the height of water in the reservoir and thus, the driving pressure for the outflow.

1) Interflow

The upper Interflow linear reservoirs represent the rapid discharge to streams that occurs after a rainfall event. This water infiltrates near small streams and drainage features where the water table is close to the surface and discharges over the following few days and weeks. Recharge from the bottom of the unsaturated zone columns is added to the Interflow reservoir below the cell, where it either discharges to a lower interflow zone within the subcatchment or directly to the stream network, if a lower zone does not exist. A portion of the infiltration percolates to the lower Baseflow reservoir.

The interflow reservoirs in the MIKE SHE model have been defined as one reservoir per catchment. This facilitates the cross calibration with MIKE BASIN, as both models then have the same structure. Also, it eliminates mass balance discrepancies associated with trying to calculate inflows and outflows on areas that do not correspond to the catchment boundaries.

Since the interflow reservoirs are limited to the catchment boundaries, it suffices to define a uniform interflow reservoir that will automatically be divided along the catchment boundaries. Calibration of the individual interflow reservoirs was beyond the scope of this model, given that the primary purpose of the model is to generate runoff and recharge for MIKE BASIN. A more detailed calibration of the interflow reservoirs would yield an improved recession curve after storm events at the various gauging stations, but would not affect the calculated runoff or recharge for MIKE BASIN.

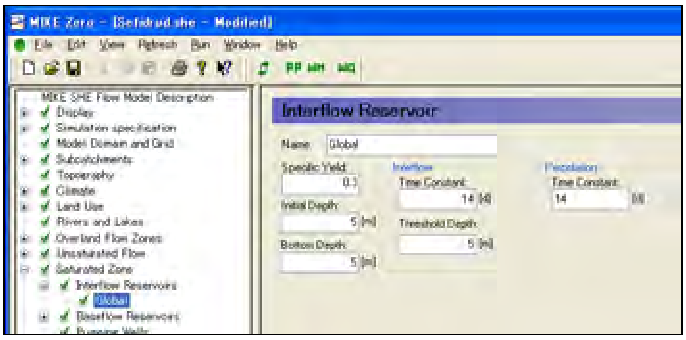


Figure 1.3.26 Interflow Parameters

2) Baseflow

In the Sefidrud model the 15 baseflow reservoirs were defined the same as the overland flow zones, taking into account a regional catchment zone map that was available, as well as the need to calibrate the model to known discharge stations. The baseflow reservoir boundaries generally follow the reach boundaries used in the catchment definition, but consist of multiple catchments.

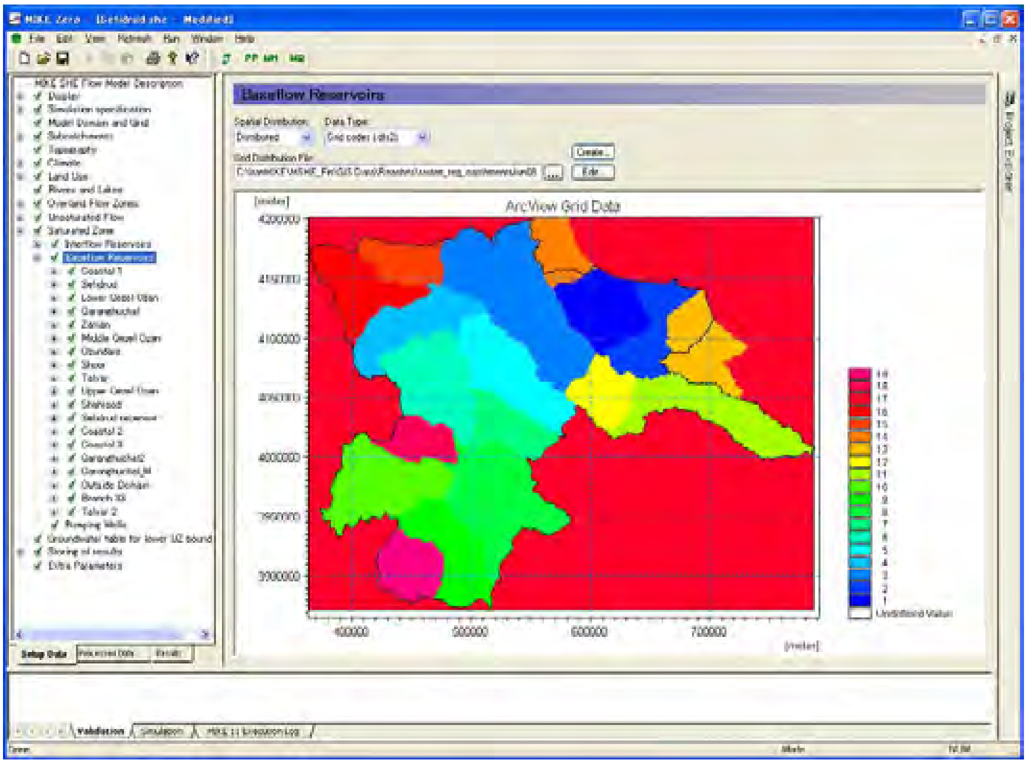


Figure 1.3.27 Interflow Parameters

The Baseflow reservoirs represent the slower discharge from deep groundwater that sustains stream flow during dry periods. In MIKE SHE, the Baseflow reservoir is divided into two parallel reservoirs, to account for both the slow (months to years) and very slow (years to decades) baseflow components.

Since deep groundwater may discharge outside of the basin, a fraction of the percolation from the interflow reservoirs to the baseflow reservoirs can be diverted to Dead Zone Storage. In the Sefidrud model, the dead zone storage is assumed to be zero except in the Talvar and Shoor catchments. In these catchments, the dead zone storage is used to reduce the amount of baseflow to the streams to more closely reflect the measured flows in these catchments. See the Calibration section for more detail on this.

Not all discharge from the baseflow reservoirs is available to the river flow. Some water will discharge in any low lying areas near the rivers, where the water table is close to the ground surface. This outflow will be rapidly consumed by ET – especially in semi-arid climates such as in the Sefidrud basin. Further, in areas with shallow water tables, plant roots will extend to the water table and extract ET directly from the water table. These processes are accounted for in MIKE SHE by the UZ feedback fraction, which removes a fraction of the available discharge and makes it available to ET.

The baseflow reservoir parameters were defined consistently between the reservoirs. The only deviations are in the local specification of specific yield, dead zone storage and UZ feedback fraction. The dead zone storage and UZ feedback fraction were used to reduce the baseflow in two catchments (Talvar and Shoor) during the calibration. The specific yield was increased from 0.15 to 0.3 in the Zanjan and Ozundare catchments to reflect the higher availability of groundwater in these catchments.

Based on the calibration, the parameters above mentioned parameters are defined as shown in next Table.

Table 1.3.4 Parameters for Saturated Zone

Parameter	**Slow Baseflow**	**Very slow Baseflow**
Specific yield	0.15	0.25
Time constant for baseflow	180 days	3600 days
Dead storage fraction	0	0
UZ feedback fraction	0.1	0.1
Initial depth	10	49
Threshold depth for baseflow	10	50
Threshold depth for pumping	10	50
Depth to the bottom of the reservoir	10	50

Annex – 2
DESCRIPTION OF SEFIDRUD- WASM

Annex - 2

DESCRIPTION OF SEFIDRUD- WASM

Table of Contents

Page

List of Tables

Tables **Page**

List of Figures

Figures **Page**

CHAPTER 1. WATER ALLOCATION SIMULATION MODEL

1.1 OUTLINE OF SIMULATION MODEL

The water balance simulation model for Sefidrud River basin by MIKE SHE (hereinafter referred to as The Sefid-WBSM) is established to calculate the natural groundwater recharge and surface runoff to input into the MIKE BASIN allocation simulation model (hereinafter referred to as The Sefid-WASM). The groundwater recharge is equal to the amount of water percolating out through the bottom of the root zone. Runoff and infiltration are surface processes and as such require detailed information on the ground surface and root zone.

As to the Sefid-WASM, the simulation result outputs in each Reach and the water transfers through the river channel in the same way as the Sefid-WBSM. The Sefid-WASM can be visually established on the screen of a computer using the GIS software “Arc Map”. Concretely, the visible figures of module for basins, river lines, dams and water users are pasted on GIS database screen and the data is input through the windows which appear when the modeler clicks the features. After the data input, the Sefid-WASM should be verified its tank parameters which express the conveyance from underground water (the recharge) to river flow.

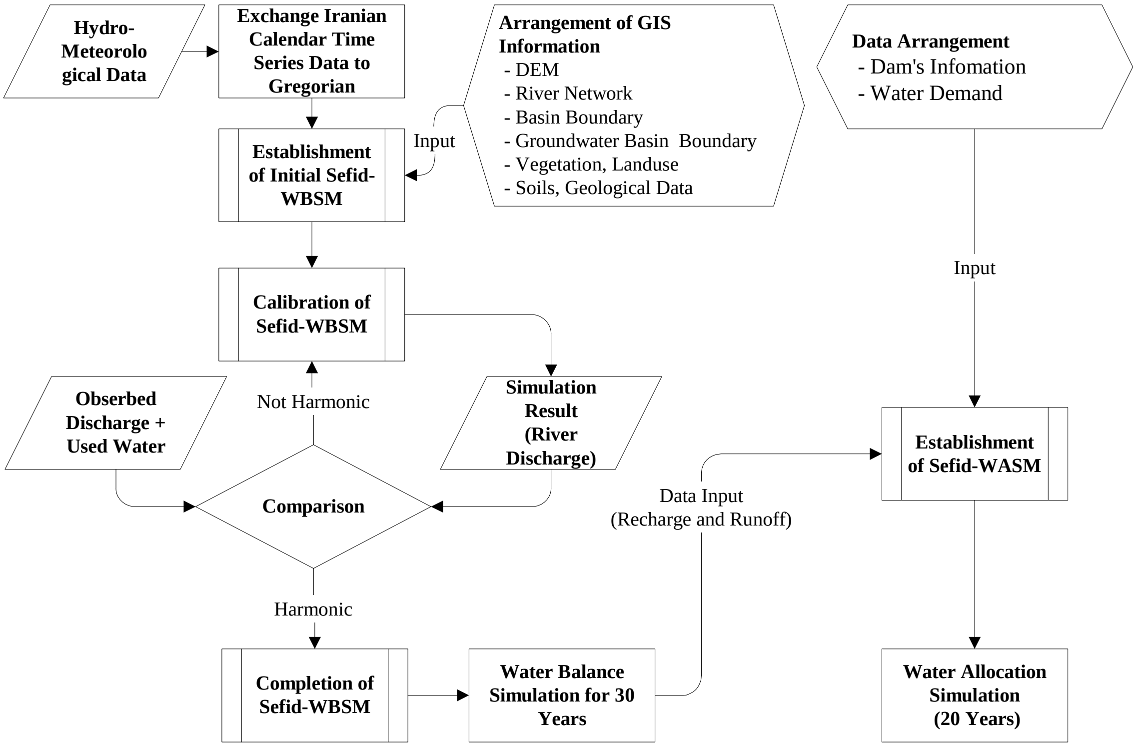


Figure 1.1.1 Flowchart of Establishment of Sefid-Models

1.2 DATABASE OF SEFIDRUD BASIN MODEL

When a user click the project file the user can browse the data base of Sefid-WASM Model via ARCMap as follows:

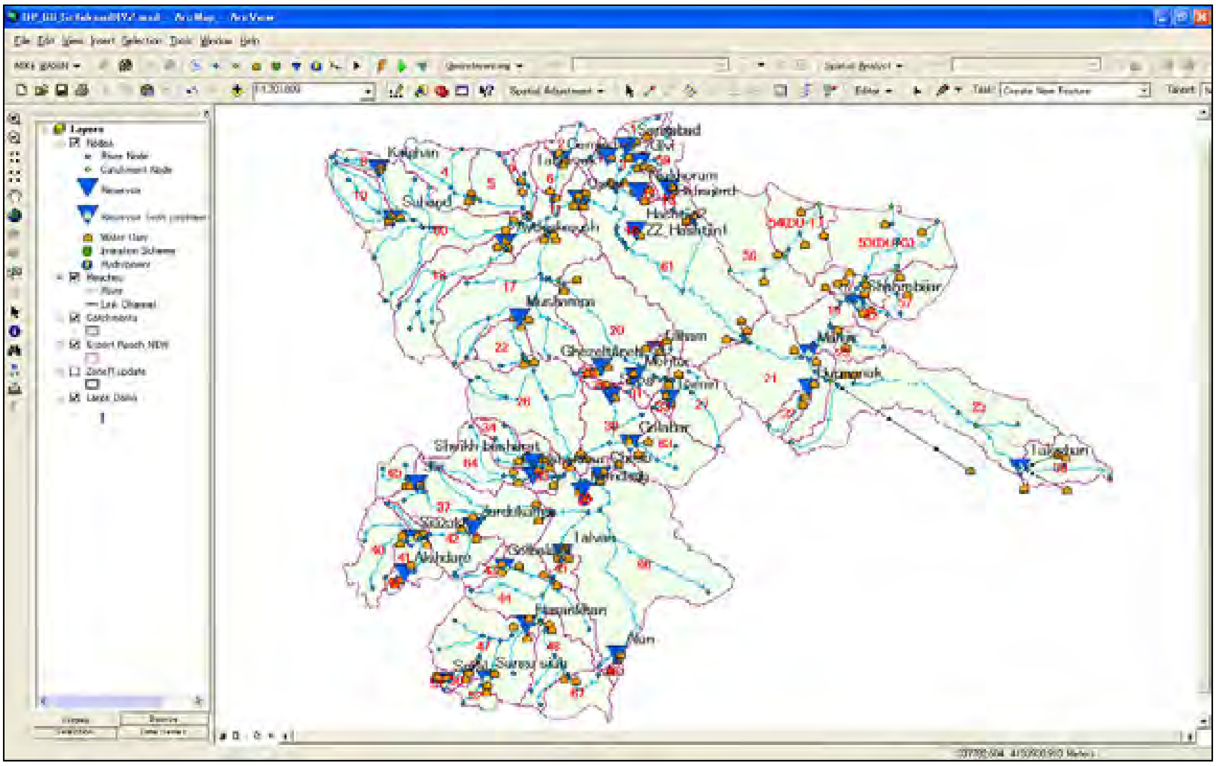


Figure 1.2.1 Display of GIS Database for Sefid-WASM

MIKE BASIN is mounted on the ARC-MAP GIS software as shown in the Figure 1.2.1. In this Study, using the output from MIKE SHE as the boundary condition, the water allocation simulation model will be established with the module which functions like dams, irrigations, other water users and so on. The modules are display as layers in the left window as shown Figure 1.2.2.

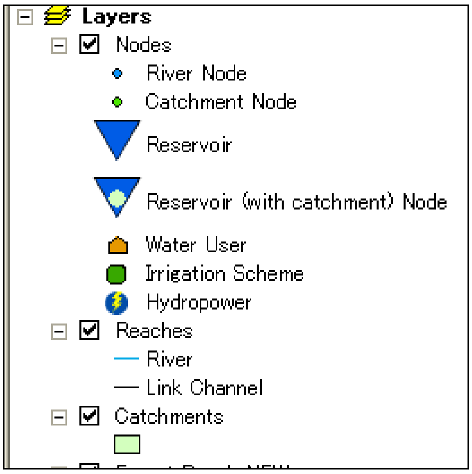


Figure 1.2.2 Display of GIS Database for Sefid-WASM

CHAPTER 2. DATA INPUT

2.1 INPUT DATA

The time series data such as evaporation, precipitation, water demand and river discharge, and the boundary information such as River network, Whole Basin, Reaches are collected to establish Sefid-WASM. These data are entered into GIS database MIKE Basin software.

Table 2.1.1 Input Data into Sefid-WBSM

Item		Duration, Contents	Remarks
Observed Data	Precipitation (Daily)	1975 - 2005	For calculation of water level of Dam Reservoir
	Evaporation (Daily)	1975 – 2005	- ditto -
	Flow Discharge (Daily)	1975 – 2005	For Calibration
Water Demand	Surface Water Demand (Daily) Ground Water Demand (Daily)	Agricultural, Industrial, Drinking water Demand in 2006, 2016 and 2031	For Water Allocation Simulation
Geographical Information	Basin Boundary	-	Same as MIKE SHE
	Reach Boundary	Sub-basins based on dam construction plan	- ditto -
	River Network	Major Rivers	- ditto -
	Position of Observatories	Hydro-Meteorological Station	- ditto -
Dams Data	H-A-V curve, Normal water level, Dead water level, Dam height	Present(2006): 3 Dams Middle Term(2015):14 Dams Long Term(2031):36 dams	

2.2 HOW TO INPUT

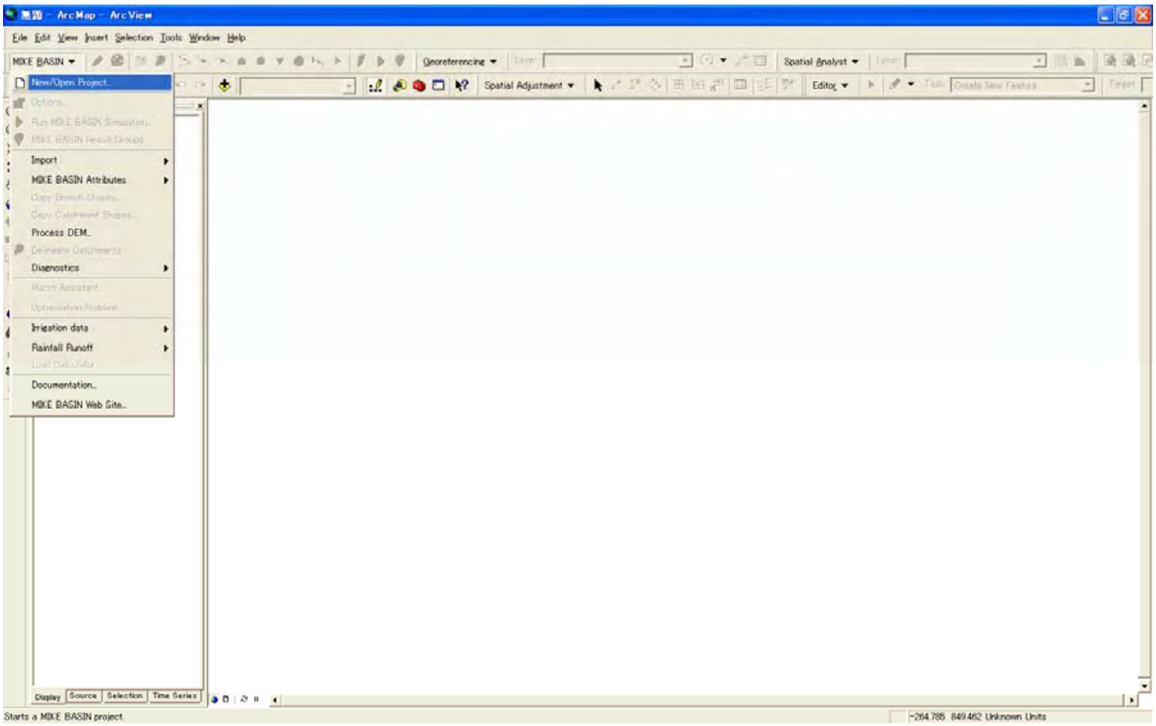
The procedure for the establishment of model is simply explained as follows: (1) Formation of river network, (2) Delineation of small basin,(3) Put on nodes for basin and River, (4)Input of time series data, (5) Mounting of water demand module, (7) Simulation start.

2.3 INITIAL DATABASE SETUP

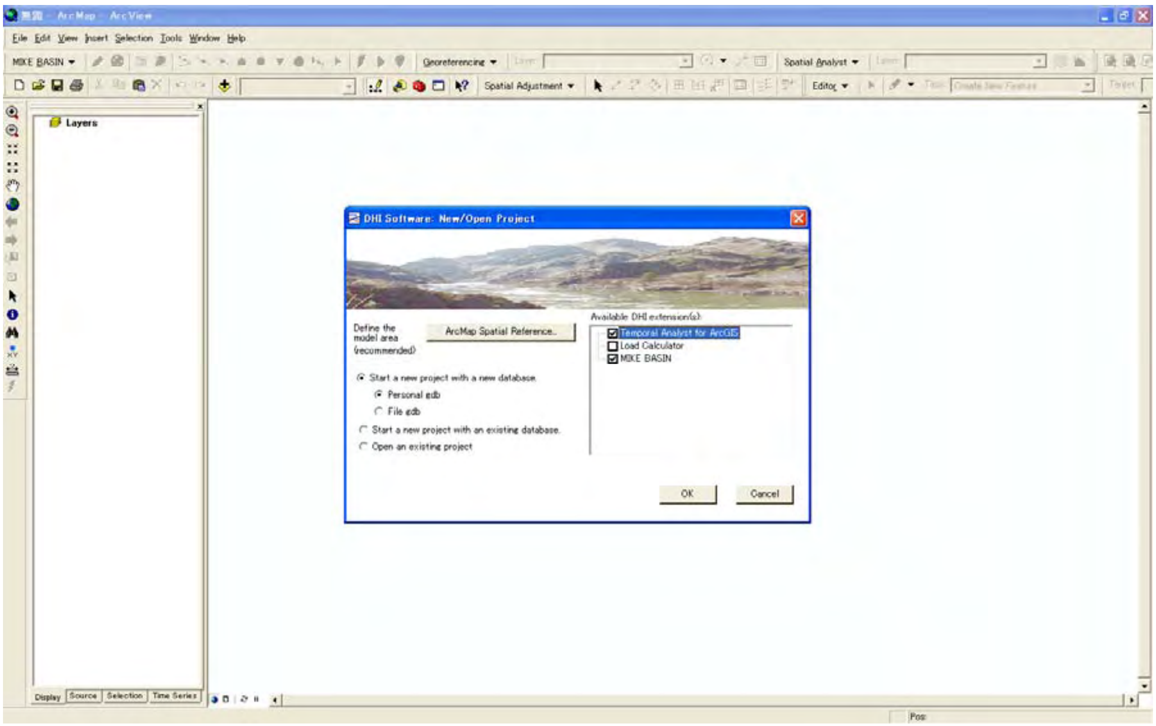
As a first step, the user should make the database to input the various data and information as follows:

2.3.1 Project File

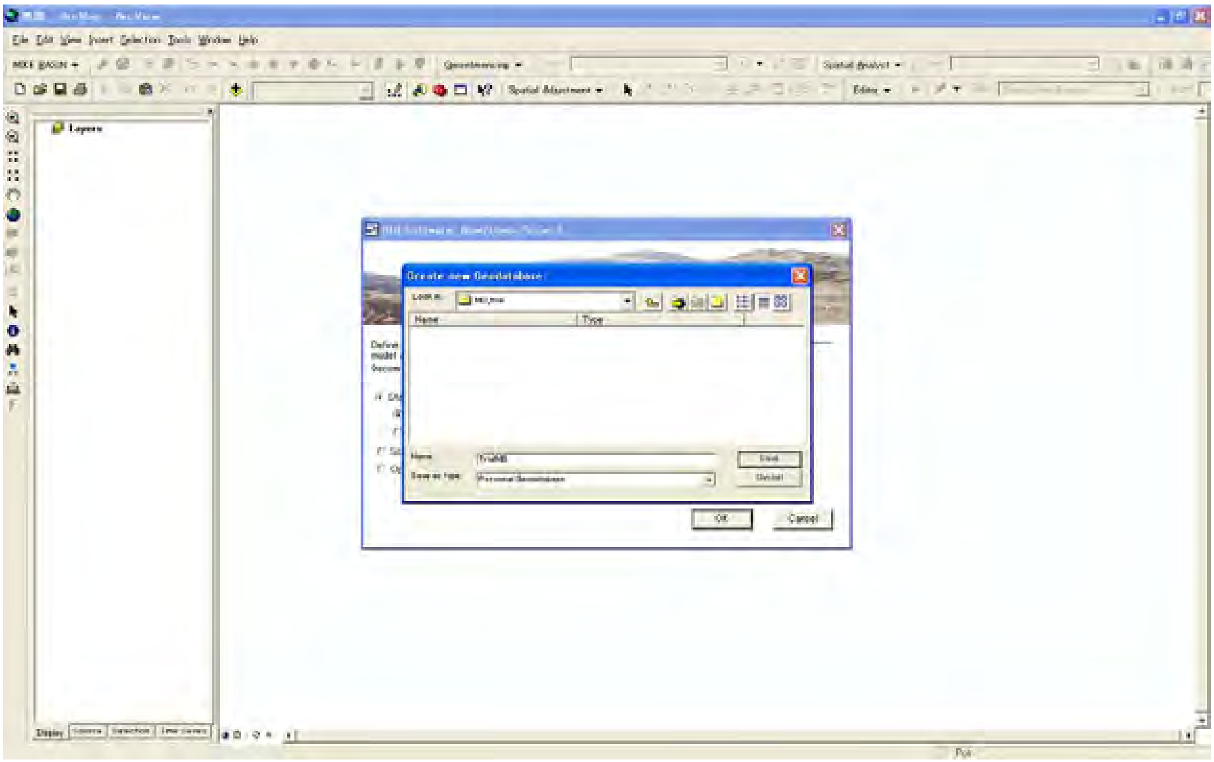
1) MIKE BASIN > New/Open Project



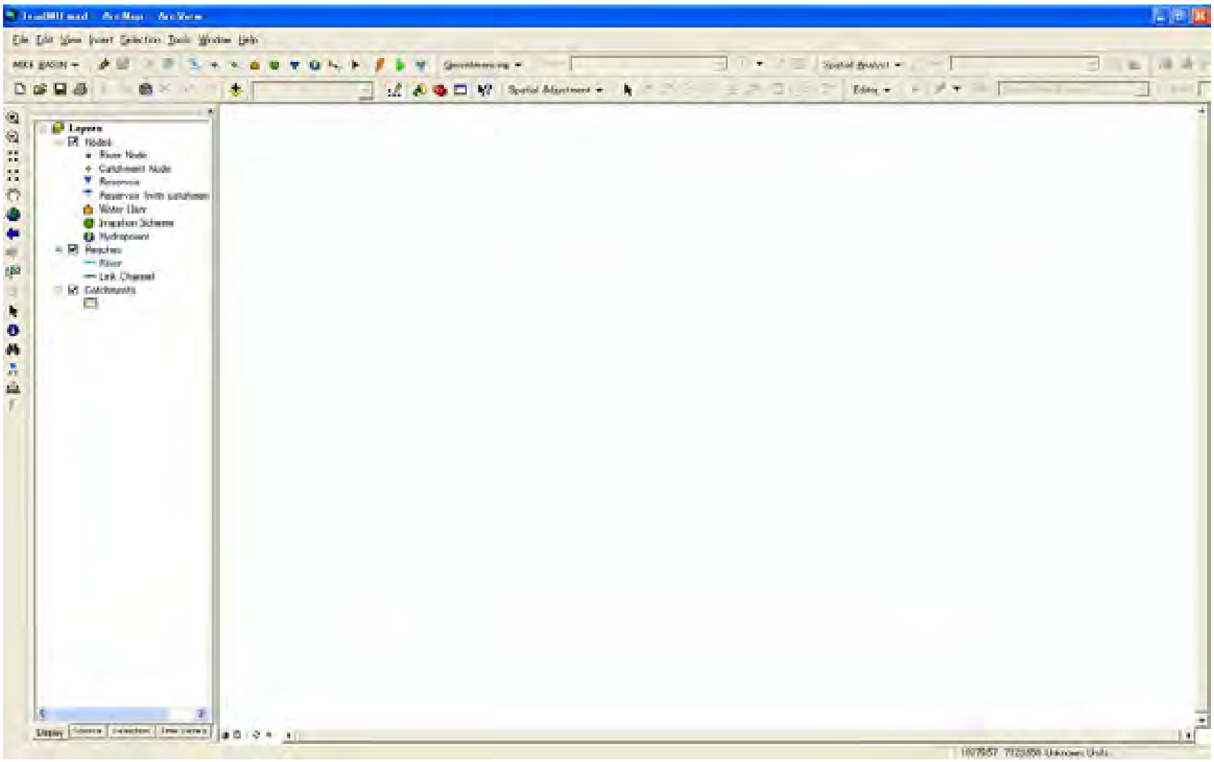
2) Start a new project with a new database > OK



3) Input a project Name > Save



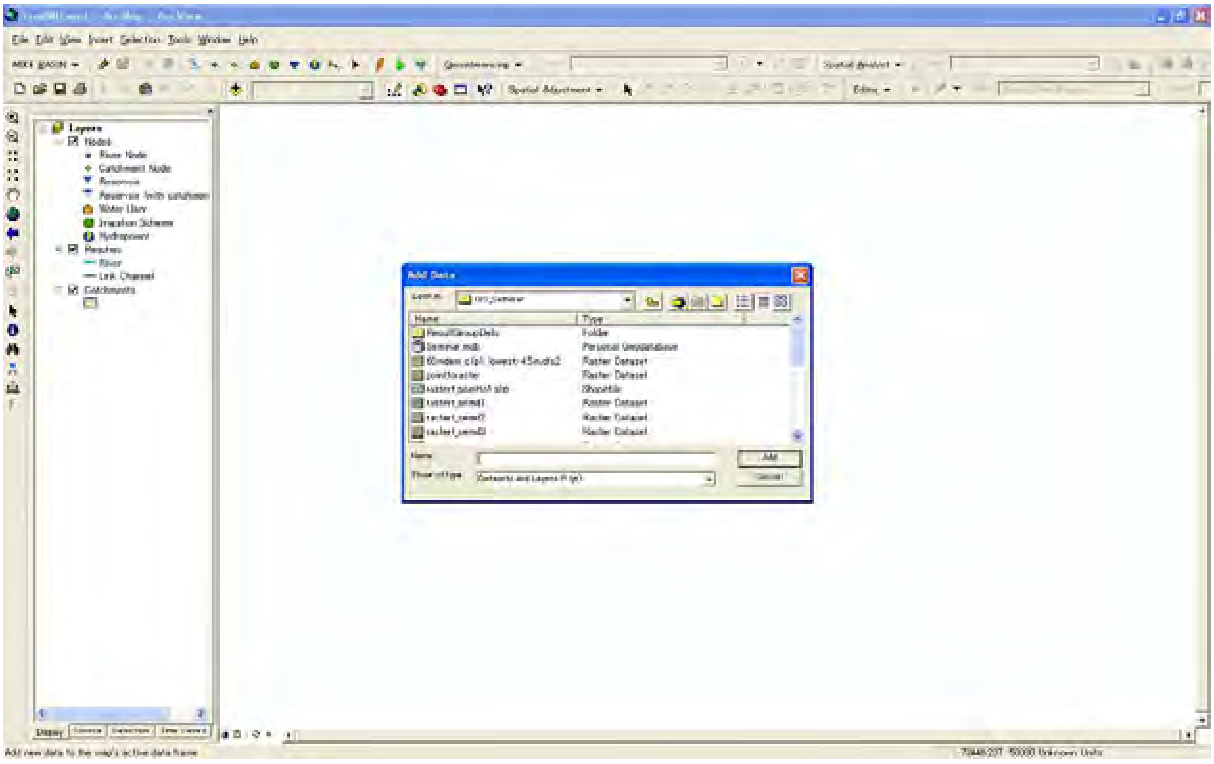
4) Initial Database



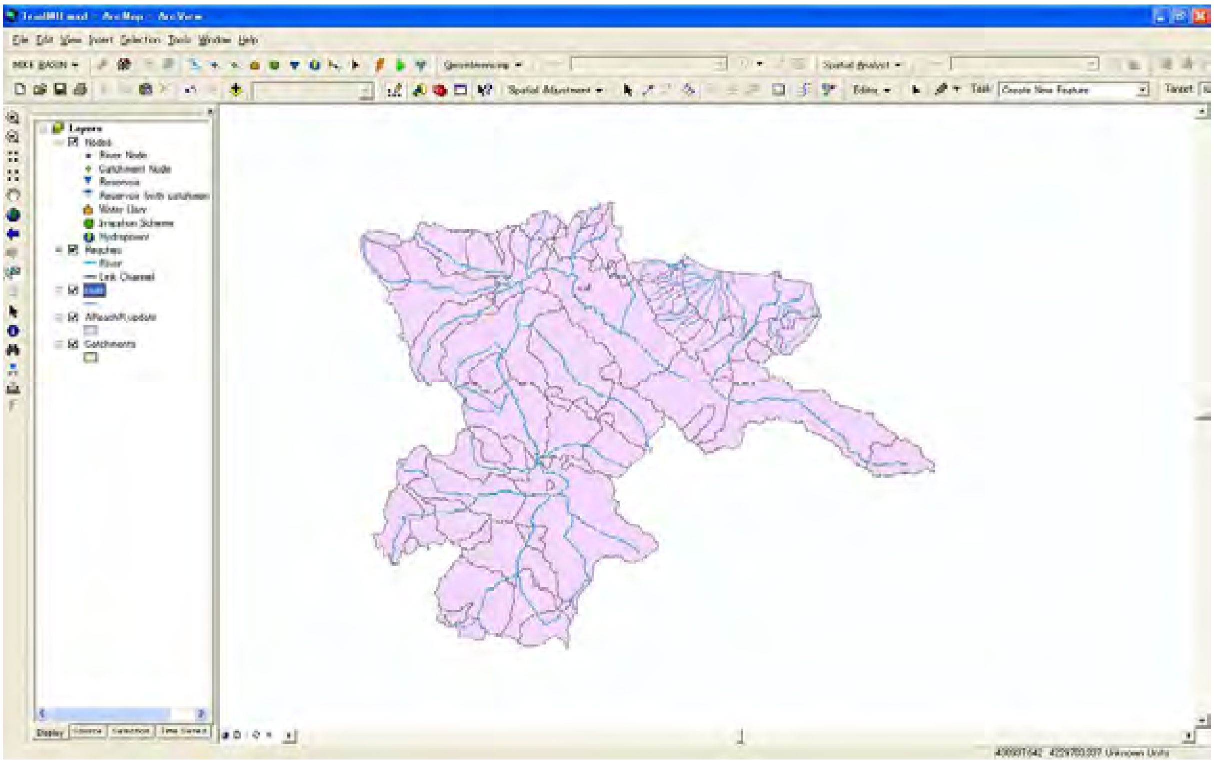
2.4 DATA INPUT

2.4.1 Catchments & River

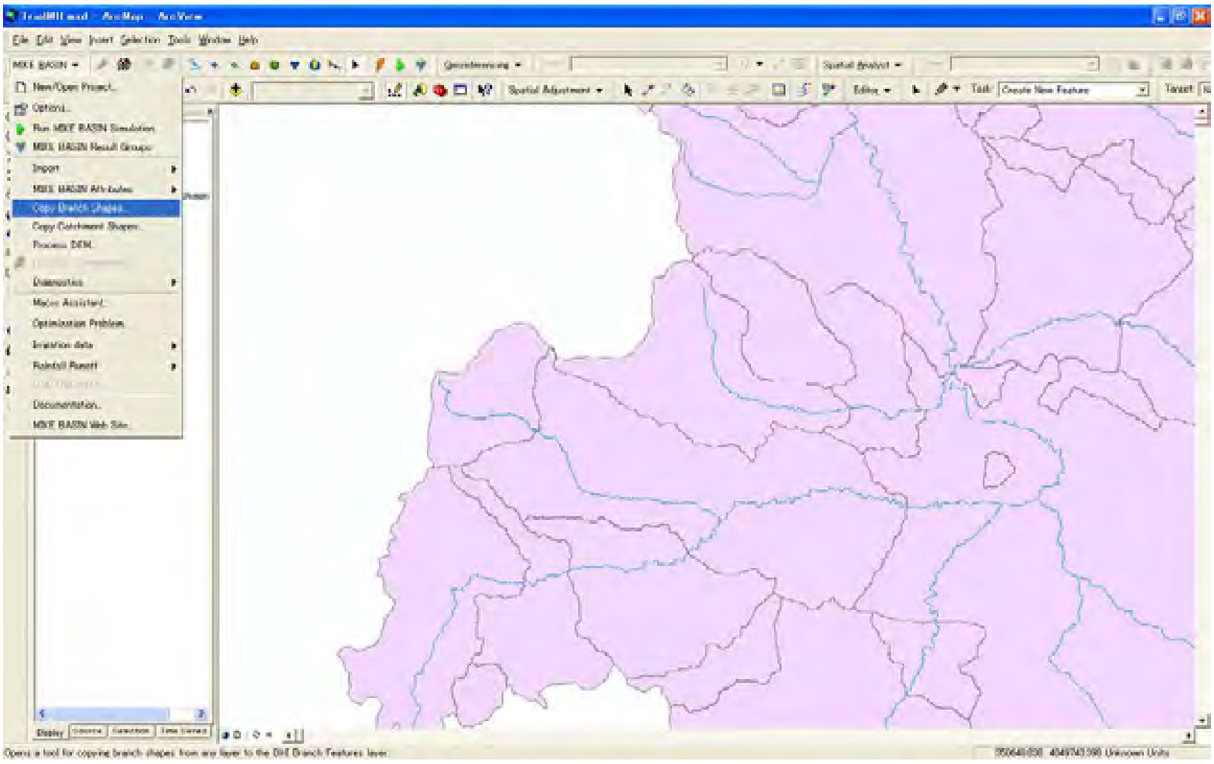
1) Push cross mark to call Basic Polygon Data for Basins > Choose a basin shape file



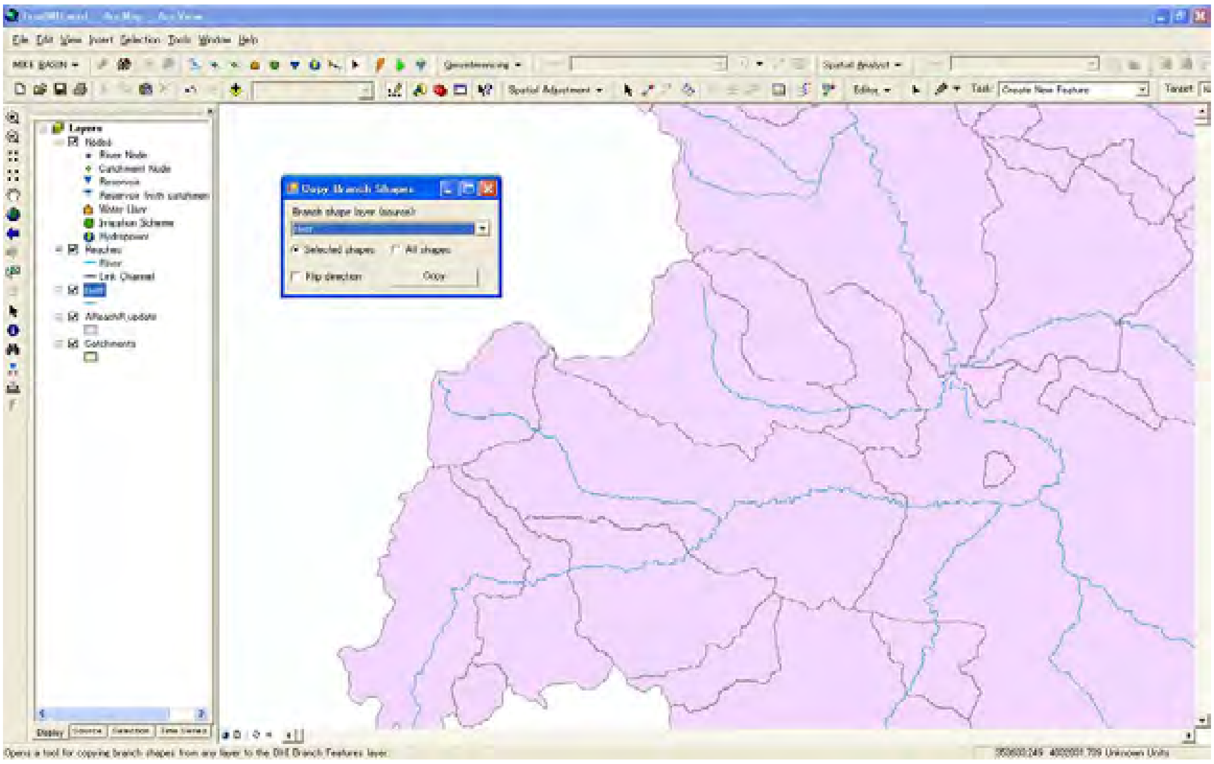
2) Push cross mark to call Basic Polygon and Plyline Data for Basins and River > Choose a basin and River shape file



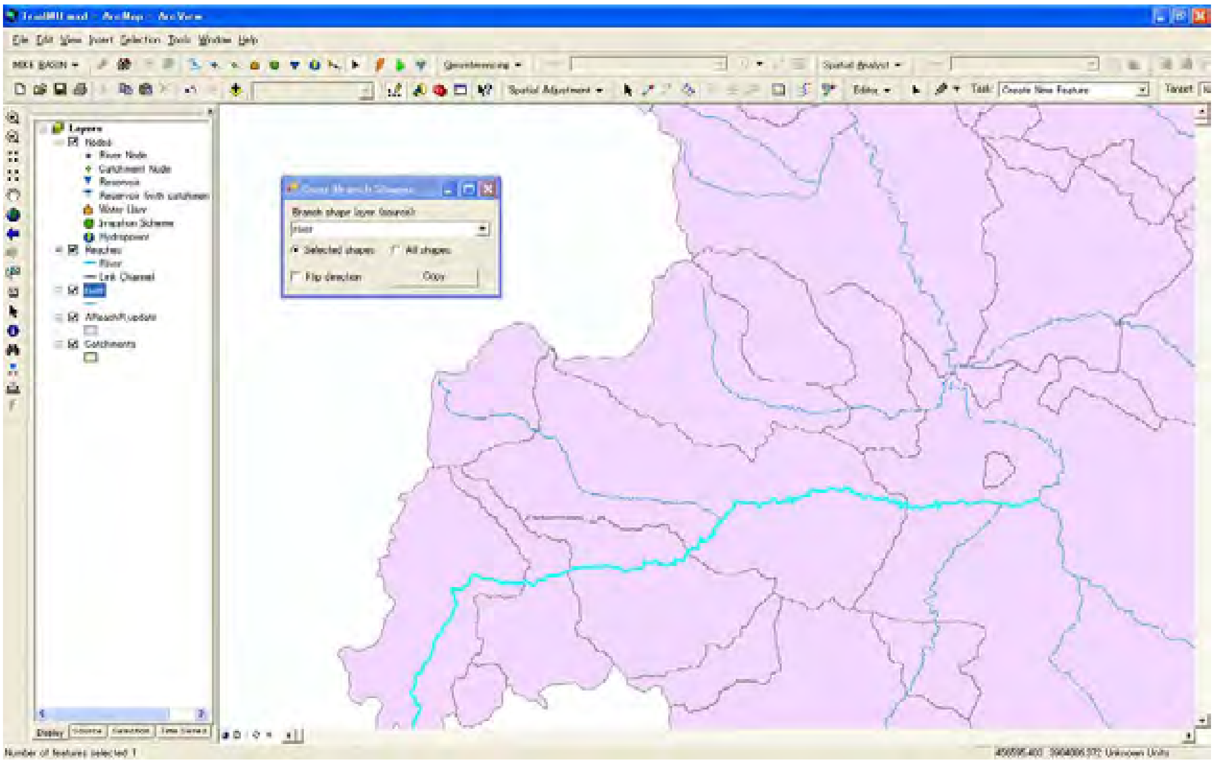
3) MIKE BASIN > Copy Branch Shapefile



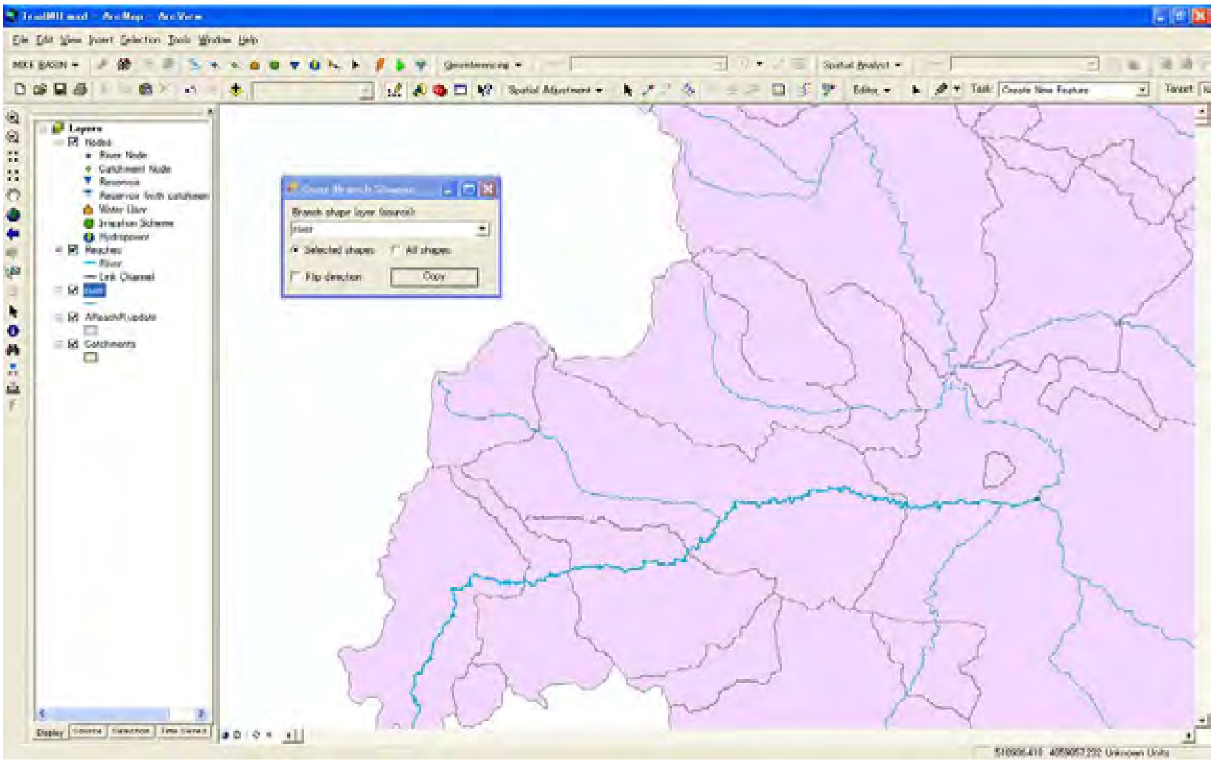
4) Select shape file for the river



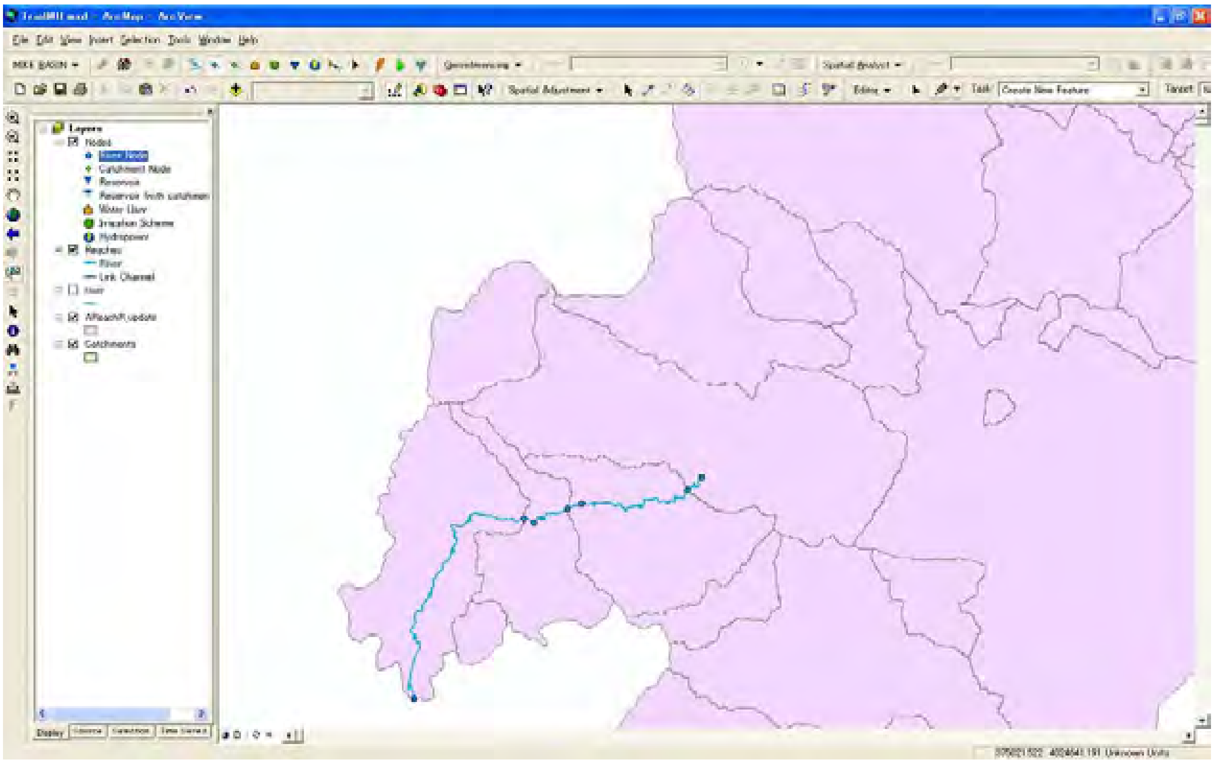
5) Push the river line you need by ▲ cursol



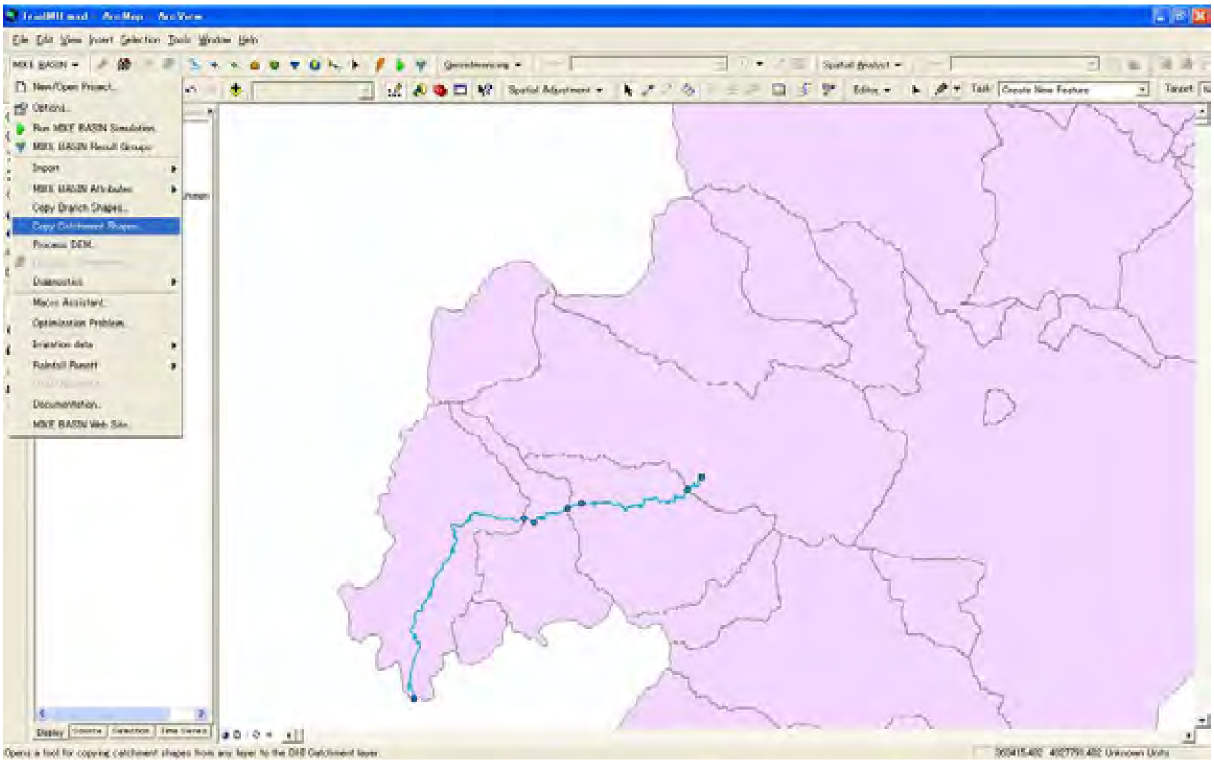
6) Push Copy button



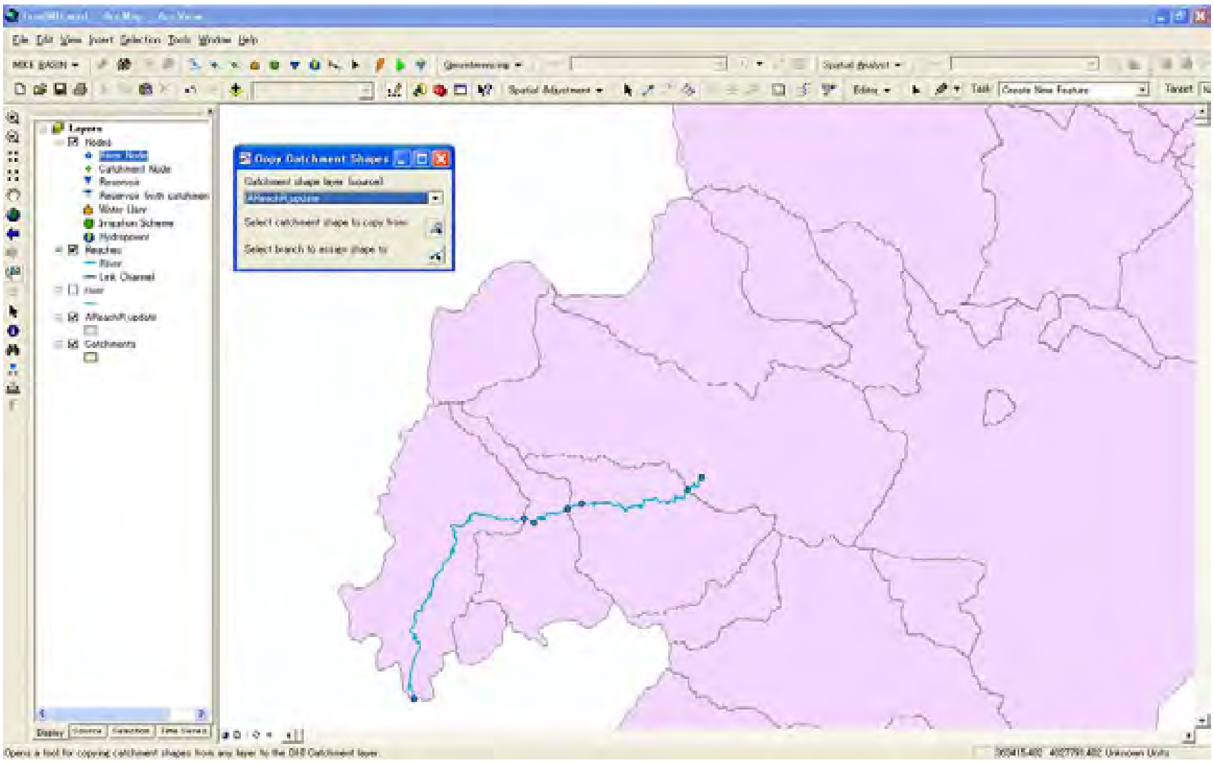
7) Arrange the River Node using "add node" and delete function



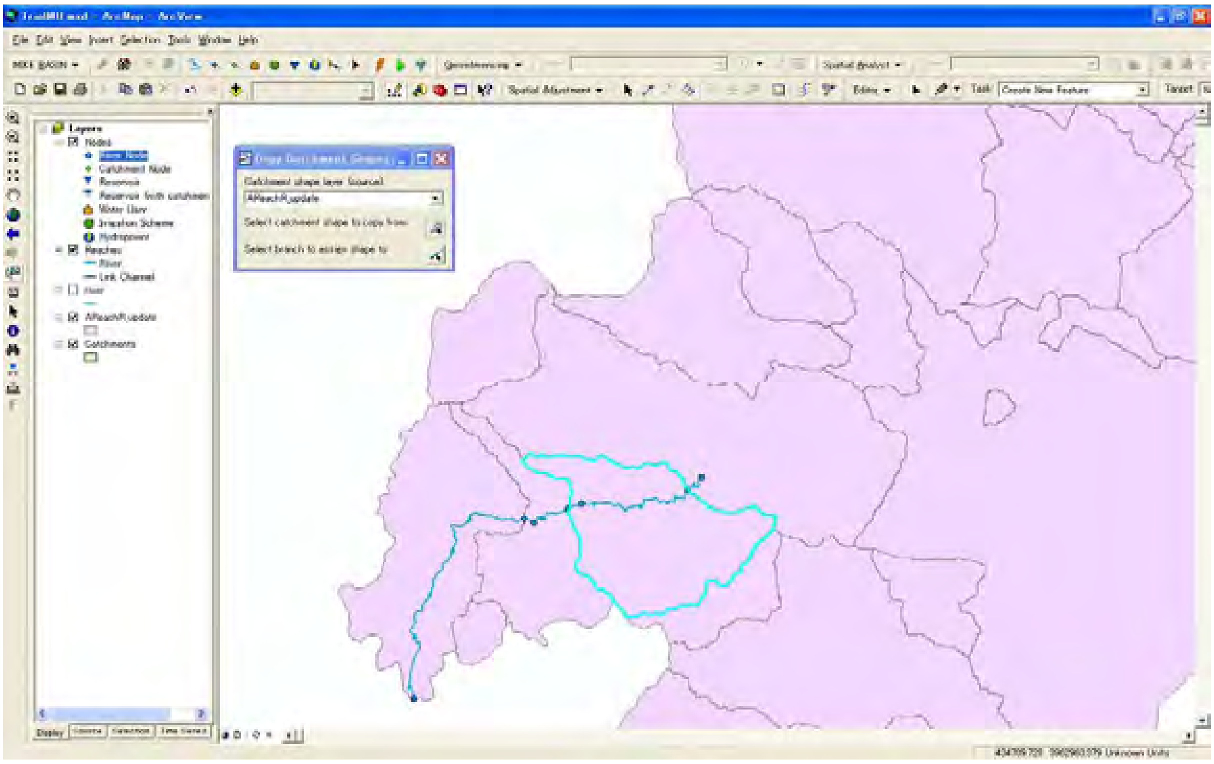
8) MIKE BASIN > Copy Catchment Shapefile



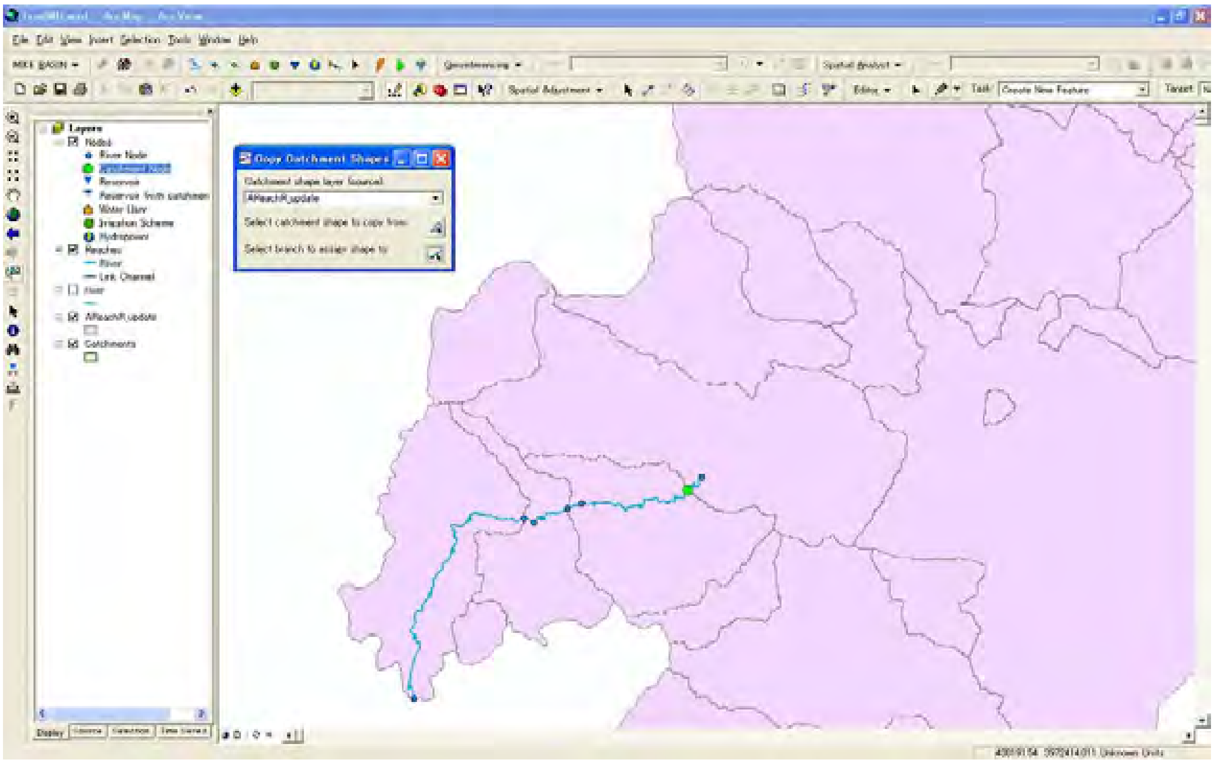
9) Select shape file for Basins you need



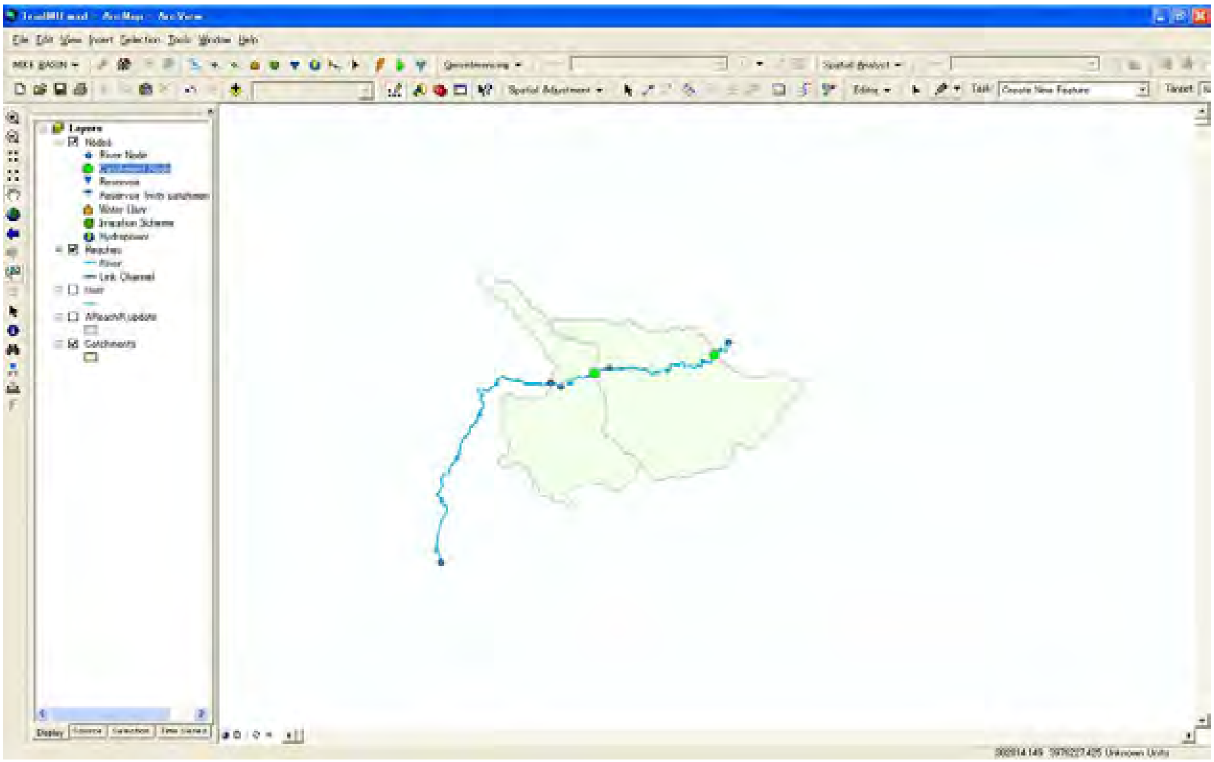
10) Push the basin polygon by ▲ cursol



11) Push the "select catchment shape to copy from" > Push the "select branch to assign shape to" > Click the river shapefile > Appearance of Basin node

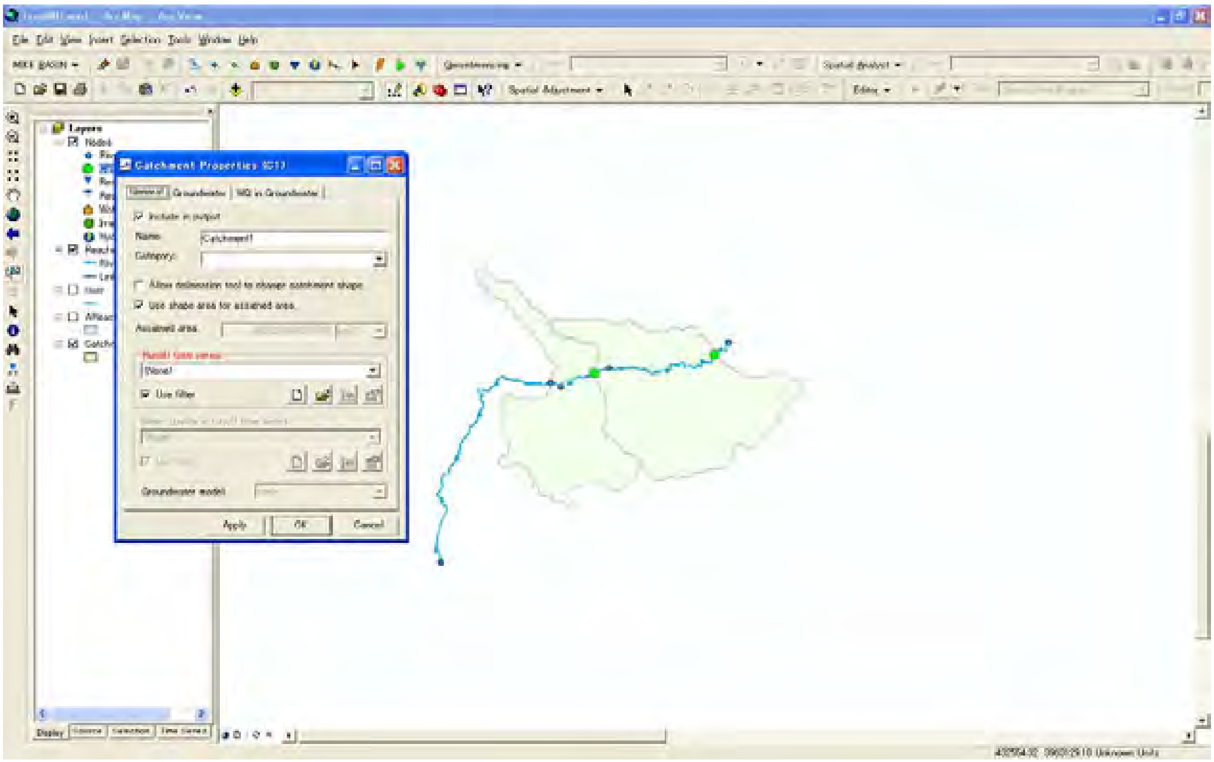


12) Push off the check mark of reference layers > Appearance of Initial Model

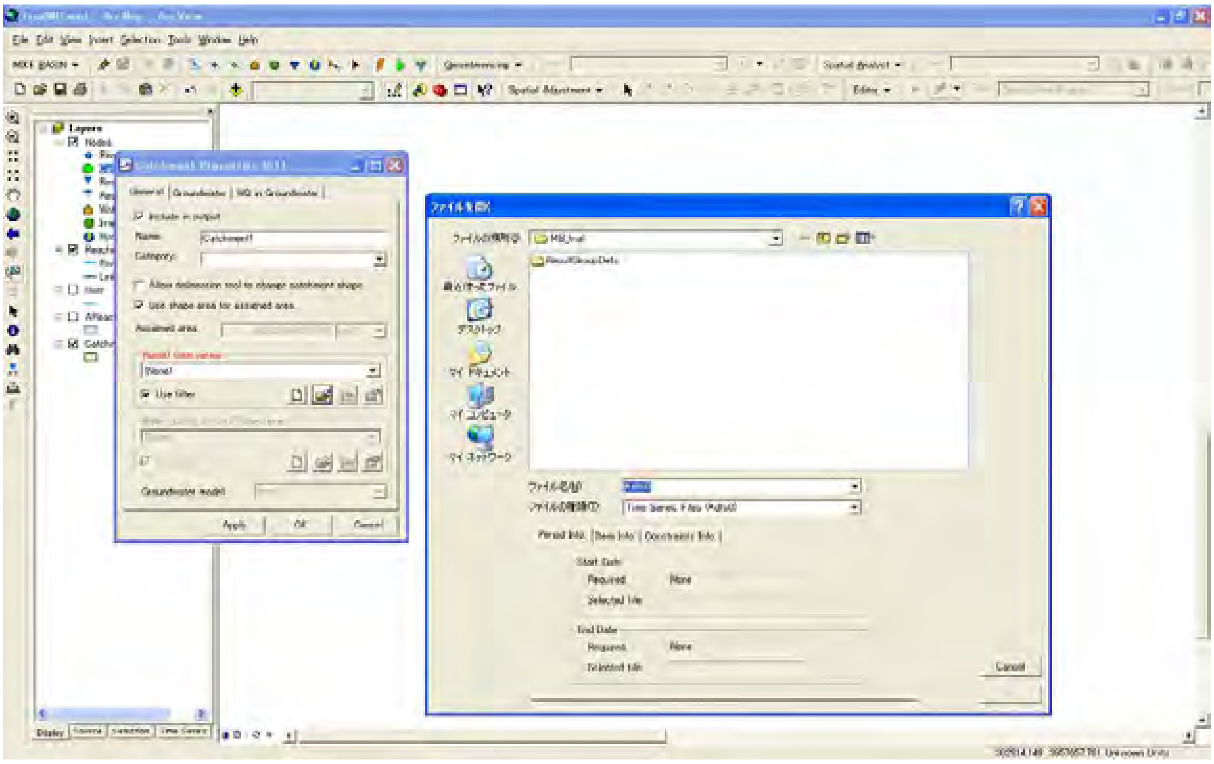


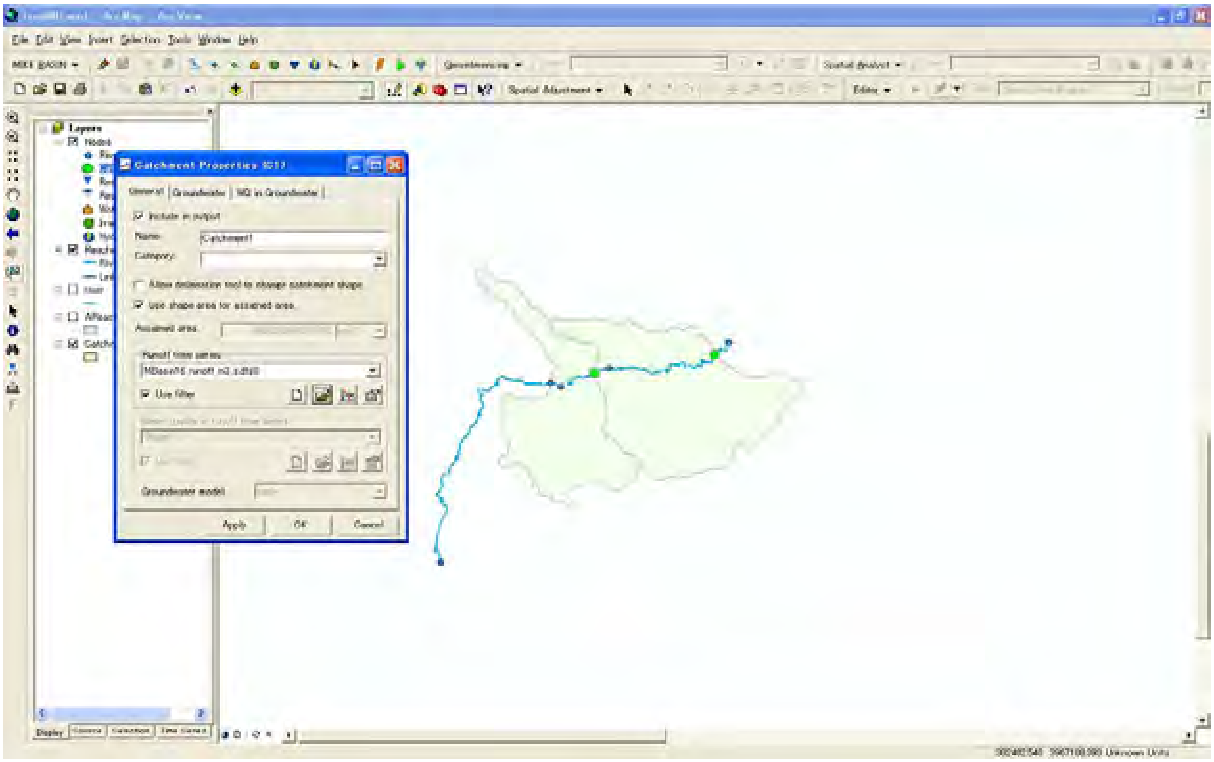
2.4.2 Input "Recharge Data" and "Runoff data"

1) Push a Basin Polygon by using "open feature property" button > Open the Input Window

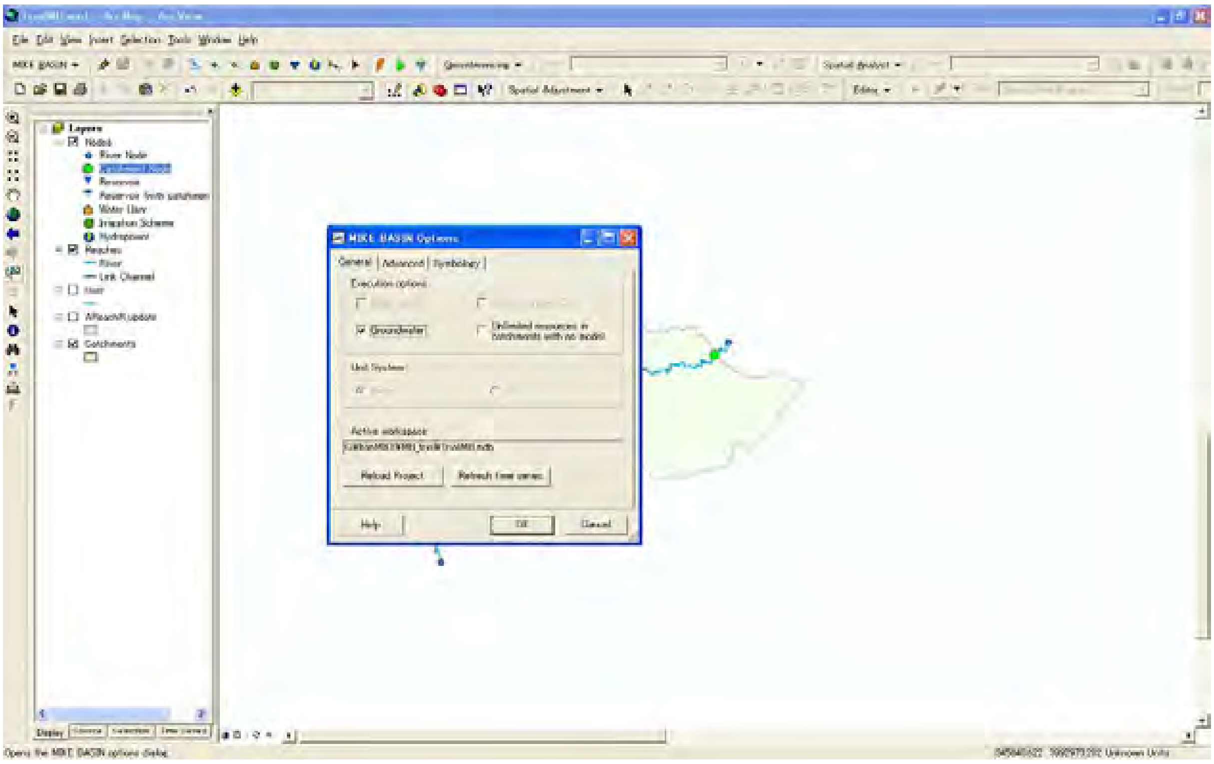


2) Push "open file button" inside Runoff time series box > Open the file selection window > select a "*.dfs0" file (should be selected runoff file – Surface flow data)**

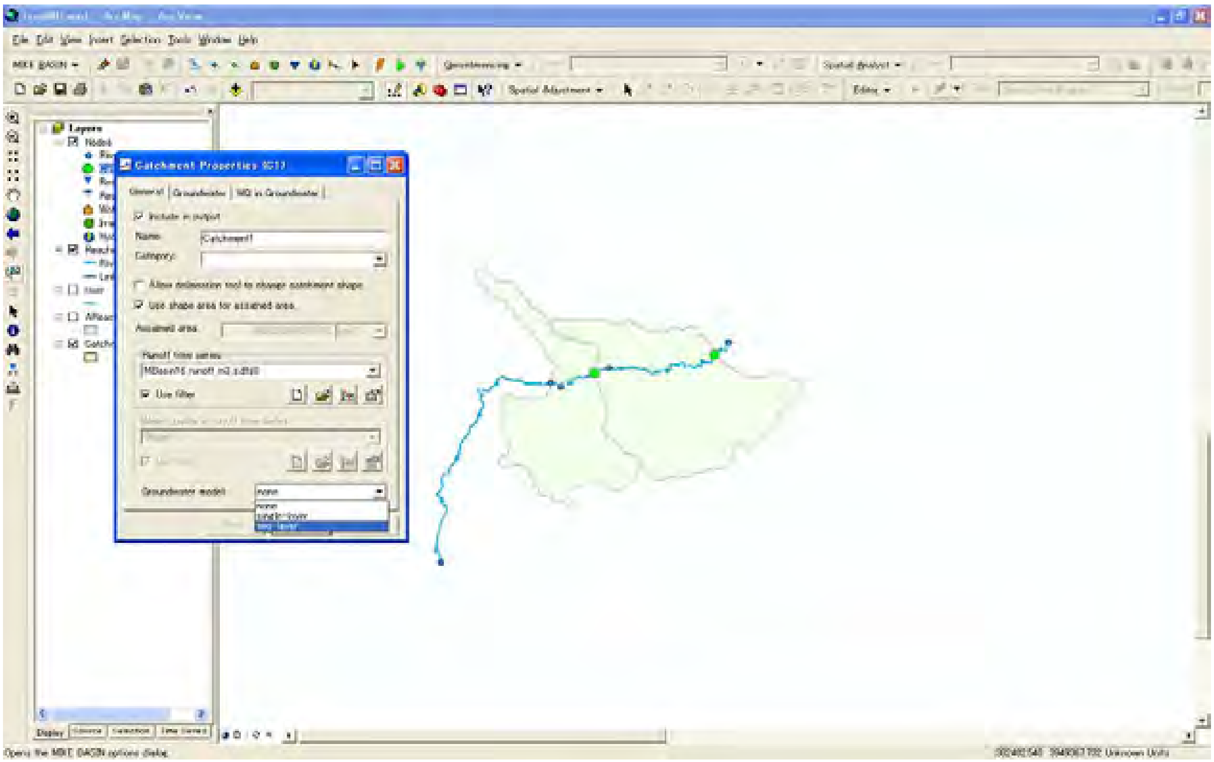




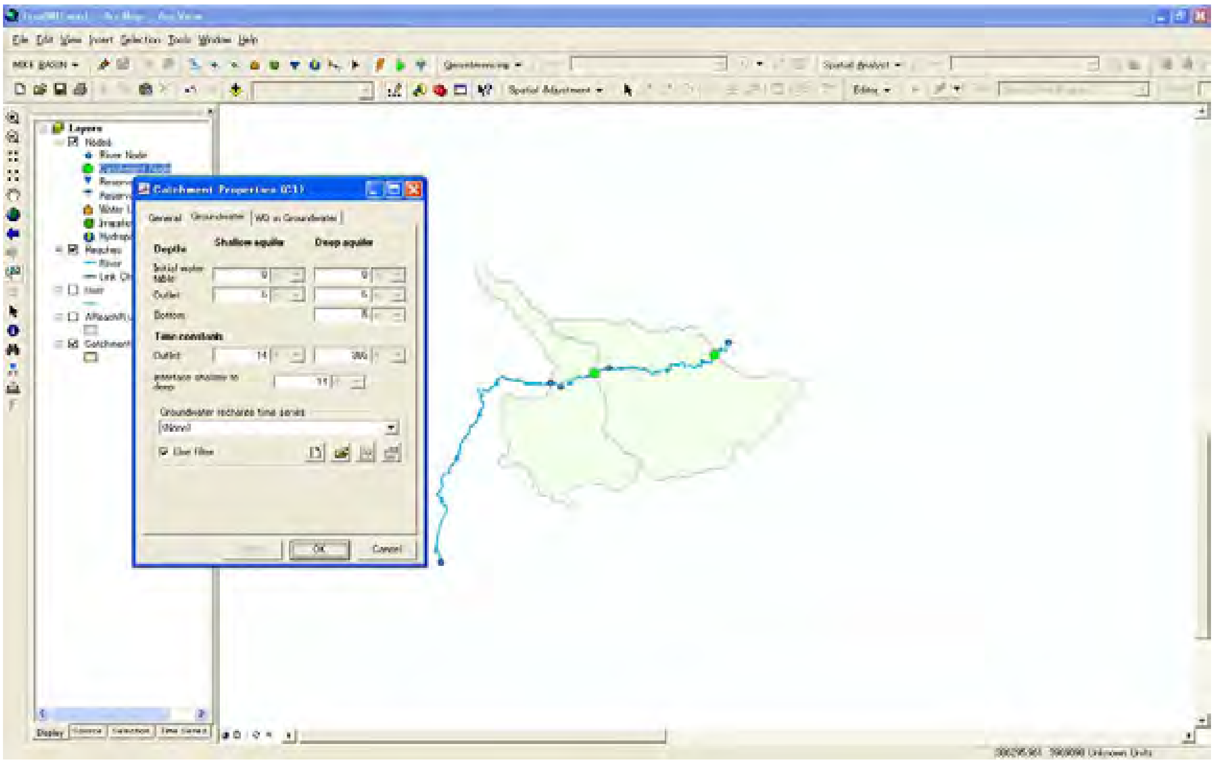
3) For the groundwater, MIKE BASIN > Option > Confirm check mark of Groundwater



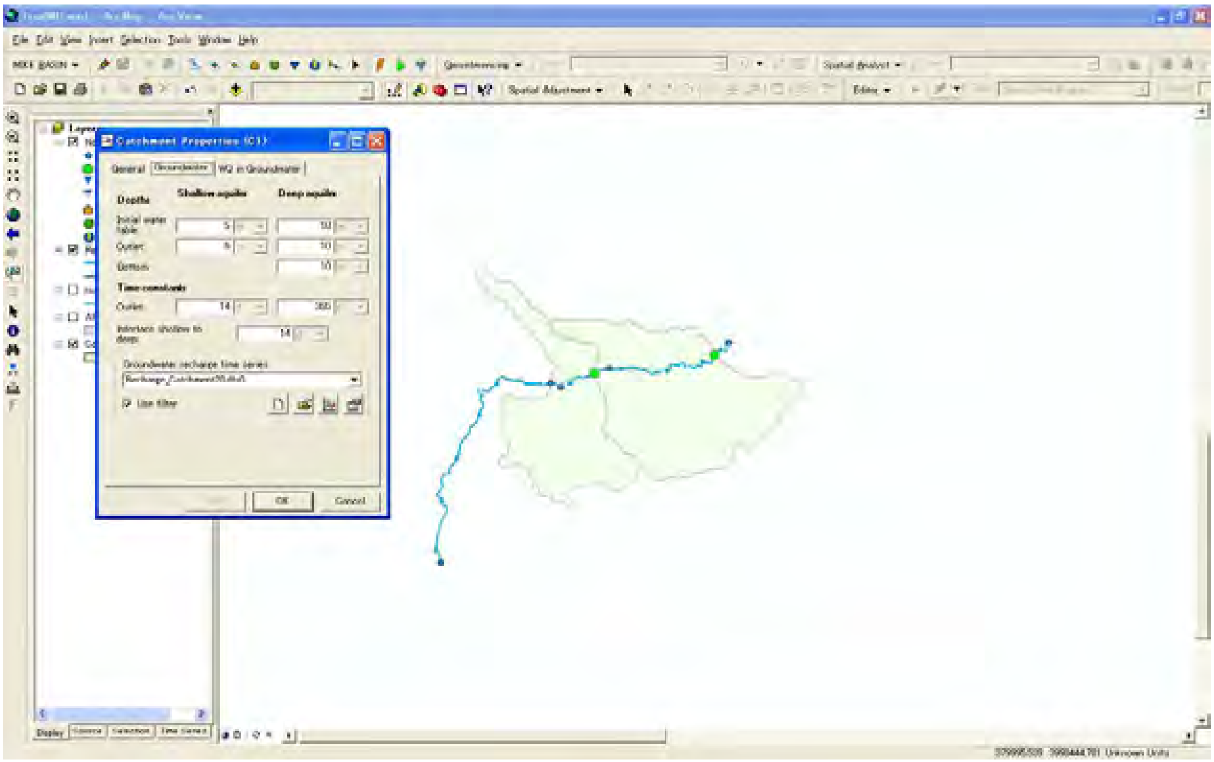
4) Select “2-layer” in Groundwater model > push “Groundwater Tab”



5) Input the tank parameters as same value as MIKE SHE” as initial condition > push “Apply button”

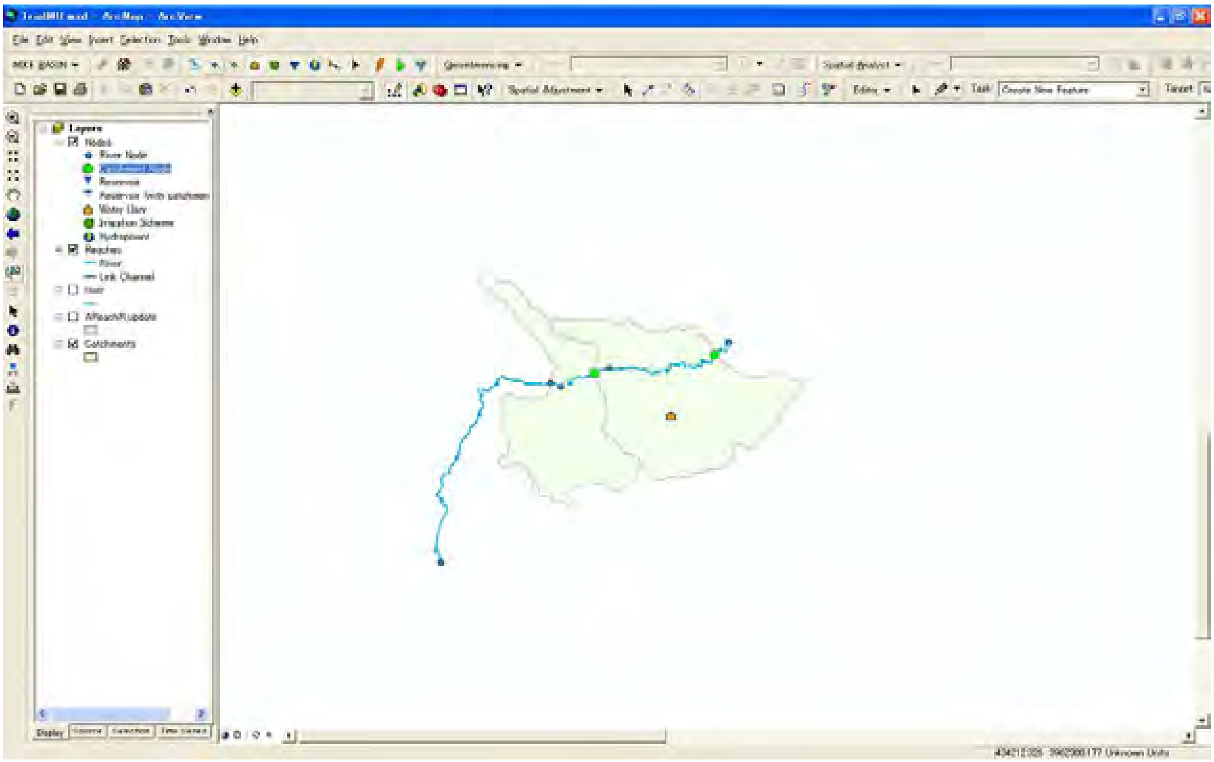


6) Push "open file button" inside ground water time series box > Open the file selection window > select a "*.dfs0" file (should be selected groundwater recharge file – Surface flow data)**

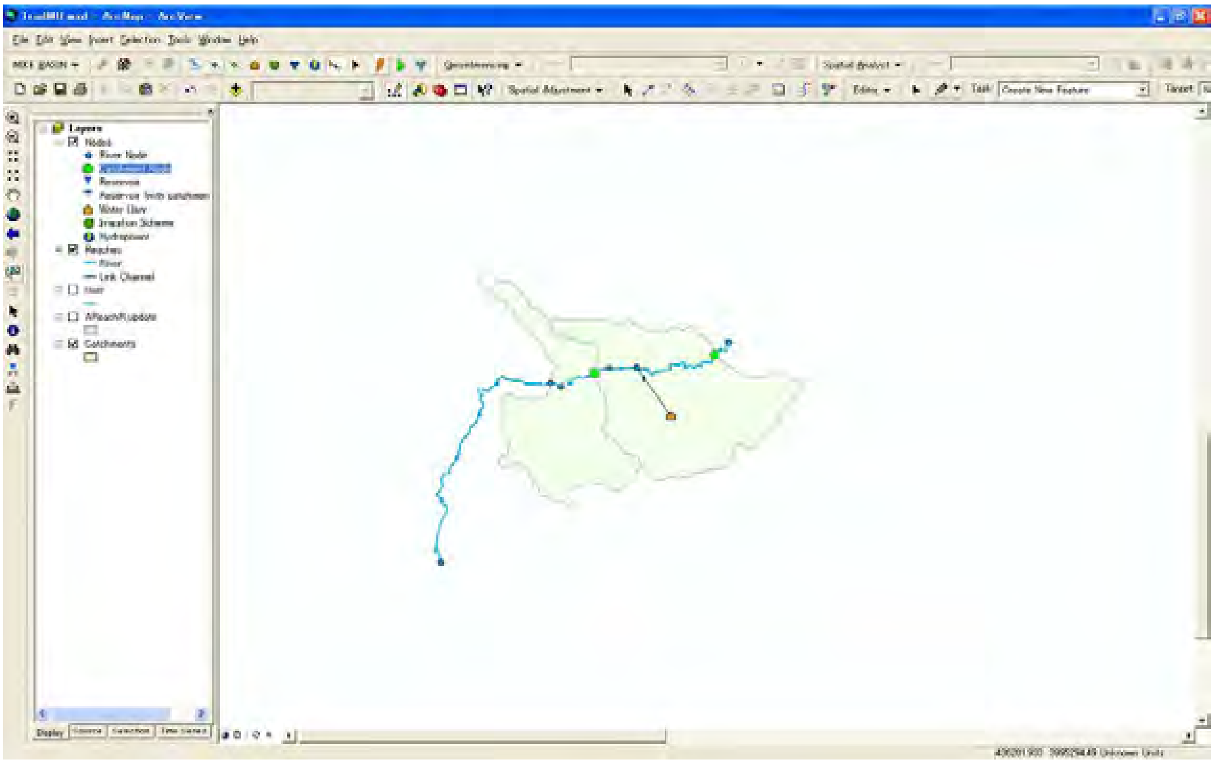


2.4.3 Input Water Users Data

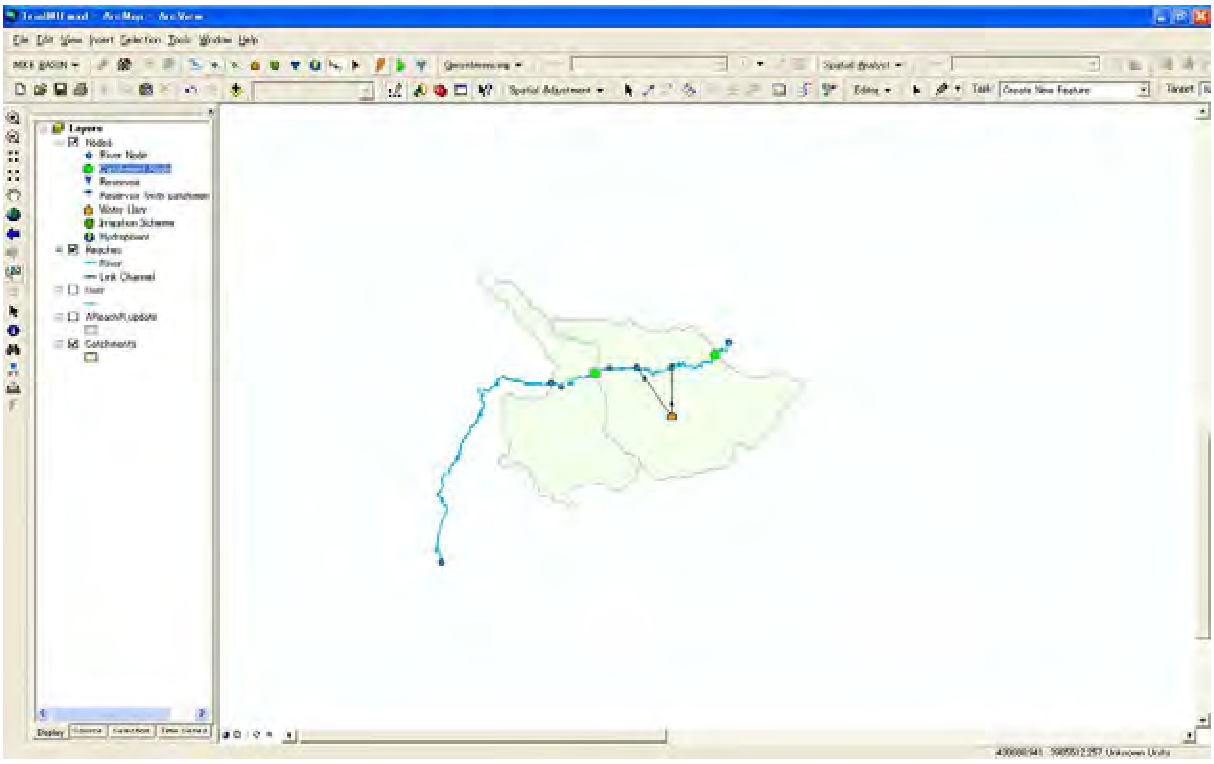
1) Push "Water Use" button on Menu bar > Click a catchment shapefile on display to add "Water users" module.



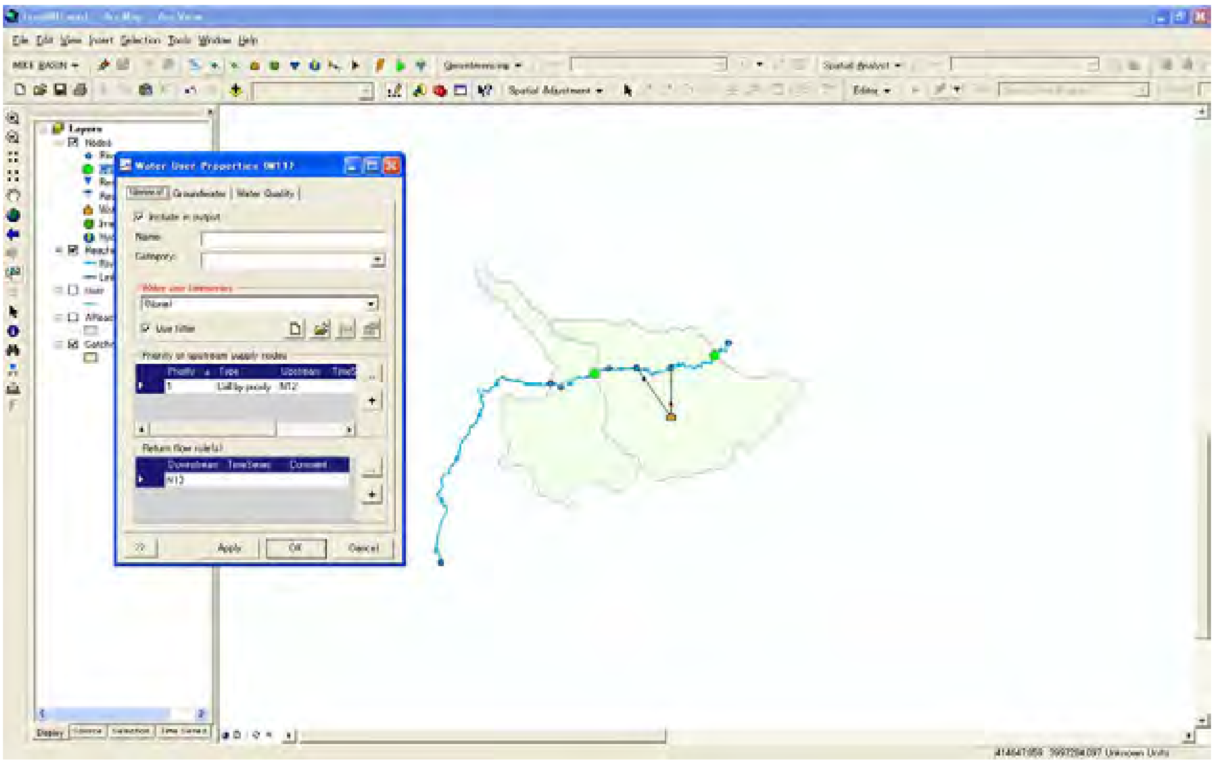
2) Push "Add Channel" button on Menu bar > Click on river line > Double lick the "Water User module" feature. (this means water extraction from river to water user.



3) Push "Add Channel" button on Menu bar > Click on "water user module" > Double lick on river at downstream of extraction node(this means return flow).

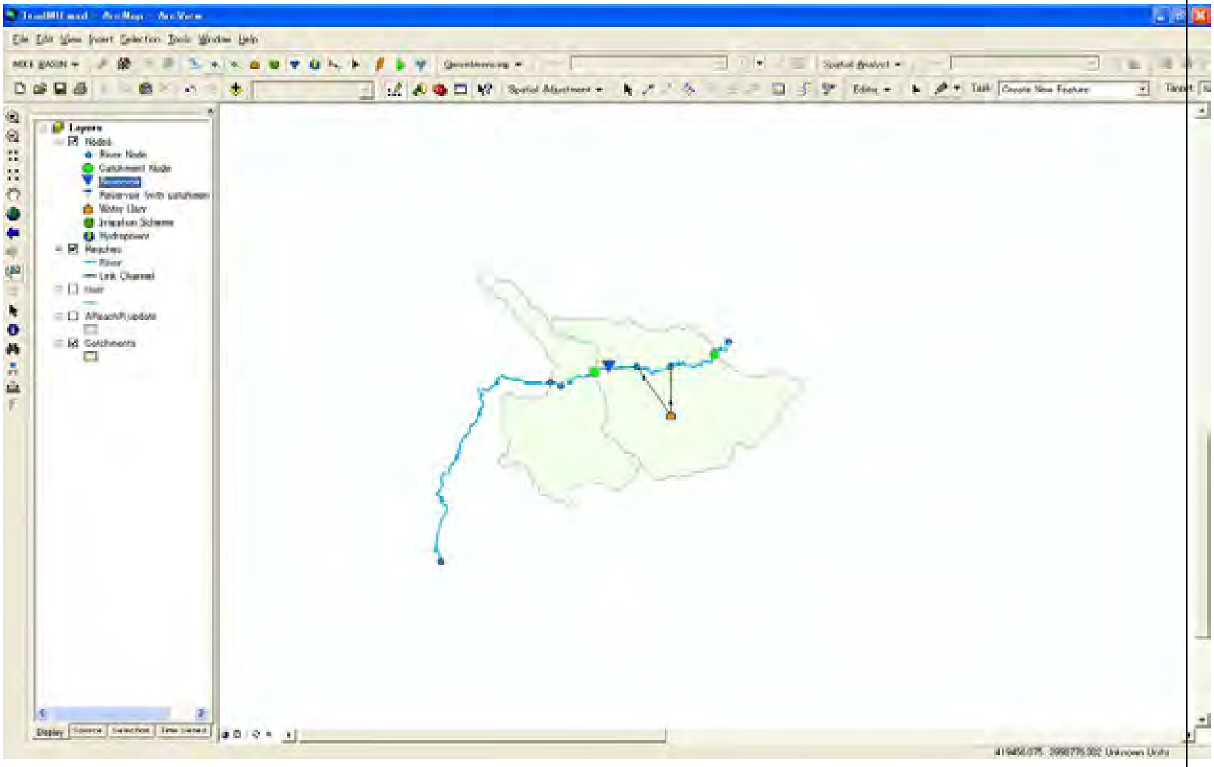


4) Open the window clicking the module by using "open feature property" button on Menu Bar > Input several information (name, Water use time series, priority for extraction and return flow rule time series)



2.4.4 Input Dams Data

1) Push "Digitize Reservoir" button on Menu bar > Click on river shape file on display to add "Reservoir" module.



2) Open the window clicking the module by using "open feature property" button on Menu Bar > Input several information <name, reservoir type, initial water level, H-A-V table, Characteristic of water levels (normal water level, flood control water level, top of dead, dam height), Loss and gain(evaporation, rainfall, infiltration) and etc.