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CLEAN ENERGY AND WATER PROGRAM

DECISION SUPPORT SUSTEM FOR INTEGRATED WATER RESOURCES MANAGEMENT USER MANUAL

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CLEAN ENERGY AND WATER PROGRAM

DECISION SUPPORT SYSTEM FOR INTEGRATED WATER RESOURCES MANAGEMENT

User Manual

DISCLAIMER

The author's views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

LIST OF ABBREVIATIONS

BMA	Basin Management Area
BMO	Basin Management Organization
CEW	Clean Energy and Water
DEM	Digital Elevation Model
DSS	Decision Support System
GIS	Geographic Information Systems
GOA	Government of Armenia
GPS	Global Positioning System
IPCC	International Panel for Climate Change
IWRM	Integrated Water Resources Management
ME&A	Mendez England and Associates
MNP	Ministry of Nature Protection
NSS	National Statistical Service
RBMP	River Basin Management Plan
SWCIS	State Water Cadastre Information System
SOW	Statement of Work
USAID	United States Agency for International Development
VBA	Visual Basic for Applications
WRMA	Water Resources Management Agency
WUP	Water Use Permit

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1. INTRODUCTION

1.1. Background

In the last decade the impact of the human economic activities on water resources has been gradually increasing. Dynamics of growth of water use and increase of pressure on water resources lead to competing water uses and negative impact on natural ecosystems. In order to achieve more effective water resources management and protection, in 2012 the CEW Program initiated development of a Decision Support System (DSS) for integrated water resources management. The system should meet modern requirements, in terms of calculation of water supply and demand balance with consideration of impacts of climate change in a longer perspective and development of economic sectors, estimation of ecological status of the river basin, integration of economic parameters in water resources management and protection and optimization of decisions based on economic efficiency.

Considering the above mentioned requirements for effective and sustainable water resources management, the DSS is programmed within the Geographical Information System (GIS) environment and eventually serves as a dynamic tool for river basin management planning for WRMA and BMOs, towards integrated water resources management in the river basin. In the future, it can also be used by other stakeholders for formulating their short-term and long-term water demand and development programs, based on projections of the water availability under various conditions and potential of the resource (i.e. hydropower potential), as well as optimal decisions based on economic efficiency.

The development of the DSS was initiated in 2012. Since the currently available datasets in Armenia do not fully meet the requirements of any of the international models/software the main objective was to construct a straightforward system which would:

- be operational by using the currently available datasets at the stakeholder institutions involved in water management in Armenia;
- be programmed in a way to allow implementing all necessary calculations in spreadsheets and GIS;
- be constructed within the ArcGIS software as a separate toolbar with a user-friendly interface;
- not be too complicated to learn for the appropriate staff members of involved institutions.

The catchment areas of the rivers of the length more than 5 km serve as the main spatial unit of operation of the DSS. The digitization and coding of river sections and their catchment areas for the territory of Armenia was implemented in 2008. The catchment areas have obtained a unique identifiers based on the internationally well-known ERICA (European Rivers and Catchment Areas) coding system.

The development of the DSS was finalized in July 2015. The components of the systems have been tested and debugged by the input data from Southern Basin Management Area of Armenia (coincides with Syunik Marz).

The DSS is open source on its nature and the script is available for further updating/upgrading.

1.2. Components of the System

The DSS is comprised of the three main models:

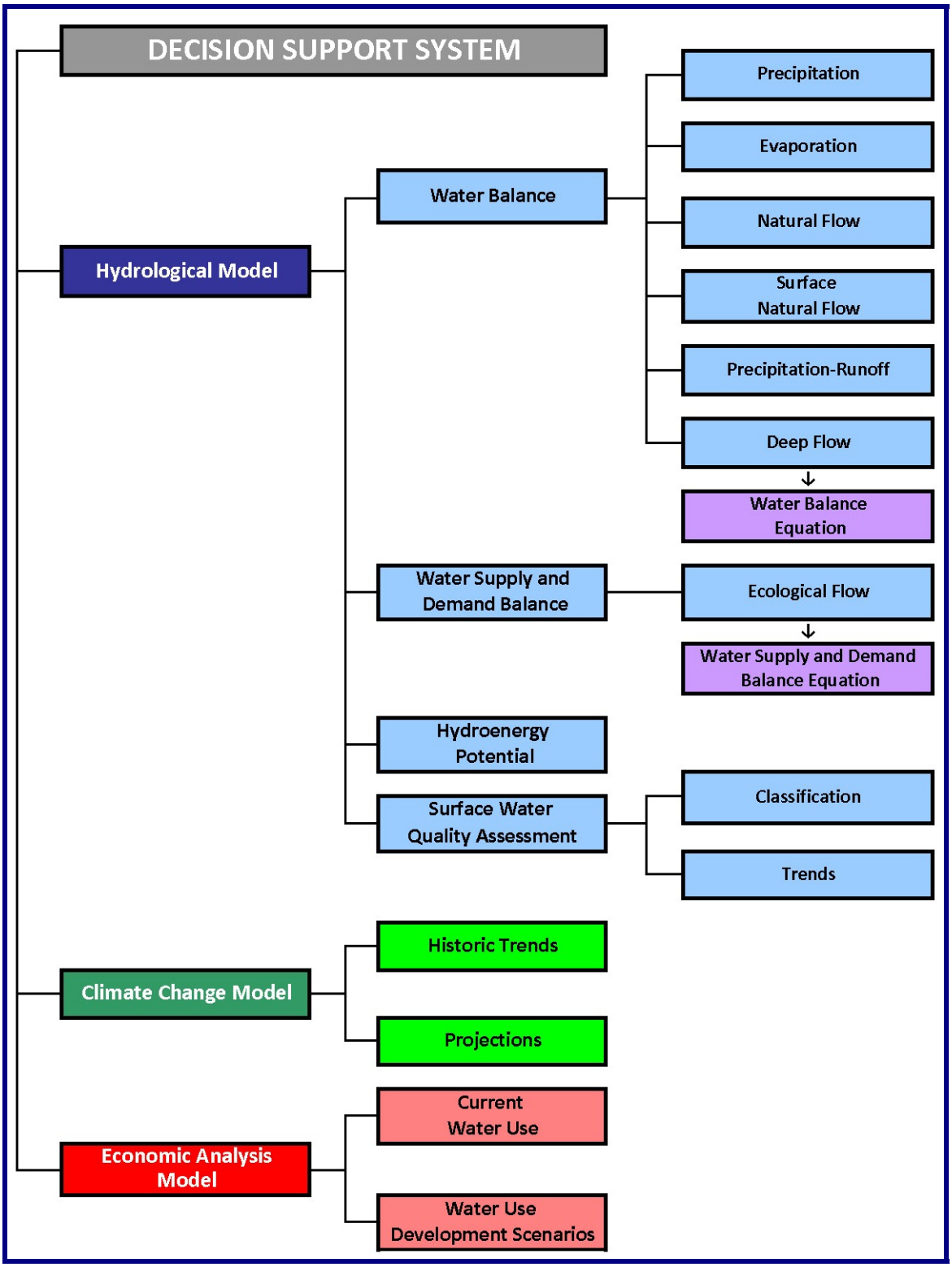
(1) **Hydrological Model**, which includes 4 components and 7 subcomponents;

(2) **Climate Change Model**, which includes 2 components; and

(3) **Economic Analysis Model**, which includes 2 components.

The mentioned three models with 8 components and 7 subcomponents were constructed using VBA scripts and compiled into .dll (dynamic-link library) module so the DSS is portable as an add-on/extension to ArcGIS like ArcHydro, Spatial Analyst, and Network Analyst.

The hierarchy of the models and components of the DSS is presented in the figure below:



1.3. Software Requirements

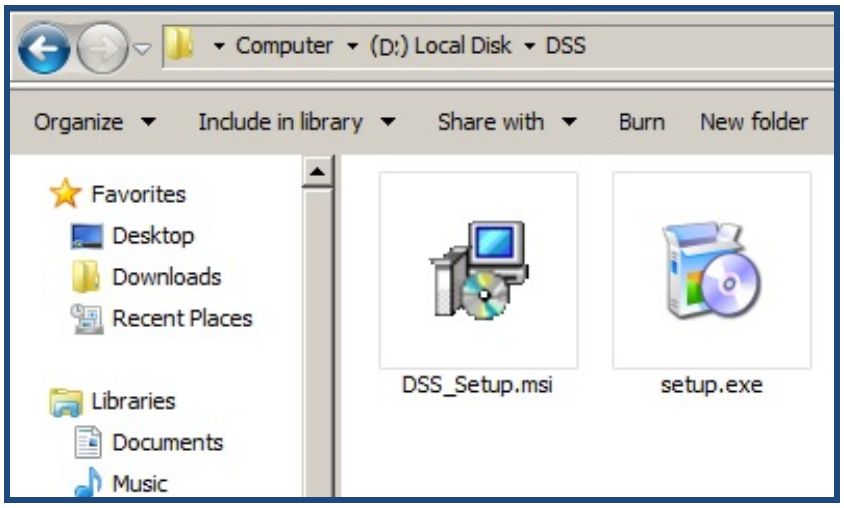
The following software is required to run the DSS:

(1) .Net Framework 3.5 for ArcGIS 10;
(2) ArcGIS 10 (Note: DSS is fully functional for ArcInfo only);
(3) 3D Analyst extension;
(4) Spatial Analyst extension;
(5) ArcHydro 2.0.

1.4. Getting Started

Start by setting up the DSS:

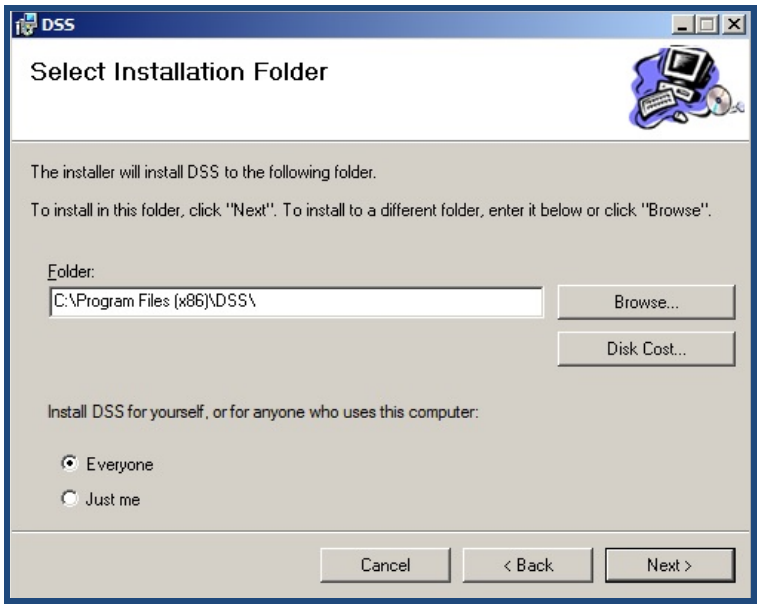
(1) Close all ArcGIS software packages
(2) Open the Drive that contains the DSS installation package



(3) Double click the "**Setup.exe**" file. A welcome screen will appear:

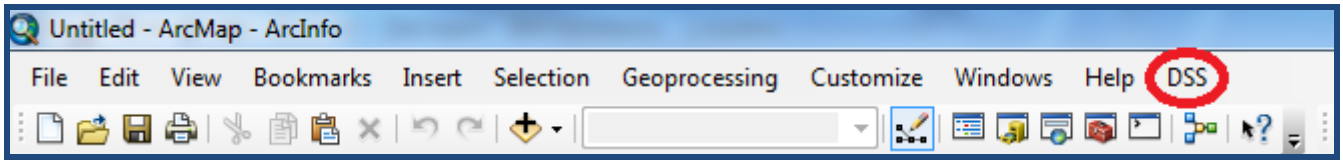
(4) A step by step installation wizard will install the DSS. Follow the instructions.

(5) Select the destination folder for installation and click the "**Next**" button.



(6) After the installation is completed, open the ArcMap 10 or double click the "**DSS.mxd**" file from the installation package.

The DSS extension will appear at the ArcMap menu as it is shown below:



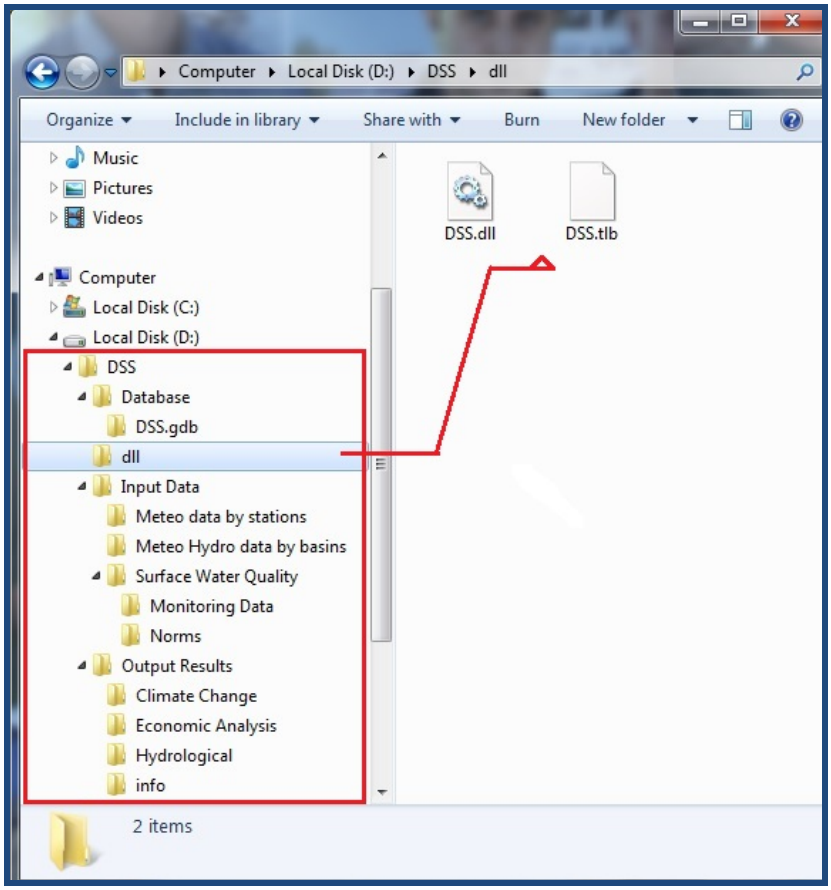
2. DATA

2.1. Overall Data Organization

The following data organization is applied in the DSS:

(1) Tabular datasets are presented in Ms Excel spreadsheets and included in the **"Input Data**" folder;
(2) Spatial datasets are comprised of
- a single consolidated geodatabase, called "DSS.gdb" and included in the "**Database**" folder;
- a collection of raster imagery, presenting the results of running of different components and models of the DSS and included in the "**Output Results**" folder;
(3) Dynamic-link library files included in the **"DLL**" folder.

After the installation of the system is completed, the DSS will reside on D: drive of the computer with the following folder hierarchy:



The sources of the input data for DSS operation include:

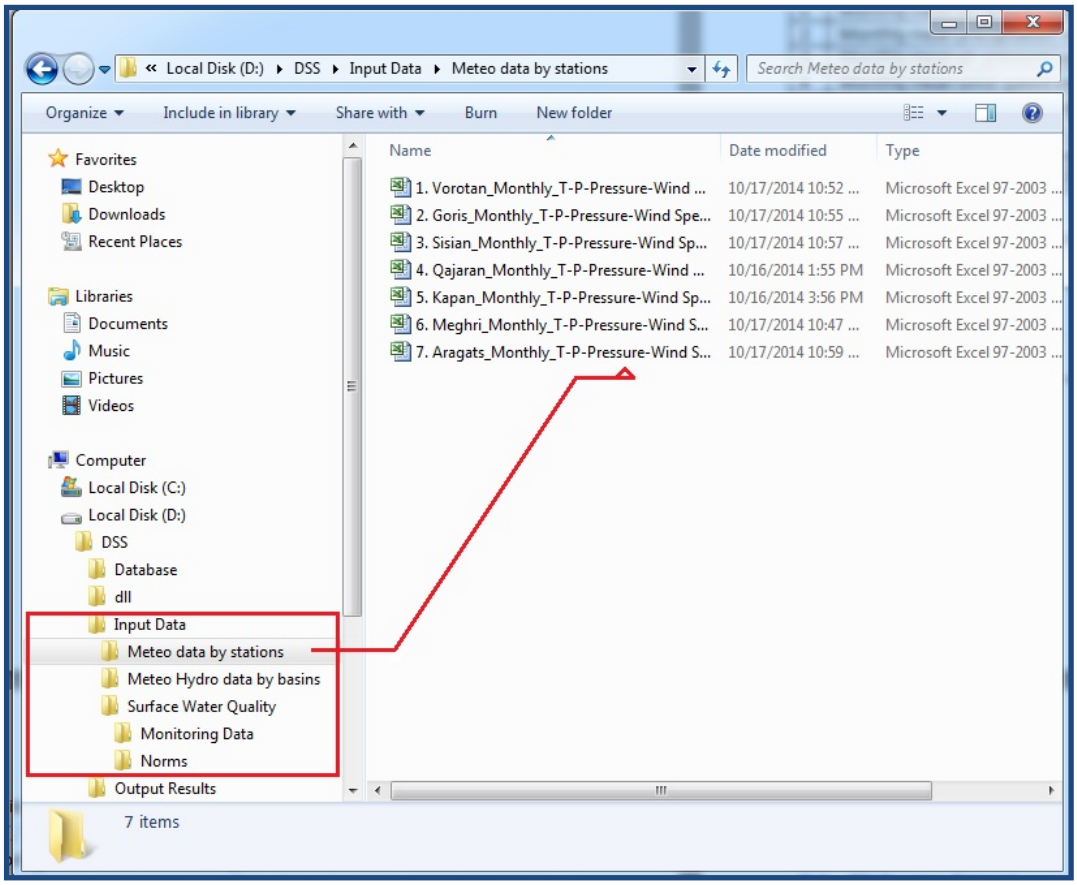
(1) Meteorological monitoring stations of the ArmStateHydromet Service of the Ministry of Territorial Administration and Emergency Situations of the Republic of Armenia;
(2) Hydrological observation posts of the ArmStateHydromet Service of the Ministry of Territorial Administration and Emergency Situations of the Republic of Armenia;
(3) Water quality sampling points of the Environmental Impact Monitoring Centre of the Ministry of Nature Protection of Armenia; and
(4) State Water Cadastre Information System (SWCIS) of the Water Resources Management Agency of the Ministry of Nature Protection of the Republic of Armenia. The SWCIS provides both tabular data on water use permitting and the entire geodatabase used within the DSS.

2.2. Tabular Datasets

The following table summarizes the format of the tabular datasets used in the DSS as input data:

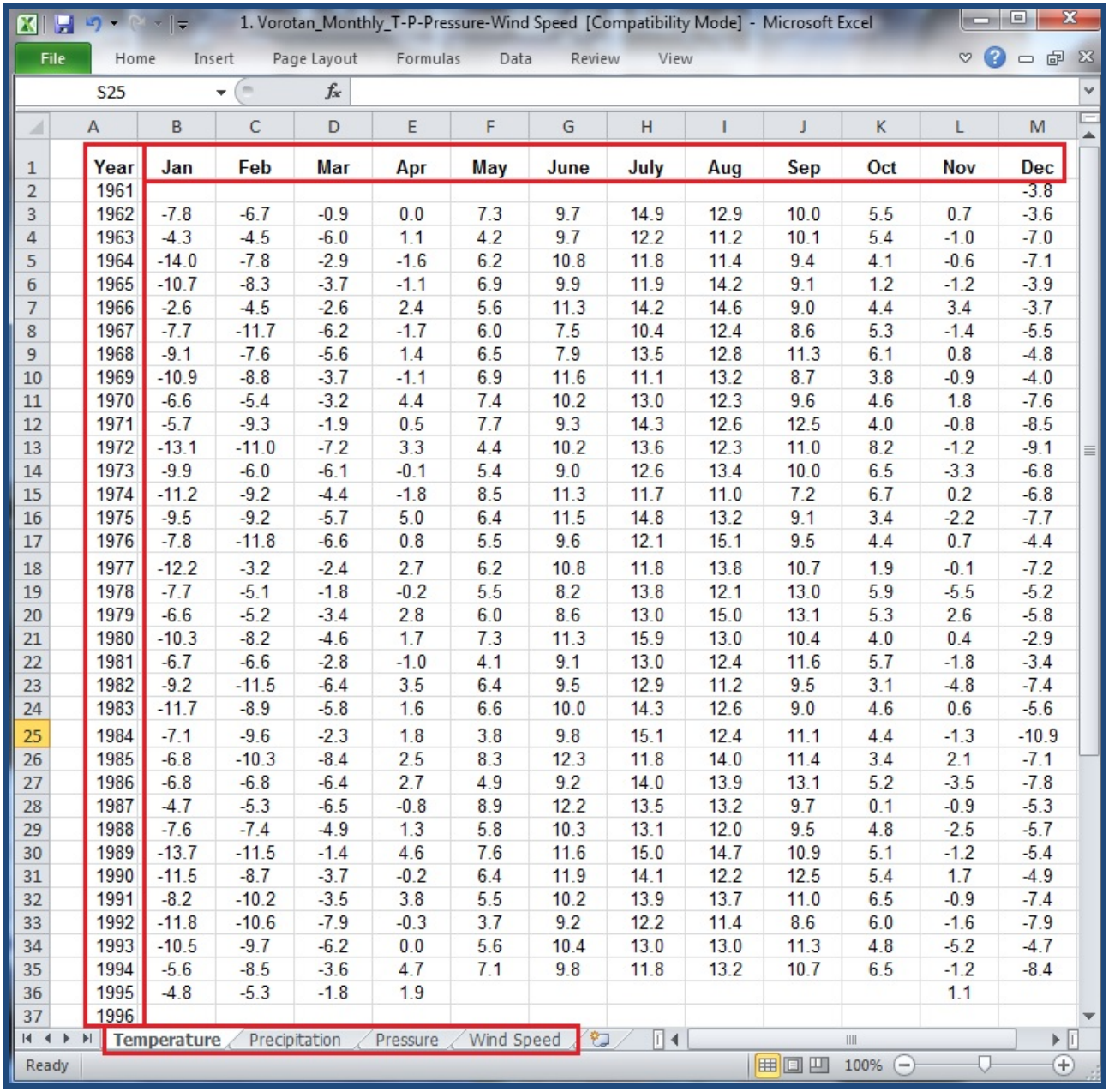
#	Description of the Dataset	Source	Format
1	Monthly mean air temperature values	Meteorological station	one Ms Excel spreadsheet form each station with the mentioned four datasets in separate sheets
2	Monthly mean precipitation values	Meteorological station	
3	Monthly mean atmospheric pressure values	Meteorological station	
4	Monthly mean relative humidity values	Meteorological station	
5	Monthly mean wind speed values	Meteorological station	
6	Annual mean precipitation values	Meteorological station	one Ms Excel spreadsheet with the mentioned four datasets in separate sheets
7	Annual mean snowfall values	Meteorological station	
8	Annual mean air temperature values	Meteorological station	
9	Annual mean surface natural flow values	Hydrological observation post	
10	Surface water quality monitoring data	Water quality sampling points	One Ms Excel spreadsheet for Armenian version and one Ms Excel spreadsheet for English version
11	Surface water quality norms	As adopted by the GoA in 2007 for the main river basins in Armenia	One Ms Excel spreadsheet for Armenian version and one Ms Excel spreadsheet for English version

Based on the above-presented list, the tabular datasets of the DSS is comprised of three folders, namely "**Meteo data by stations**", "**Meteo Hydro data by basins**" and "**Surface Water Quality**". The latter contains two sub-folders: "Monitoring data" and "Norms". The figure below presents the screenshot of the sub-folders within the DSS/Input Data folder and the content of the "**Meteo data by stations**" sub-folder.



Each of the Ms Excel files in the "**Meteo data by stations**" folder contains four sheets with monthly mean values of Temperature, Precipitation, Air Pressure and Wind Speed for the given meteorological station. In Each sheet the first column indicates the Year, while the columns from 2 to 13 show mean values calculated for each month within the year.

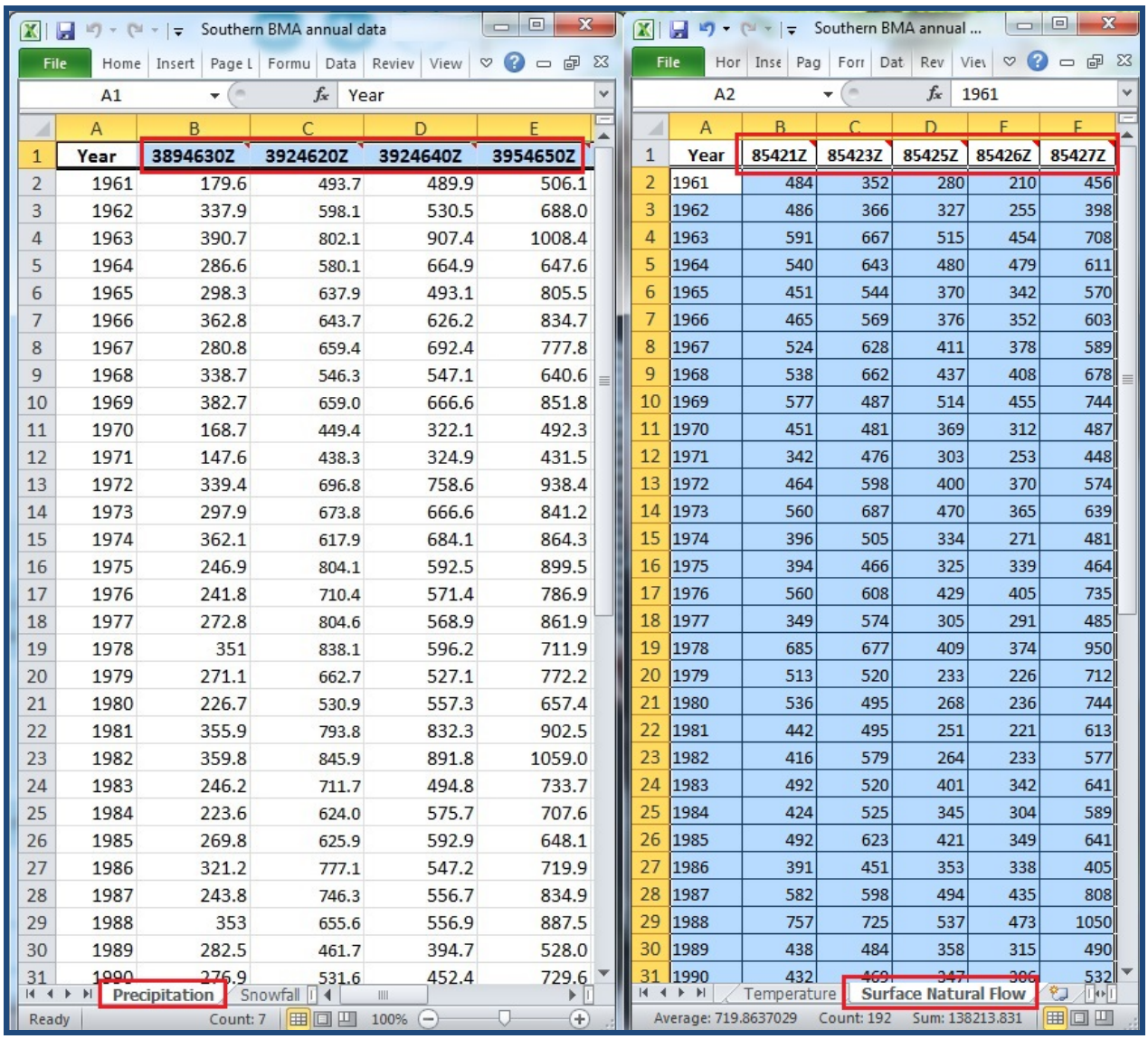
The screenshot below presents the "Temperature" sheet of the Ms Excel file containing data from Vorotan meteorological station.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2	1961												-3.8
3	1962	-7.8	-6.7	-0.9	0.0	7.3	9.7	14.9	12.9	10.0	5.5	0.7	-3.6
4	1963	-4.3	-4.5	-6.0	1.1	4.2	9.7	12.2	11.2	10.1	5.4	-1.0	-7.0
5	1964	-14.0	-7.8	-2.9	-1.6	6.2	10.8	11.8	11.4	9.4	4.1	-0.6	-7.1
6	1965	-10.7	-8.3	-3.7	-1.1	6.9	9.9	11.9	14.2	9.1	1.2	-1.2	-3.9
7	1966	-2.6	-4.5	-2.6	2.4	5.6	11.3	14.2	14.6	9.0	4.4	3.4	-3.7
8	1967	-7.7	-11.7	-6.2	-1.7	6.0	7.5	10.4	12.4	8.6	5.3	-1.4	-5.5
9	1968	-9.1	-7.6	-5.6	1.4	6.5	7.9	13.5	12.8	11.3	6.1	0.8	-4.8
10	1969	-10.9	-8.8	-3.7	-1.1	6.9	11.6	11.1	13.2	8.7	3.8	-0.9	-4.0
11	1970	-6.6	-5.4	-3.2	4.4	7.4	10.2	13.0	12.3	9.6	4.6	1.8	-7.6
12	1971	-5.7	-9.3	-1.9	0.5	7.7	9.3	14.3	12.6	12.5	4.0	-0.8	-8.5
13	1972	-13.1	-11.0	-7.2	3.3	4.4	10.2	13.6	12.3	11.0	8.2	-1.2	-9.1
14	1973	-9.9	-6.0	-6.1	-0.1	5.4	9.0	12.6	13.4	10.0	6.5	-3.3	-6.8
15	1974	-11.2	-9.2	-4.4	-1.8	8.5	11.3	11.7	11.0	7.2	6.7	0.2	-6.8
16	1975	-9.5	-9.2	-5.7	5.0	6.4	11.5	14.8	13.2	9.1	3.4	-2.2	-7.7
17	1976	-7.8	-11.8	-6.6	0.8	5.5	9.6	12.1	15.1	9.5	4.4	0.7	-4.4
18	1977	-12.2	-3.2	-2.4	2.7	6.2	10.8	11.8	13.8	10.7	1.9	-0.1	-7.2
19	1978	-7.7	-5.1	-1.8	-0.2	5.5	8.2	13.8	12.1	13.0	5.9	-5.5	-5.2
20	1979	-6.6	-5.2	-3.4	2.8	6.0	8.6	13.0	15.0	13.1	5.3	2.6	-5.8
21	1980	-10.3	-8.2	-4.6	1.7	7.3	11.3	15.9	13.0	10.4	4.0	0.4	-2.9
22	1981	-6.7	-6.6	-2.8	-1.0	4.1	9.1	13.0	12.4	11.6	5.7	-1.8	-3.4
23	1982	-9.2	-11.5	-6.4	3.5	6.4	9.5	12.9	11.2	9.5	3.1	-4.8	-7.4
24	1983	-11.7	-8.9	-5.8	1.6	6.6	10.0	14.3	12.6	9.0	4.6	0.6	-5.6
25	1984	-7.1	-9.6	-2.3	1.8	3.8	9.8	15.1	12.4	11.1	4.4	-1.3	-10.9
26	1985	-6.8	-10.3	-8.4	2.5	8.3	12.3	11.8	14.0	11.4	3.4	2.1	-7.1
27	1986	-6.8	-6.8	-6.4	2.7	4.9	9.2	14.0	13.9	13.1	5.2	-3.5	-7.8
28	1987	-4.7	-5.3	-6.5	-0.8	8.9	12.2	13.5	13.2	9.7	0.1	-0.9	-5.3
29	1988	-7.6	-7.4	-4.9	1.3	5.8	10.3	13.1	12.0	9.5	4.8	-2.5	-5.7
30	1989	-13.7	-11.5	-1.4	4.6	7.6	11.6	15.0	14.7	10.9	5.1	-1.2	-5.4
31	1990	-11.5	-8.7	-3.7	-0.2	6.4	11.9	14.1	12.2	12.5	5.4	1.7	-4.9
32	1991	-8.2	-10.2	-3.5	3.8	5.5	10.2	13.9	13.7	11.0	6.5	-0.9	-7.4
33	1992	-11.8	-10.6	-7.9	-0.3	3.7	9.2	12.2	11.4	8.6	6.0	-1.6	-7.9
34	1993	-10.5	-9.7	-6.2	0.0	5.6	10.4	13.0	13.0	11.3	4.8	-5.2	-4.7
35	1994	-5.6	-8.5	-3.6	4.7	7.1	9.8	11.8	13.2	10.7	6.5	-1.2	-8.4
36	1995	-4.8	-5.3	-1.8	1.9							1.1	
37	1996												

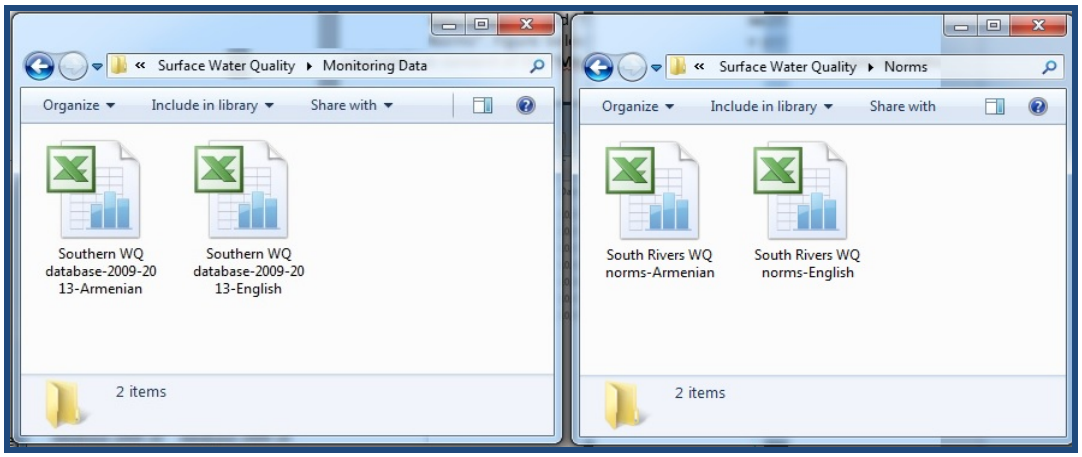
The Ms Excel files in the "**Meteo Hydro data by basins**" folder represent consolidated annual data for one of six Basin Management Areas (BMA) of Armenia. Each of the files is composed of four sheets, namely Precipitation, Snowfall, Air Temperature and Surface Natural Flow and contains the calculated annual mean values of the mentioned parameters. The first column on each sheet indicates the year, while the next columns indicate the ID numbers of the meteorological station in the case of precipitation, snowfall and air temperature and the ID numbers of the hydrological observation post in the case of natural flow.

The screenshot with the data on annual mean precipitation and natural flow values for the Southern BMA is presented below.



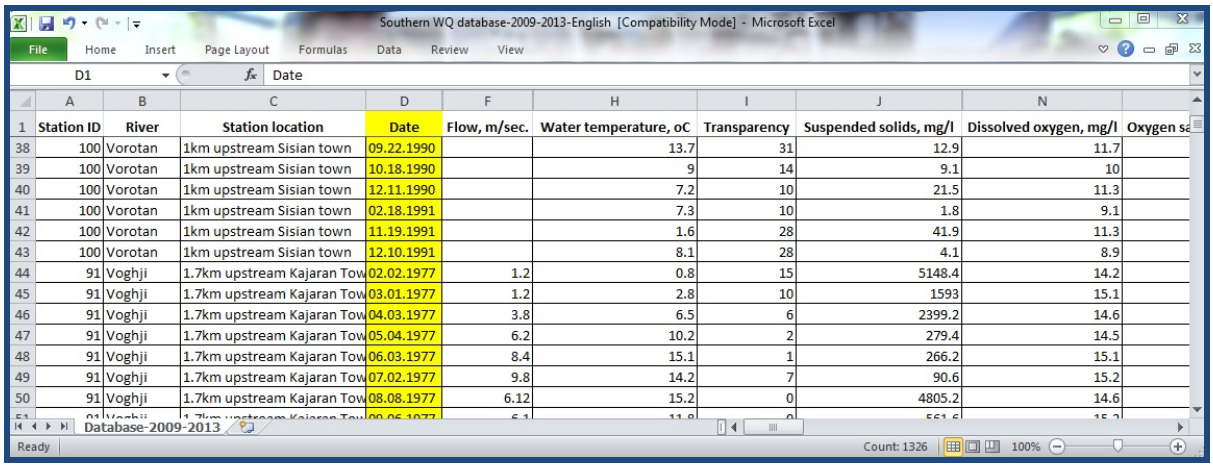
Since the above mentioned datasets are collected based on unique ID numbers of meteorological stations and hydrological observation posts, the same Ms Excel files are used for both Armenian and English versions of the DSS.

The input data on surface water quality are located in two sub-folders, namely "**Monitoring data**" and "**Norms**". The screenshots below present a sample of Ms Excel files in each of the sub-folders. The files are replicated for Armenian and English languages to be uploaded into the respective version of the DSS.



The format of the Ms Excel file with surface water quality monitoring data is as follows:

- each record in the sheet represents the results of one sampling from a specified sampling point at specified date;
- the first three columns of the sheet describe the sampling point itself (ID, water resource, location);
- the fourth column specifies the date when the given sampling was performed;
- the rest of the fields represent the values of parameters measured at the specified sampling point.



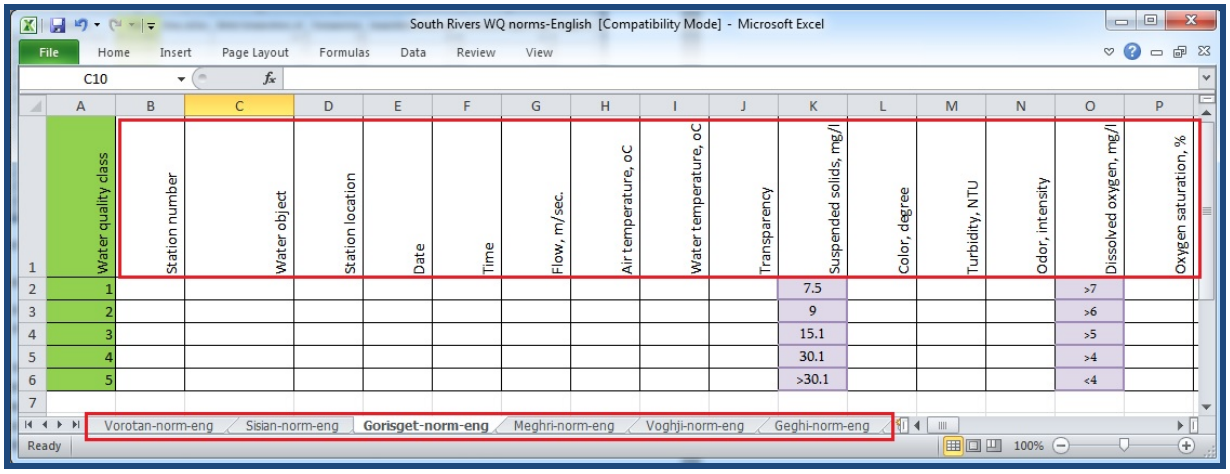
	A	B	C	D	F	H	I	J	N	
1	Station ID	River	Station location	Date	Flow, m/sec.	Water temperature, oC	Transparency	Suspended solids, mg/l	Dissolved oxygen, mg/l	Oxygen sa
38	100	Vorotan	1km upstream Sisian town	09.22.1990		13.7	31	12.9	11.7	
39	100	Vorotan	1km upstream Sisian town	10.18.1990		9	14	9.1	10	
40	100	Vorotan	1km upstream Sisian town	12.11.1990		7.2	10	21.5	11.3	
41	100	Vorotan	1km upstream Sisian town	02.18.1991		7.3	10	1.8	9.1	
42	100	Vorotan	1km upstream Sisian town	11.19.1991		1.6	28	41.9	11.3	
43	100	Vorotan	1km upstream Sisian town	12.10.1991		8.1	28	4.1	8.9	
44	91	Voghji	1.7km upstream Kajaran Tow	02.02.1977	1.2	0.8	15	5148.4	14.2	
45	91	Voghji	1.7km upstream Kajaran Tow	03.01.1977	1.2	2.8	10	1593	15.1	
46	91	Voghji	1.7km upstream Kajaran Tow	04.03.1977	3.8	6.5	6	2399.2	14.6	
47	91	Voghji	1.7km upstream Kajaran Tow	05.04.1977	6.2	10.2	2	279.4	14.5	
48	91	Voghji	1.7km upstream Kajaran Tow	06.03.1977	8.4	15.1	1	266.2	15.1	
49	91	Voghji	1.7km upstream Kajaran Tow	07.02.1977	9.8	14.2	7	90.6	15.2	
50	91	Voghji	1.7km upstream Kajaran Tow	08.08.1977	6.12	15.2	0	4805.2	14.6	

The Armenian version of the file contains the same information with textual data in Armenian.

The input Ms Excel file with water quality norms has the following structure:

- each sheet in the Ms Excel file represents the water quality norms adopted by the GoA for one of the main rivers in the country;
- the first column of each sheet contains the list of the water quality classes (from 1 to 5);
- the structure of the columns starting from the second coincides with the sequence of the columns in the Ms Excel spreadsheet with the surface water quality monitoring data;
- the cells of the sheets contains threshold values for each of the 5 water quality classes. The cells are filled in with either numerical data or “expression” values only for those parameters the thresholds of which were defined by the Government resolution.

The screenshot below demonstrates the water quality norm file for 6 main rivers of Armenia in the Southern BMA, namely, Vorotan, Sisian, Gorisget, Meghtriget, Voghji and Geghi. The sheet with Gorisget is active. On the given section of the sheets the threshold values of only two parameters (namely “Suspended solids” and “Dissolved oxygen”) are filled in.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Water quality class	Station number	Water object	Station location	Date	Time	Flow, m/sec.	Air temperature, oC	Water temperature, oC	Transparency	Suspended solids, mg/l	Color, degree	Turbidity, NTU	Odor, intensity	Dissolved oxygen, mg/l	Oxygen saturation, %
2	1										7.5				>7	
3	2										9				>6	
4	3										15.1				>5	
5	4										30.1				>4	
6	5										>30.1				<4	
7																

The Armenian version of the file contains the same information with textual data in Armenian.

For running the Climate Change Model it is required that both meteorological and hydrological data, i.e. for temperature, precipitation, snowfall, and surface natural flow, are arranged in vertical format in one Excel file – with each parameter on one separate sheet for the whole river basin. The first column represents the years, and the following columns represent time-series of data, with the top row representing the code of each meteorological station and hydrological observation post, ending in a "Z". Before the data are imported into the DSS, the user makes sure the data are accurate, heterogeneous, and formatted as demonstrated in the table below.

Year	3894630Z	3924620Z	3924640Z	3954650Z	3954600Z	3
1961	179.6	493.7	489.9	506.1	192.2	
1962	337.9	598.1	530.5	688.0	329.2	
1963	390.7	802.1	907.4	1008.4	558.7	
1964	286.6	580.1	664.9	647.6	294	
1965	298.3	637.9	493.1	805.5	412.5	
1966	362.8	643.7	626.2	834.7	371	
1967	280.8	659.4	692.4	777.8	401.1	
1968	338.7	546.3	547.1	640.6	289.7	
1969	382.7	659.0	666.6	851.8	462.8	
1970	168.7	449.4	322.1	492.3	226.8	
1971	147.6	438.3	324.9	431.5	273.4	
1972	339.4	696.8	758.6	938.4	459.7	
1973	297.9	673.8	666.6	841.2	338.1	
1974	362.1	617.9	684.1	864.3	398.8	
1975	246.9	804.1	592.5	899.5	398.8	
1976	241.8	710.4	571.4	786.9	451.3	
1977	272.8	804.6	568.9	861.9	395.6	
1978	351	838.1	596.2	711.9	424.9	
1979	271.1	662.7	527.1	772.2	411.8	
1980	226.7	530.9	557.3	657.4	280.6	
1981	355.9	793.8	832.3	902.5	476.3	
1982	359.8	845.9	891.8	1059.0	453.2	
1983	246.2	711.7	494.8	733.7	474.5	
1984	223.6	624.0	575.7	707.6	241.9	
1985	269.8	625.9	592.9	648.1	361.4	
1986	321.2	777.1	547.2	719.9	503.3	
1987	243.8	746.3	556.7	834.9	510.5	
1988	353	655.6	556.9	887.5	505.4	
1989	282.5	461.7	394.7	528.0	256.7	
1990	276.9	531.6	452.4	729.6	273.8	
1991	316.4	615.4	485.9	653.2	438.7	
1992	306.4	558.8	540.6	596.7	460	

Precipitation | Temperature | Snowfall | Surface Natural Flow

NOTE: It is important to make sure the Ms Excel spreadsheet does not contain any formulas, merged or other formatted cells, to avoid program errors.

Missing values are dealt with either of these ways:

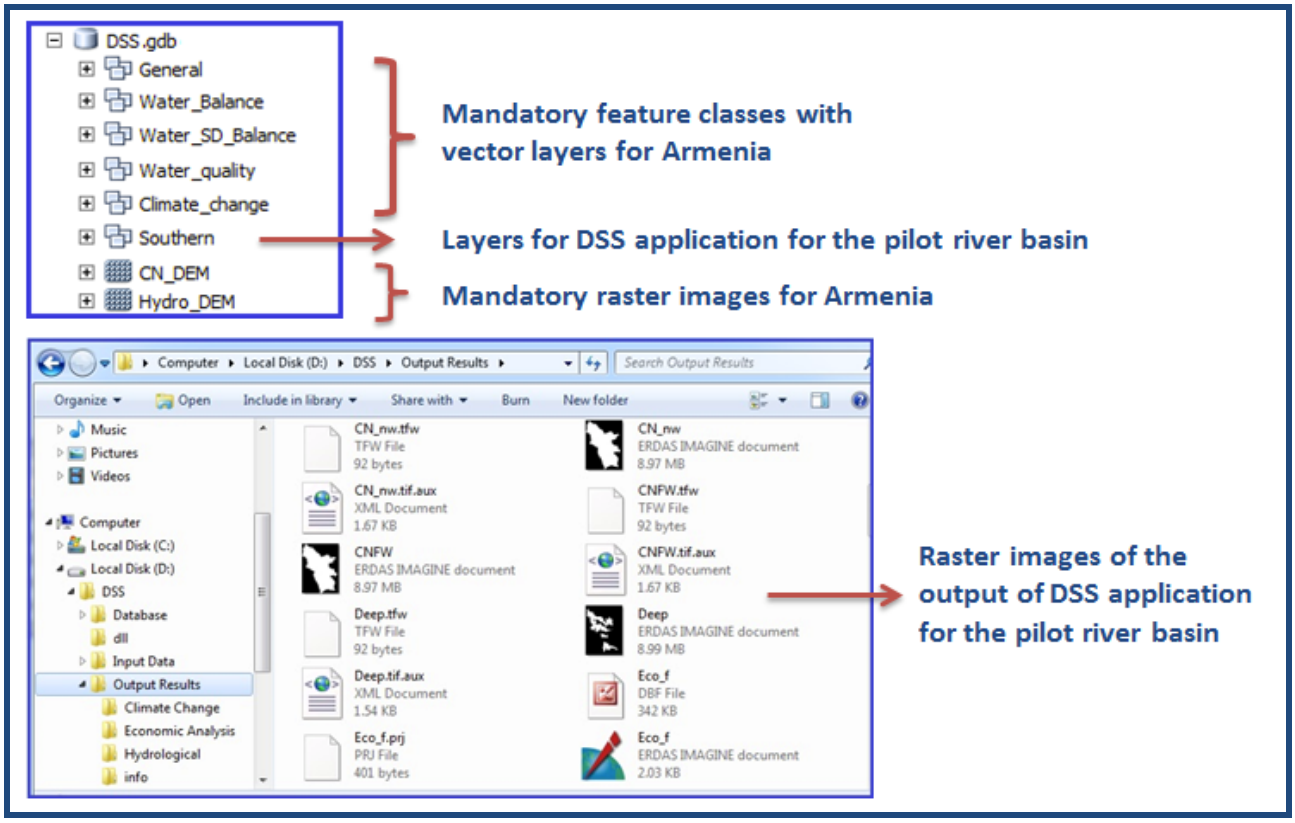
- The values are completed by establishing correlation function with other similar/neighbouring meteorological station data;
- The values are completed using mean annual values;
- The values are left blank.

2.3. Spatial Datasets

The spatial component of the DSS includes vector and raster datasets. The main vector layers as well as two raster images with Digital Elevation Model (DEM) of Armenia are included into a single geodatabase called "**DSS.gdb**". All the layers within the geodatabase are assembled in **WGS-1984** coordinate system, and **UTM Zone 38N** geographic projection.

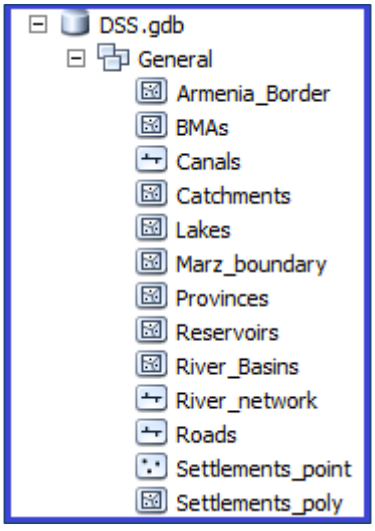
The geodatabase includes five mandatory dataset feature classes, as well as vector layers representing the river basin for which the DSS is being applied. The screenshot below represents the "**Southern**" dataset feature class, which contains the layers on the Southern BMA of Armenia.

During the application of the system, the resulting output raster images are being accumulated in the "**Output Results**" folder and its sub-folders. The location of the spatial datasets in the DSS is shown below.



2.3.1. Vector Data

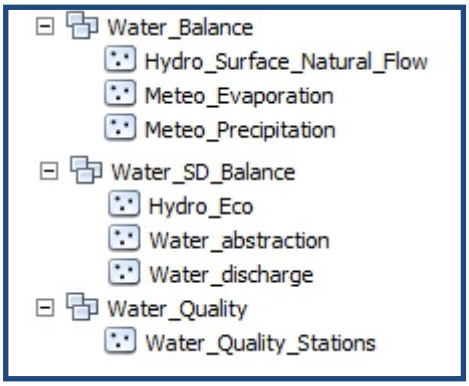
Vector data are accumulated in a single geodatabase within 6 dataset feature classes, out of which 5 are pre-requisites for DSS operation. Currently total of **45 GIS layers** are assembled in 6 dataset feature classes of the **DSS.gdb** geodatabase.



The first feature class called "**General**" contains the following 13 GIS layers:

- administrative border of Armenia;
- administrative boundaries of 11 marzes and 39 provinces of Armenia;
- boundaries of 6 basin management areas and 14 main river basins;
- point and polygon layers with 1000 settlements of Armenia;
- hydrological features of Armenia, such as river network, lakes, reservoirs, catchment areas, canals;
- road network of Armenia.

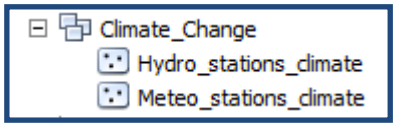
The next three dataset feature classes contain GIS layers used in the Hydrological Model of the DSS (Chapter 4 of the User Manual).



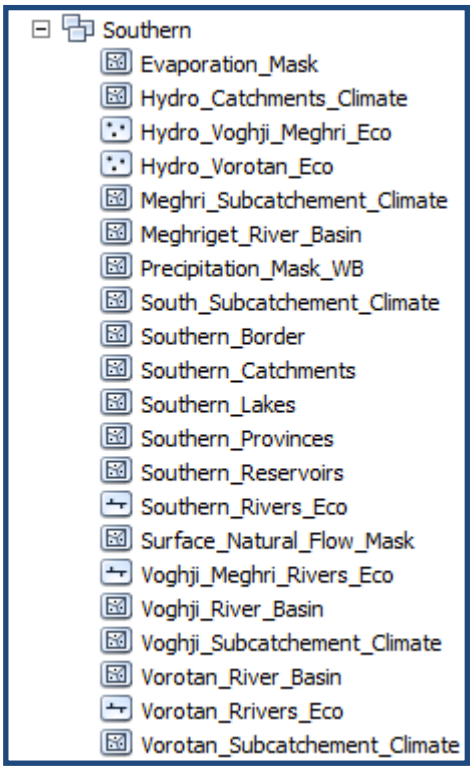
Three point layers are included in the "**Water_Balance**" dataset feature class that are used in the Water Balance component of the Hydrological Model (Section 4.2 of the User Manual) , where data from meteorological stations and hydrological observation posts are being accumulated. The **Hydro_Surface_Natural_Flow** point layer contains annual mean natural flow values calculated based on the data from 92 hydrological observation posts throughout the country. Each field of the attribute table corresponds to one year data. The **Meteo_Evaporation** and **Meteo_Precipitation** layers are populated with the annual mean values of evaporation and precipitation respectively, from 47 meteorological stations of Armenia. Each field of the attribute table corresponds to one year data.

The "**Water_SD_Balance**" dataset feature class contains three layers that are used in the Water Supply and Demand component of the Hydrological Model (Section 4.3 of the User Manual). The **Hydro_Eco** layer contains data on calculated ecological flow values at the hydrological junctions (confluence points at the river network). The next two layers, namely **Water_abstraction** and **Water_discharge,** are imported from the State Water Cadastre Information System and contain point data on the locations and volumes of the water abstraction and wastewater return according to the issued water use permits.

The "**Water_Quality**" dataset feature class is composed of one point layer with the locations of 131 water quality observation point of Armenia and is used in the Surface Water Quality Assessment component of the Hydrological Model (Section 4.7 of the User Manual).



The "**Climate_Change**" dataset feature classes contain GIS layers used in the Climate Change Model of the DSS (Chapter 5 of the User Manual). Two GIS layers of this dataset feature class accumulate values on climate change trends and projections at the meteorological stations and hydrological observation posts throughout Armenia.



To run the DSS for a single river basin of basin management area, it is necessary to establish a separate dataset feature class and accumulate the GIS layers that are peculiar to the area under consideration (this approach is discussed in Section 3.2 of the User Manual).

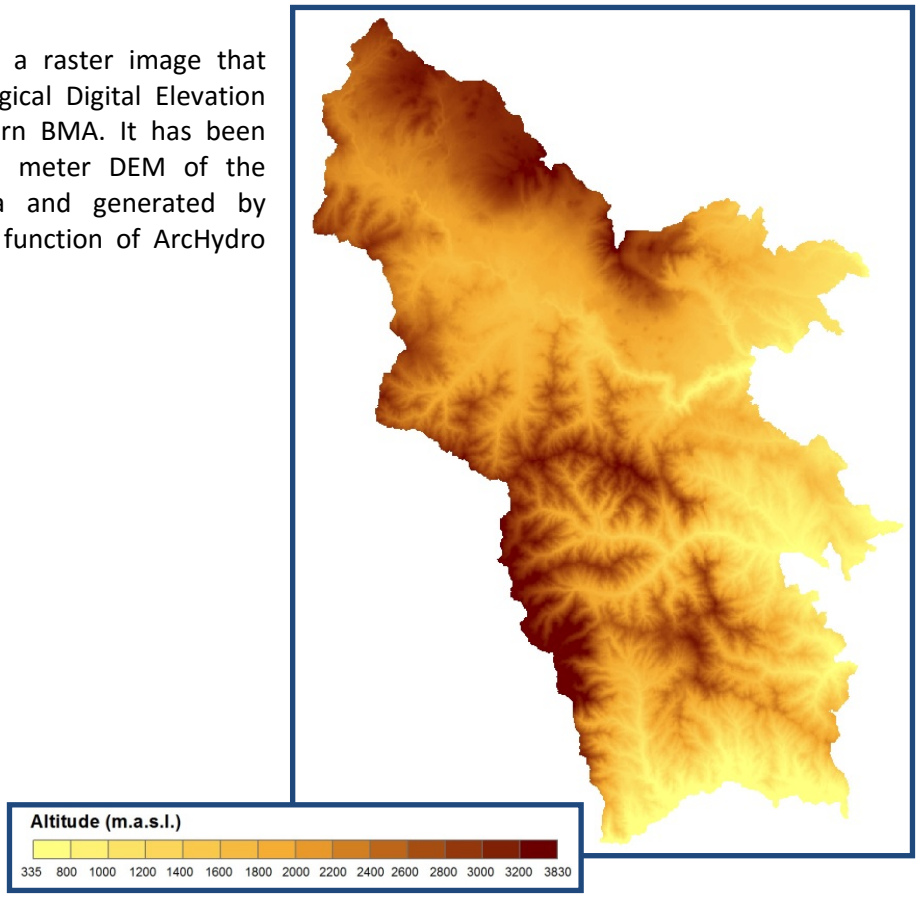
Currently the **DSS.gdb** geodatabase has a separate dataset feature class called "**Southern**", which contains 23 GIS layers on the Southern BMA of Armenia. In particular, those layers include:

- Boundary of the BMA and hydrological boundaries of the three river basins within the BMA;
- Hydrological features of the BMA, including river network, lakes, reservoirs, catchment areas and canals;
- Hydrological sub-catchment layers used for conducting climate change analysis;
- Mask layers with generate relationships between the altitudes and precipitation, altitudes and evaporation and altitudes and natural flow;
- Layers with calculated ecological flows at the hydrological junctions in the river basins of the Southern BMA.

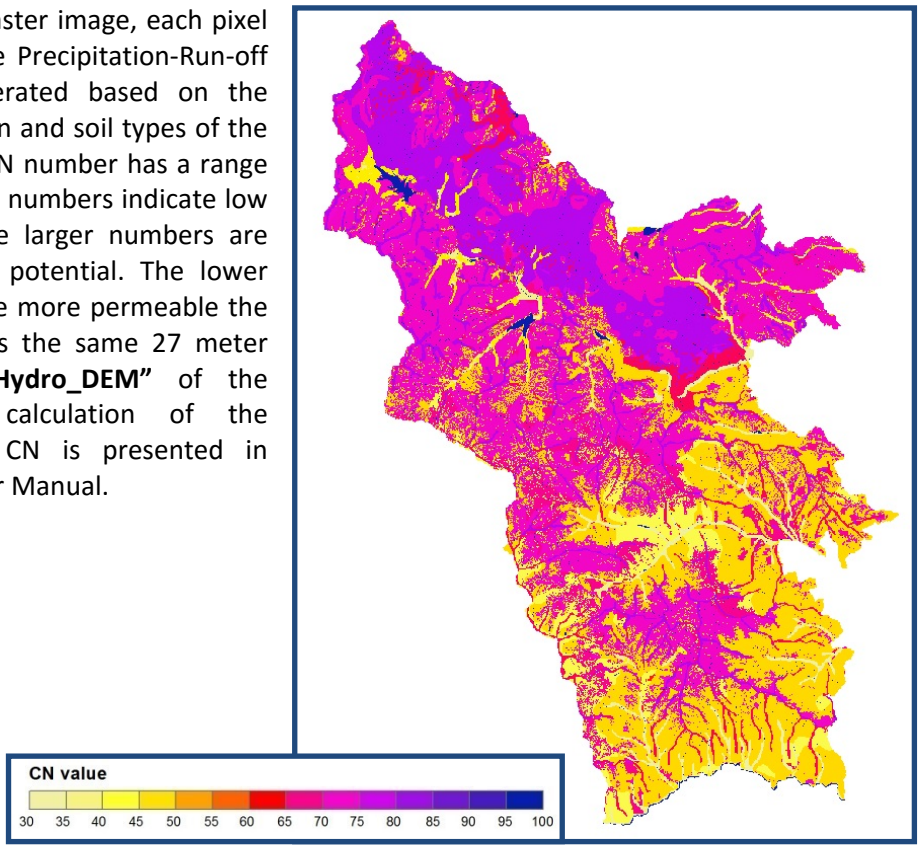
2.3.2. Raster Data

The following two raster datasets are included in the **DSS.gdb** geodatabase:

(1) The "**Hydro_DEM**" is a raster image that presents the Hydrological Digital Elevation Model of the Southern BMA. It has been clipped form the 27 meter DEM of the Republic of Armenia and generated by Streamflow direction function of ArcHydro extension.



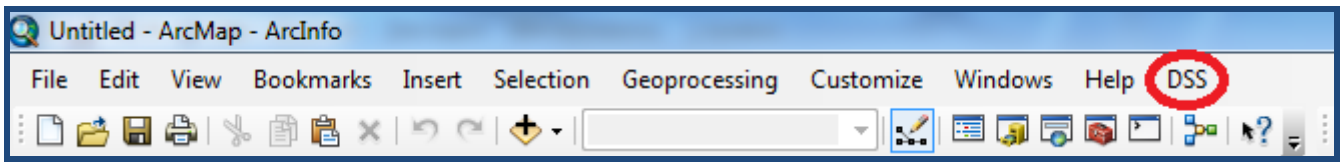
(2) The "**CN_DEM**" is a raster image, each pixel of which presents the Precipitation-Run-off Curve Number, generated based on the landcover classification and soil types of the Southern BMA. The CN number has a range from **30 to 100**: lower numbers indicate low runoff potential while larger numbers are for increasing runoff potential. The lower the curve number, the more permeable the soil is. The raster has the same 27 meter accuracy as the "**Hydro_DEM"** of the geodatabase. The calculation of the Precipitation-Run-off CN is presented in Section 4.5 of the User Manual.



3. STRUCTURE

3.1. Command Menu

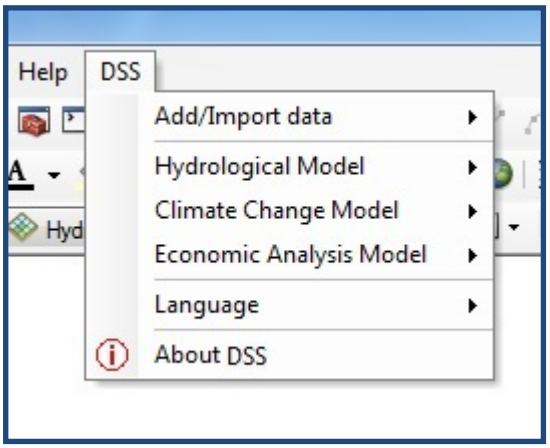
After the installation of the system, DSS extension will appear at the ArcMap menu as it is shown below:



The DSS menu contains the following commands at the first level:

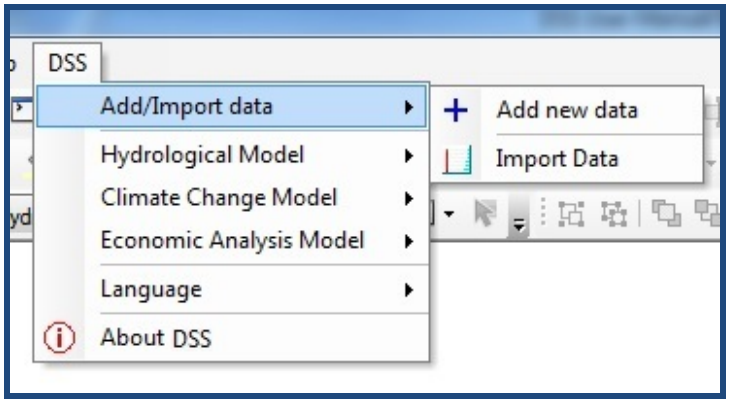
(1) Add/Import Data;
(2) Hydrologic Model;
(3) Climate Change Model;
(4) Economic Analysis Model;
(5) Language;
(6) About.

The following sections will describe each command in details.



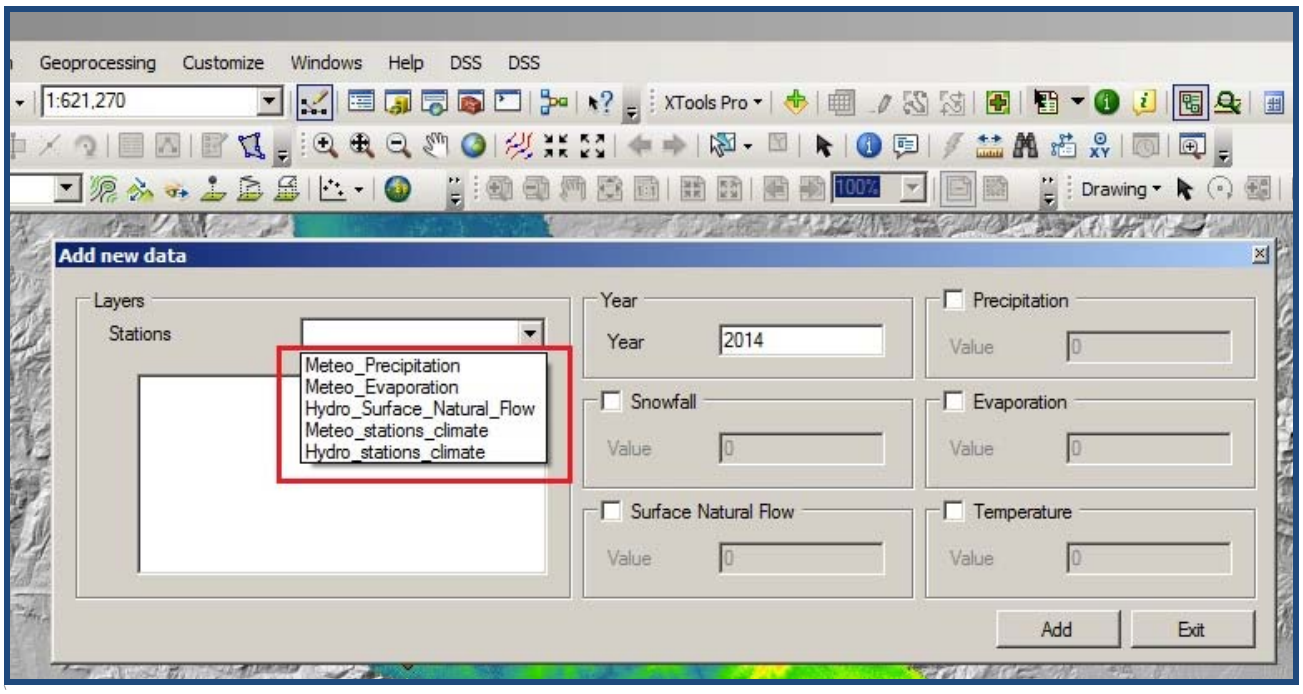
3.1.1. Add/Import Data

The first command of the DSS menu is for adding or importing new data to the system. There are two sub-menus at this level: "**Add new data**" and **"Import data**".



The **"Add new data"** command provides for an opportunity to amend the existing GIS layers with new data on (1) precipitation; (2) evaporation; (3) temperature; (4) snowfall; and (5) surface natural flow. The table below specifies the GIS layers to be selected for adding the specific data for specific purpose.

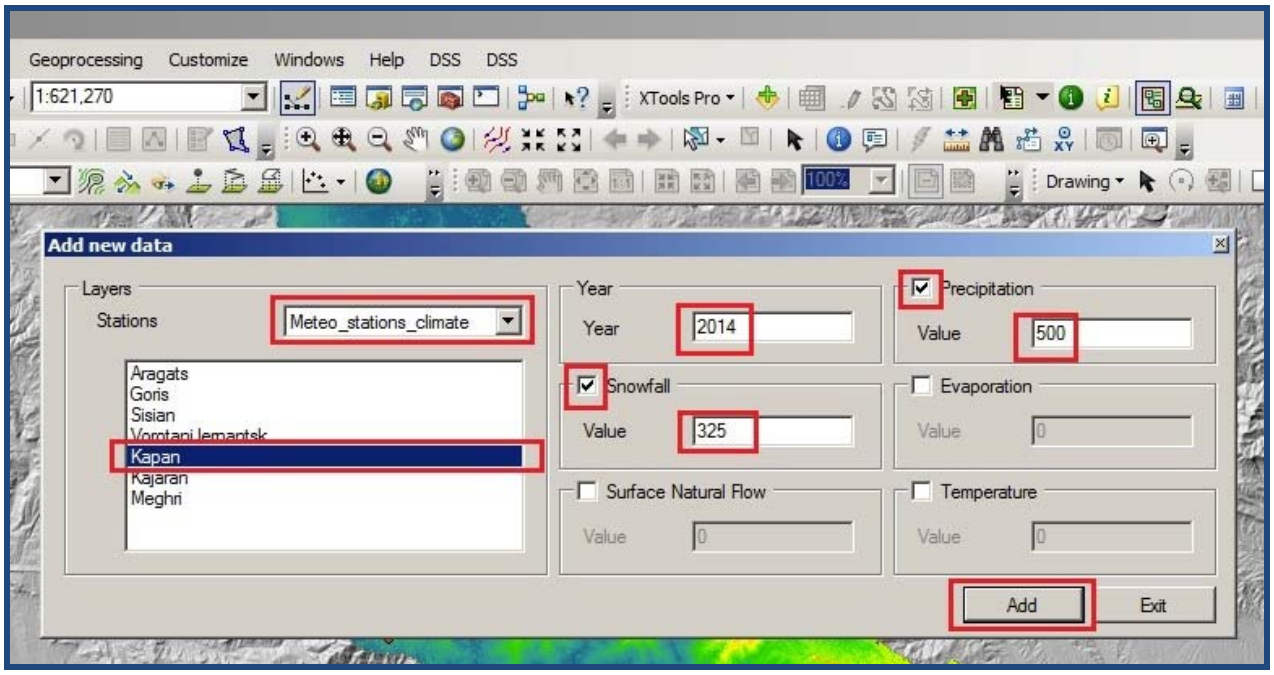
To add data on ….	*To run…*	*Select the layer*
Precipitation	Hydrological Model	Meteo_Precipitation
Evaporation	Hydrological Model	Meteo_Evaporation
Surface Natural Flow	Hydrological Model	Hydro_Surface_Natural_Flow
Precipitation, evaporation or snowfall	Climate Change Model	Meteo_stations_climate
Surface natural flow	Climate Change Model	Hydro_stations_climate



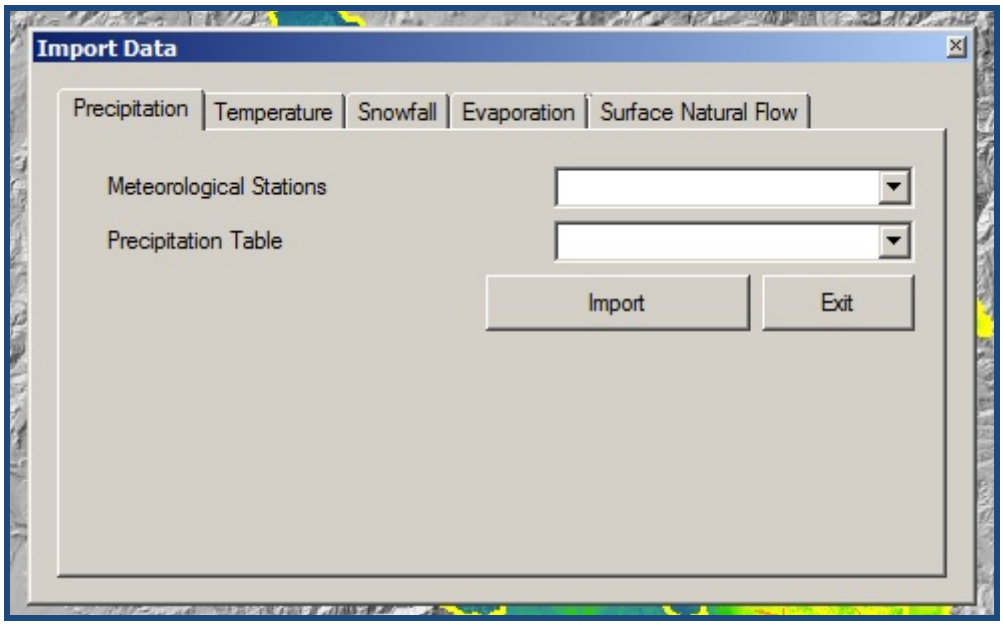
After selecting the GIS layer, the name list of Meteorological stations or Hydrological observation posts will appear in the box below "**Stations**" list. The following actions should be done to add the specific data:

(1) Select the name of Meteorological station or Hydrological observation post, the data is added for;
(2) Select the year, for which the annual mean data is going to be added;
(3) Select the parameter;
(4) Enter the annual mean value for the selected parameter for the selected year;
(5) Press the "**Add**" button to add the data entered into the form;
(6) Repeat the steps (1) through (5) to add more data;
(7) At the end press "**Exit**" button to quit the form.

The screenshot below presents a sample form for adding the annual mean **precipitation** value of 500mm and annual mean **snowfall** value of 325mm for the Meteorological station "**Kapan**" for the year **2014** in order to perform analysis under the **Climate Change Model**.



The **“Import data”** command is used to add data from Ms Excel spreadsheet into the respective GIS layers of the **DSS.gdb.** The following windows appears when clicking the **“Import data”** command:

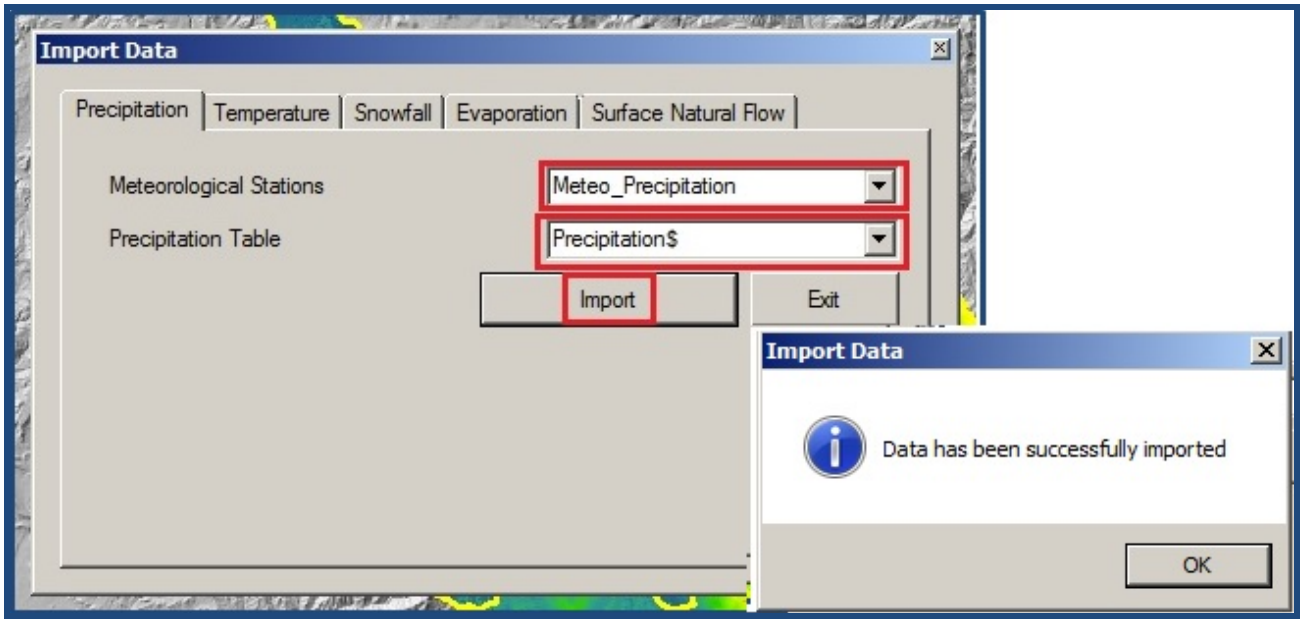


The data import window has 5 tabs for importing data on annual mean precipitation, temperature, snowfall ad evaporation based on the data received from meteorological stations as well as data on annual mean surface natural flow received from the hydrological observation posts. The format of the Ms Excel spreadsheets (see also Section 2.1 of the User Manual) should match the field structure of the attribute tables.

To import data the following sequence of steps is needed:

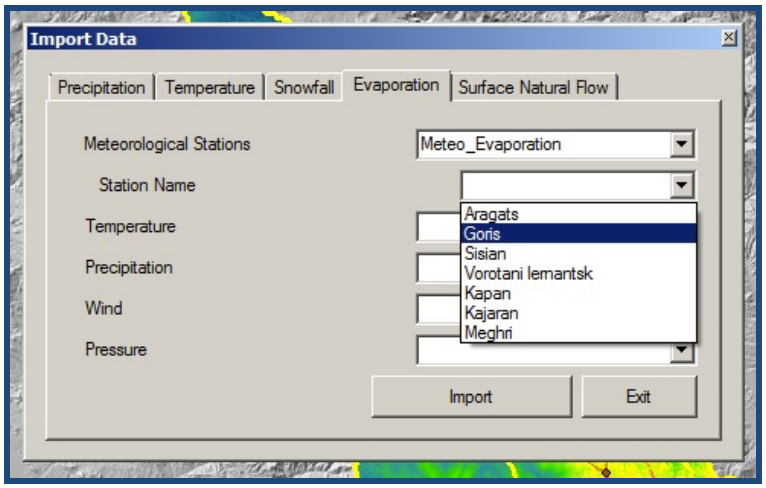
(1) Select the tab with the parameter needed;
(2) Select the name of the layer with meteo/hydro stations the data should be imported into;
(3) Select the name of the Ms Excel sheet where the source data is located;
(4) Click “**Import**” button.

If imported correctly, the appropriate message will appear. In case of errors during data importing it is suggested to revisit the appropriate Ms Excel sheet to check the field structure and data type of each field.



In the case of importing data on evaporation the following steps are to be taken:

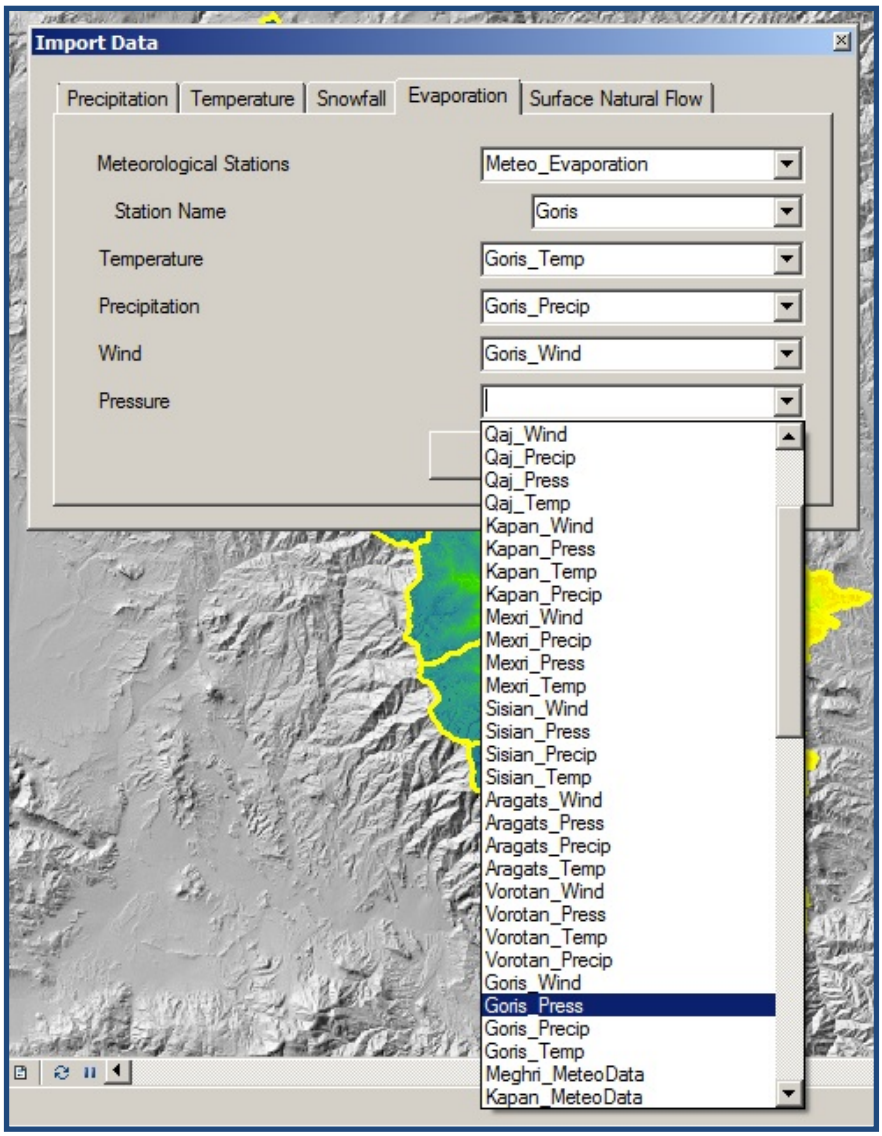
(1) Select the "**Evaporation**" tab in the "**Import Data**" window;
(2) Select the name of the layer with meteorological data: "**Meteo_Evaporation**";
(3) Select the name of the Meteorological station in the list below the layer name;



(4) Select the appropriate Ms Excel sheets with data on temperature, precipitation, wind and pressure;
(5) Click "**Import**" button.

As a result of the above-mentioned steps, the mean values of evaporation will be automatically calculated using a built-in formula and imported into the specified GIS layer.

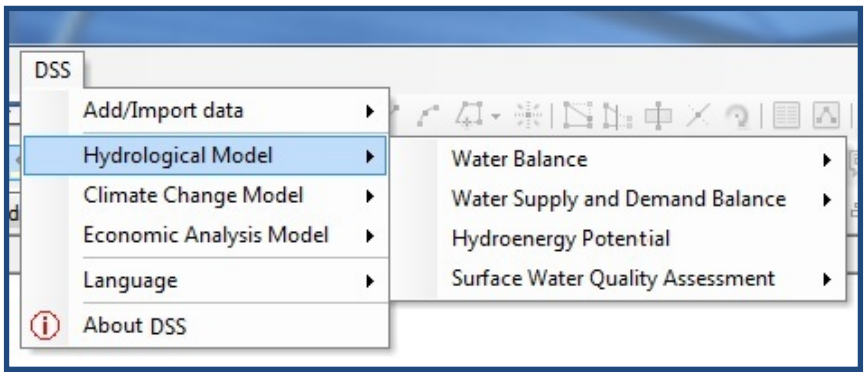
If imported correctly the appropriate message will appear. In case of errors during data importing it is suggested to revisit the appropriate Ms Excel sheet to check the field structure and data type of each field.



3.1.2. Hydrological Model

The **"Hydrological Model"** menu item has four sub-menus to different components of the model:

1. Determination of water balance for the river basin or any catchment area;
2. Determination of water supply and demand balance for the river basin or any catchment area;
3. Calculation of hydro-energy potential between any two points along the river reach;
4. Assessment of surface water quality based on monitoring data and water quality norms adopted by the Government of Armenia.

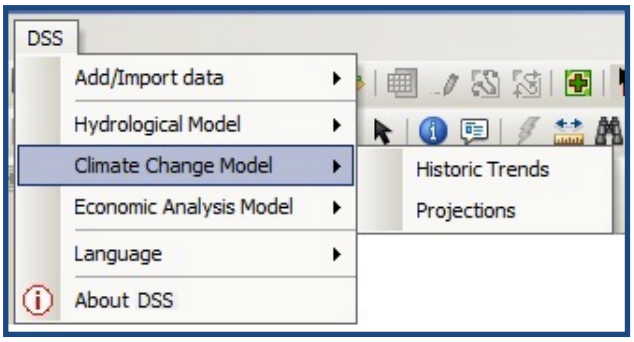


Refer to the Chapter 4 of the User Manual for more details.

3.1.3. Climate Change Model

The **"Climate Change Model"** menu item has two sub-menus to different components of the model:

1. Assessment of historic trends of changes in temperature, precipitation and snow flow values for the river basins compared to baseline period of 1961-1990;
2. Projections of the alteration of temperature and precipitation values at given meteorological stations in case of different climate change scenarios.

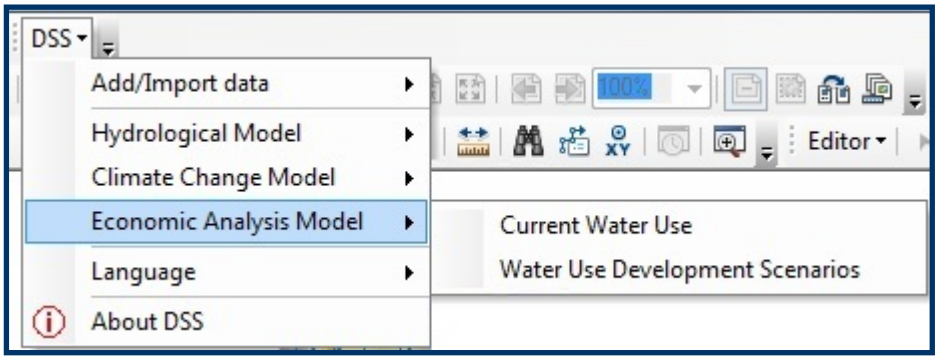


Refer to the Chapter 5 of the User Manual for more details.

3.1.4. Economic Analysis Model

The **"Economic Analysis Model"** menu item has two sub-menus to different components of the model :

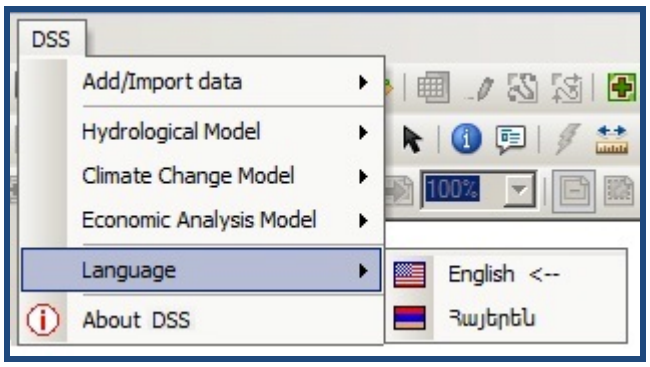
1. Cost-benefit analysis of water resources management for the given basin management area;
2. Economic analysis of water use, including baseline situation and development scenarios for river basins and basin management area.



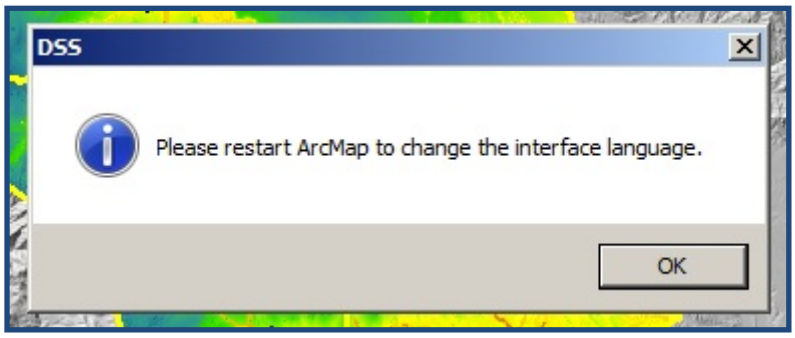
Refer to the Chapter 6 of the User Manual for more details.

3.1.5. Language

The "**Language**" menu item allows changing the language of the system between Armenian and English.



After changing the language the conversion will occur after restarting the ArcMap application.

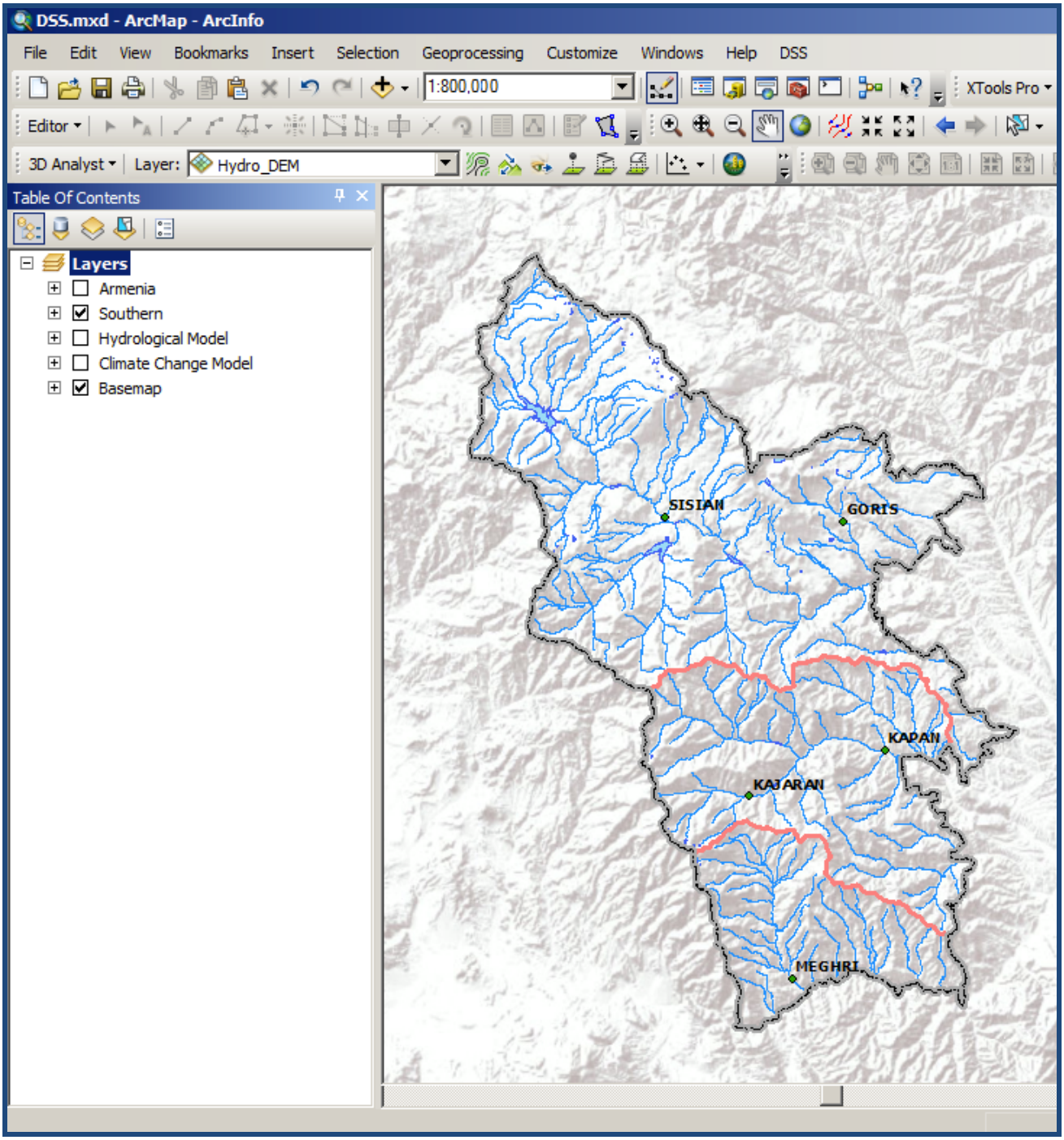


3.1.6. About

The last menu item of the "DSS" extension is "**About DSS**" section, where the brief information on the system development is presented.

3.2. Setting up the Analysis

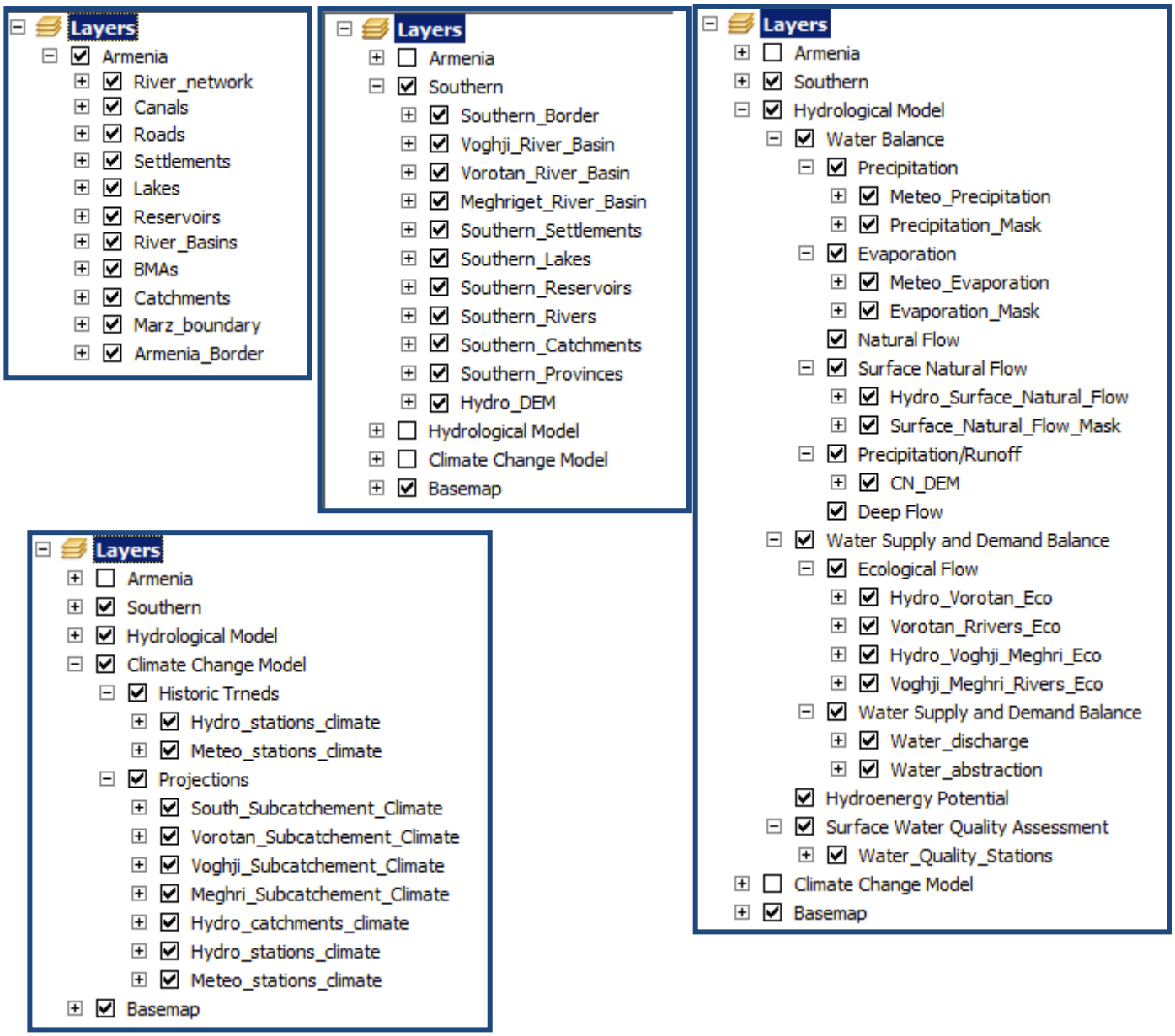
After the installation process is completed, a GIS application "**DSS.mxd**" will appear in the destination folder. The application incorporates the initial set of GIS layers organized in groups in order to facilitate running of different components of the system. The initial screen of the DSS.mxd demonstrates the Southern basin management area of Armenia and has 5 layer groups, namely "**Armenia**", "**Southern**", "**Hydrological Model**", "**Climate Change Model**" and "**Basemap**".



The "**Armenia**" layer group contains 11 vector layers on the administrative division (state border, marz boundaries, basin management areas boundaries, settlements) and hydrological features (rivers, canals, lakes, reservoirs, catchment areas, main river basins) of the country. This layer group includes also the road network of Armenia, as well as general spatial datasets that can be used for setting up the analysis for other river basins or basin management areas of Armenia.

The "**Southern**" layer group contains GIS layers used for running the DSS for the Southern BMA of Armenia. It incorporates the hydrological boundaries of river basins encompassing the BMA, as well as the **hydrologically conditioned DEM (Hydro_DEM)** of the territory. The Hydro_DEM has been obtained by using HEC-GeoHMS 'DEM Reconditioning' with stream/river layer and then running 'Fill Sinks' function. The HydroDEM raster layer served as an input to the CN grid generation.

The shapefiles used specifically in Hydrological and Climate Change Models are assembled in respective layer groups of the **DSS.mxd** application. The "Precipitation/Runoff" layer group within the Hydrological Model contains the **CN_DEM** for the Southern BMA, which was obtained based on HydroDEM, by reclassifying the soil cover layer, land cover layers, and CN look-up table using: "Utility > Generate CN Grid" function of HEC-GeoHMS.



To assemble datasets for a **new** basin management area or river basin, the following steps should be taken:

(1) Save the existing DSS.mxd application as a new file;
(2) Remove "Southern" layer group;
(3) Perform DEM reconditioning to Hydro DEM for the new basin management area or river basin;
(4) Add a new layer group with all specific GIS layers on the new basin management area or river basin;
(5) Run models of the DSS for a new area.

4. HYDROLOGICAL MODEL

4.1. Main objective

The main objective of the Hydrological Model is calculation and assessment of quantitative and qualitative characteristics of water resources based on their availability, meteorological conditions of river basins and other data on natural resources.

The Hydrological Model includes four components for:

(1) Calculation of the water balance;
(2) Calculation of the water supply and demand balance;
(3) Calculation of the hydroenergy potential of the rivers; and
(4) Assessment of the surface water quality.

The following sections will present the objectives, functionalities and outputs of each component in detail.

4.2. Water Balance Component

4.2.1. Objective and methodology

The calculation of water balance is aimed at performing proper inventory, management and planning of water resources within a river basin. It has great significance for quantitative characterization of water resources. Water balance is meant to quantitatively express natural water cycle through linking rainwater, evaporation, surface and deep flows occurring in the river basin.

Water balance equation is: $\mathbf{X = Y_{nf.} + E,}$

where:

$\mathbf{Y_{nf.} = Y_{snf.} \pm Y_{df.}}$

X is precipitation;

E is evapotranspiration;

Y_{nf} is natural flow;

Y_{snf} is surface natural flow;

Y_{df} is deep flow.

Precipitation (X) is determined based on construction of graphical correlation between values measured at meteorological stations of the river basin and the altitudes of the stations. Evapotranspiration (E) values are calculated at meteorological stations using the following equation:

$\mathbf{E = E_g[(1+0.07\ (\ V_i - V_{ave})]H_{ave}/\ H_i\ ,}$

where:

E is average monthly evapotranspiration in millimeters

E_g is the evapotranspiration that is determined through graphical correlation between average monthly values of precipitation and temperature

V_i is average monthly wind speed,

V_{ave} is average monthly wind speed within the country, accepted as 3.3 m/s,

H_{ave} is average value of the atmospheric pressure within the country, accepted to be 605 mm,

H_i is average value of atmospheric pressure for a given month

Evapotranspiration within a river basin is estimated based on construction of graphical correlation between values measured at meteorological stations and their altitudes.

Natural flow is determined by difference between precipitation and evapotranspiration values

$Y_{nf.}=X – E$:

The natural flow is classified into surface natural flow and deep flow:

$Y_{nf}= Y_{snf.}+ Y_{df.}$:

Surface natural flow ($Y_{snf.}$) is calculated using two methods:

(1) Graphical correlation between the actual river flow values measured at hydrological observation posts and average altitudes of the observation points;
(2) Generation of precipitation-runoff curve number by the following equation:

$$\mathbf{Y_{snf.}=(P-0,2S)^2/(P+0,8S)},$$

where:

P is precipitation,

and S is calculated based on the following formula:

$$\mathbf{S=25400/CN-254},$$

where:

CN is determined based on land use class and soil types.

Deep flow is estimated based on the difference between natural flow and surface natural flow:

$$\mathbf{Y_{df.} = Y_{nf.}- Y_{snf.}}$$

4.2.2. Input data

The following datasets are required as input data to run the Water Balance component:

Tabular:

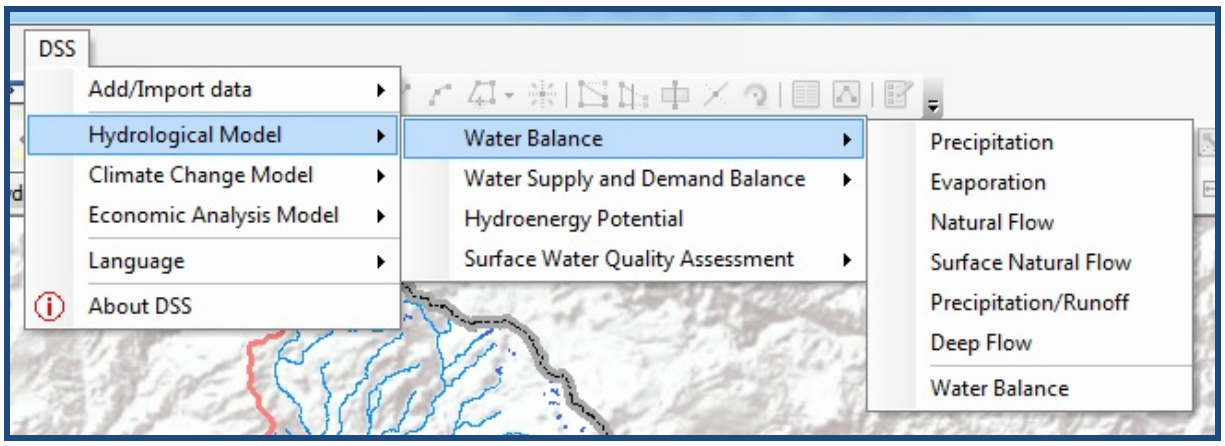
(1) Monthly mean air temperature, precipitation, atmospheric pressure, relative humidity and wind speed values obtained from the meteorological stations located within the river basin of interest;
(2) Annual mean precipitation, snowfall, air temperature values obtained from the meteorological stations located within the river basin of interest;
(3) Annual mean measured surface natural flow values obtained from the hydrological observation posts located within the river basin;

Spatial:

(4) Boundaries of the river basin(s) or basin management area(s) of interest;
(5) Rivers longer than 5 km of the river basin(s) or basin management area(s) of interest, coded using the ERICA system;
(6) Catchment areas of the rivers longer than 5 km, coded using the ERICA system;
(7) Point shape files with locations of meteorological stations located within the river basin of interest for water balance parameters (“Meteo_precipitation”and “Meteo_evaporation”);
(8) Point shape file with locations of hydrological observation posts located within the river basin;
(9) Mask shape files for the river basin of interest with the relationships among elevations and water balance parameters (“Precipitation_Mask”, “Evaporation_Mask”, etc);
(10) Hydrological DEM and CN DEM of the river basin of interest.

4.2.3. Running the component

The figure below presents the command menu of the Water Balance component of the Hydrological Model:

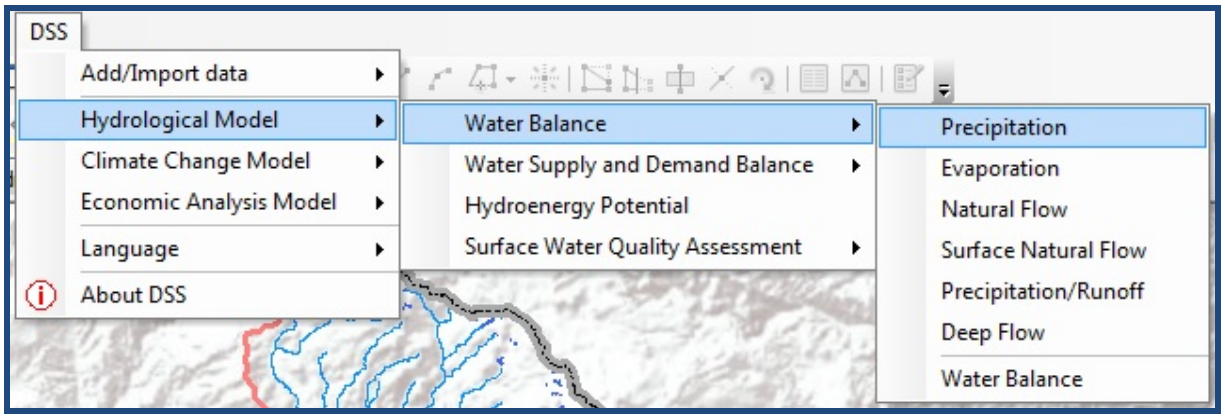


The Water Balance component has the following consecutive steps to be taken for any given river basin or catchment area:

(1) Determining annual mean precipitation pattern;
(2) Determining annual mean evaporation pattern;
(3) Calculating annual mean natural flow based on the obtained precipitation and evaporation data;
(4) Calculating annual mean surface natural flow using “data interpolation” method;
(5) Calculating annual mean surface natural flow using “precipitation/runoff curve” method;
(6) Determining annual mean deep flow based on the obtained natural flow and surface runoff;
(7) Estimation of the annual water balance equation for a selected river basin or catchment area.

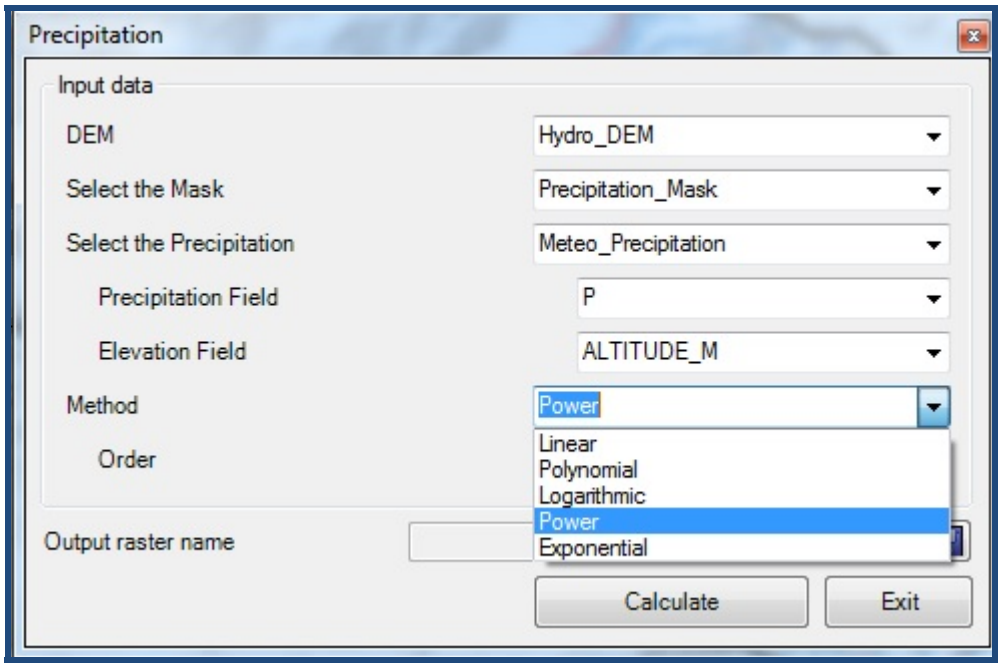
To determine the annual mean precipitation the following steps should be taken:

(1) Click the “Precipitation” command item under the “Water Balance” sub-menu.



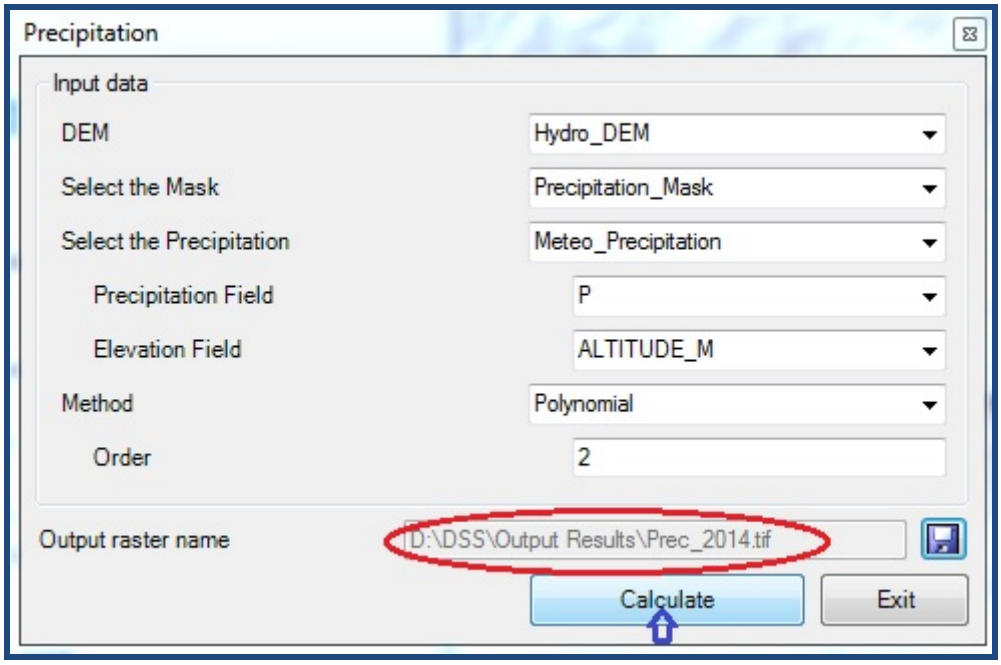
(2) A window titled “Precipitation” will appear. Select the Hydrological Digital Elevation Model in the “DEM” drop-down list. By default, the “Hydro_DEM” raster image of the “DSS.mxd” application appears in the window.
(3) Select the area of study in the “Select the Mask” drop-down list. By default, the “Precipitation_ Mask” layer of the “DSS.mxd” application appears in the window.
(4) Select the GIS layer with precipitation data from meteorological stations in the “Select the Precipitation” drop-down list. By default, the “Meteo_Precipitation” layer of the “DSS.mxd” application appears in the window. When the layer is selected, the “Precipitation Field” and “Elevation Field” will be identified automatically. Check the consistency and change the field names, if needed.

(5) Select the method of calculation in the “Method” drop-down list among the 5 available methods. By default the “Power” method is selected.



(6) In case the “Polynomial” method is selected, specify the order of calculations in the “Order” field.

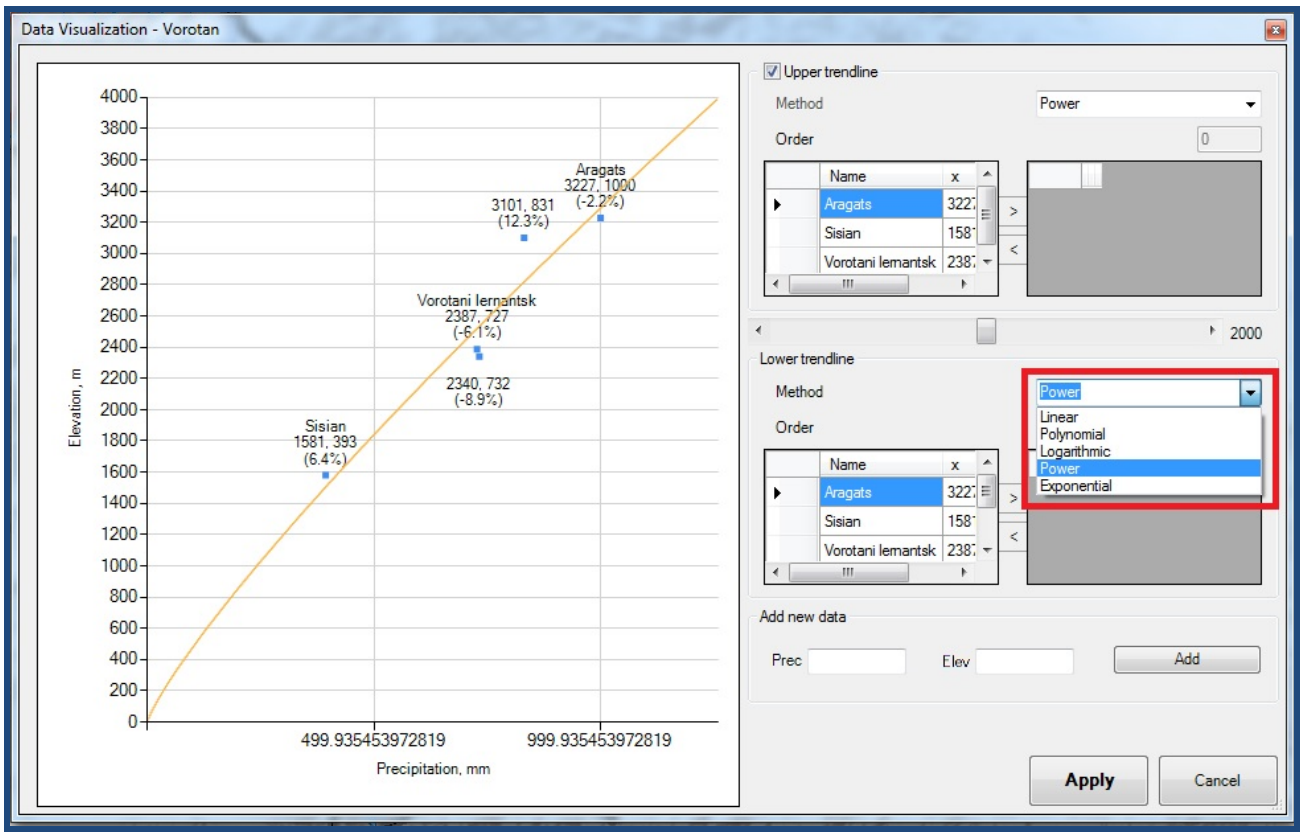
(7) Specify the location and the name of the output raster in the “Output raster name” field. It is recommended to mention the year in the raster name, as well as to locate it in the “Output results” folder.



(8) Click the “Calculate” button.

(9) For the given meteorological station, a separate window will appear where the user has the opportunity to fine-tune the relationships between the elevation and precipitation values by changing the methods of calculation for two trend lines: “upper” for the higher altitudes and “lower” for the lower altitudes. The selection can be made among the five methods mentioned in step (5).

(10) When methods are identified, the relationship function of elevation and precipitation values will be presented at the left side of the window.

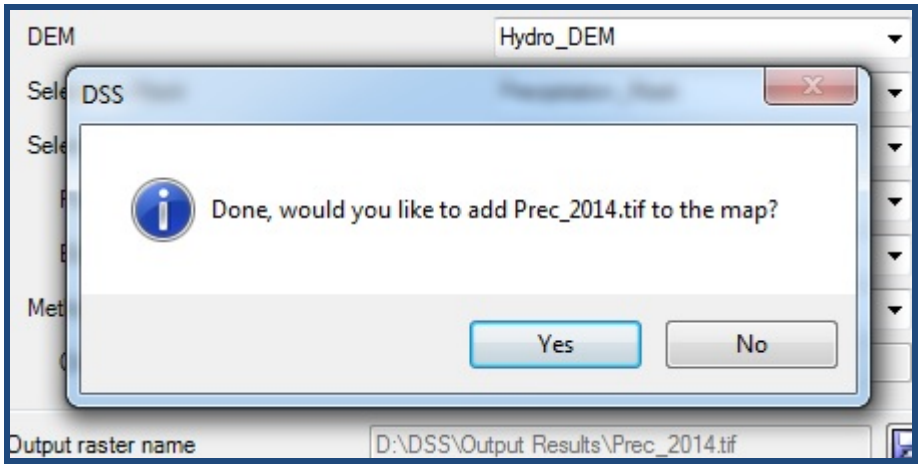


(11) There is a possibility to add a "virtual meteorological station" to adjust the relationship further. This can be done in "Add new data" section of the window by filling in the values of elevation and precipitation manually and pressing the "Add" button.

(12) When a smooth line of the precipitation-elevation function is obtained for the given meteorological station, press "Apply" button. A new window will appear for the next station.

(13) Repeat the steps (9) through (12) for each meteorological station.

(14) After the last meteorological station is processed in terms of smoothing the precipitation-elevation relationships, the raster image of the annual mean precipitation pattern will be created and the following message will appear.

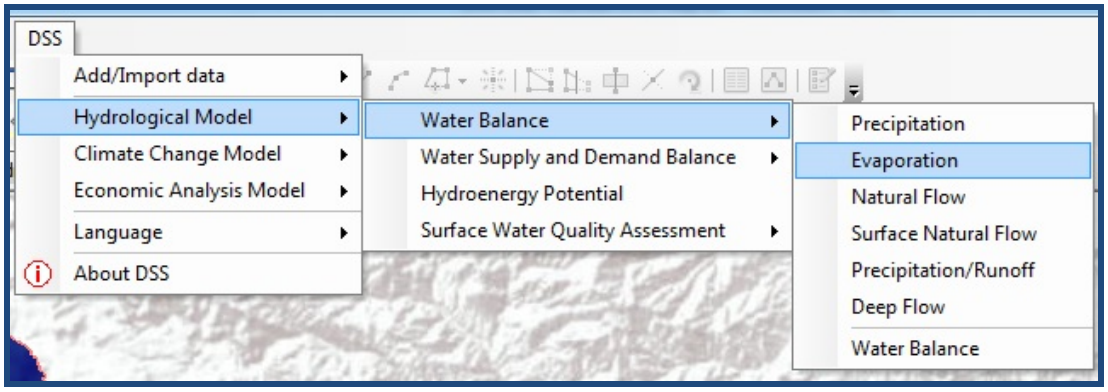


(15) Click the "Yes" button.

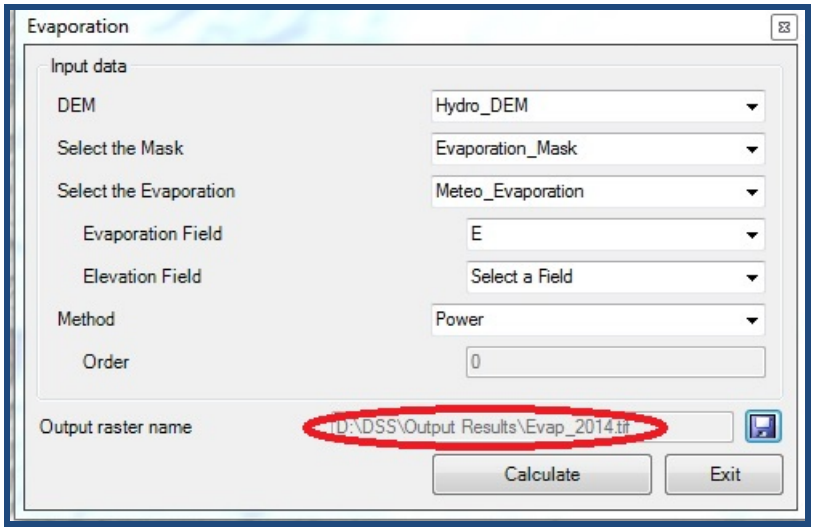
(16)The output raster image will be added into the DSS.mxd application.

The next step of calculation of water balance is estimation of annual mean evaporation pattern for a given river basin. The approach is similar to the one used in obtaining the annual mean precipitation values.

(1) Click the “Evaporation” command item under the “Water Balance” sub-menu.



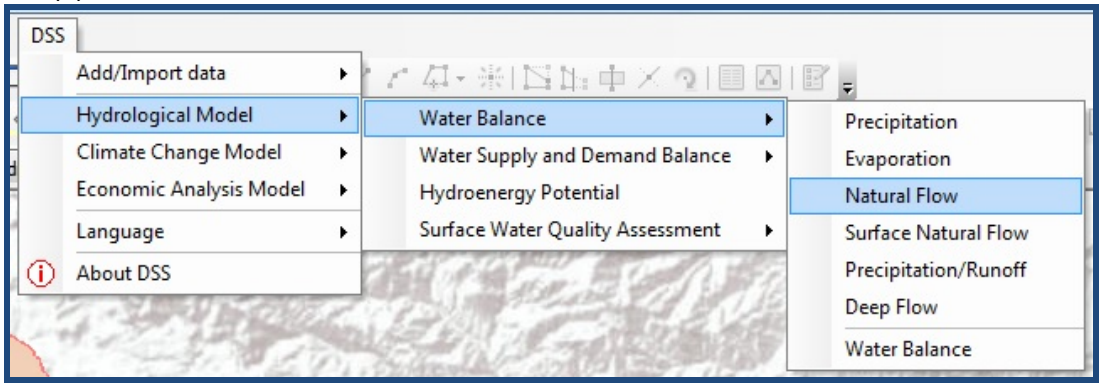
(2) A window titled “Evaporation” will appear. Follow steps (2) to (14) described above for obtaining the annual mean precipitation pattern. Select the GIS layer with evaporation data in the “Select the Evaporation” drop-down list. By default, the “Meteo_Evaporation” layer of the “DSS.mxd” application appears in the window. Similarly, the “Evaporation_ Mask” layer of the “DSS.mxd” application will be selected by default in the “Select the Mask” drop-down list.



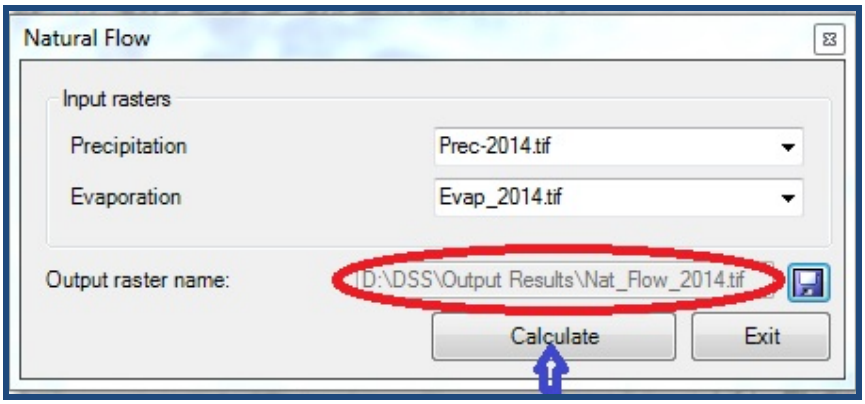
(3) The output raster image titled “Evap-2014” will be added into the DSS.mxd application.

The third step of calculation of water balance is determining the annual mean natural flow by subtracting the obtained evaporation raster from obtained precipitation raster. This is done by the following two steps:

(1) Click the “Natural Flow” command item under the “Water Balance” menu item.



(2) In the opened window specify the name of the raster images generated in the previous steps and specify the location and name of the future raster image on annual mean natural flow. Click the "Calculate" button.

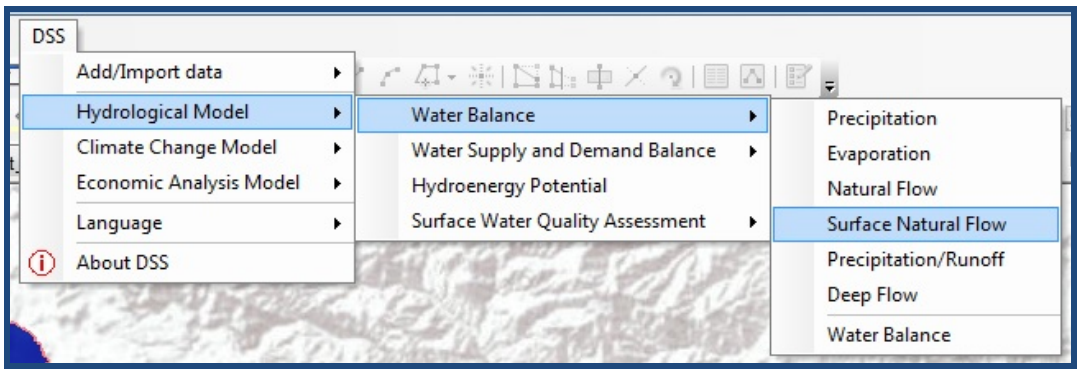


(3) The new raster image with the annual mean natural flow values will be generated and added to the "DSS.mxd" application.

The next step towards calculation of water balance is related to estimation of the annual mean surface natural flow (or surface runoff) as part of the determined natural flow. There are two alternative methods for its determination: (1) interpolation approach; and (2) application of precipitation-runoff curve number (CN) approach.

To calculate the surface natural flow by interpolation method:

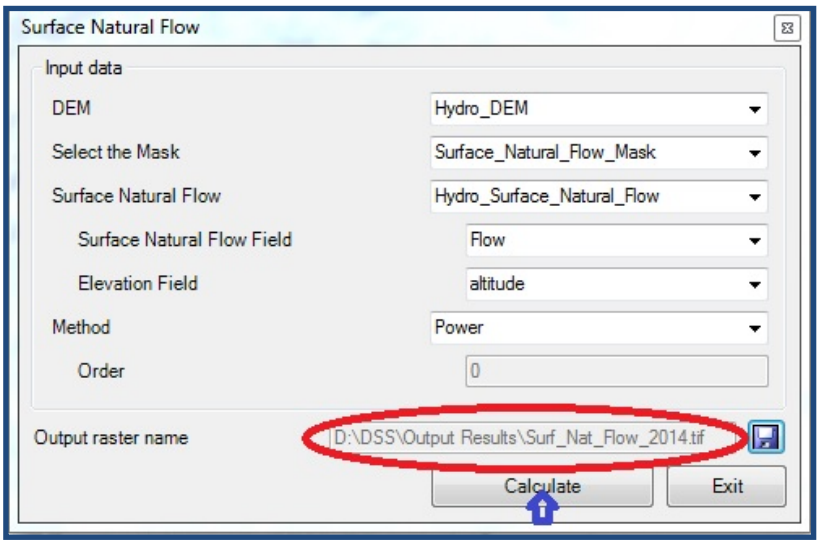
(1) Click the "Surface Natural Flow" command item of the "Water Balance" sub-menu.



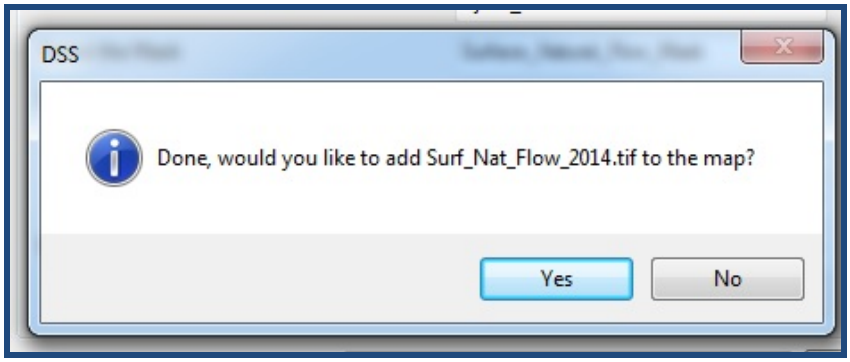
(2) A window will appear that is very similar to the one in precipitation and evaporation calculation steps. The fields of the form will be filled in automatically. The GIS layer with values filled in for annual mean natural flow should be selected in the "Surface Natural Flow" drop down list.

(3) Again one of the 5 embedded methods for interpolation should be selected in the "Method" drop-down list.

(4) Specify the location and the name of the output raster and press "Calculate" button.



(5) For each hydrological observation post, a separate window will appear, where the user has the opportunity to fine-tune the relationships between the elevation and surface natural flow values by changing the 5 embedded methods of calculation for two trend lines: the "upper" one for higher altitudes and the "lower" one for lower altitudes.
(6) When methods are identified the relationship function of elevation and precipitation values will be presented at the left side of the window.
(7) There is a possibility to add a "virtual hydrological observation post" to adjust the relationship further. This can be done in the "Add new data" section of the window by filling in the values of surface natural flow and precipitation manually and pressing the "Add" button.
(8) When a smooth line of the surface natural flow-elevation function is obtained for a given hydrological observation post, press the "Apply" button. A new window will appear for the next point.
(9) Repeat the steps (5) through (8) for each hydrological observation post.
(10) After the last hydrological observation post is processed in terms of smoothing the surface natural flow- elevation relationships, the raster image of the annual mean surface natural flow pattern will be created and the following message will appear.

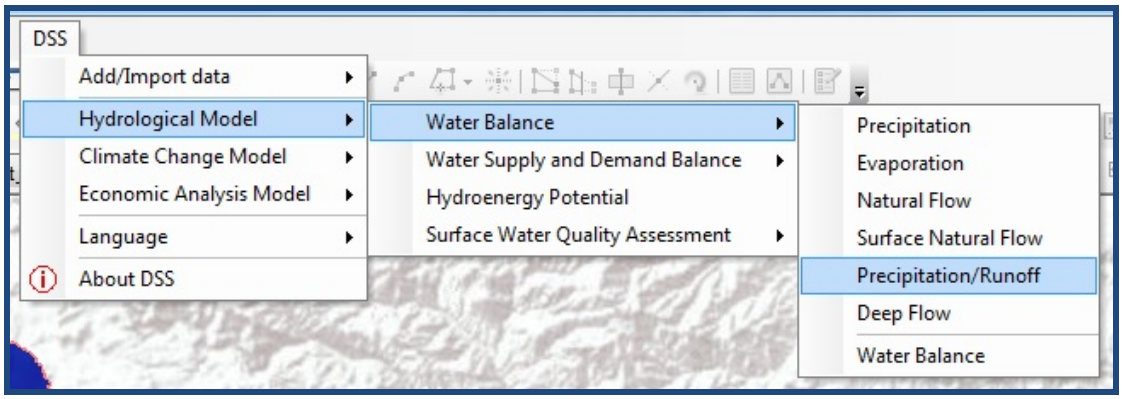


(11) Click the "Yes" button.

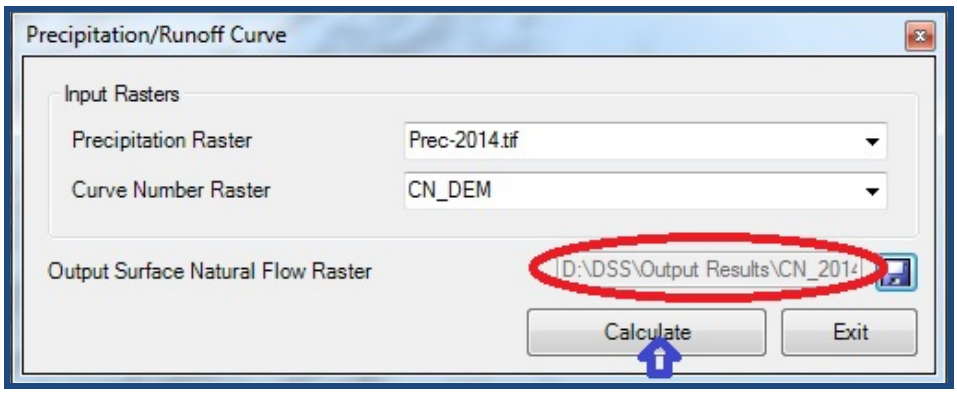
(12) The output raster image will be added into the DSS.mxd application.

To calculate the surface natural flow by "precipitation-runoff curve" method:

(1) Click the "Precipitation/Runoff" command item of the "Water Balance" sub-menu;



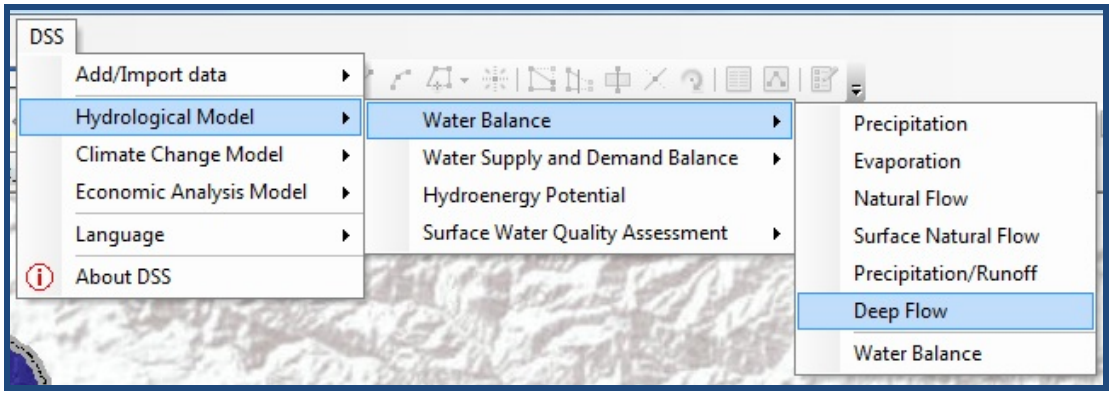
(2) A window titled "Precipitation/Runoff curve" will appear;
(3) Select the precipitation raster name in the "Precipitation Raster" field;
(4) Select the "CN_DEM" in the "Curve Number Raster" field;
(5) Specify the location and the name of the output raster image;
(6) Click the "Calculate" button.



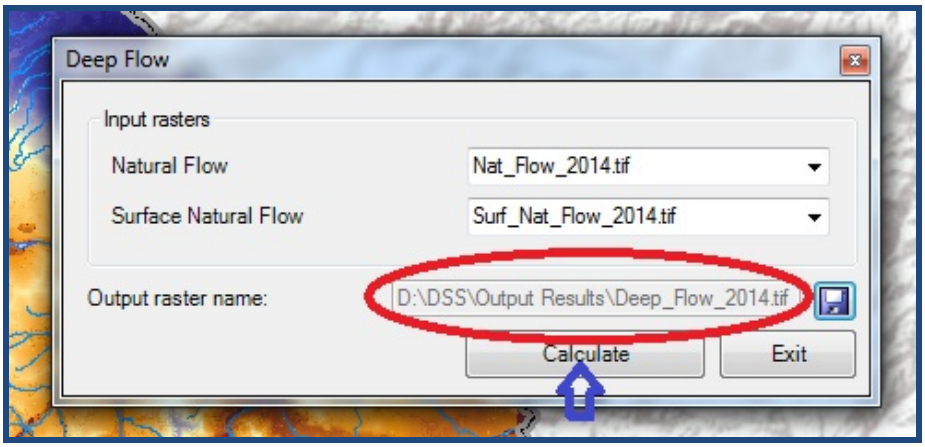
The output raster image will be added into the DSS.mxd application.

The last step towards calculation of water balance is related to estimation of annual mean deep flow based on the determined annual mean natural flow and the annual mean surface natural flow. To calculate the annual mean deep flow pattern:

(1) Click the “Deep flow” command item of the “Water Balance” sub-menu;



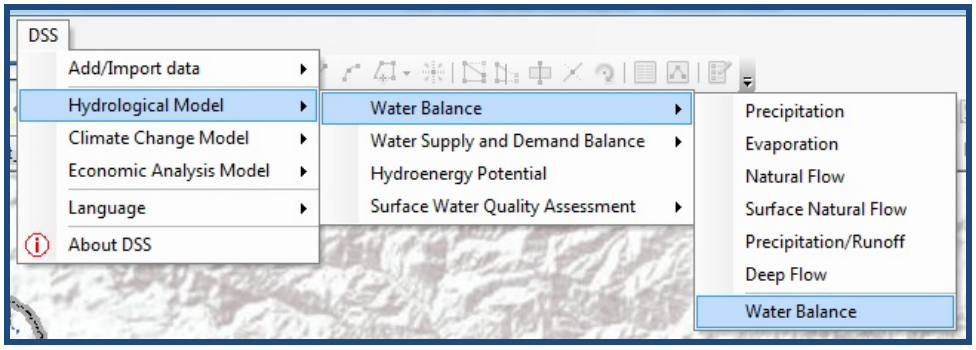
(2) The “Deep Flow” window will appear;
(3) In the “Natural Flow” field select the raster image of natural flow generated during previous steps;
(4) In the “Surface Natural Flow” field select the raster image of surface natural flow (surface runoff) generated either by interpolation method or “precipitation-runoff curve” approach;
(5) Specify the location and the name of the output raster image;
(6) Click the “Calculate” button.



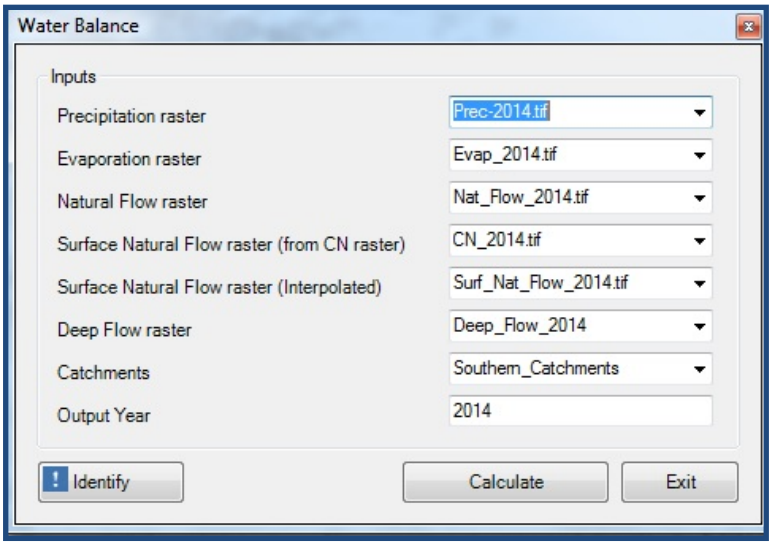
The output raster image will be added into the DSS.mxd application.

When all the components of water balance for a given year are generated it is possible to obtain the water balance equation for any given catchment area within a river basin. The following steps should be taken to view the report on numeric values of all the parameters of the water balance equation:

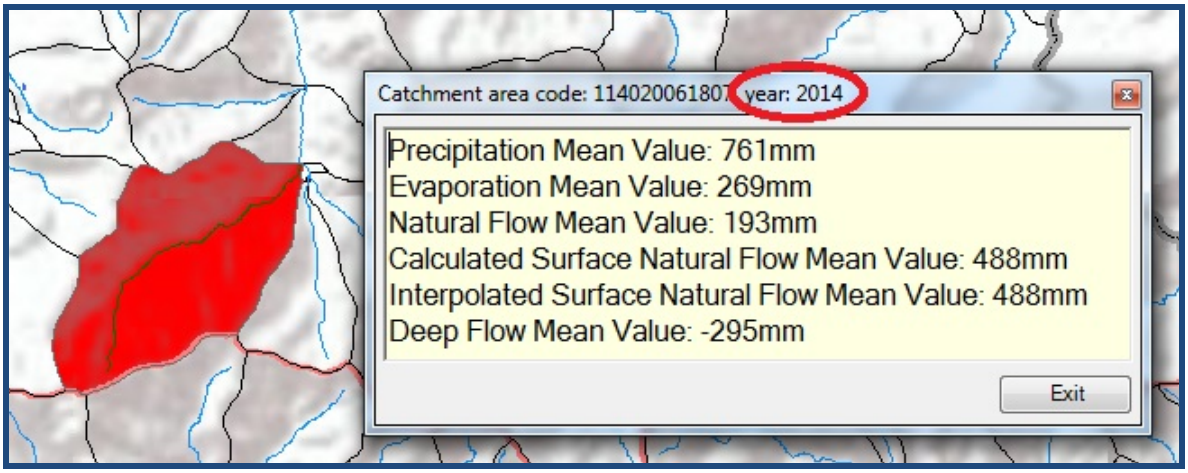
(1) Click the “Water Balance” command item of the “Water Balance” sub-menu;



(2) A “Water Balance” window will appear. In the fields of the window select the raster images generated during the previous steps;
(3) Specify the year in the “Output Year” field;
(4) Click the “Calculate” button;
(5) Activate the ‘Catchments” GIS layer for the “Armenia” dataset feature class;
(6) Zoom in to the catchment area of interest;
(7) Click the “Identify” button;
(8) Click in the catchment area of interest.



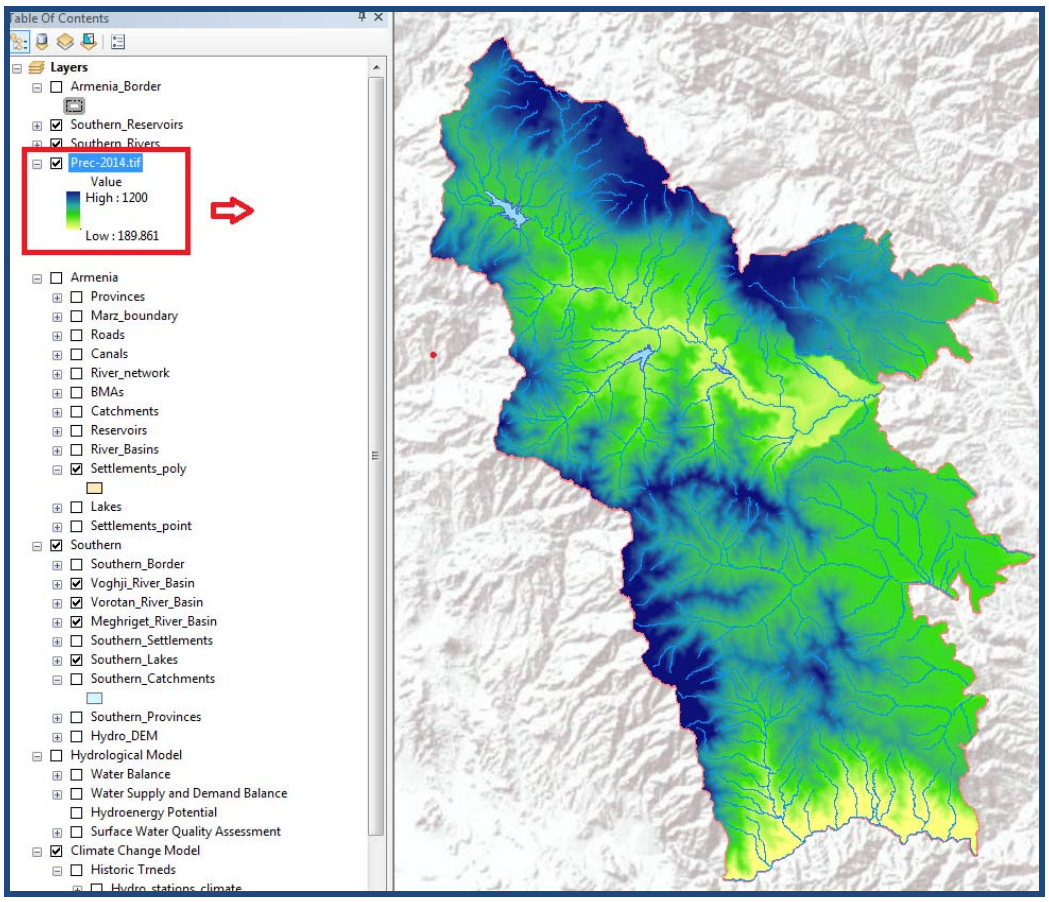
A summary report on the water balance of the given catchment area will appear on the screen.



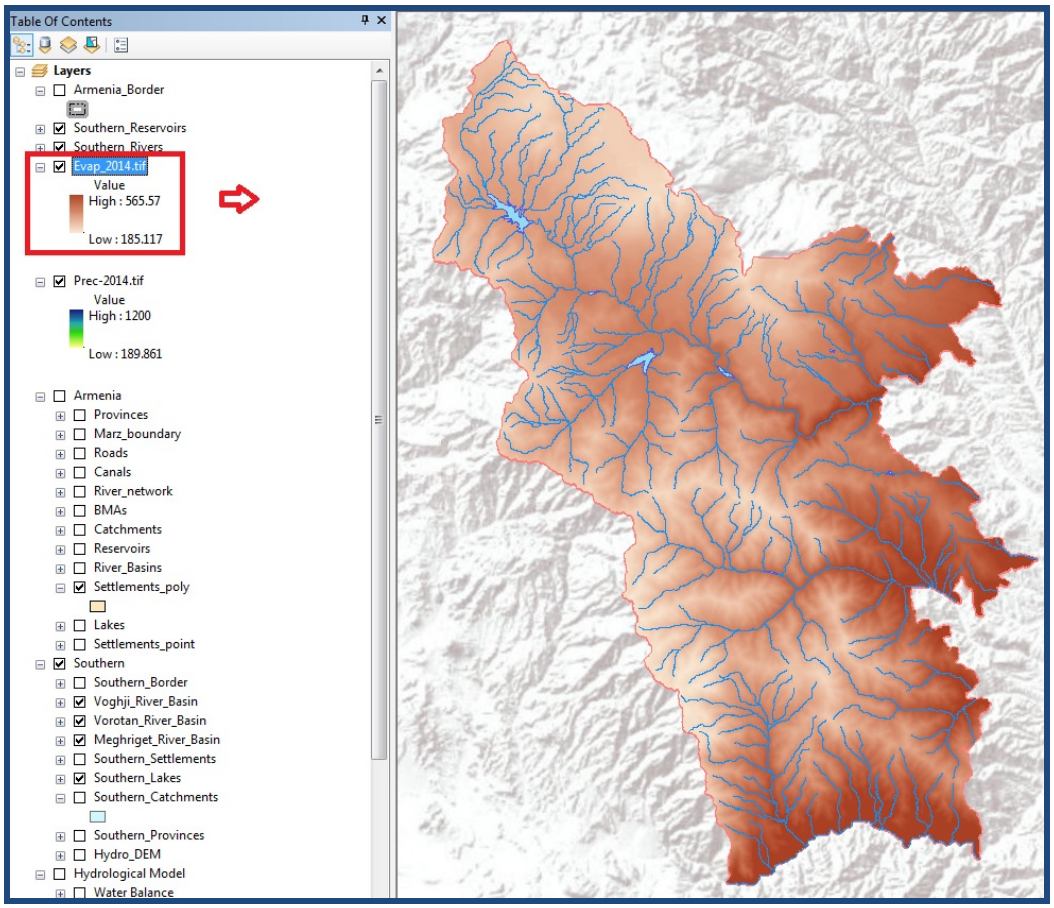
4.2.4. Main outputs

The outputs of the Water balance component are presented on the example of the Southern BMA of Armenia.

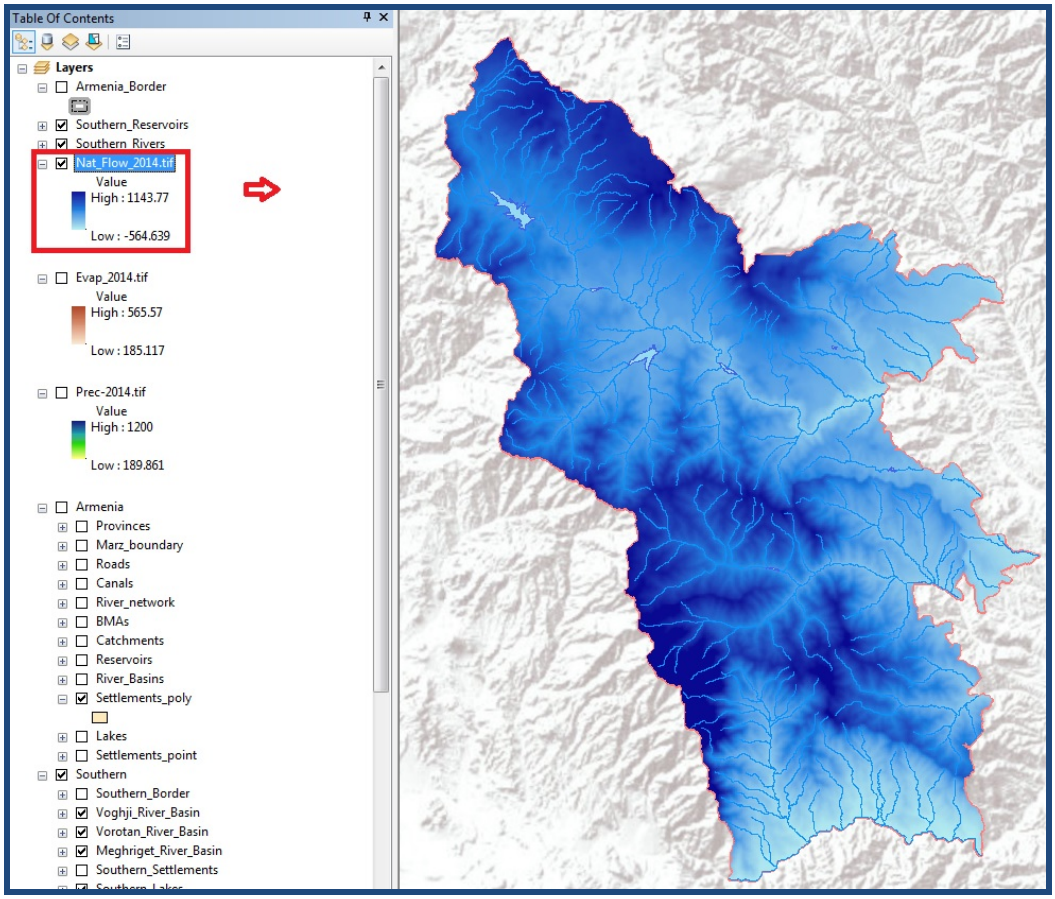
(1) Annual mean precipitation raster image



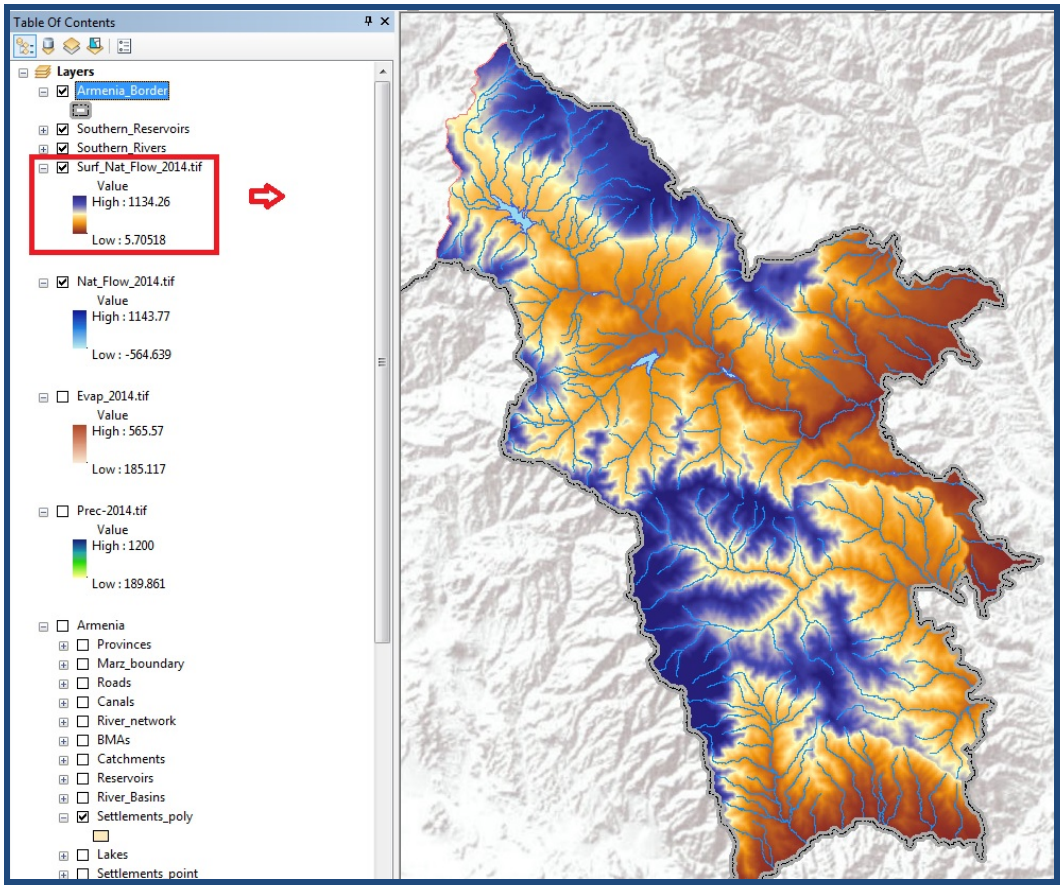
(2) Annual mean evaporation raster image



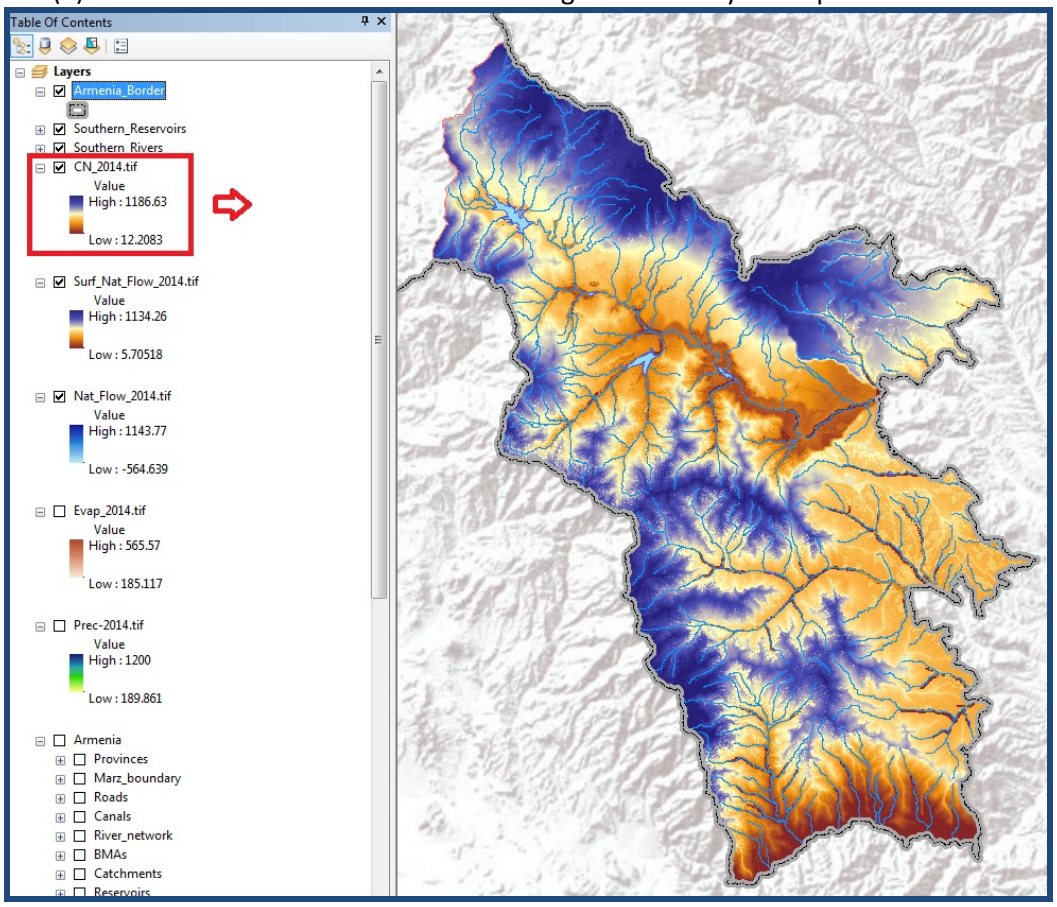
(3) Annual mean natural flow raster image



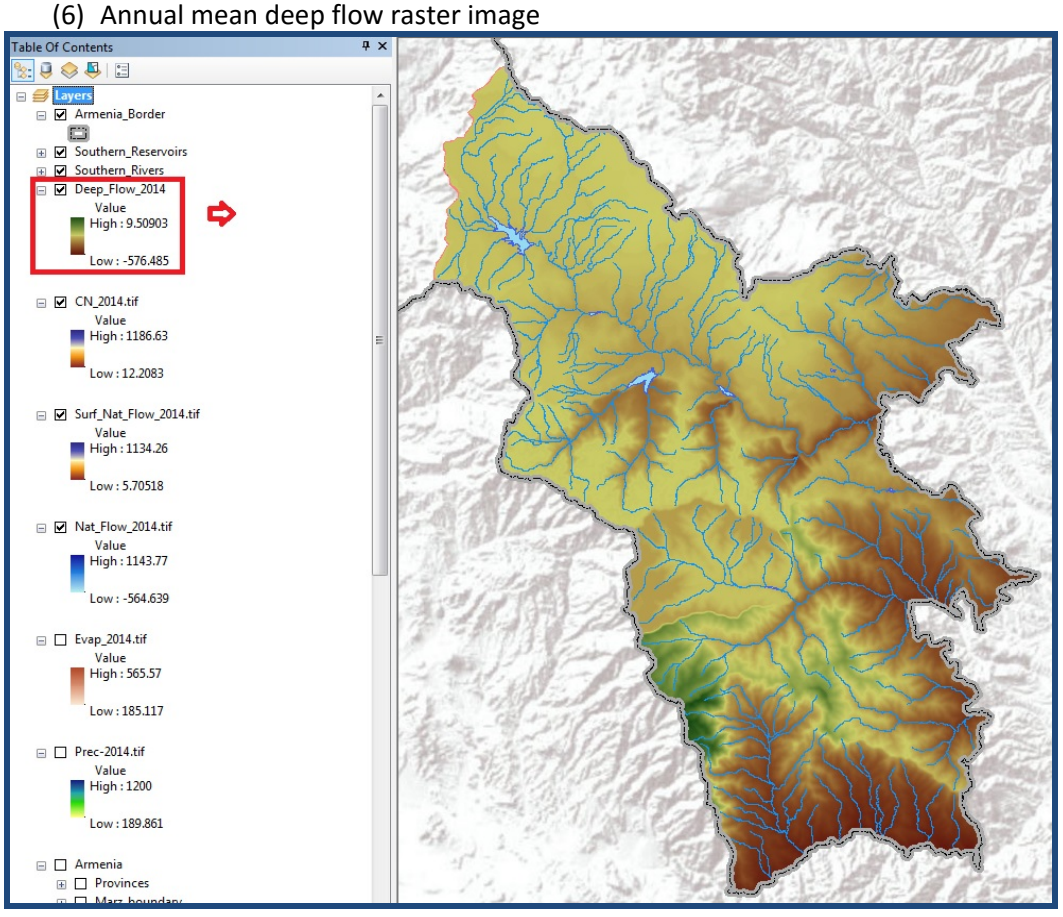
(4) Annual mean surface natural flow raster image obtained by interpolation method



(5) Annual mean surface runoff raster image obtained by “Precipitation-runoff curve” method



(6) Annual mean deep flow raster image



4.3. Water Supply and Demand Balance Component

4.3.1. Objective and methodology

The water supply and demand balance is aimed at the determination of surplus or deficit of water resources at a given river basin or its any section. The water supply and demand balance allows understanding the water supply and water demand of both overall river basin and its sections.
The water supply and demand balance is calculated by river section catchments and allows decision making authorities to provide water use permits based on reliable information, as well as set realistic goals for river basin management and conservation, thereof, supporting the identification of environmental objectives necessary for implementation of a river basin management plan.

The water supply and demand balance is calculated on the basis of the following equation:
$$\mathbf{B=Y_{snf.}-Y_{ef.}- Y_{wa.}\pm Y_{dr}+\Delta V\pm T\pm U,}$$

where:
B is the balance itself, defined as difference of water supply and demand, which shows surplus or deficit of water resources in the river basin or its sections;
$Y_{nsf.}$ is surface natural flow within a given river section;
$Y_{ef.}$ is ecological flow required to maintain the ecosystem within a given river section;
Y_{wa} is cumulative water abstraction;
Y_{dr} is cumulative wastewater discharge;
ΔV is water volume stored in reservoirs located within a given catchment area;
T is water volume flowing into or out of a given catchment area;
U is volume of groundwater resources within a given catchment area, in case groundwater is envisaged for water use (it should not exceed the approved operational amount of groundwater resources defined for a given catchment area).

The calculation of ecological flow of water resources of the Republic of Armenia is performed in accordance with the methodology approved by the Resolution # 927-N (2011) of the Government of Armenia. The calculations are done for the main rivers of the river basin where hydrological observation posts exist. According to the mentioned methodology, the ecological flow is determined as the minimum average observed flow of 10 consequent days of the winter period (December-February). For the rivers without hydrological observation data, a graphical correlation between ecological flow and natural river flow values is used.

4.3.2. Input data

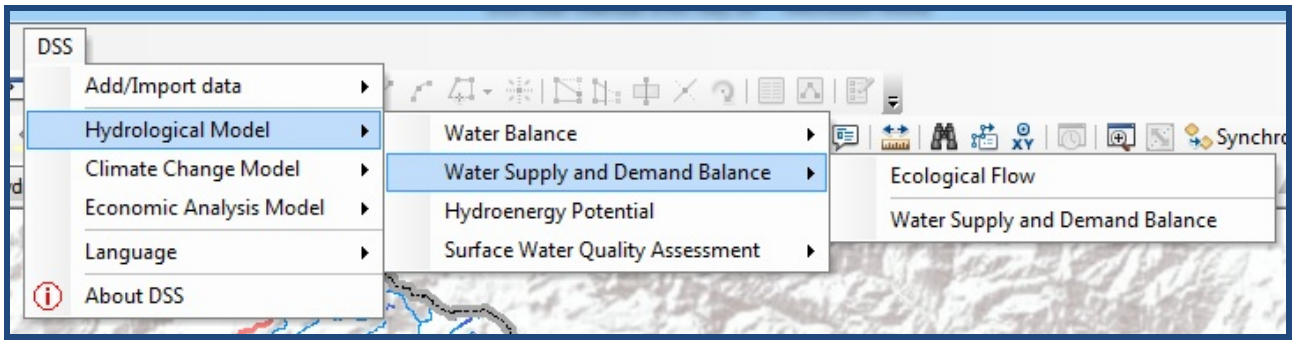
The following datasets are required as input data to run the Water Supply and Demand Balance component:

Spatial:

(1) Boundaries of river basin(s) or basin management area(s) of interest;
(2) Rivers longer than 5 km of a river basin(s) or basin management area(s) of interest, coded using the ERICA system;
(3) Catchment areas of rivers longer than 5 km, coded using the ERICA system;
(4) A point shape file with locations of hydrological observation posts that include calculated values of ecological flow;
(5) A point shape file with water abstraction data according to the issued water use permits;
(6) A point shape file with wastewater discharge data according to the issued water use permits.

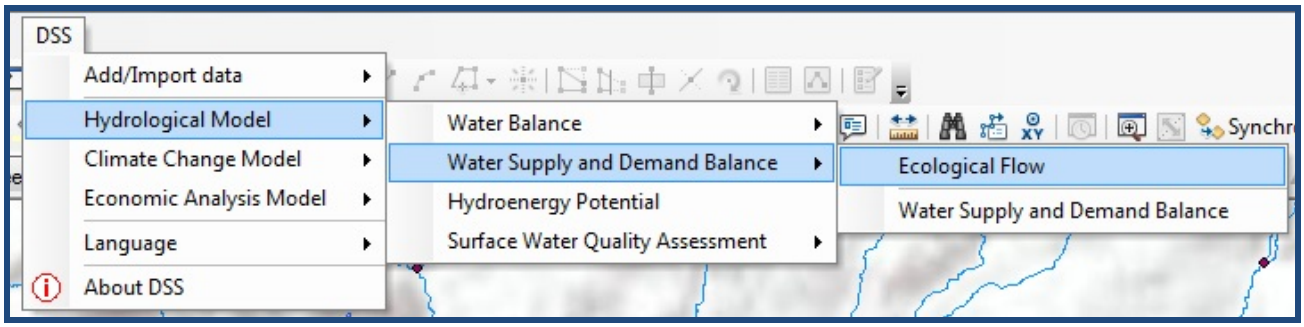
4.3.3. Running the component

The figure below presents the command menu of the Water Supply and Demand Balance component of the Hydrological Model:

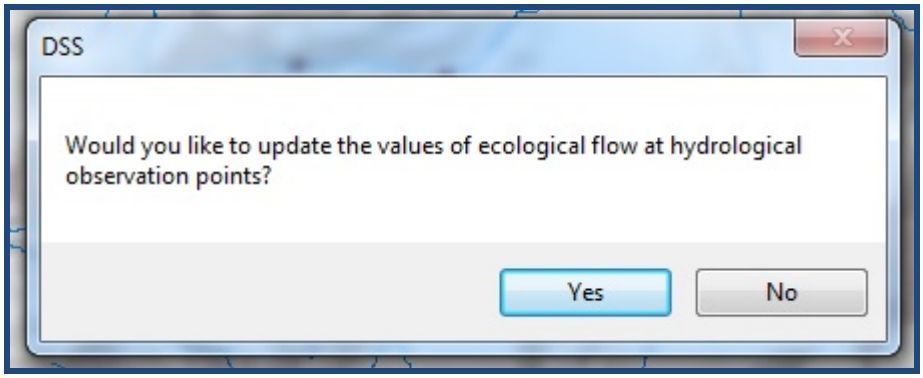


The component includes two main steps: (1) calculation of ecological flow in the rivers of a given river basin or basin management area; and (2) estimation of water supply and demand to demonstrate if there is a water resources surplus or deficit in a given area.

For calculation of ecological flow, the appropriate menu command should be activated.

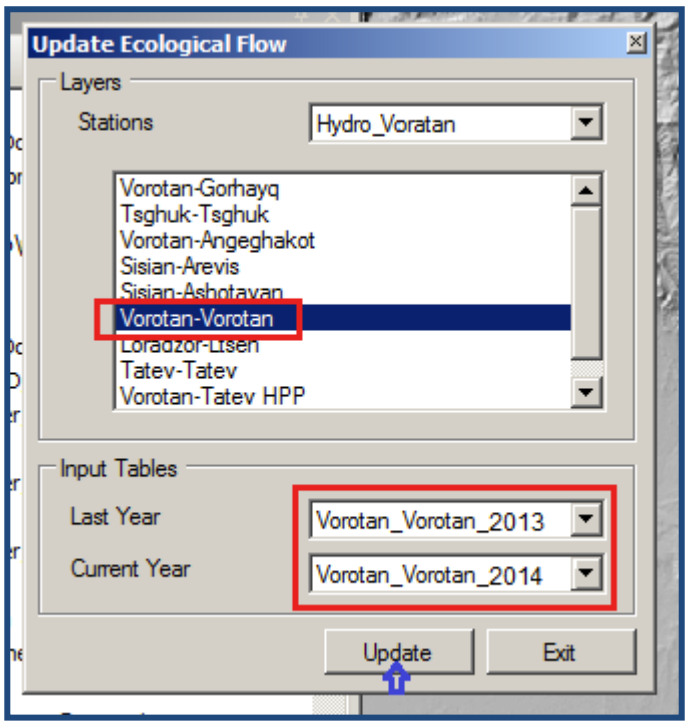


A message will appear that asks whether the values of ecological flow need updating.

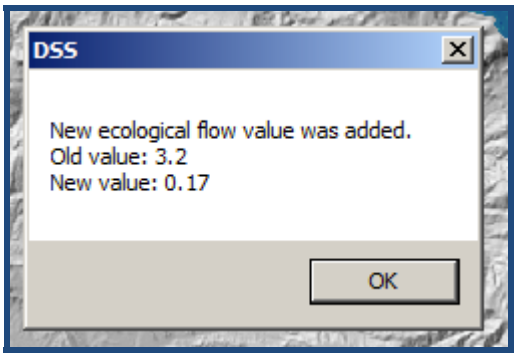


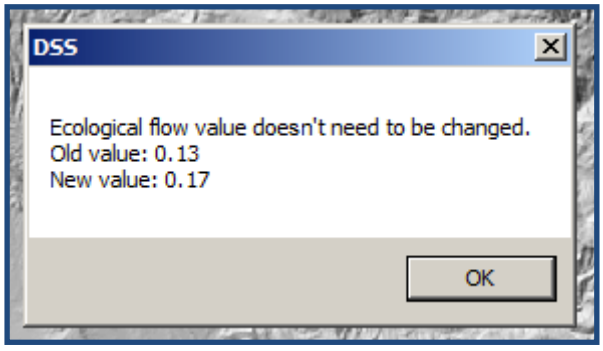
The “yes” answer to this question leads to the window titled “Update Ecological Flow”. Take the following steps to update the values of ecological flow for a given hydrological observation post:

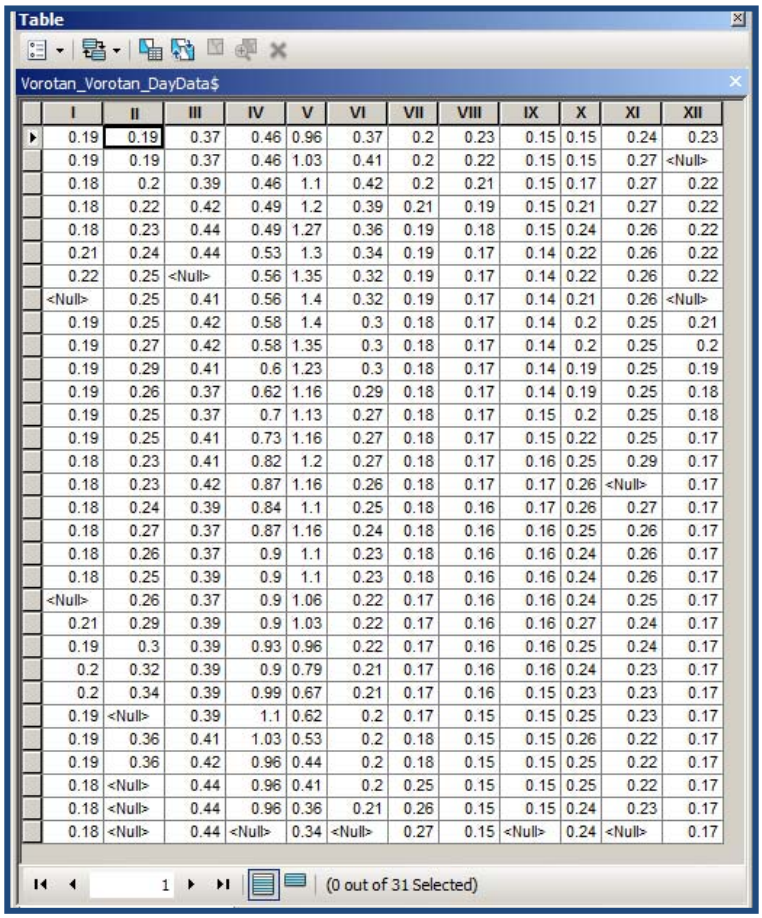
(1) Select a point layer of hydrological observation posts of a river basin in the “stations” field; The names of the points will appear in the list below.
(2) Select the hydrological observation posts where the value of ecological flow need to be updated;
(3) Upload two Ms Excel files with daily values of measured river flow – for the previous and current years. The algorithm will pick up the values of December month of the “previous” year and values of January and February months of the “current” year;
(4) Click the “Update” button.



The built-in algorithm will determine the value of the ecological flow for the specified "current" year at the specified hydrological observation post. As a result of calculations, the value of the ecological flow will be either updated or not. The appropriate messages will appear.



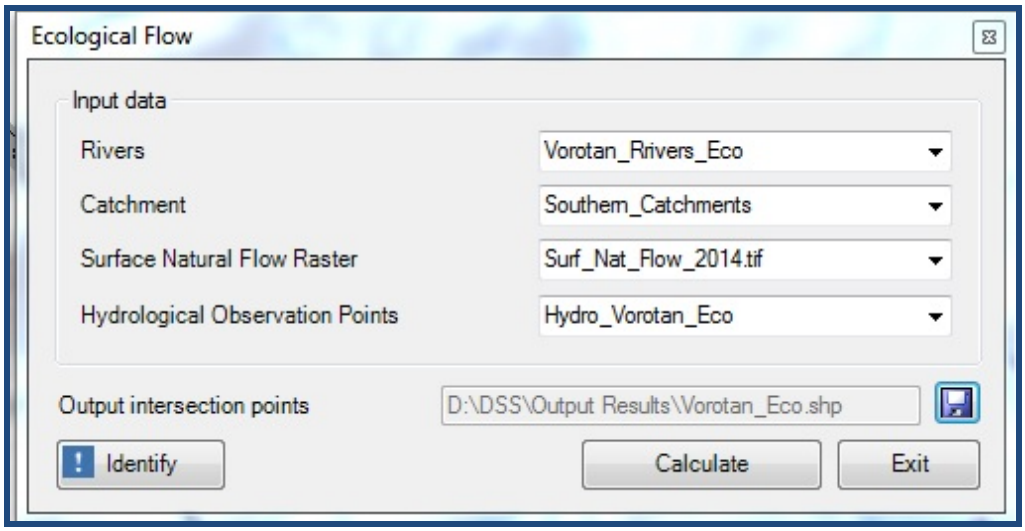




I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0.19	0.19	0.37	0.46	0.96	0.37	0.2	0.23	0.15	0.15	0.24	0.23
0.19	0.19	0.37	0.46	1.03	0.41	0.2	0.22	0.15	0.15	0.27	<Null>
0.18	0.2	0.39	0.46	1.1	0.42	0.2	0.21	0.15	0.17	0.27	0.22
0.18	0.22	0.42	0.49	1.2	0.39	0.21	0.19	0.15	0.21	0.27	0.22
0.18	0.23	0.44	0.49	1.27	0.36	0.19	0.18	0.15	0.24	0.26	0.22
0.21	0.24	0.44	0.53	1.3	0.34	0.19	0.17	0.14	0.22	0.26	0.22
0.22	0.25	<Null>	0.56	1.35	0.32	0.19	0.17	0.14	0.22	0.26	0.22
<Null>	0.25	0.41	0.56	1.4	0.32	0.19	0.17	0.14	0.21	0.26	<Null>
0.19	0.25	0.42	0.58	1.4	0.3	0.18	0.17	0.14	0.2	0.25	0.21
0.19	0.27	0.42	0.58	1.35	0.3	0.18	0.17	0.14	0.2	0.25	0.2
0.19	0.29	0.41	0.6	1.23	0.3	0.18	0.17	0.14	0.19	0.25	0.19
0.19	0.26	0.37	0.62	1.16	0.29	0.18	0.17	0.14	0.19	0.25	0.18
0.19	0.25	0.37	0.7	1.13	0.27	0.18	0.17	0.15	0.2	0.25	0.18
0.19	0.25	0.41	0.73	1.16	0.27	0.18	0.17	0.15	0.22	0.25	0.17
0.18	0.23	0.41	0.82	1.2	0.27	0.18	0.17	0.16	0.25	0.29	0.17
0.18	0.23	0.42	0.87	1.16	0.26	0.18	0.17	0.17	0.26	<Null>	0.17
0.18	0.24	0.39	0.84	1.1	0.25	0.18	0.16	0.17	0.26	0.27	0.17
0.18	0.27	0.37	0.87	1.16	0.24	0.18	0.16	0.16	0.25	0.26	0.17
0.18	0.26	0.37	0.9	1.1	0.23	0.18	0.16	0.16	0.24	0.26	0.17
0.18	0.25	0.39	0.9	1.1	0.23	0.18	0.16	0.16	0.24	0.26	0.17
<Null>	0.26	0.37	0.9	1.06	0.22	0.17	0.16	0.16	0.24	0.25	0.17
0.21	0.29	0.39	0.9	1.03	0.22	0.17	0.16	0.16	0.27	0.24	0.17
0.19	0.3	0.39	0.93	0.96	0.22	0.17	0.16	0.16	0.25	0.24	0.17
0.2	0.32	0.39	0.9	0.79	0.21	0.17	0.16	0.16	0.24	0.23	0.17
0.2	0.34	0.39	0.99	0.67	0.21	0.17	0.16	0.15	0.23	0.23	0.17
0.19	<Null>	0.39	1.1	0.62	0.2	0.17	0.15	0.15	0.25	0.23	0.17
0.19	0.36	0.41	1.03	0.53	0.2	0.18	0.15	0.15	0.26	0.22	0.17
0.19	0.36	0.42	0.96	0.44	0.2	0.18	0.15	0.15	0.25	0.22	0.17
0.18	<Null>	0.44	0.96	0.41	0.2	0.25	0.15	0.15	0.25	0.22	0.17
0.18	<Null>	0.44	0.96	0.36	0.21	0.26	0.15	0.15	0.24	0.23	0.17
0.18	<Null>	0.44	<Null>	0.34	<Null>	0.27	0.15	<Null>	0.24	<Null>	0.17

The Ms Excel spreadsheet will be transferred into the GIS layer with appropriate attribute table, where the values of the measured natural flow will be stored with fields representing the months within the year and records representing the days within the month. A sample format of the attribute table is presented below.

The “no” answer to the initial question of the Ecological Flow component leads to the data input window:

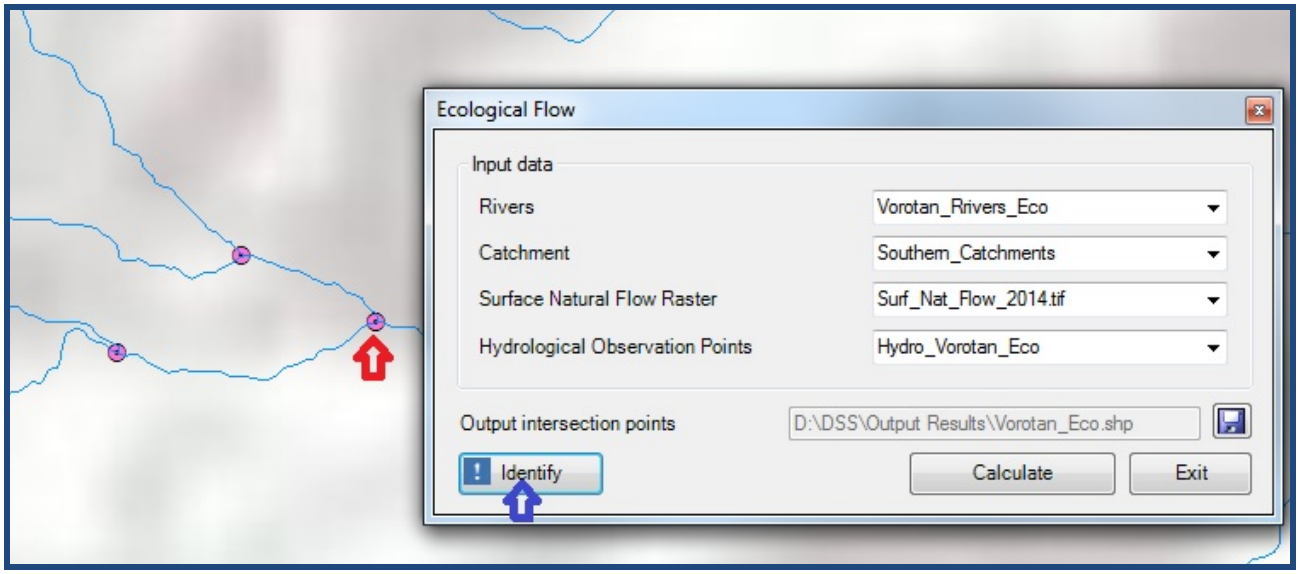


To calculate the ecological flow values at the junction points of the river network for the given year:

(1) Select the shape file with river network of the river basin of interest in the “Rivers” field;
(2) Select the shape file with catchment areas in the “Catchment” field;
(3) Select the output raster of the Water Balance component with the surface natural flow values of the year of interest in the “Surface Natural Flow Raster” field;
(4) Select the shape file with the calculated values of ecological flow at hydrological observation posts at the “Hydrological Observation Posts” field;
(5) Specify the location and the name of the output point shape file;
(6) Click the “Calculate” button.

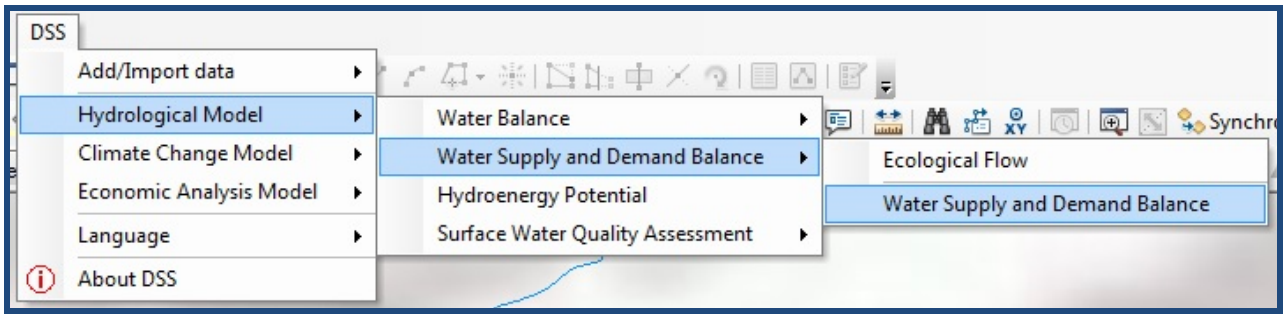
As a result of calculations the output point shape file will contain the values of ecological flow at the junctions of the rivers. To view the obtained values:

(1) Zoom the map to the river of interest;
(2) Click the “Identify” button at the lower left angle of the window;
(3) Click on the junction of the rivers at the map.

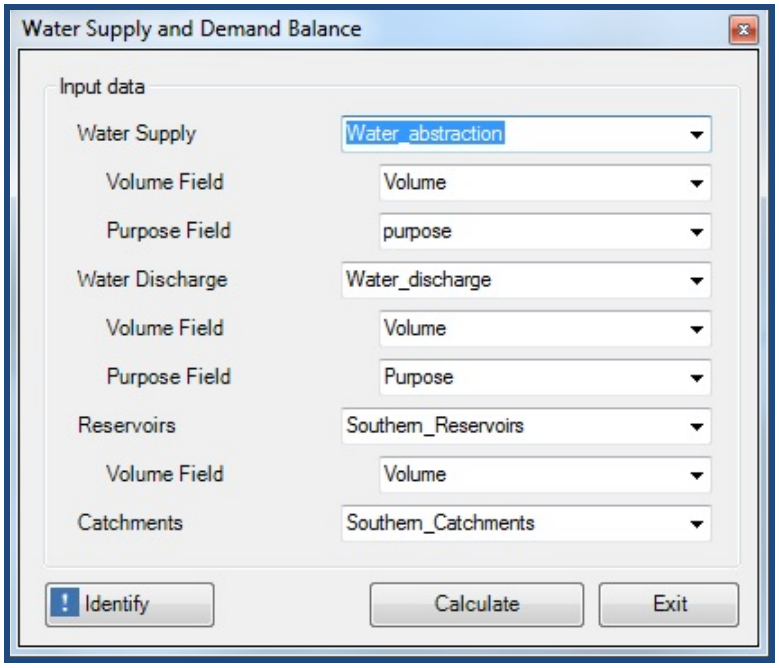


As a result, a report will appear on the screen which will show the value of ecological flow for a given river for a given year.

Calculation of ecological flow values for junction points of rivers for a given river basin is an intermediate result for obtaining water supply and demand balance. To do this, it is necessary to activate the appropriate menu command.



As a result, the following window will appear:



To calculate the ecological flow values at junction points of a river network for a given year:

(1) Select the shape file with water abstraction data in the “Water Supply” field. The “Volume” and “Purpose” fields will be selected automatically. If not, select them from the drop-down list;
(2) Select the shape file with wastewater discharge data in the “Water Discharge” field. The “Volume” and the “Purpose” fields will be selected automatically. If not, select them from the drop-down list;
(3) Select the shape file with reservoirs of a river basin in the “Reservoirs” field. The “Volume” field will be selected automatically. If not, select it from the drop-down list;
(4) Select the shape file with catchment areas in the “Catchment” field;
(5) Click the “Calculate” button.

As a result, the map of the river basin(s) will demonstrate the catchments with water surplus and deficit.

To view more detailed information on the water supply and water balance in the particular catchment area:

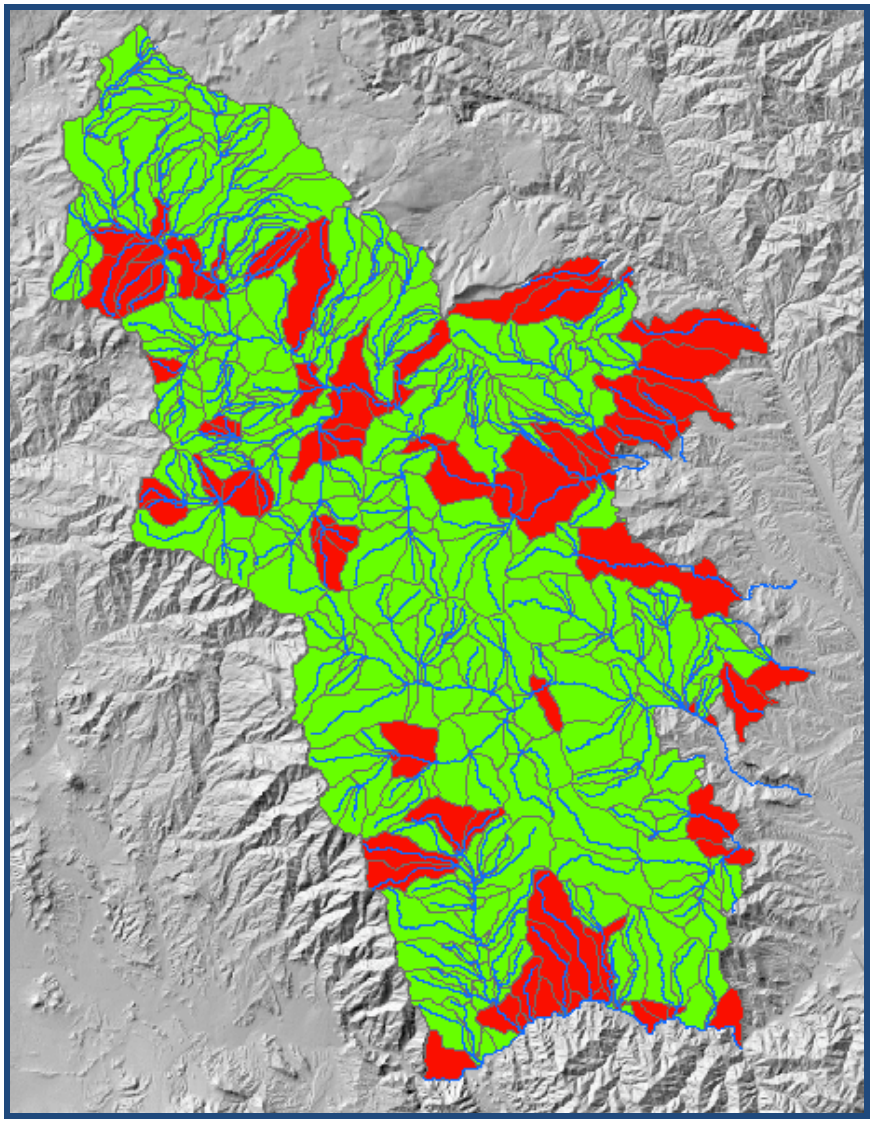
(1) Zoom the map to the catchment area of interest;
(2) Click the “Identify” button at the lower left angle of the window;
(3) Click inside the catchment area of interest.

A report will appear on the screen.
Next section of the user manual will demonstrate the outputs of this component.

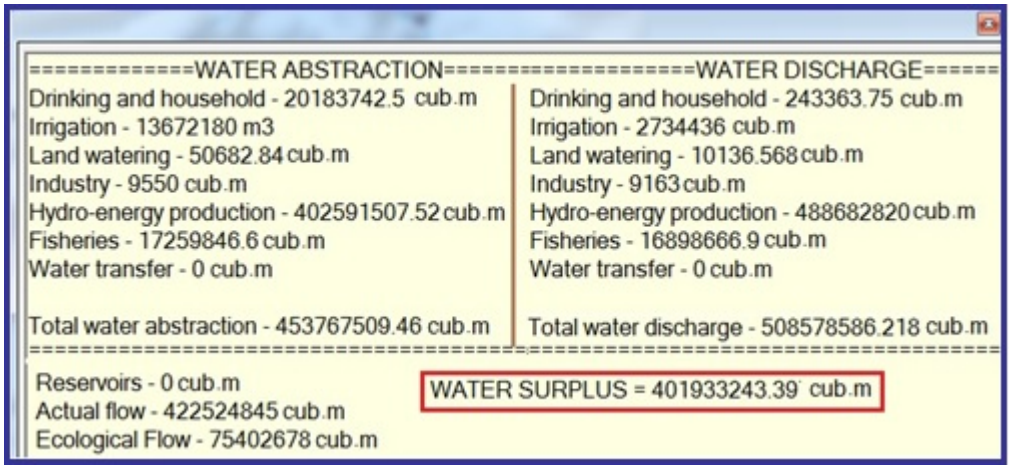
4.3.4. Main outputs

The two main outputs of the Water Supply and Demand Balance component are presented on the example of the Southern BMA of Armenia.

(1) A general map of river basin(s) with two-coloured catchment areas, where the red colour represents the catchments with water deficit and green colours with water surplus for a given year.



(2) A report on water supply and demand balance in the particular catchment area.



4.4. Hydroenergy Potential Estimation Component

4.4.1. Objective and methodology

Calculation of hydroenergy potential of rivers provides the opportunity to assess the potential for hydropower generation, which is important for proper assessment and use of hydropower generation resources of rivers.

Water discharge and water fall are determinant basic data used for the estimation of hydroenergy potential of river sections. The equation is as follows:

$$N = 7.5 * Qu * \Delta H,$$

where:
N is capacity expressed in kW;
Qu is average multi-year natural water discharge at the river mouth;
ΔH is river fall at a given section, that is the difference between the lower and upper altitudes of the section.

4.4.2. Input data

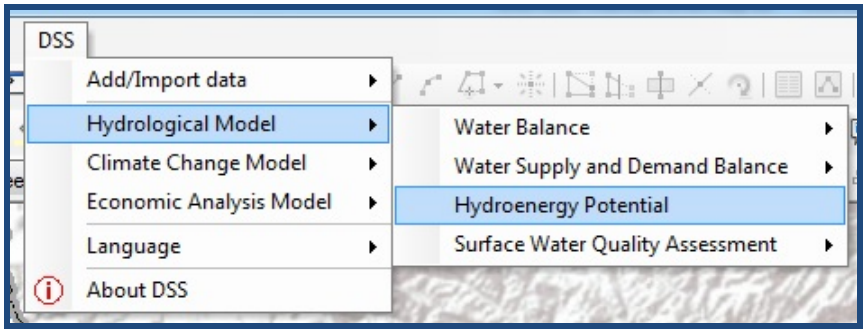
The following datasets are required as input data to run the Hydroenergy Potential Estimation component:

Spatial:

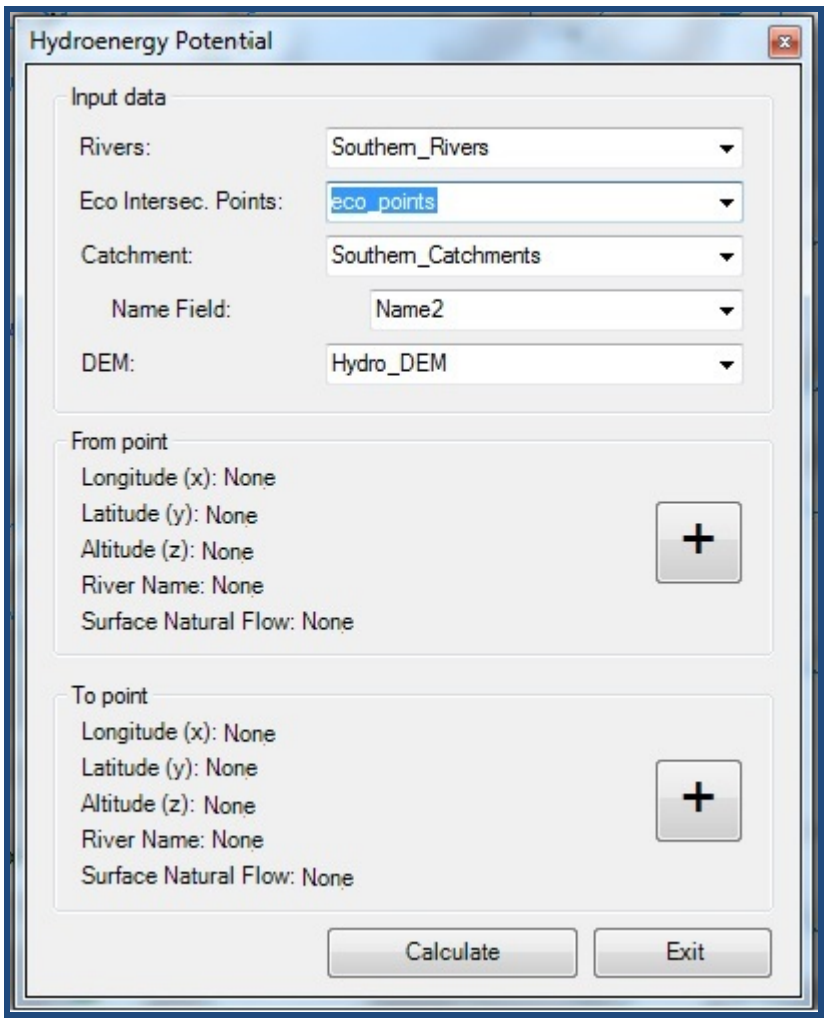
(1) Rivers longer than 5 km of a river basin(s) or basin management area(s) of interest, coded using the ERICA system;
(2) Point shape file with interception points of rivers, obtained as a result of running the Ecological Flow calculation sub-component of the Water Supply and Demand Balance component;
(3) Catchment areas of rivers longer than 5 km, coded using the ERICA system;
(4) Hydrological DEM of the river basin of interest.

4.4.3. Running the component

To run the Hydroenergy Potential Estimation component, the appropriate command in the "Hydrological Model" menu should be clicked.

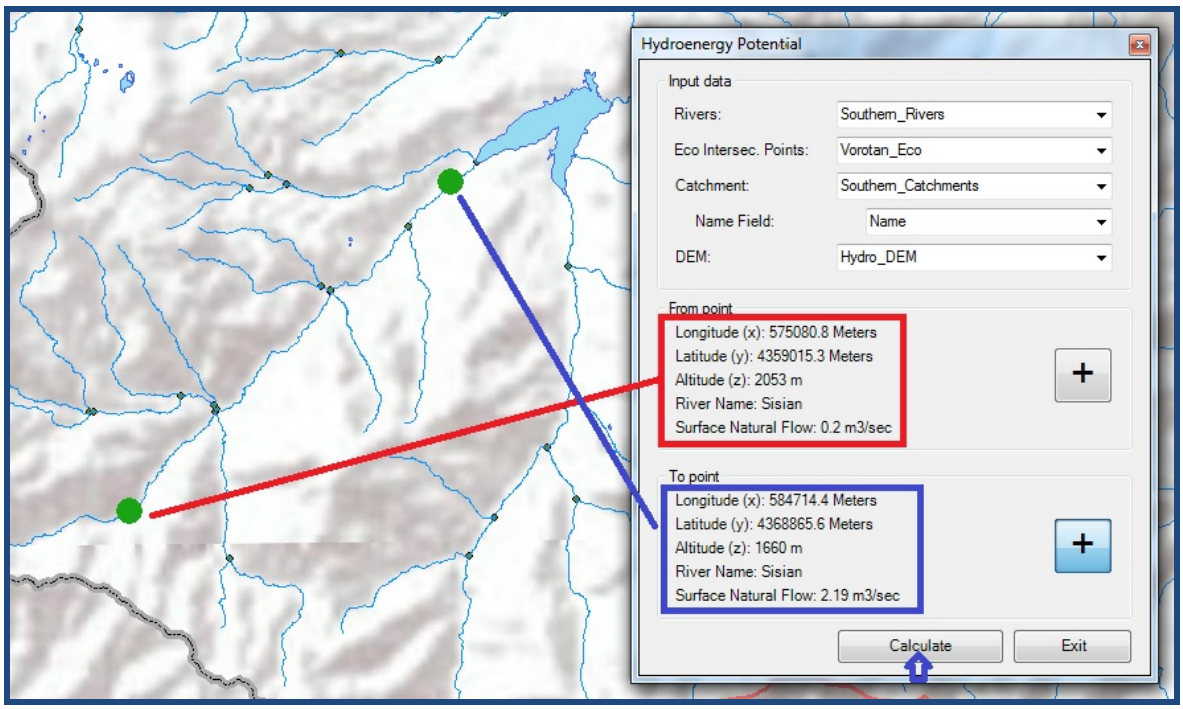


The following window will appear:



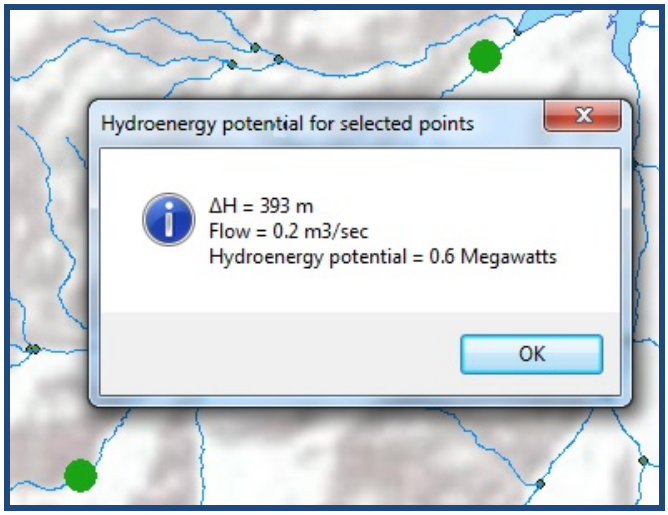
Take the following steps to calculate the hydroenergy potential of a river section of interest:

(1) Select the river network layer in the “Rivers” field;
(2) Select the shape file with river intersection points obtained as a result of running the Ecological Flow sub-component of the Water Supply and Demand Balance component in the “Eco Intersect. Points” field;
(3) Select the shape file with catchment areas coded by the ERICA system in the “Catchment” field;
(4) The name field will be automatically filled in. if not, select the name field in drop-down box;
(5) Select the Hydro DEM in the “DEM” field;
(6) Zoom in the map to the river section of interest;
(7) Click the “**+**” button under the “From point” section;
(8) Double click to intersect the river section on the map to select the upper point for calculation of the hydroenergy potential;
(9) The point will be selected on the map, the coordinates and altitude of the point will appear in the window in the “From point” section;
(10) Click the “**+**” button under the “To point” section;
(11) Double click to intersect the river section on the map to select the lower point for calculation of the hydroenergy potential;
(12) The point will be selected on the map, the coordinates and altitude of the point will appear in the window in the “To point” section;



(13) Click the "Calculate" button.

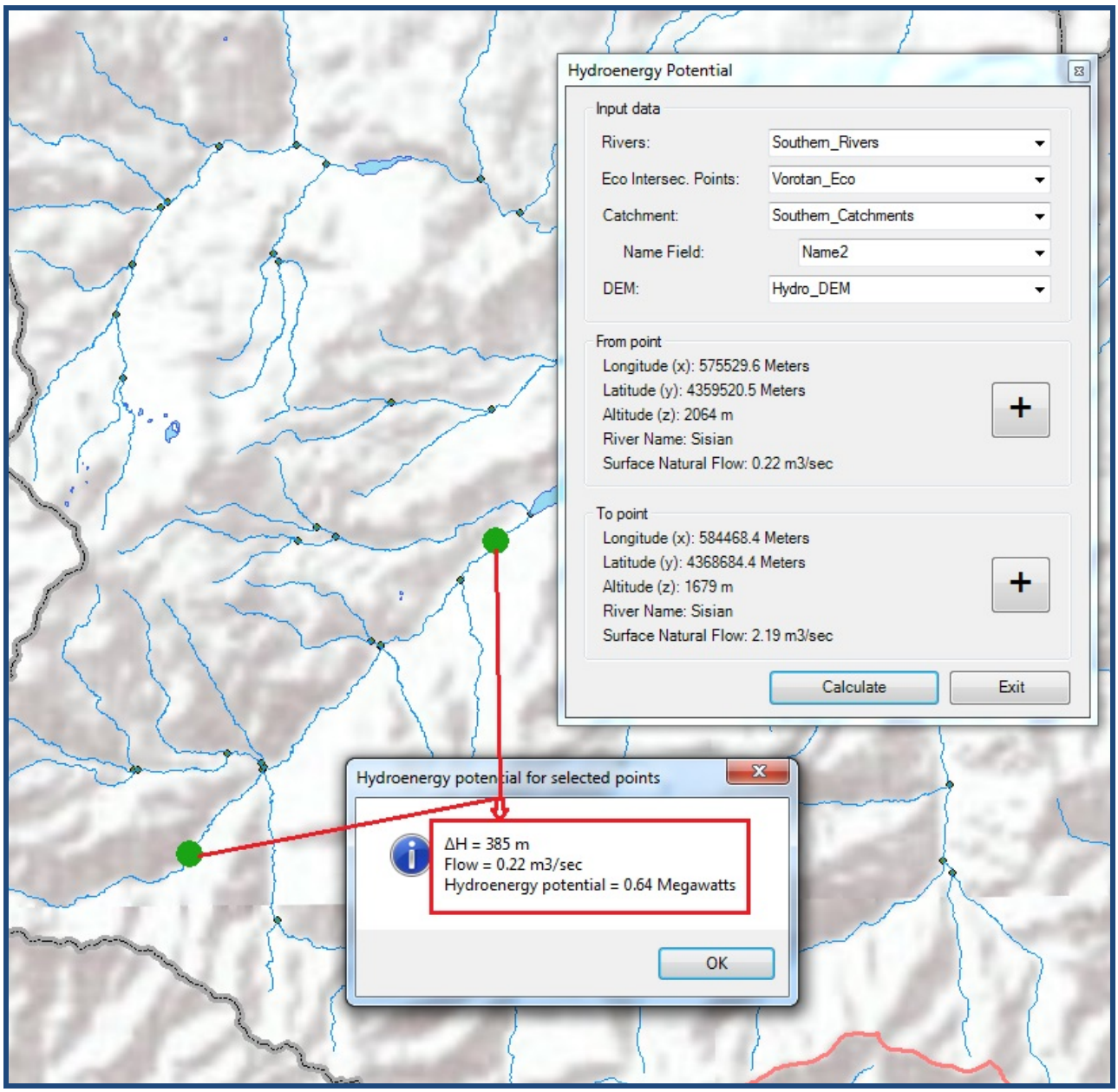
As a result of calculations, a brief report will appear on the screen presenting the difference in altitudes, the calculated surface natural flow in the given section and the estimated hydroenergy potential of the given section of the river.



NOTE: the component will not work if (1) the Ecological Flow estimation sub-component has not been run for the given river basin in advance, and (2) the starting and ending points have been selected on different river sections.

4.4.4. Main outputs

Sample output of the component is presented in the figure below as a report on estimated hydroenergy potential between two selected points in the Vorotan River Basin of the Southern BMA of Armenia.



4.5. Surface Water Quality Assessment Component

4.5.1. Objective and methodology

The objective of the Surface Water Quality Component is to reveal ecological status and annual changes in water quality of rivers in Armenia, based on long-term data of hydro-chemical monitoring.

The assessment of the surface water quality is carried out in accordance with surface water quality norms, established by the Resolution #75 (2011) of the Government of Armenia. According to the methodology defined by the resolution, water quality of a river is classified into high (I), good (II), moderate (III), poor (IV) or bad (V) classes. The water quality norms identify the threshold values of the mentioned classes for each hydro-chemical parameter. The list of hydro-chemical parameters in the assessment of water quality is optional and depends on the availability of data.

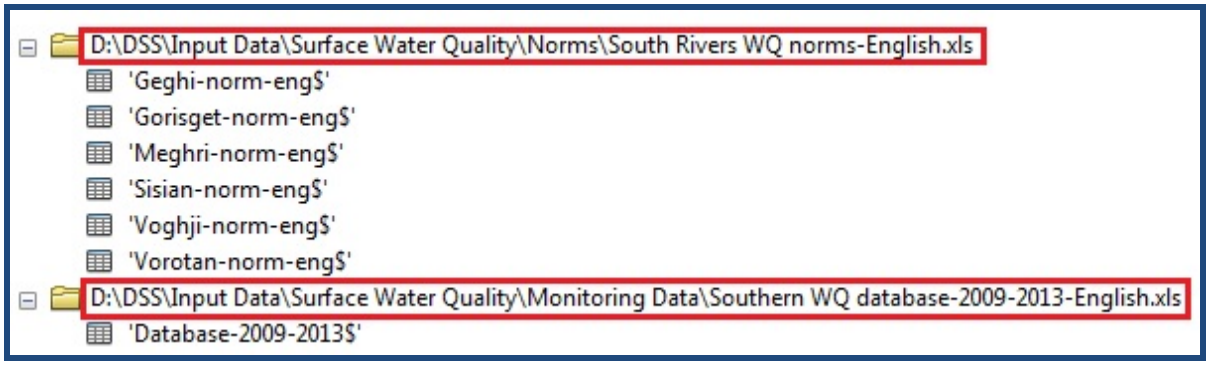
As a result of the assessment, the water quality class for each sampling point is identified based on the worst class of all the hydro-chemical parameters sampled and analyzed.

4.5.2. Input data

The following datasets are required as input data to run the Surface Water Quality component of the Hydrological Model:

Tabular:

(1) Surface water quality norms in the form of Ms Excel spreadsheets, indicating the threshold values for 1-5 classes for each hydro-chemical parameter.
(2) Surface water quality monitoring data on hydro-chemical parameters in the form of Ms Excel spreadsheet, where the ID number of the sampling point and the date of sampling are required to be filled in. The date format should have the "mm.dd.yyyy" format.

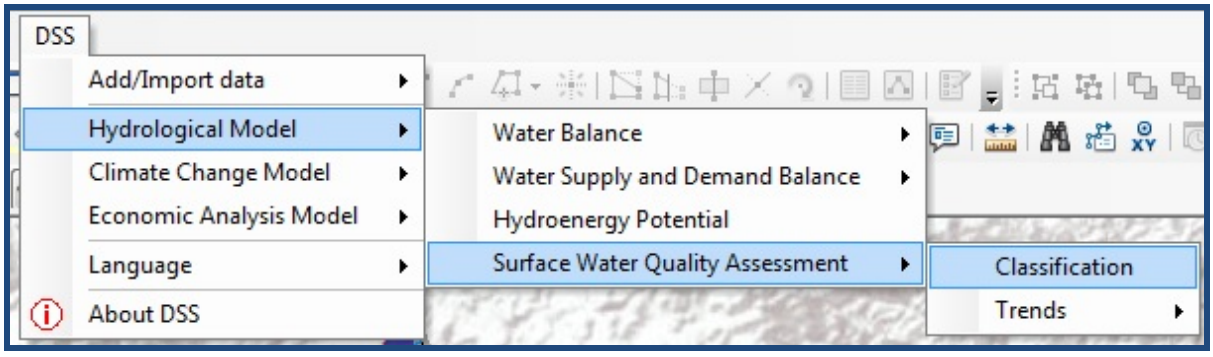


Spatial:

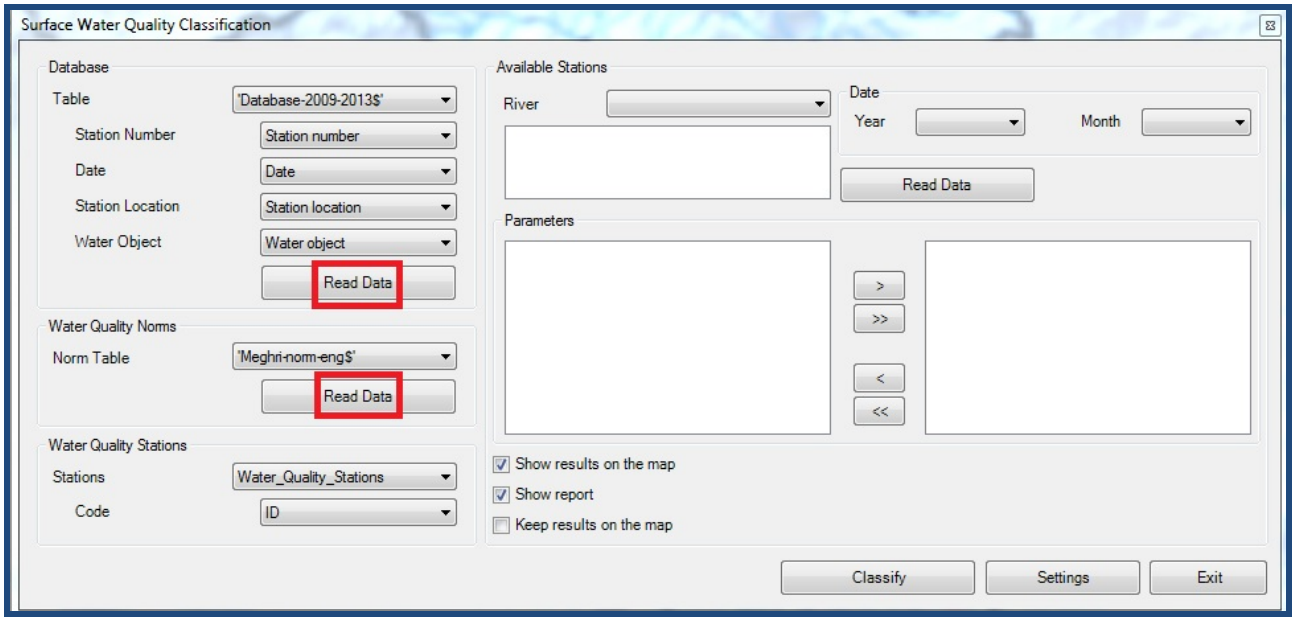
(3) Boundaries of a river basin(s) or basin management area(s) of interest;
(4) Rivers longer than 5 km of a river basin(s) or basin management area(s) of interest, coded using the ERICA system;
(5) Catchment areas of rivers longer than 5 km, coded using the ERICA system;
(6) Point shape files with locations of surface water quality sampling points located within a river basin of interest.

4.5.3. Running the component

To run the Surface quality assessment component, first click the "Classification" command line in the appropriate menu item.



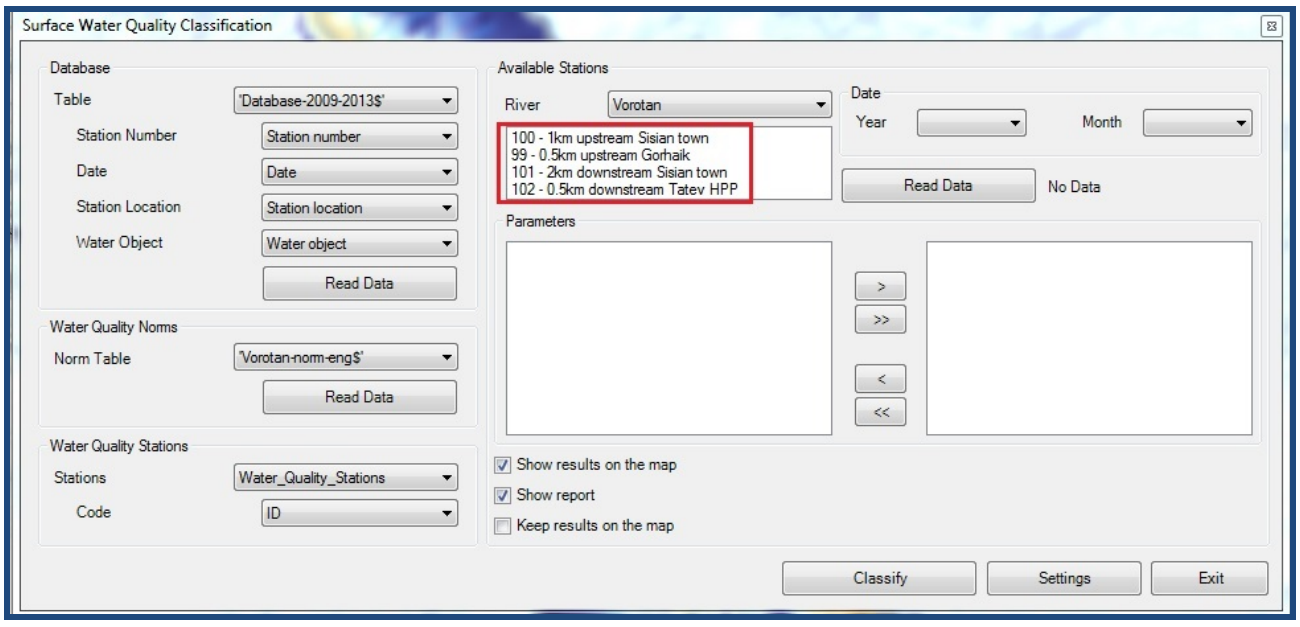
The following window will appear:



Take the following steps need to be taken to perform the surface water quality classification:

(1) Select the Ms Excel file with surface water quality monitoring data in the “Table” field. The “Station number”, “Date”, “Station location” and “Water object” fields will be filled in automatically. If not, select the appropriate field names in the drop-down lists;
(2) Click the “Read Data” button;
(3) Select the Ms Excel file with water quality norms in the “Norm Table” field;
(4) Click the “Read Data” button;
(5) Select the shape file with water quality sampling points in the “Stations” field. The “Code” field will be filled in automatically. If not, select the appropriate field name in the drop-down list;
(6) Select the river name from the drop-down list under the Available Stations” section.

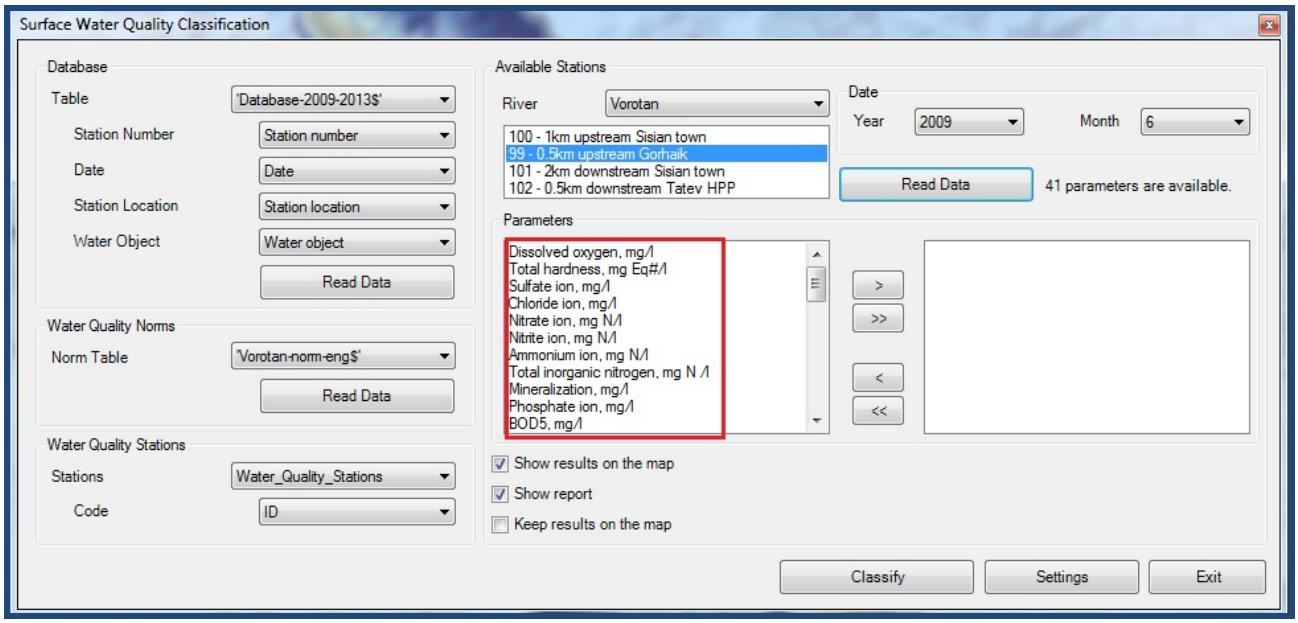
As a result, the water quality sampling points located in the given river basin will appear:



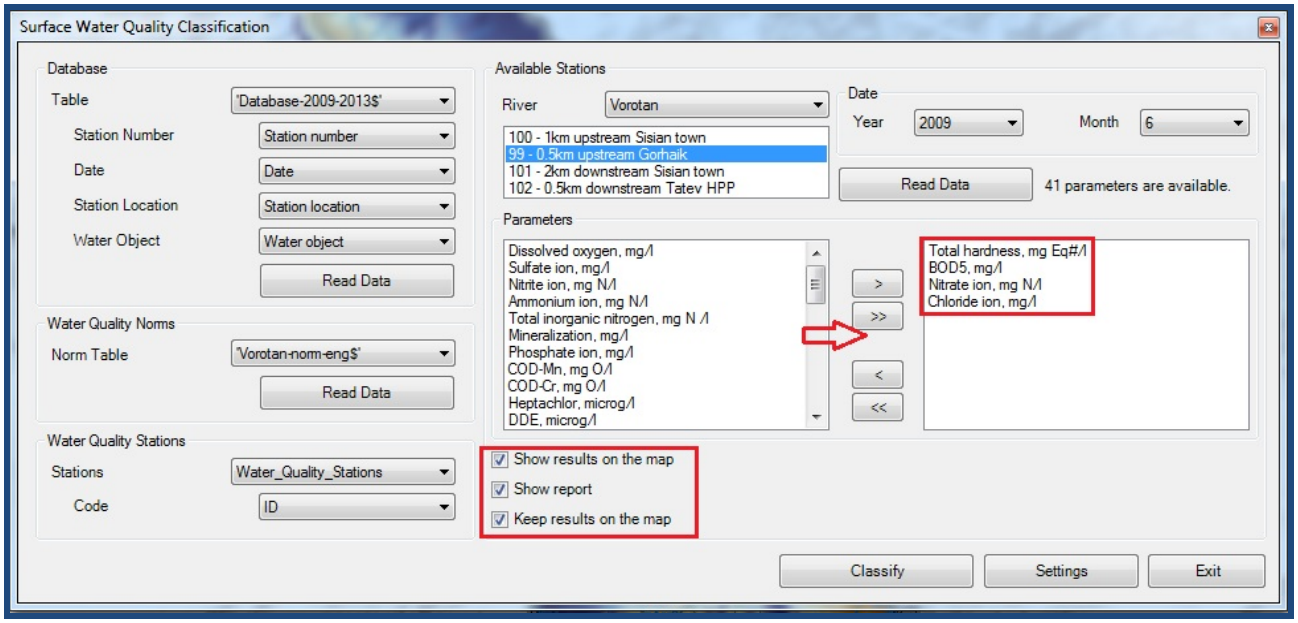
(7) Choose the water quality sampling point of interest from the list;
(8) Specify the year and month for which the classification is to be performed;

(9) Click the “Read Data” button.

As a result, the list of chemical parameters will appear that corresponds to the data available from the selected water quality sampling point in the selected month or year:



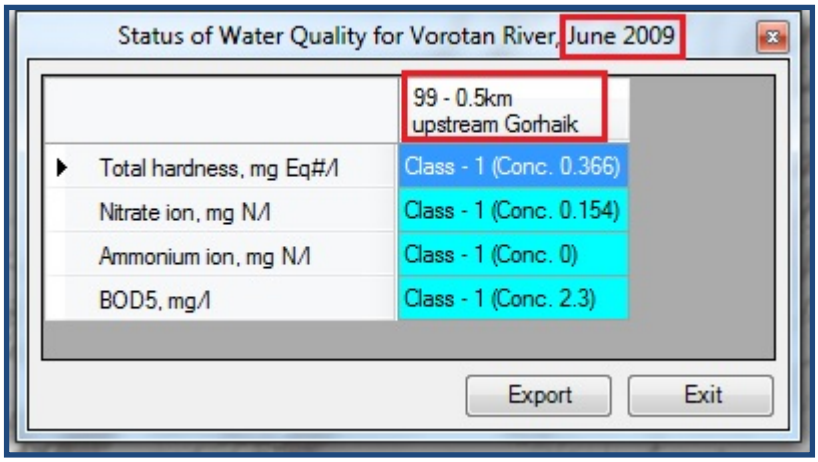
(10) Select one, several or all the chemical parameters from the list and move them to the right;
(11) Make sure that the “Show results on the map” and “Show report” options are selected;
(12) If there is a need to complement the classification with new parameters of the same year from the same sampling station in the future, make sure that the “Keep results on the map” option is checked;



(13) Click the “Classify” button.

As a result, both a report and a map with classified water quality sampling points will appear on the screen.

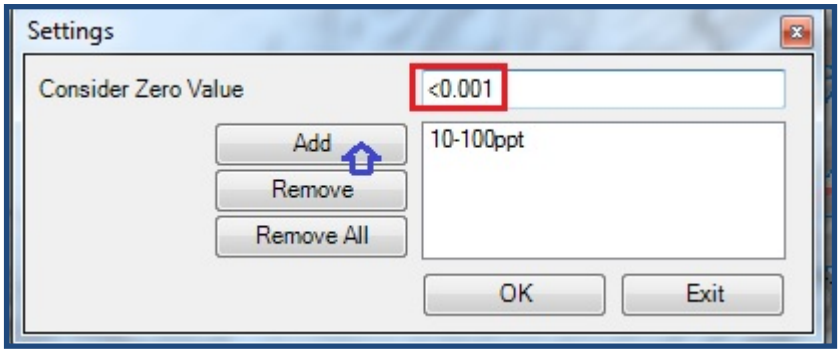
The report will list the selected parameters and show their values for the specified year and month. The colour will indicate the class: blue for “high”; green for “good”; yellow for “moderate”; orange for “poor” and red for “bad”.



There is a possibility to export the report into Ms Excel spreadsheet by clicking the “Export” button.

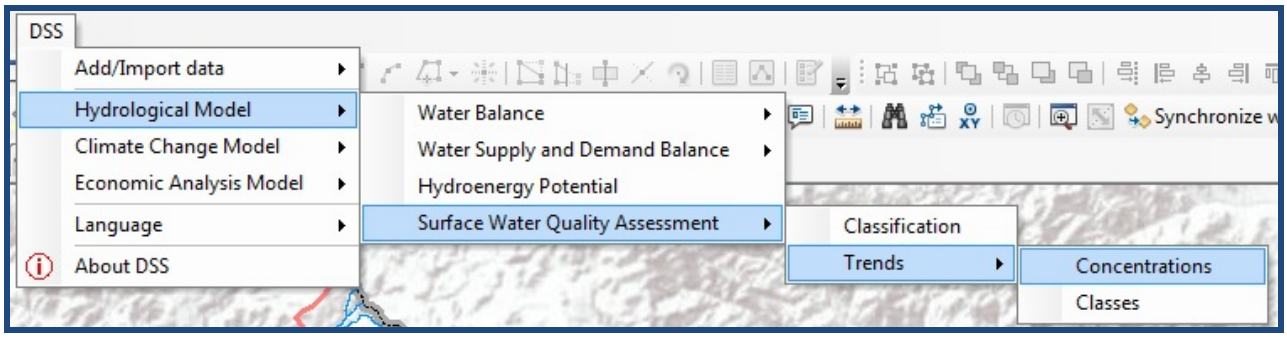
If more than 1 water quality sampling points were chosen, the report will demonstrate the comparative classification of the selected parameters. See the screenshot below for the comparative classification of surface water quality by 16 chemical parameters for Vorotan River at all 4 sampling points for the year 2012.

The “Settings” button of the “Surface Water Quality Classification” window allows specifying the value that should be considered “0” during calculations. This refers mainly to the extremely small values of the chemical parameters, such as “10-100ppt”, “1-10ppt”, “0.1-1ppt”, or values that are smaller than 0.001. All such values should be added only once in the “Settings” window and will be saved for future calculations within the component.

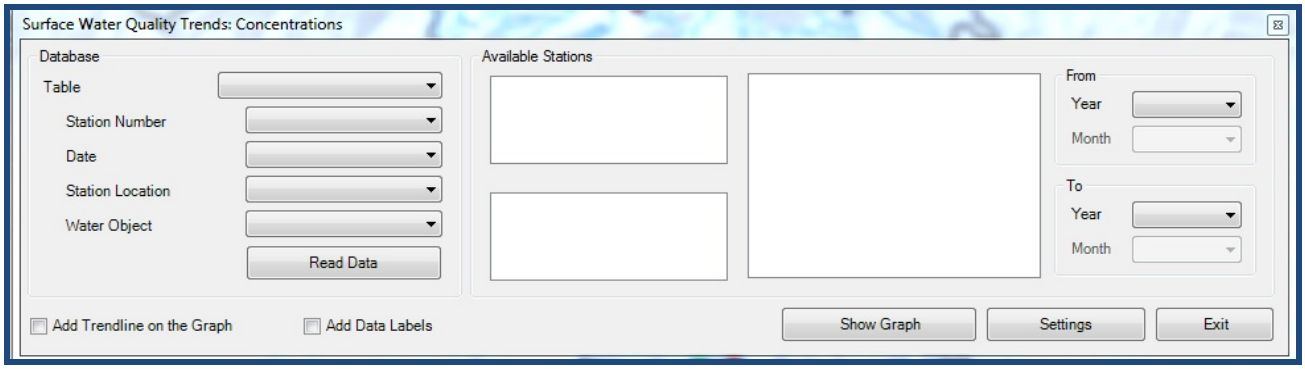


The output map with surface water classification is shown in the Section 4.5.4 of this User Manual.

The next step in the surface water quality assessment is the analysis of the trends in changes in the quality of water. Firstly, to assess the trends in concentration changes, activate the appropriate command item.

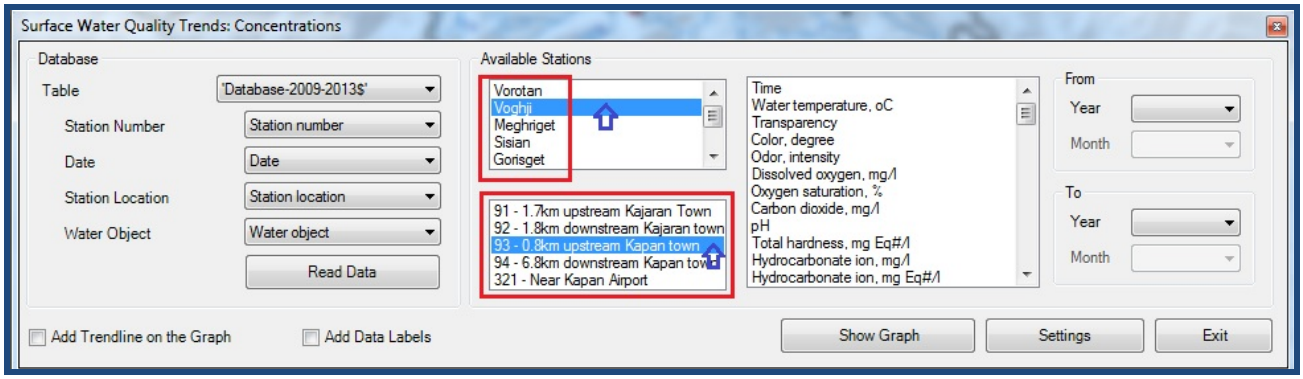


The following window will appear:

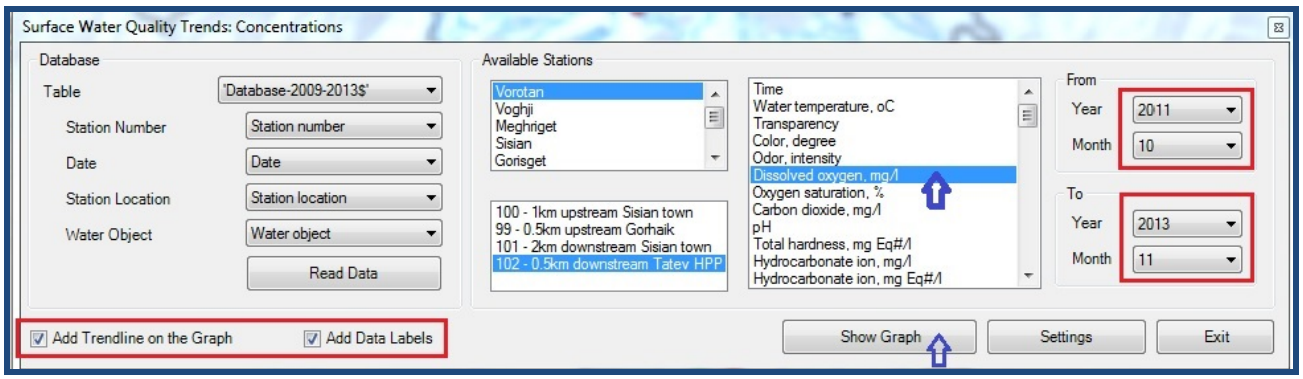


Take the following steps to perform trend assessment:

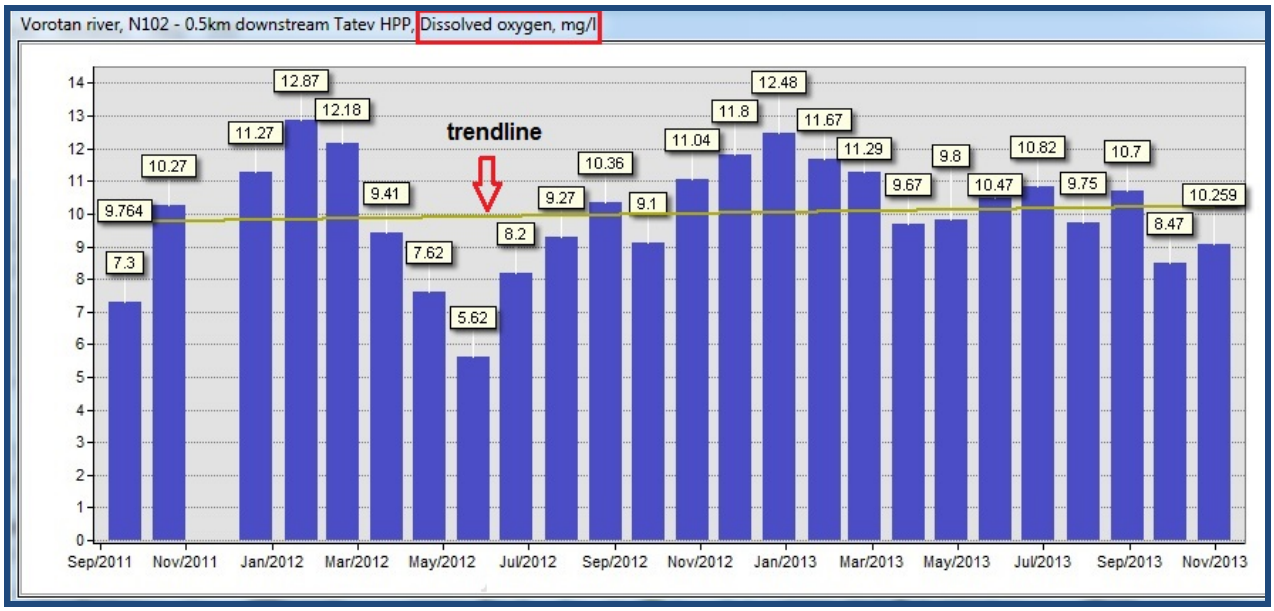
(1) Select the Ms Excel file with surface water quality monitoring data in the “Table” field. The “Station The “Station number”, “Date”, “Station location” and “Water object” fields will be filled in automatically. If not, select the appropriate field names in the drop-down lists
(2) Click the “Read Data” button. A list of rivers will appear under the “Available Stations” section
(3) Select the river of interest within the list. A list of sampling stations will appear beneath.
(4) Select the sampling station of interest. A list of chemical parameters will appear in the right column



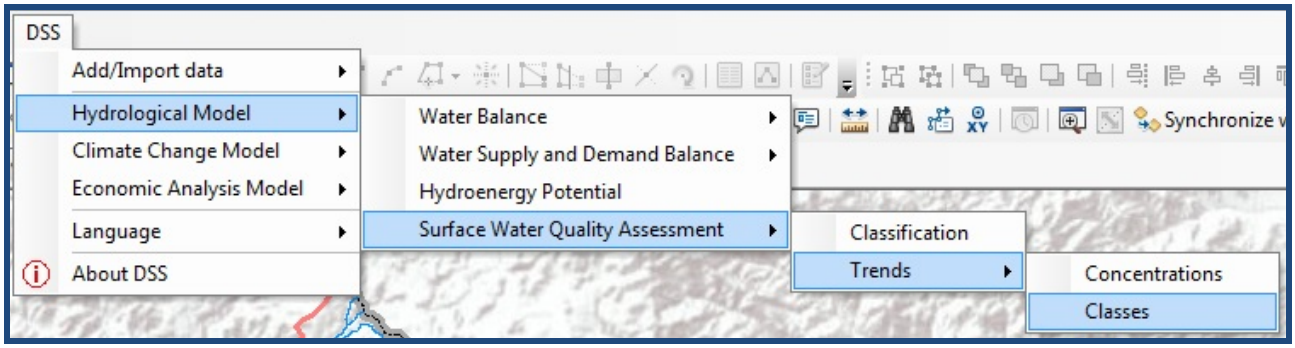
(5) Select one chemical parameter from the list
(6) Specify the starting and end year and month for trend analysis
(7) If you need a trendline be present on the resulting graph, check the “Add Trend line on the Graph” box
(8) If you need to see labels on the graph, check the “Add Data Labels” box
(9) Click the “Show Graph” button



As a result the graph showing the trends of the change of the selected parameter will appear on the screen.



There is an opportunity to view the trend in changing of the water quality class in the given sampling station. To perform such analysis the appropriate command item in the menu should be clicked.

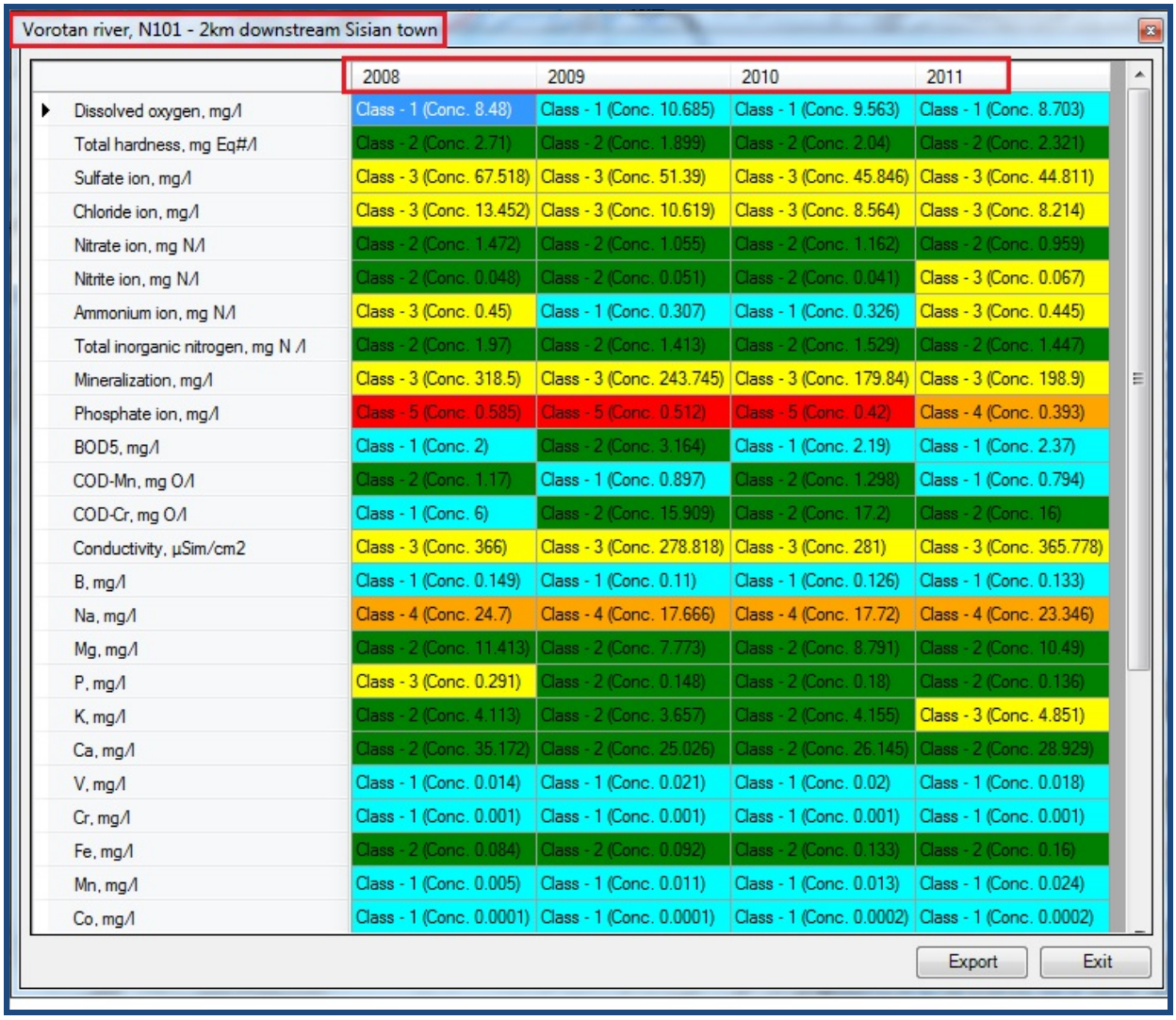


The same data input window will appear as during the surface water quality classification step. The steps for filling in the window fields are identical and include:

(1) Select the Ms Excel file with surface water quality monitoring data in the “Table” field. The “Station number”, “Date”, “Station location” and “Water object” fields will be filled in automatically. If not, select the appropriate field names in the drop-down lists
(2) Click the “Read Data” button
(3) Select the Ms Excel file with water quality norms in the “Norm Table” field
(4) Click the “Read Data” button

(5) Select the shape file with water quality sampling points in the “Stations” field. The “Code” field will be filled in automatically. If not, select the appropriate field name in the drop-down list.
(6) Select the river name from the drop-down list under the Available Stations” section. As a result, the water quality sampling points located in the given river basin will appear
(7) Choose the water quality sampling point of interest from the list
(8) Specify the starting and end year and month for trend analysis
(9) Click the “Read Data” button. As a result, the list of chemical parameters will appear that corresponds to the data available from the selected water quality sampling point in the selected month or year
(10) Select one, several or all the chemical parameters from the list and move them to the right
(11) Make sure that the “Show results on the map” and “Show report” options are selected
(12) If there is a need to complement the classification with new parameters of the same year from the same sampling station in the future, make sure that the “Keep results on the map” option is checked.
(13) Click the “Classify” button

The report will list the selected parameters and show their values for the selected period (in years). The color will indicate the class: blue for “high”; green for “good”; yellow for “moderate”; orange for “poor” and red for “bad”. The screenshot below demonstrates the trends in classification of surface water quality by 25 chemical parameters in one sampling station at Vorotan River for the period of 2008-2012.

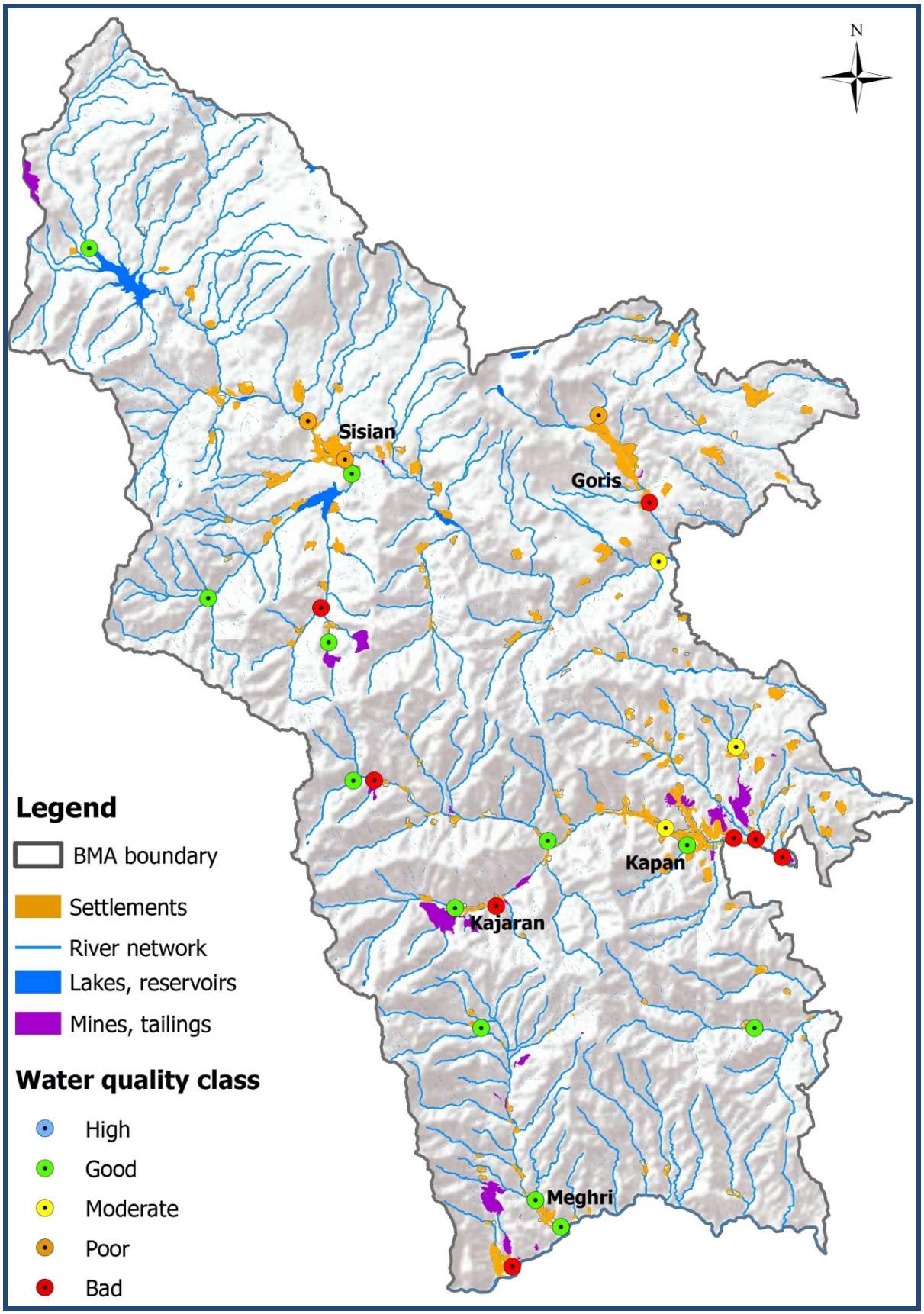


	2008	2009	2010	2011
Dissolved oxygen, mg/l	Class - 1 (Conc. 8.48)	Class - 1 (Conc. 10.685)	Class - 1 (Conc. 9.563)	Class - 1 (Conc. 8.703)
Total hardness, mg Eq#/l	Class - 2 (Conc. 2.71)	Class - 2 (Conc. 1.899)	Class - 2 (Conc. 2.04)	Class - 2 (Conc. 2.321)
Sulfate ion, mg/l	Class - 3 (Conc. 67.518)	Class - 3 (Conc. 51.39)	Class - 3 (Conc. 45.846)	Class - 3 (Conc. 44.811)
Chloride ion, mg/l	Class - 3 (Conc. 13.452)	Class - 3 (Conc. 10.619)	Class - 3 (Conc. 8.564)	Class - 3 (Conc. 8.214)
Nitrate ion, mg N/l	Class - 2 (Conc. 1.472)	Class - 2 (Conc. 1.055)	Class - 2 (Conc. 1.162)	Class - 2 (Conc. 0.959)
Nitrite ion, mg N/l	Class - 2 (Conc. 0.048)	Class - 2 (Conc. 0.051)	Class - 2 (Conc. 0.041)	Class - 3 (Conc. 0.067)
Ammonium ion, mg N/l	Class - 3 (Conc. 0.45)	Class - 1 (Conc. 0.307)	Class - 1 (Conc. 0.326)	Class - 3 (Conc. 0.445)
Total inorganic nitrogen, mg N /l	Class - 2 (Conc. 1.97)	Class - 2 (Conc. 1.413)	Class - 2 (Conc. 1.529)	Class - 2 (Conc. 1.447)
Mineralization, mg/l	Class - 3 (Conc. 318.5)	Class - 3 (Conc. 243.745)	Class - 3 (Conc. 179.84)	Class - 3 (Conc. 198.9)
Phosphate ion, mg/l	Class - 5 (Conc. 0.585)	Class - 5 (Conc. 0.512)	Class - 5 (Conc. 0.42)	Class - 4 (Conc. 0.393)
BOD5, mg/l	Class - 1 (Conc. 2)	Class - 2 (Conc. 3.164)	Class - 1 (Conc. 2.19)	Class - 1 (Conc. 2.37)
COD-Mn, mg O/l	Class - 2 (Conc. 1.17)	Class - 1 (Conc. 0.897)	Class - 2 (Conc. 1.298)	Class - 1 (Conc. 0.794)
COD-Cr, mg O/l	Class - 1 (Conc. 6)	Class - 2 (Conc. 15.909)	Class - 2 (Conc. 17.2)	Class - 2 (Conc. 16)
Conductivity, µSim/cm2	Class - 3 (Conc. 366)	Class - 3 (Conc. 278.818)	Class - 3 (Conc. 281)	Class - 3 (Conc. 365.778)
B, mg/l	Class - 1 (Conc. 0.149)	Class - 1 (Conc. 0.11)	Class - 1 (Conc. 0.126)	Class - 1 (Conc. 0.133)
Na, mg/l	Class - 4 (Conc. 24.7)	Class - 4 (Conc. 17.666)	Class - 4 (Conc. 17.72)	Class - 4 (Conc. 23.346)
Mg, mg/l	Class - 2 (Conc. 11.413)	Class - 2 (Conc. 7.773)	Class - 2 (Conc. 8.791)	Class - 2 (Conc. 10.49)
P, mg/l	Class - 3 (Conc. 0.291)	Class - 2 (Conc. 0.148)	Class - 2 (Conc. 0.18)	Class - 2 (Conc. 0.136)
K, mg/l	Class - 2 (Conc. 4.113)	Class - 2 (Conc. 3.657)	Class - 2 (Conc. 4.155)	Class - 3 (Conc. 4.851)
Ca, mg/l	Class - 2 (Conc. 35.172)	Class - 2 (Conc. 25.026)	Class - 2 (Conc. 26.145)	Class - 2 (Conc. 28.929)
V, mg/l	Class - 1 (Conc. 0.014)	Class - 1 (Conc. 0.021)	Class - 1 (Conc. 0.02)	Class - 1 (Conc. 0.018)
Cr, mg/l	Class - 1 (Conc. 0.001)	Class - 1 (Conc. 0.001)	Class - 1 (Conc. 0.001)	Class - 1 (Conc. 0.001)
Fe, mg/l	Class - 2 (Conc. 0.084)	Class - 2 (Conc. 0.092)	Class - 2 (Conc. 0.133)	Class - 2 (Conc. 0.16)
Mn, mg/l	Class - 1 (Conc. 0.005)	Class - 1 (Conc. 0.011)	Class - 1 (Conc. 0.013)	Class - 1 (Conc. 0.024)
Co, mg/l	Class - 1 (Conc. 0.0001)	Class - 1 (Conc. 0.0001)	Class - 1 (Conc. 0.0002)	Class - 1 (Conc. 0.0002)

There is a possibility to export the report into Ms Excel spreadsheet by clicking the “Export” button.

4.5.4. Main outputs

The main output of the Surface water quality assessment component is presented on the example of the Southern BMA of Armenia. Below is the map of surface water classification of the Southern BMA.



5. CLIMATE CHANGE MODEL

5.1. Main objective

The Climate Change Model of the DSS aims at assisting the decision makers of GoA in bridging the gap between availability of water resources and future climate change predictions in order to make informed decisions on water use permit allocation. The Model provides an integrated platform for assessing the historic trends of climatic parameters in selected catchments, and based on the future trajectory of climate change, considering the emission scenarios defined by the Intergovernmental Panel on Climate Change (IPCC), it allows modelling the short- and long-term impacts of climate change on water resources.

The assessment of vulnerability of water resources to climate change is significant for decision makers to plan and implement respective adaptation measures to minimize the adverse impacts of climate change on water resources and build the resilience of affected ecosystems and communities to the projected changes in the climatic system. The projected natural flow under climate change scenarios further enables decision makers to carry out water supply and demand balance analysis and assess implications of changes in water availability on different sectors of economy based on development scenarios.

The Climate Change Model includes two components for:

(1) Assessment of historic trends of climatic parameters against the baseline period; and
(2) Simulation of the natural flow considering the projected scenarios of climate change.

The following sections will present the objectives, functionalities and outputs of each component in detail.

5.2. Historic Trends Component

5.2.1. Objective and methodology

The Historic Trends component of the Climate Change Model aims at assessing changing patterns in climatic and hydrological parameters over a certain period of time in the history.

In order to assess these changes, the model uses the 1961-1990 30-year period, as the latest baseline period established by the World Meteorological Organization (WMO) for use in the climate change research. The 30 year period of consecutive records of historic climate data is considered long enough to smooth out year to year variations, including wet, dry, warm and cool periods. According to the WMO and IPCC, this period represents the climate before significant changes attributable to human activity were detected.

Thus, the model calculates the annual average value of a given parameter for the period of 1961-1990, and assesses the deviation of values for the period of 1991-2011 against the baseline period average values.

5.2.2. Input data

The following datasets are required as input data to run the Historic trends component:

Tabular:

(1) Annual mean air temperature, precipitation, snowfall values obtained from the meteorological stations located within the river basin of interest;
(2) Annual mean surface natural flow, calculated based on the methodology summarized below:

Surface Natural flow is calculated using the following equation:

$$Y_{natural} = Y_{actual} + U_{irrigation} + U_{other} \pm T_{inter\text{-}basin\ transfer}$$

where,

$Y_{natural}$ – is the natural flow, to be calculated;

Y_{actual} – is the actual flow, based on the hydrological yearbooks;

$U_{irrigation}$ – is the water used for irrigation;

U_{other} – is the water used for domestic and industrial purposes, taking into account the return flow to the river basin;

$T_{transfer}$ – is the water transferred from one basin/catchment to another.

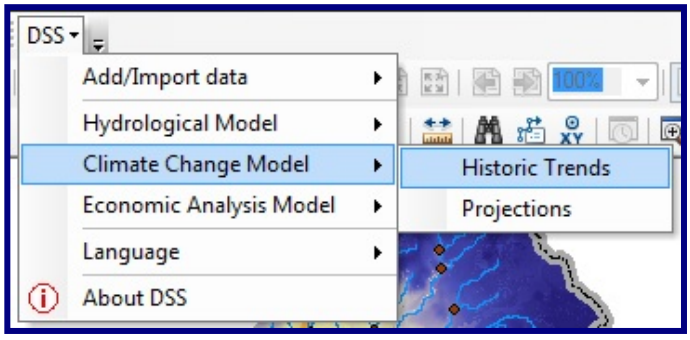
The data for water used for irrigation, domestic and industrial purposes, as well as those on inter-basin transfer for the period 1961-1995 are based on archived data of Armstatehydromet. Water use data for 2003-2012 are based on water use permits issued by the Water Resources Management Agency of the MNP.

Spatial:

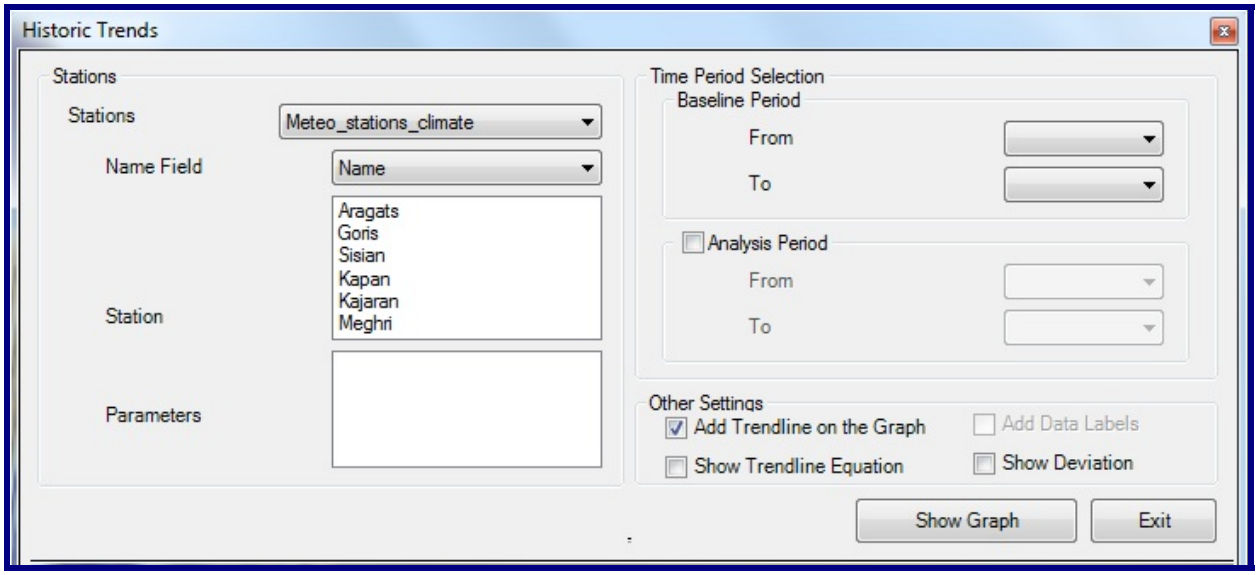
(1) Boundaries of the river basin(s) or basin management area(s) of interest;
(2) Shapefiles of catchment areas (including transition catchments) of hydrological observation posts;
(3) Point shapefiles with locations of meteorological stations located within the river basin of interest ("Meteo_climate");
(4) Point shapefile with locations of hydrological observation posts located within the river basin of interest ; ("Hydro_climate");
(5) Hydrological DEM and CN DEM of the river basin of interest (optional, for map visualization).

5.2.3. Running the component

To run the Historic trends component, click the appropriate command item under the "Climate Change Model" menu of the DSS.

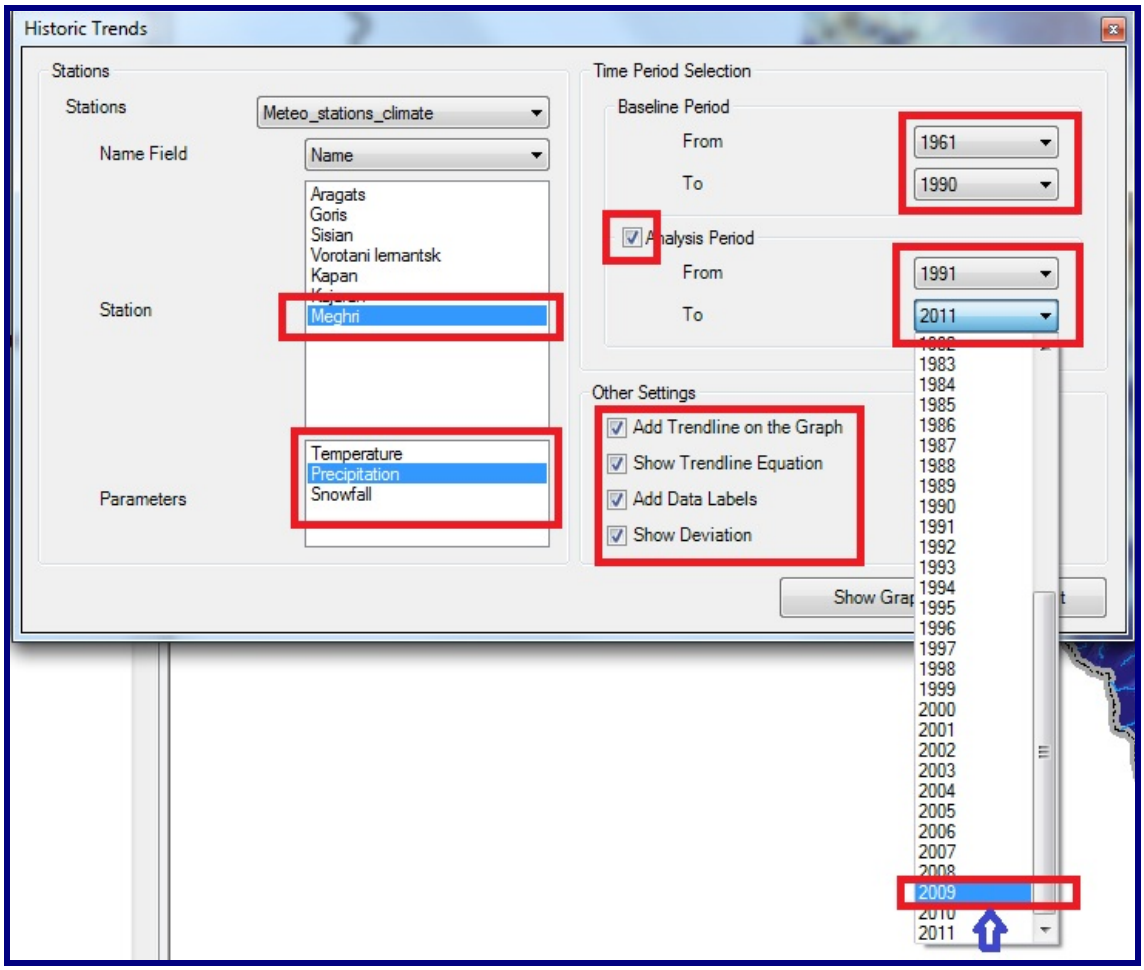


The following data input window will appear:



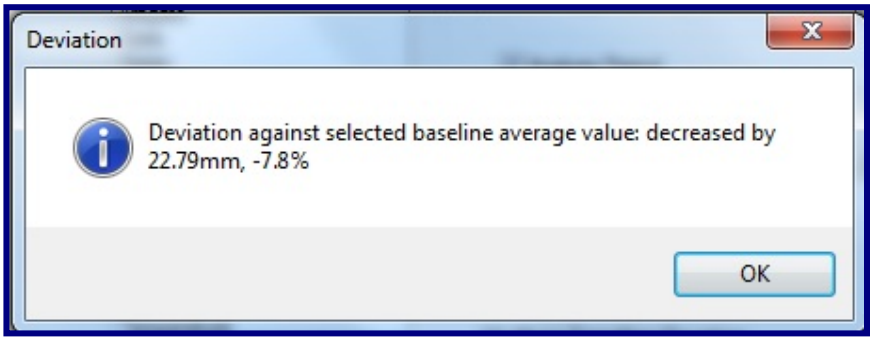
Take the following steps to obtain the graph of the trends of climate change parameters:

(1) In the “Stations” field select the point shape layer of meteorological stations in case of analysing the trends of temperature, precipitation and snowfall and the point shape layer of hydrological observation posts in case of analysing the trends in surface natural flow. The “Name” field will be filed in automatically. If not, select the appropriate field in the drop down list under the “Name Field” field.
(2) Select the meteorological or hydrological station of interest in the “station” list below. A list of parameters available for the specified station will appear in the “parameters” section.
(3) Select the parameter of interest from the list in “parameters” section.
(4) The are two options of analysing the trend: (1) to view the changes in the values of the specified parameters for one baseline period; and (2) to view the changes within specified periods in comparison with the baseline period. In the second case the “Analysis Period” box should be checked.
(5) Select the starting and end years in the drop down lists for the Baseline Period
(6) Select the starting and end years in the drop down lists for the Analysis Period, if needed and the “Analysis Period” check-box is checked.
(7) Check the “Add Trendline on the Graph” check-box if there is a need to show the trend line on the output analysis graph
(8) Check the “Show Trendline Equation” check-box if there is a need to see the equation of the changes of the selected parameter within the specified period
(9) Check the “Add Data Labels” check-box if there is a need to see the values of the mentioned parameter on the graph for each year step
(10) Check the “Show Deviation” check-box to view the absolute value and percentage of deviation of the specified parameter within the specified period compared to baseline period.



(11) Click the “Show Graph” button

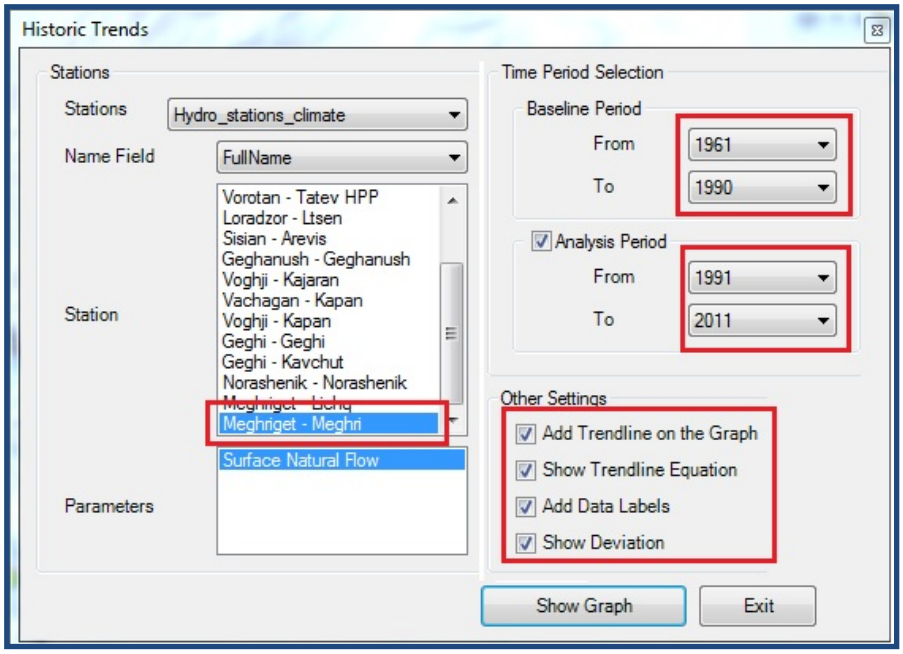
As a result, the comparative graphs of the changes in the values of the selected parameter for the selected period at the selected meteorological station will appear on the screen. Meanwhile a short summary report on the deviation of the values against the control period will be shown.

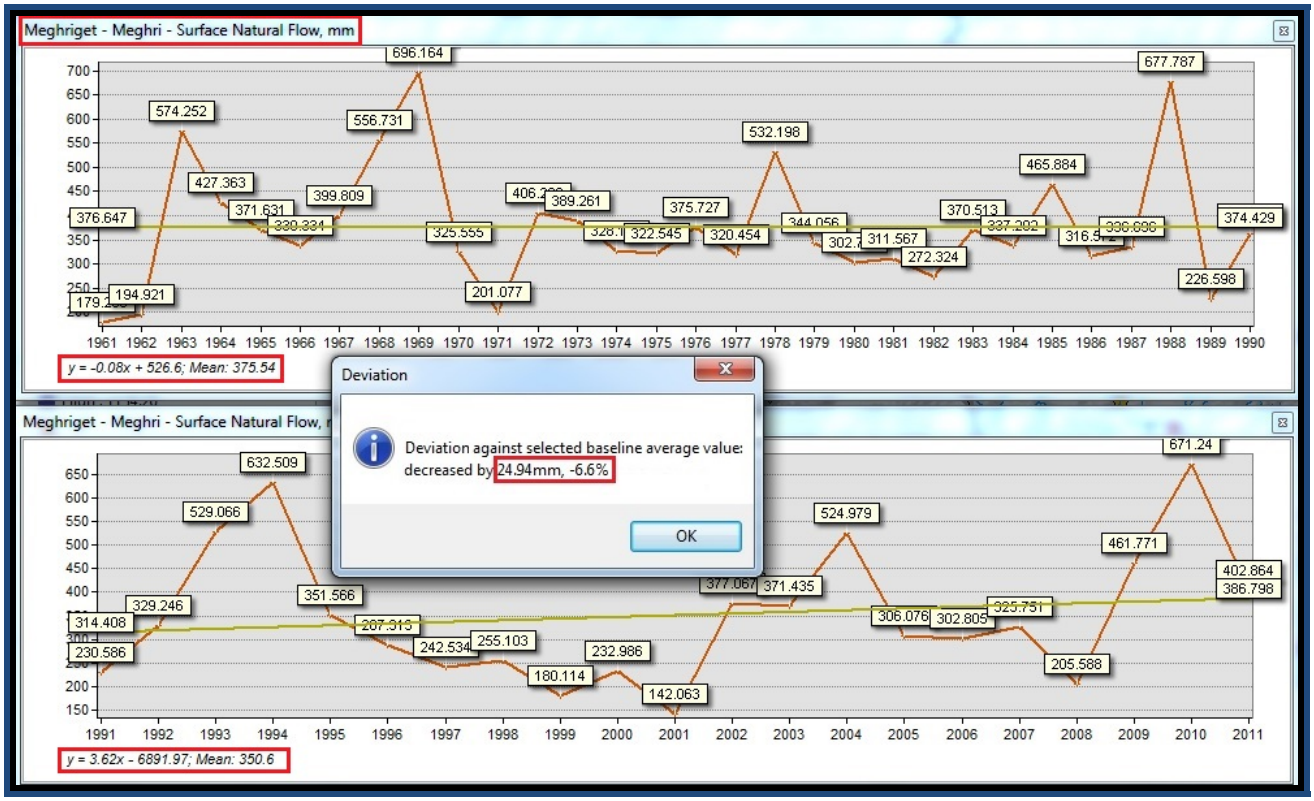


If no more trend analysis is needed, click the “Exit” button to quit the Historic trends component.

In the case of analysing the trends in surface natural flow change, the full names of the hydrological observation posts will appear in the “Station” section. The “Name Field” will be filed in automatically.

In the case of checking all the check boxes for the analysis of the trends during the period of 1991-2011 compared with the baseline period of 1961-1990, two graphs and one short report will appear on the screen.



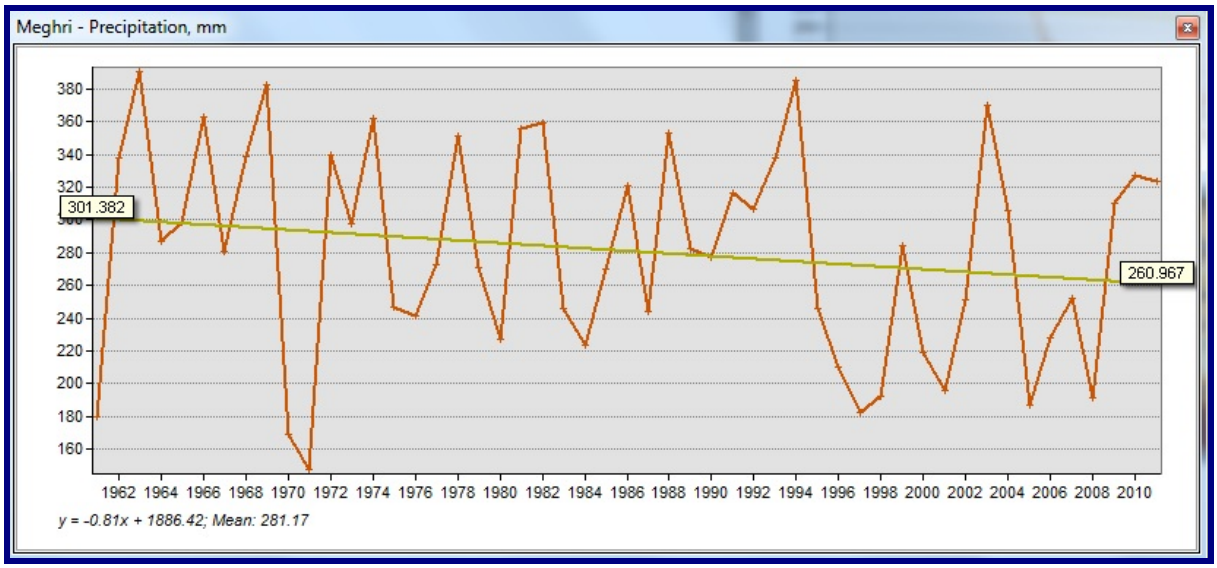


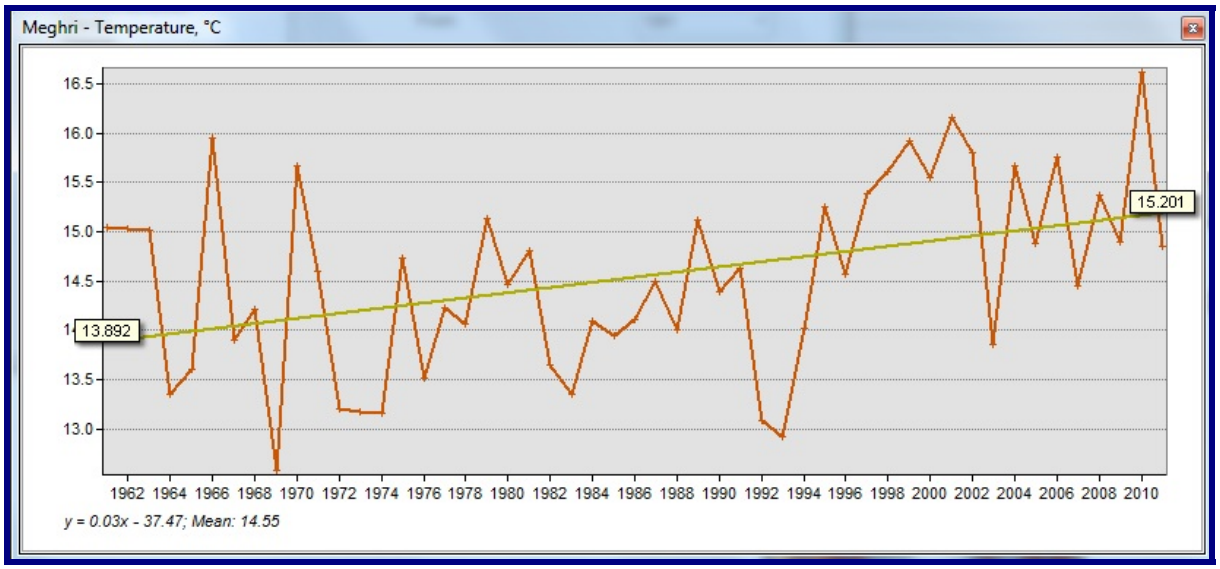
5.2.4. Main outputs

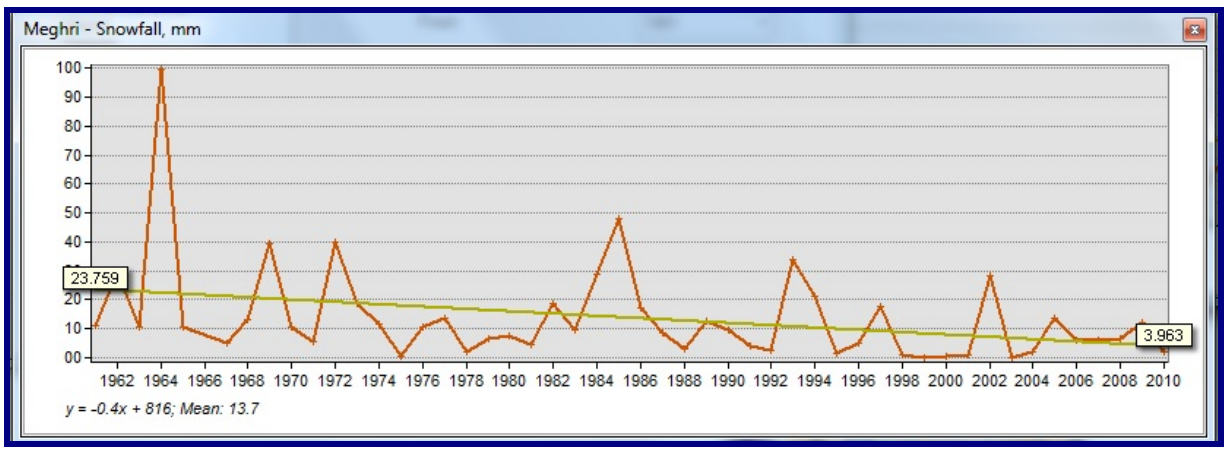
The outputs of the Historic trends component are presented on the example of the Meghri meteorological station of the Southern BMA of Armenia.

(1) Annual mean precipitation, temperature and snowfall trends:

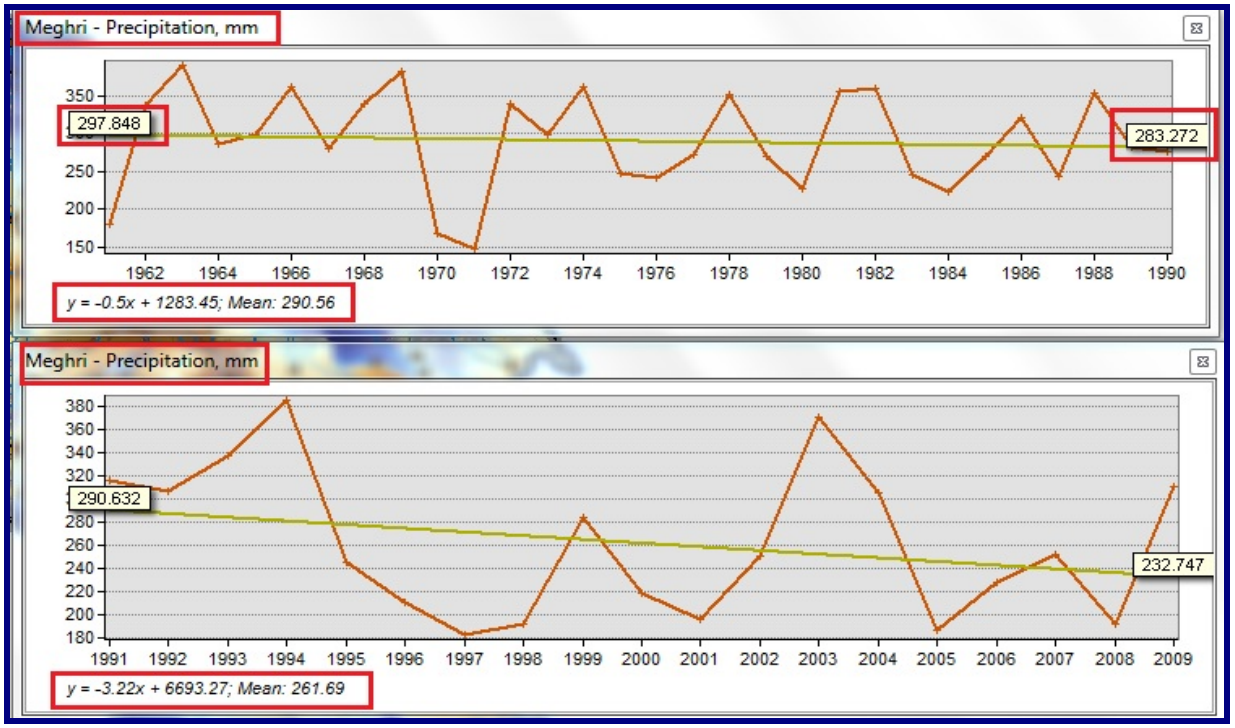
(1a) for 1961-2011 period





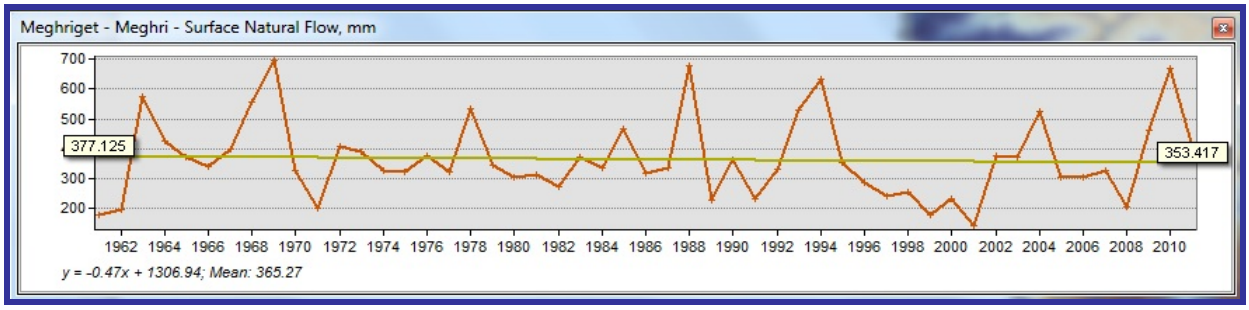


(1b) for 1961-1990 (baseline period) compared with 1991-2011 assessment period

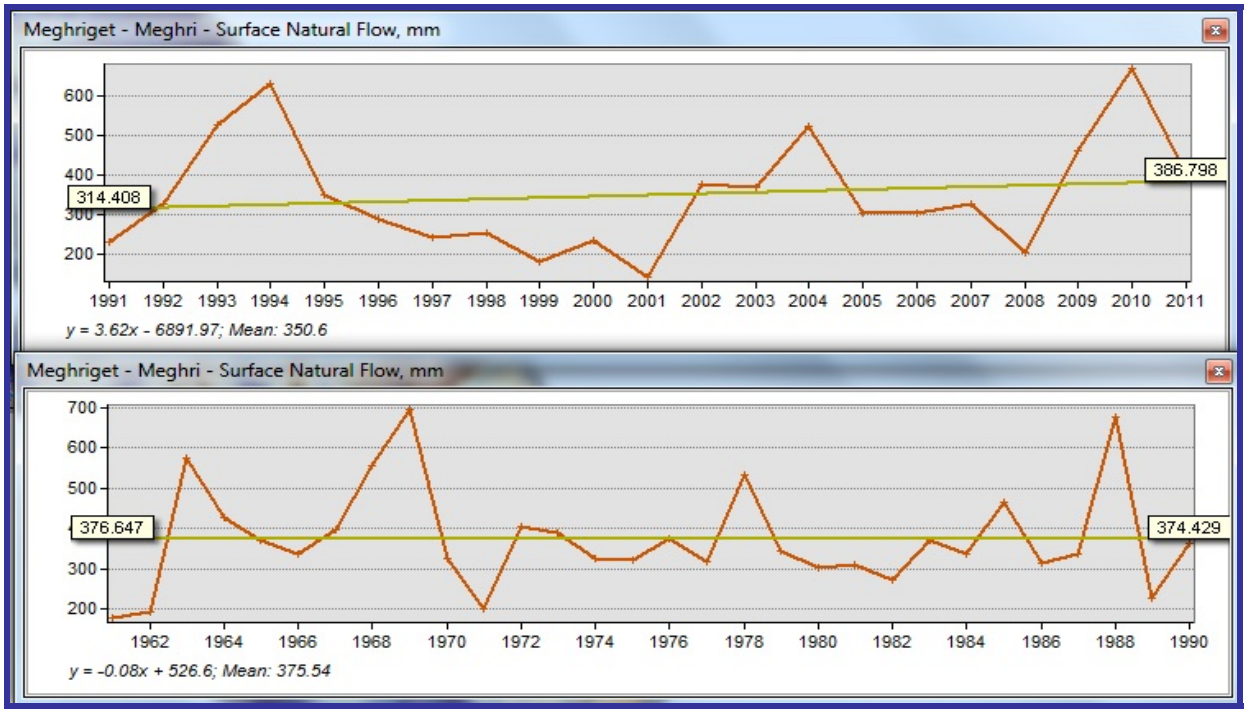


(2) Annual mean surface natural flow trends:

(2a) for 1961-2011 period



(2b) for 1961-1990 (baseline period) compared with 1991-2011 assessment period



5.3. Projections Component

5.3.1 Objective and methodology

The purpose of the Projections component of the Climate Change Model aims at modelling natural flow under the projected scenarios of climate change defined by IPCC in order to allow further assessment of water availability for making informed decisions on water use.

The model uses the multiple linear regression methodology for simulating the projected surface natural flow. Firstly, the model establishes correlation between the dependant variable, i.e. surface natural flow, and the two independent variables - temperature and precipitation to assess the multi-annual mean surface natural flow (for the baseline period of 1961-1990). For this, the model needs to create linkages between respective hydrological observation posts and meteorological stations, taking into account the geographic characteristics. The equation for regression analysis looks like the following:

$$Y = \beta_1 x_1 + \beta_2 x_2 + \epsilon$$

Where,

Y -value (surface natural flow) is a function of the independent x-values (temperature and precipitation), β-values are regression coefficients, and ϵ -value is the random error.

Once the observed multi-annual mean flow value (for 1961-1990) is validated, the projected values of temperature and precipitation for the period of interest and for the selected IPCC scenario are used in the equation to simulate the surface natural flow.

For projections of temperature and precipitation, the model uses the output data of PRECIS regional climate modelling system, which is based on the third generation regional climate model (HadRM3), developed by the UK Met Office Hedley Centre. The HadRM3, in its turn, uses the output data of global climate models (GCMs) and performs a dynamic downscaling, in order to acquire regional scale climate projections with resolution of 0.22^0 x 0.22^0 (25 x 25km). Projections for temperature and precipitation are conducted for the long-term period of 2040, 2070, and 2100, under A2 and B1 emission scenarios of IPCC, as well as for short-term, 6-year periods to match with basin planning cycles.

5.3.2 Input data

The following datasets are required as input data to run the Projections component:

Tabular:

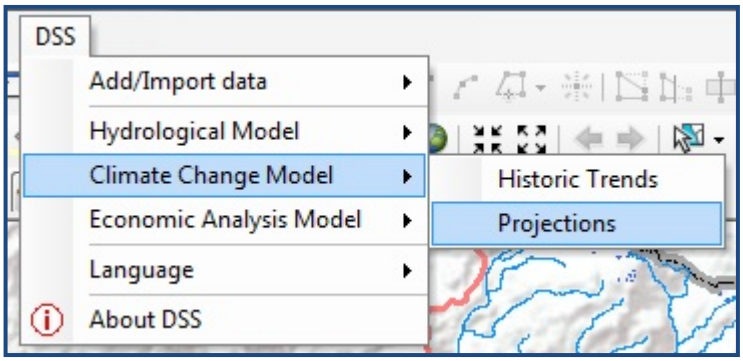
(1) Annual mean air temperature and precipitation values obtained from the meteorological stations located within the river basin of interest;
(2) Annual mean surface natural flow values calculated based on the data and methodology described above;
(3) Projected temperature and precipitation values by IPCC scenarios for the river basin of interest, obtained from Armstatehydromet, or published National Communications on Climate Change.

Spatial:

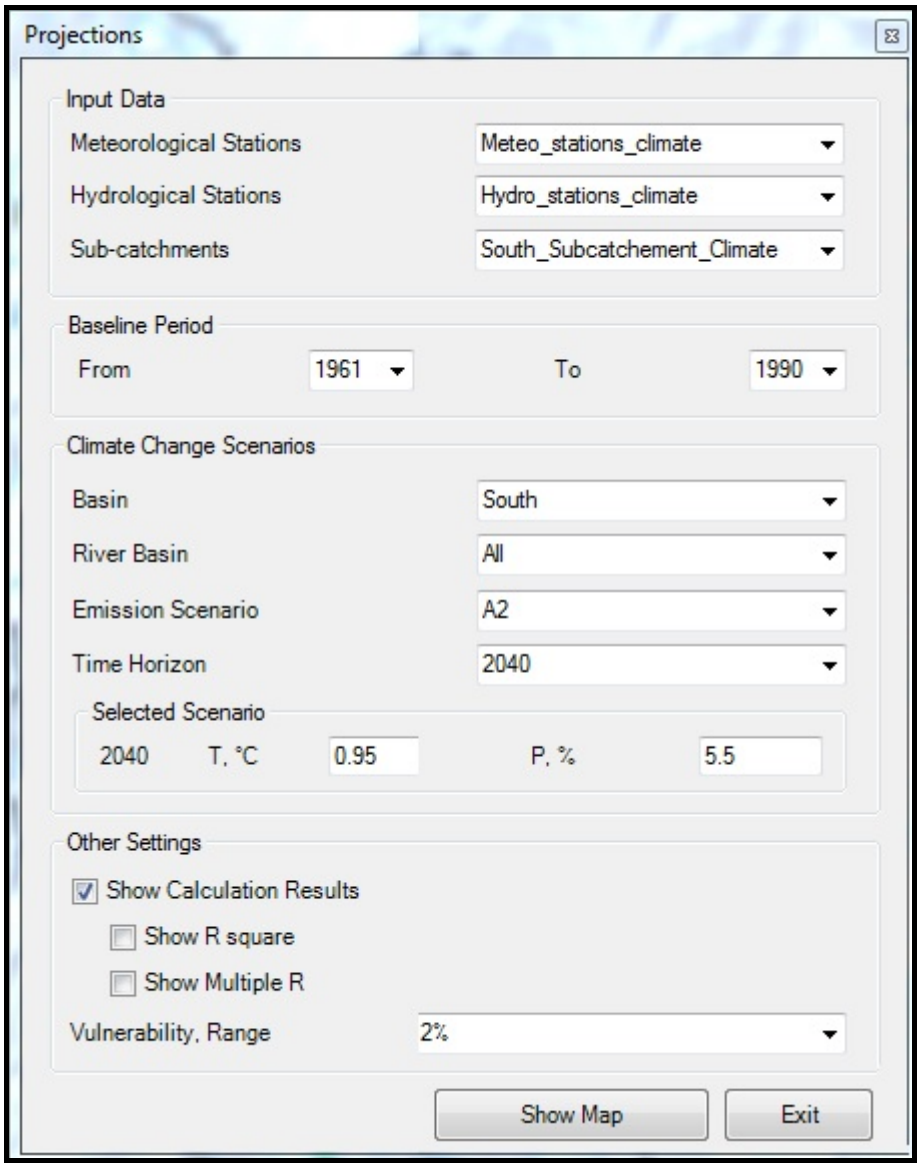
(1) Boundaries of the river basin(s) or basin management area(s) of interest;
(2) Shapefiles of catchment areas (including transition catchments) of hydrological observation posts;
(3) Point shapefiles with locations of meteorological stations located within the river basin of interest for water balance parameters ("Meteo_climate");
(4) Point shapefile with locations of hydrological observation posts located within the river basin; ("Hydro_climate");
(5) Hydrological DEM and CN DEM of the river basin of interest (optional, for map visualization).

5.3.3 Running the component

To run the Projections component, click the appropriate command item under the "Climate Change Model" menu of the DSS.



The following data input form will appear:



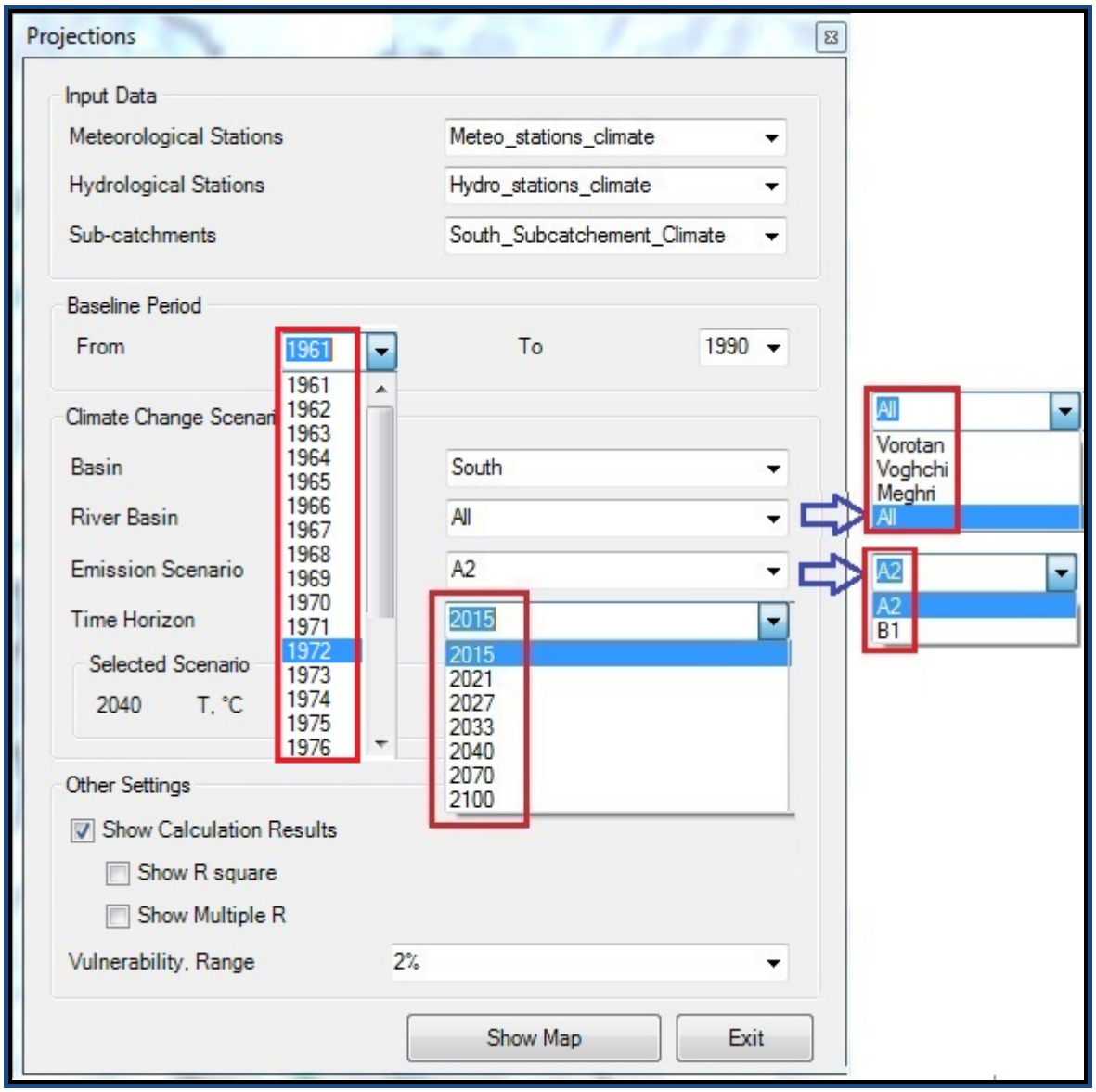
Take the following steps to obtain the map with projections of climate change parameters:

(1) In the "Meteorological Stations" field select the point shape layer of meteorological stations containing the values of climate change parameters ("Meteo_stations_climate")
(2) In the "Hydrological Stations" field select the point shape layer of hydrological observation posts containing the values of climate change parameters ("Hydro_stations_climate")
(3) In the "Sub-catchments" field select the polygon shape layer that contains the catchment areas of the river basin in interest, delineated by the locations of meteorological stations and hydrological

observation posts. This layer is usually located in the “climate change” dataset feature class of DSS geodatabase

(4) Select the starting and end years of the period of analysis within the “Baseline Period” section

(5) Within the “Climate Change Scenarios” section:
- select the basin management area in the “Basin” field
- specify one river basin or select “All” in the “River Basin” field for spatial coverage of the projection
- select one of the available IPCC scenarios in the “Emission Scenario” field
- select the year of projection in the “Time Horizon” field. The available options have 6-year steps for short term projections (2015, 2021, 2027, 2033) as well as IPCC recommended time-steps for long-term projections (2040, 2070, 2100).



(6) Make sure the “Show Calculation Results” check-box is active. If needed, check the “Show R square” and “Show Multiple R” check-boxes.

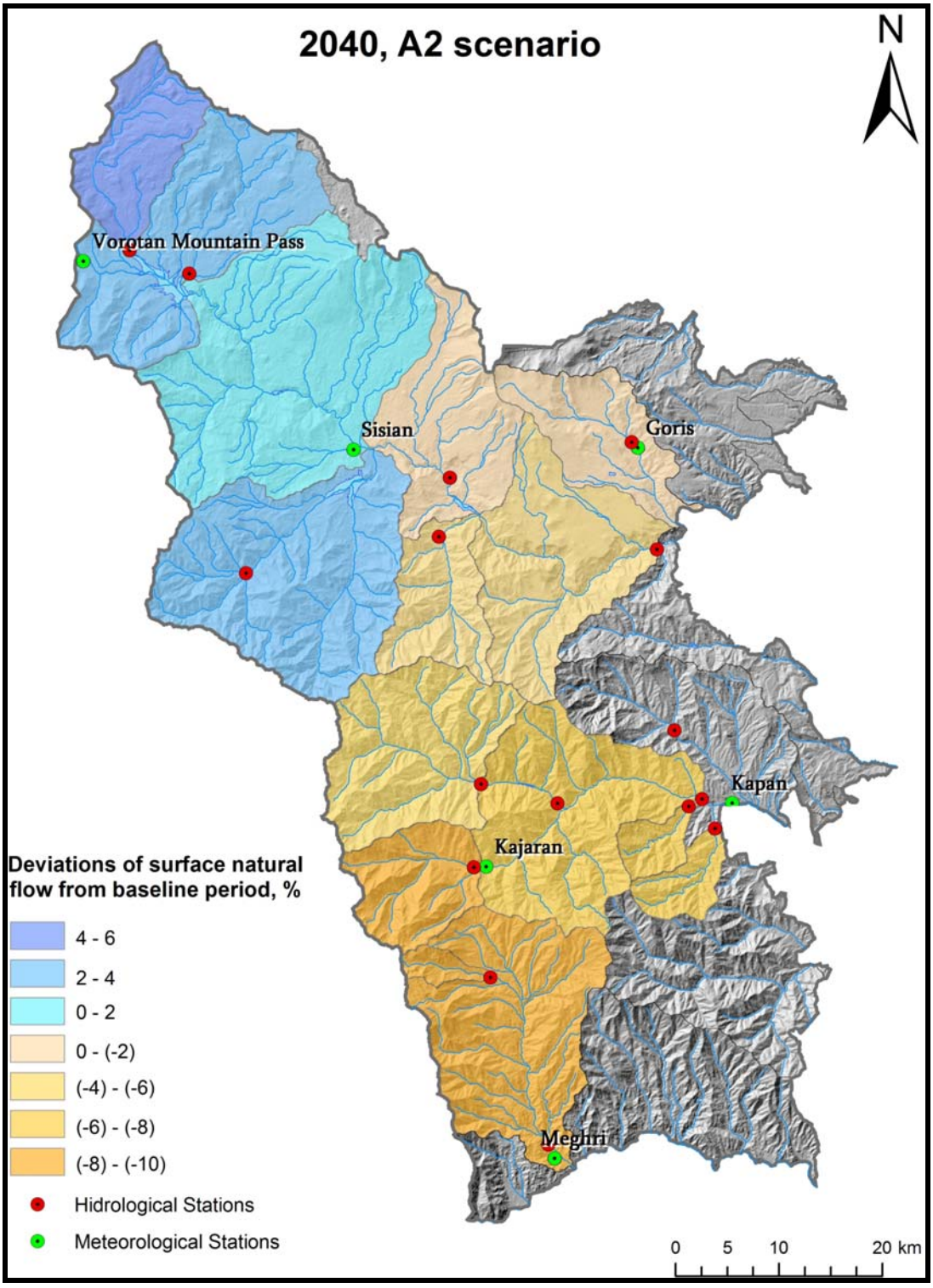
(7) Specify the range of the deviation values to be demonstrated by separate colors on the output map. It is recommended to use the value of “2%” for short-term and values of “5%” or “10%” for long-term projections

(8) Click the “Show Map” button.

As a result, a map with projected deviation values of surface natural flow for the specified year using the specified IPCC scenario will be generated.

5.3.4 Main outputs

The outputs of the Projections component include simulated natural flow for each catchment of a river basin under IPCC A2 and B1 scenarios for short-term (2021, 2027, 2033) and long-term (2040, 2070, 2100) projections. The sample below represents the deviations of surface natural flow by 2040 in the case of IPCC A2 scenario.



6. ECONOMIC ANALYSIS MODEL

6.1. Main objective

The main objective of economic analysis module of DSS is to provide information for decision makers on water use by different sectors of economy; economic value of water used by different sectors, as well as forecasted water use needs by different sectors based on the projected economic development scenarios.
The Economic Analysis Module includes two components:

(1) Economic analysis of the current water use; and
(2) Economic analysis of the water use development scenarios.

The following sections will present the objectives, functionalities and outputs of each component in details.

6.2. Current Water Use Component

6.2.1. Objective and methodology

The objective of Current Water Use Component is to generate analytical results on water use structure by sectors of economy, and by river basins, as well as to derive analytical insights on economic value of water used by different sectors.

The components uses the methods of descriptive statistics to provide outcome for the water use structure, as well as specific approaches have been designed and applied for water use economic assessment.

- Cost approach - based on the water use fees for water abstraction.
- Revenue approach - based on the revenue that was generated by the water use sector.

The component has 3 main calculation phases:

(1) Based on Water Use Permits data and statistical data on number of inhabitants and headcounts of animals structures and sorts out water use amounts by sectors of economy, by river basin, by type of source;
    - It uses the information given in the Water Use Permits and structures it by sectors of economy and river basin;
    - Estimates water use normative amounts for re-allocation of water use amounts for animal drinking water and drinking water, where Water User Permits are not providing accurate data;
    - Classifies water use amounts by type of source (ground or surface water);
    - Derives analytical output on water use structure by sectors of economy and river basin.
(2) Applies cost approach for water use economic assessment;
    - Matches and applies specific water use fee to sector of economy and water source;
    - Derives analytical output on water use structure and economic value by sectors of economy and river basin.
(3) Applies revenue approach for water use added value assessment.
    - Uses statistical data of revenue generated by the sector of economy, matching it to the water use amount and calculates “Sector revenue to Water use amount” ratio.
    - Applies contribution factor adjustment for adjusting the “Sector revenue to Water use amount” ratio for estimation of water contribution added value in the sector of the economy.
    - Derives analytical output on the water use structures and added value by sectors of economy.

The following key equations were used:

- **Animal water drinking water abstraction** = "Litre per day per animal" *365*"Headcount of animals"*0.2 /(1-"unaccounted water (network losses)")+ "Litre per day per animal" *365*"Headcount of animals"*0.8
- **Cost approach economic use and drinking water fee (including animal drinking) =** "Volume of water abstraction from surface for common pricing users" *"Surface water use fee for common pricing users" + "Volume of water abstraction from ground water for common pricing users" * "Ground water use fee for common pricing users"+ "Volume of water abstraction from surface for special pricing users" *"Surface water use fee for special pricing users" + "Volume of water abstraction from ground water for special pricing users" * "Ground water use fee for special pricing users"
- **Cost approach total water use fee** =∑ "Surface water use volume by sector"*"Surface water use fee for the sector" +∑ "Ground water use volume by sector"*"Ground water use fee for the sector" + **"Cost approach economic use and drinking water fee (including animal drinking)"**
- **Revenue approach: Added value after adjustment for contributing factor = "**Revenue for the sector"/"Water use by the sector" * "Contributing factor".

6.2.2. Input data

The following datasets are required as input data to run the Current water use component:

Tabular:

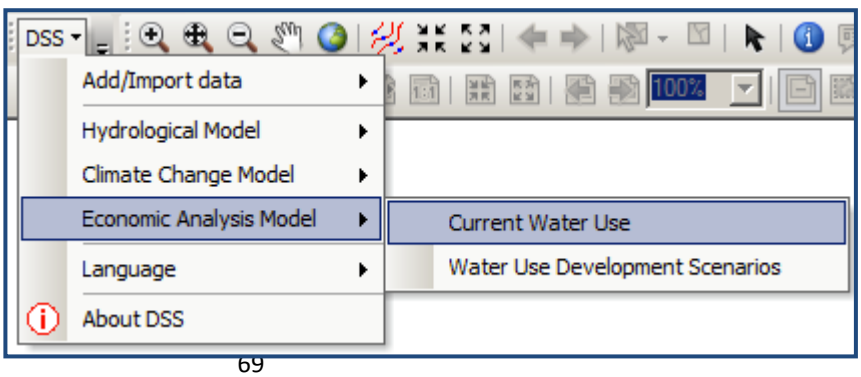
(1) Water Use Permits with volumes of water abstraction (both surface and groundwater) by sectors of economy and river basins;
(2) Revenues of the sectors of water use based on the data of National Statistical Service of RA and Regional Authorities Statistics;
(3) Headcounts of animals by types obtained from Regional Authorities Statistics.
(4) Number of inhabitants by river basin obtained from Regional Authorities Statistics.
(5) Russian water use normative for animals of ВНТП-Н-97
(6) Unaccounted water figures are based on Armenian Water and Sewerage Company CJSC Annual reports, data for 2013
(7) Water use calculation mechanism as defined by RA Law "On Nature Protection and Natural Resources Use Fees" as of 28/12/1998
(8) Water use fees as defined by RA Government Decree "On Rates of Fees for Natural Resources Use" as of 30/12/1998.

Spatial:

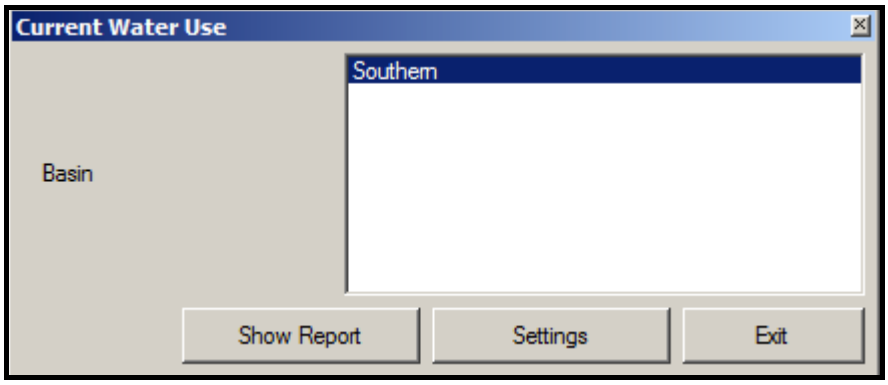
(9) Boundaries of the river basin(s) or basin management area(s) of interest;
(10) Point shape files with water abstraction data based on water use permits.

6.2.3. Running the component

To run the Current water use component, click the appropriate command item under the "Economic Analysis" menu of the DSS.



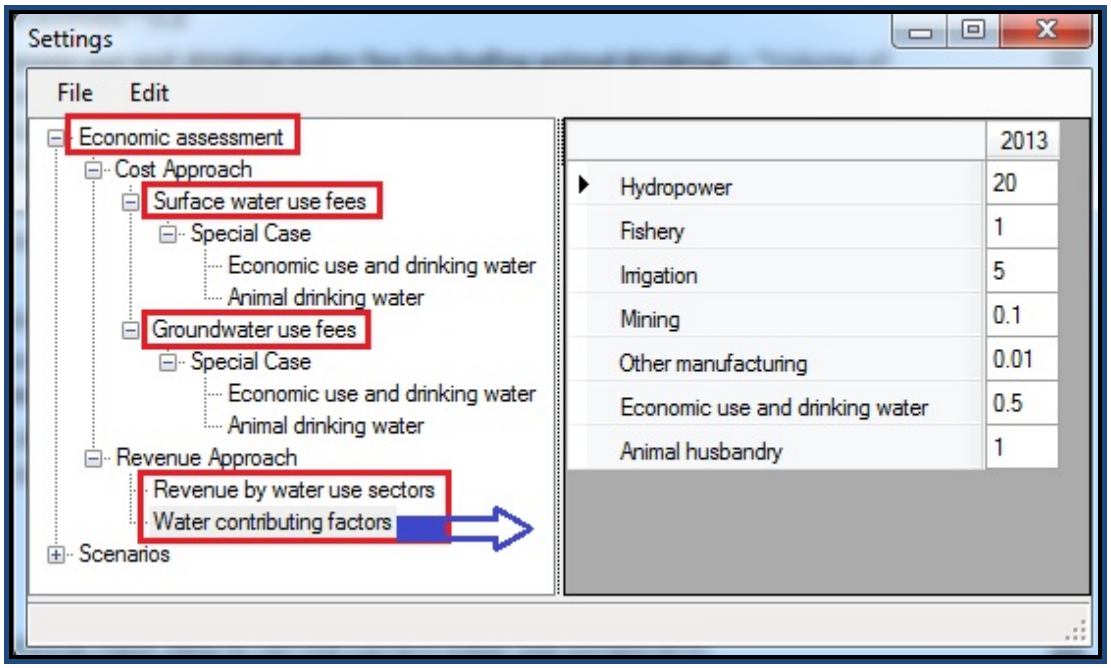
The following window will appear:



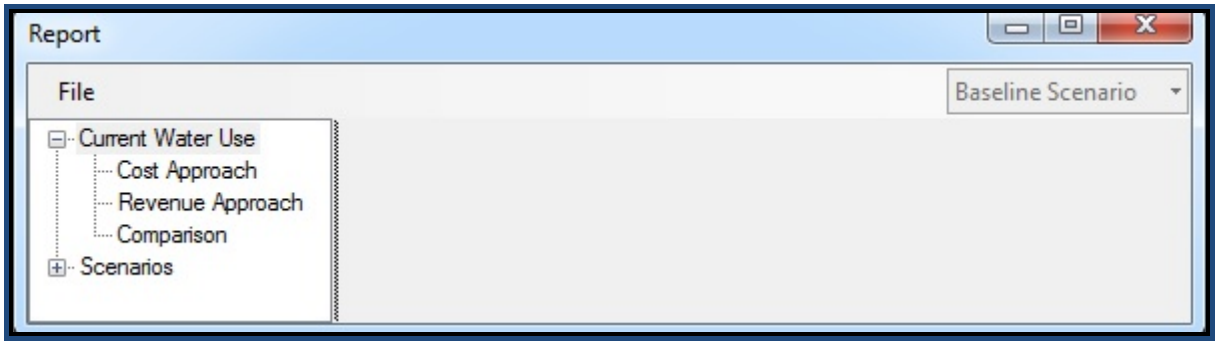
(1) Select the name of the basin in the list and click the **"Settings**" button.

A window will appear where in the **"Economic assessment"** section the values of the following parameters can be set or changed:

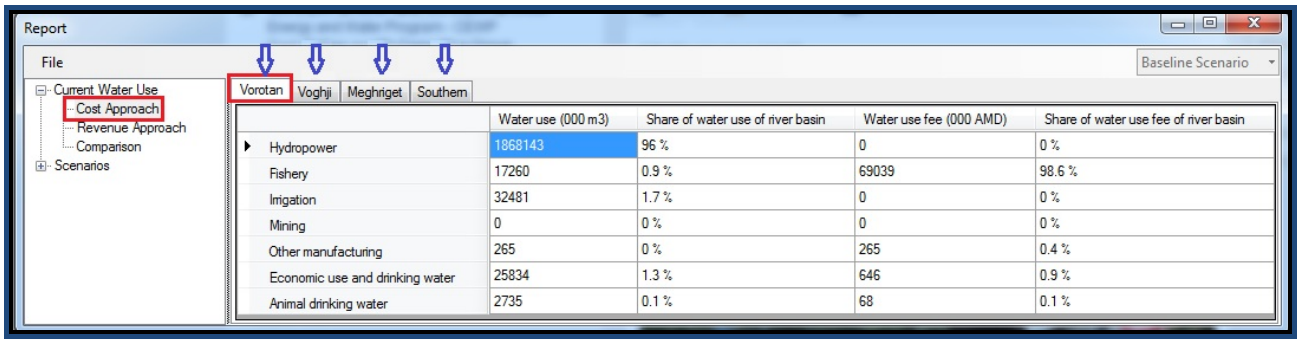
- Surface water use fees, included cases for special pricing defined by the legislation
- Groundwater use fees, included cases for special pricing defined by the legislation
- Revenues by water use sectors for the given year
- Water contributing coefficients / factors for the given year



(2) Click the **"Show Report"** button. The following window will appear:

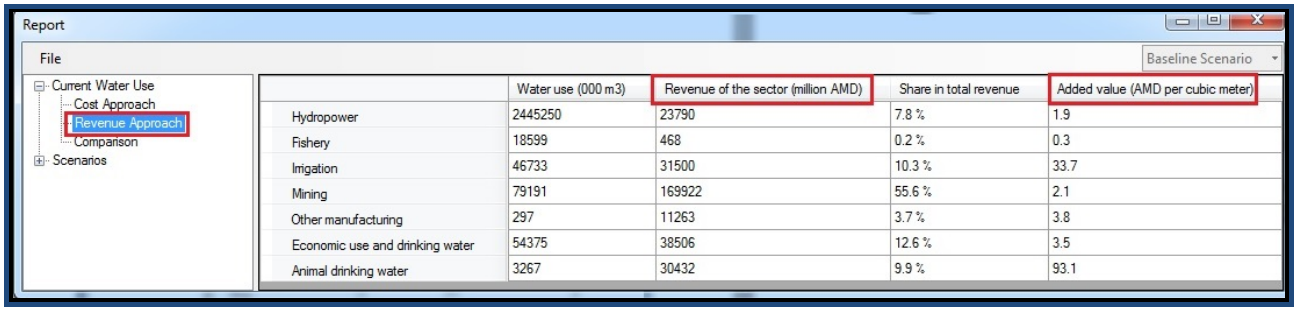


(3) Click the **"Cost Approach"** item under the "Current Water Use" menu to view the water use structure by sectors of water use and estimated water use fee figures generated by each sector of economy. The data is shown in absolute and relative (share in total) basis for the basin management area and each river basin separately. Click the tabs with the names of separate river basins and the basin management area to view appropriate reports.



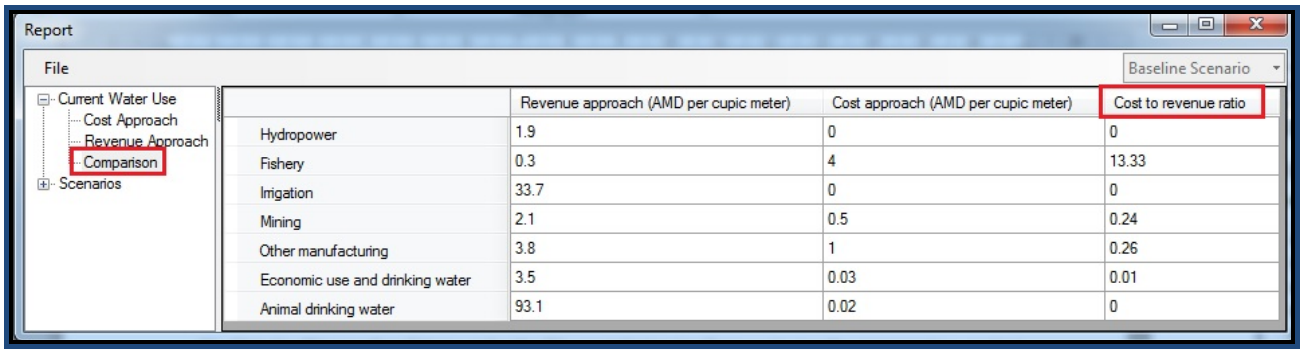
	Water use (000 m3)	Share of water use of river basin	Water use fee (000 AMD)	Share of water use fee of river basin
Hydropower	1868143	96 %	0	0 %
Fishery	17260	0.9 %	69039	98.6 %
Irrigation	32481	1.7 %	0	0 %
Mining	0	0 %	0	0 %
Other manufacturing	265	0 %	265	0.4 %
Economic use and drinking water	25834	1.3 %	646	0.9 %
Animal drinking water	2735	0.1 %	68	0.1 %

(4) Click the "**Revenue Approach**" item under the "Current Water Use" menu to view the water use structure by sectors of water use, revenue of the sector and estimated water use added value of the sector. The data is shown in absolute and relative (share in total) basis.



	Water use (000 m3)	Revenue of the sector (million AMD)	Share in total revenue	Added value (AMD per cubic meter)
Hydropower	2445250	23790	7.8 %	1.9
Fishery	18599	468	0.2 %	0.3
Irrigation	46733	31500	10.3 %	33.7
Mining	79191	169922	55.6 %	2.1
Other manufacturing	297	11263	3.7 %	3.8
Economic use and drinking water	54375	38506	12.6 %	3.5
Animal drinking water	3267	30432	9.9 %	93.1

(5) Click the "**Comparison**" item under the "Current Water Use" menu to see the comparative analysis of the revenue and cost approach assessments per cubic meter of water use.



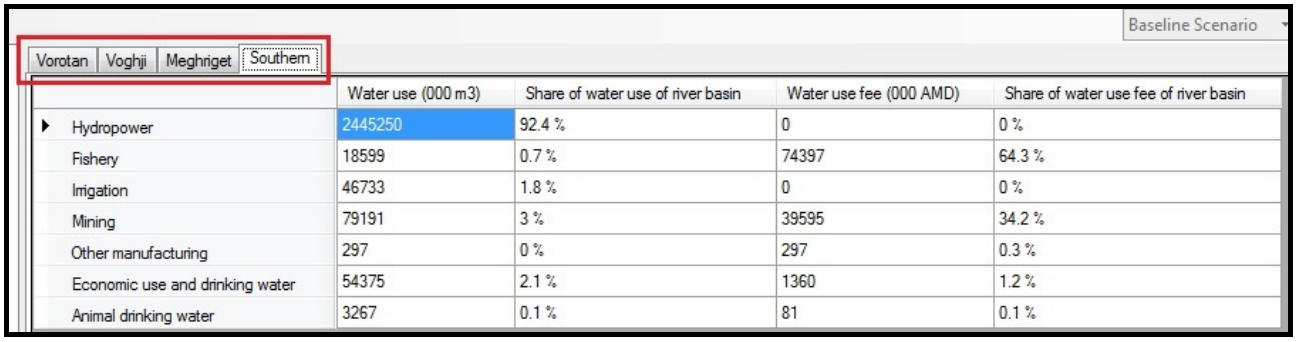
	Revenue approach (AMD per cupic meter)	Cost approach (AMD per cupic meter)	Cost to revenue ratio
Hydropower	1.9	0	0
Fishery	0.3	4	13.33
Irrigation	33.7	0	0
Mining	2.1	0.5	0.24
Other manufacturing	3.8	1	0.26
Economic use and drinking water	3.5	0.03	0.01
Animal drinking water	93.1	0.02	0

Any of the resulted report tables can be exported to a Ms Excel spreadsheet by clicking the "File" menu and selecting the "Export" command.

6.2.4. Main outputs

The outputs of the Current water use component are presented on the example of the Southern BMA of Armenia.

(1) Table showing water use structure by sectors of water use and estimated water use fee figures generated by each sector of economy.

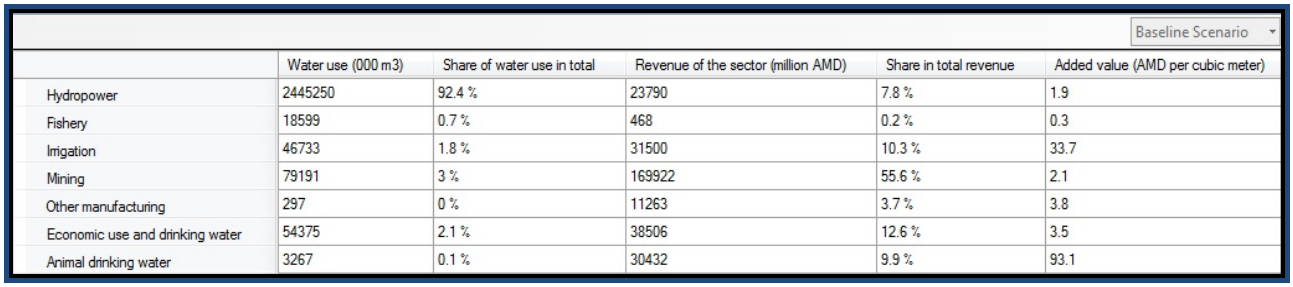


Baseline Scenario

Vorotan | Voghji | Meghriget | Southern

	Water use (000 m3)	Share of water use of river basin	Water use fee (000 AMD)	Share of water use fee of river basin
Hydropower	2445250	92.4 %	0	0 %
Fishery	18599	0.7 %	74397	64.3 %
Irrigation	46733	1.8 %	0	0 %
Mining	79191	3 %	39595	34.2 %
Other manufacturing	297	0 %	297	0.3 %
Economic use and drinking water	54375	2.1 %	1360	1.2 %
Animal drinking water	3267	0.1 %	81	0.1 %

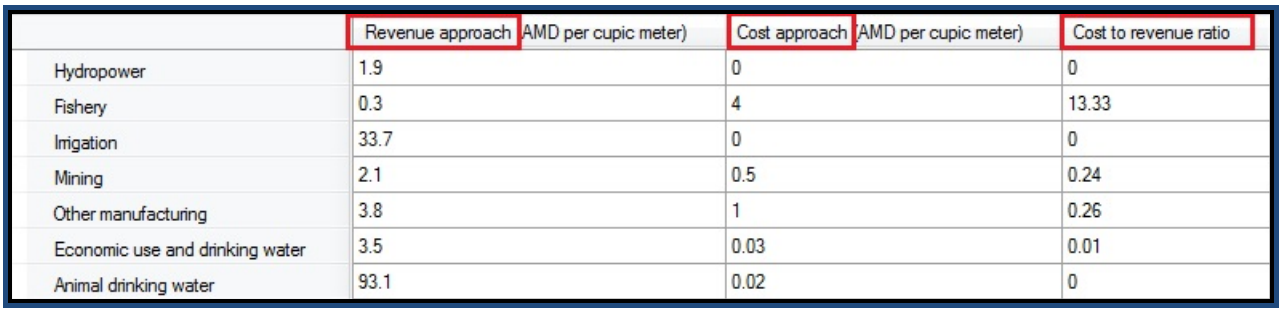
(2) Table showing water use structure by sectors of water use, revenue of the sector and estimated water use added value of the sector in the Southern BMA.



Baseline Scenario

	Water use (000 m3)	Share of water use in total	Revenue of the sector (million AMD)	Share in total revenue	Added value (AMD per cubic meter)
Hydropower	2445250	92.4 %	23790	7.8 %	1.9
Fishery	18599	0.7 %	468	0.2 %	0.3
Irrigation	46733	1.8 %	31500	10.3 %	33.7
Mining	79191	3 %	169922	55.6 %	2.1
Other manufacturing	297	0 %	11263	3.7 %	3.8
Economic use and drinking water	54375	2.1 %	38506	12.6 %	3.5
Animal drinking water	3267	0.1 %	30432	9.9 %	93.1

(3) Table showing comparison of revenue and cost approach assessments per cubic meter of water use.



	Revenue approach (AMD per cupic meter)	Cost approach (AMD per cupic meter)	Cost to revenue ratio
Hydropower	1.9	0	0
Fishery	0.3	4	13.33
Irrigation	33.7	0	0
Mining	2.1	0.5	0.24
Other manufacturing	3.8	1	0.26
Economic use and drinking water	3.5	0.03	0.01
Animal drinking water	93.1	0.02	0

6.3. Water Use Development Scenarios Component

6.3.1. Objective and methodology

The main objective of the component is to provide water use forecast by different sectors of economy of the river basin or basin management area based on the forecasted economic development scenarios. The component also generates results on economic assessment of forecasted water use by cost and revenue approaches. The components uses the methods of statistical inference by forecasting water use amounts based on the historical use amounts as per the base year.

The component employs the following 5 calculation phases:

(1) Economic development forecasts by sectors of economy, including
   - Uses the base year sector revenues and applies growth rates as targeted by the responsible authorities, as well as uses forecasted inflation rate,
   - For Hydropower sector the module uses new HPP construction permits additional capacity to forecast the sector growth rate,
   - For mining sector uses main 3 mining companies' planned target production figures to assess the implied growth rate for each company.
   - Based on the above mentioned data the module generates economic development projections for each sector of water use.

(2) Water use forecasts based on the economic development forecast, including
   - Estimates water use amounts based on the sector growth data and key water use growth drivers for each sector. For example average number of inhabitants and normative water use per capita,
   - Derives water use projected data by sectors of economy, including

(3) Cost approach assessment based on the forecasted water use data.
   - Classifies water use forecasted amounts by type of source for each sector of economy,
   - Matches and applies specific water use fee to water use projected amount of sector and water source,
   - Derives projected output on water use structure and economic value by sectors of economy and river basin.

(4) Revenue approach assessment based on the forecasted water use and economic development scenarios, including
   - Matches water use forecasted amounts to forecasted revenue of the sector to calculate the "Sector revenue to Water use amount" ratio.
   - Applies contribution factor adjustment for adjusting the "Sector revenue to Water use amount" ratio for estimation of projected water contribution added value in the sector of the economy.
   - Derives projected output on the water use structures and added value by sectors of economy for the Southern BMA.

(5) Scenario analysis.

Based on the above mention approach the DSS economic module designs Base Case Scenario and Optimistic Scenario, as well as it provides opportunity for the user to stimulates other "Custom" scenarios by changing key forecasting inputs.

6.3.2. Input data

The following datasets are required as input data to run the Water use development scenarios component:

Tabular:

(1) Water Use Permits with volumes of water abstraction (both surface and groundwater) by sectors of economy and river basins;
(2) Revenues of the sectors of water use based on the data of National Statistical Service of RA and Regional Authorities Statistics;
(3) Headcounts of animals by types obtained from Regional Authorities Statistics;
(4) Number of inhabitants by river basin obtained from Regional Authorities Statistics;
(5) Russian water use normative for animals of ВНТП-Н-97;

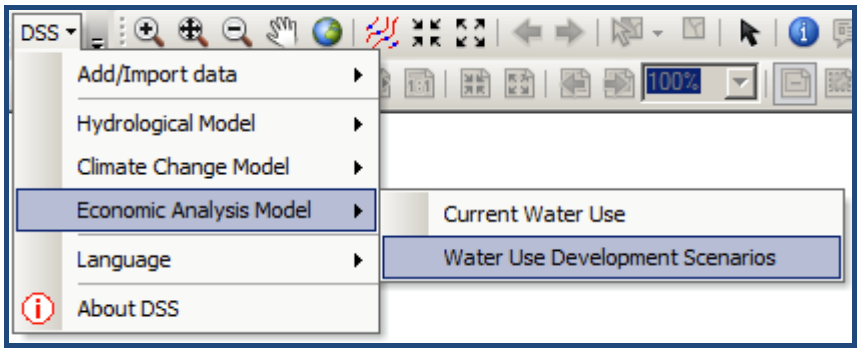
(6) Unaccounted water figures are based on Armenian Water and Sewerage Company CJSC Annual reports;
(7) Water use calculation mechanism as defined by RA Law "On Nature Protection and Natural Resources Use Fees" as of 28/12/1998;
(8) Water use fees as defined by RA Government Decree "On Rates of Fees for Natural Resources Use" as of 30/12/1998;
(9) New HPPs construction permits authorised by Public Service Regulatory Commission of RA;
(10) International Monetary Fund World Economic Outlook Data 2015.

Spatial:

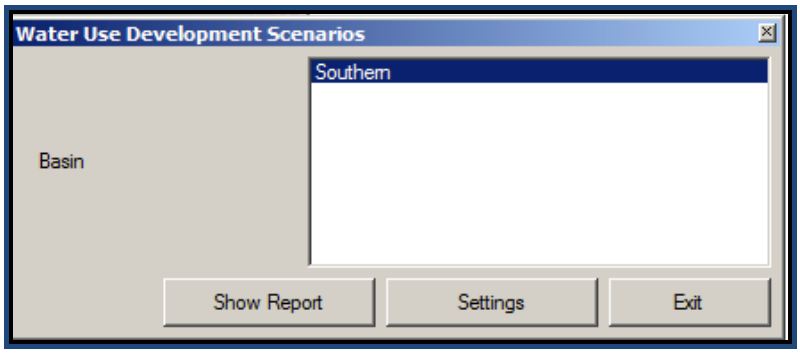
(1) Boundaries of the river basin(s) or basin management area(s) of interest;
(2) Point shape files with water abstraction data based on water use permits.

6.3.3. Running the component

To run the Water use development scenarios component, click the appropriate command item under the "Economic Analysis" menu of the DSS.

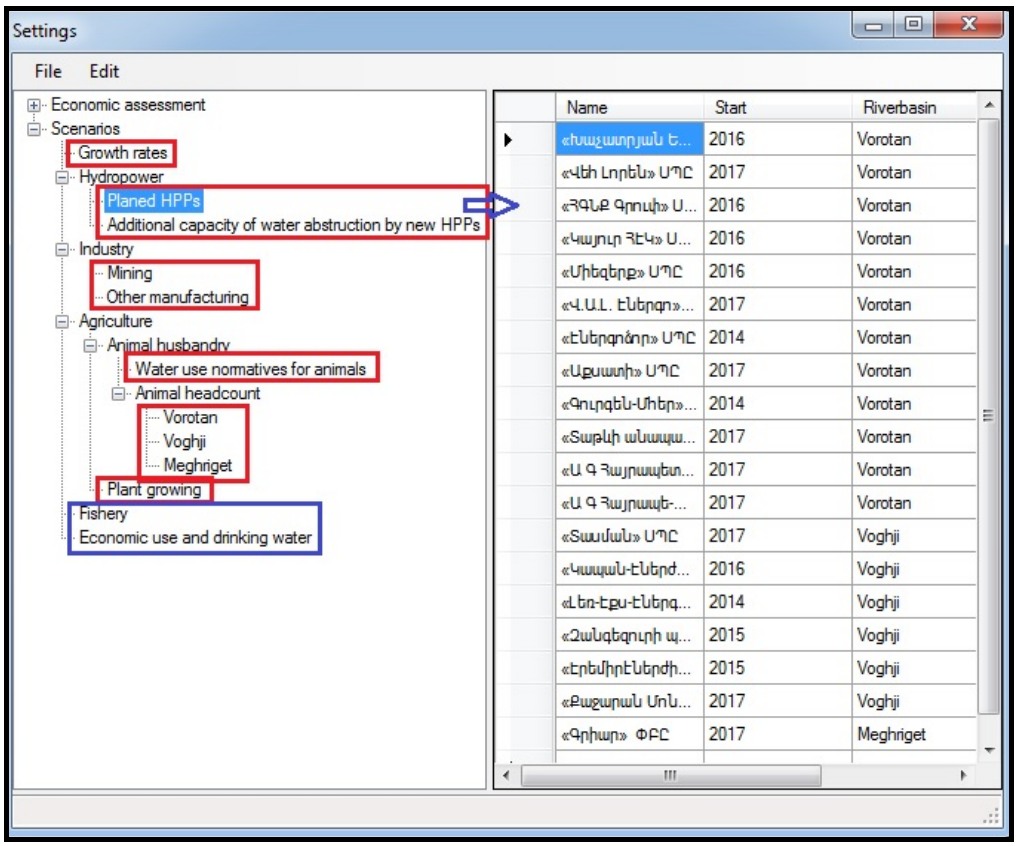


The following window will appear:

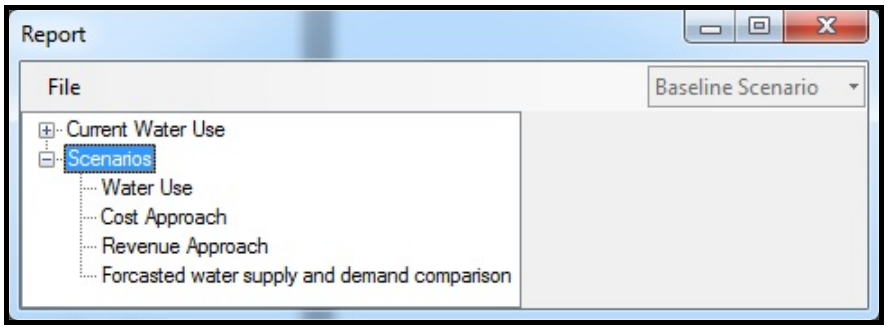


(1) Select the name of the basin in the list and click the "Settings" button. A window will appear where in the "Scenarios" section the values of the following parameters can be set or changed:

- Growth rates of different sectors of economy for baseline and optimistic scenarios;
- List of planned HPPs and their potential capacities;
- Volumes of water use to generate one unit of yield by mining industry;
- Number of other manufacturing industry enterprises in the river basins or in BMA;
- Water use norms for animal breeding (in litre of water per day);
- Number of animals (headcount) in the river basins or in BMA;
- Plant growing rates and average water use rates for 1 ha;
- Number of fisheries planned in the river basins or in BMA;
- Volume of water planned for economic use purposes in the river basins or in BMA.



(2) Click the “Show Report” button. The following window will appear:



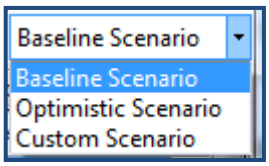
(3) Click the “**Water Use**” item under the “Scenarios” menu to view the forecasted water use amount by sectors of economy of the BMA or separate river basins for the period of 2014-2021.

(4) Click the “**Cost Approach**” item under the “Scenarios” menu to view the forecasted water use fees by sectors of water in the BMA or in river basins for the period of 2014-2021.

(5) Click the “**Revenue Approach**” item under the “Scenarios” menu to view the water use added value by sectors of water use in absolute values in the BMA or in separate river basins for the period of 2014-2021.

(6) Click the “**Forecasted water supply and demand comparison**” item under the “Scenarios” menu to view the comparison table on forecasted water supply/demand for the BMA or separate river basins for the period of 2014-2021.

(7) For all the above-mentioned 4 reports it is possible to change the scenarios at the top right corner of the window. There are three options: (a) baseline scenario; (b) optimistic scenario; and (c) Custom scenario, for which the user may enter arbitrary coefficients for the growth of different sectors of economy.

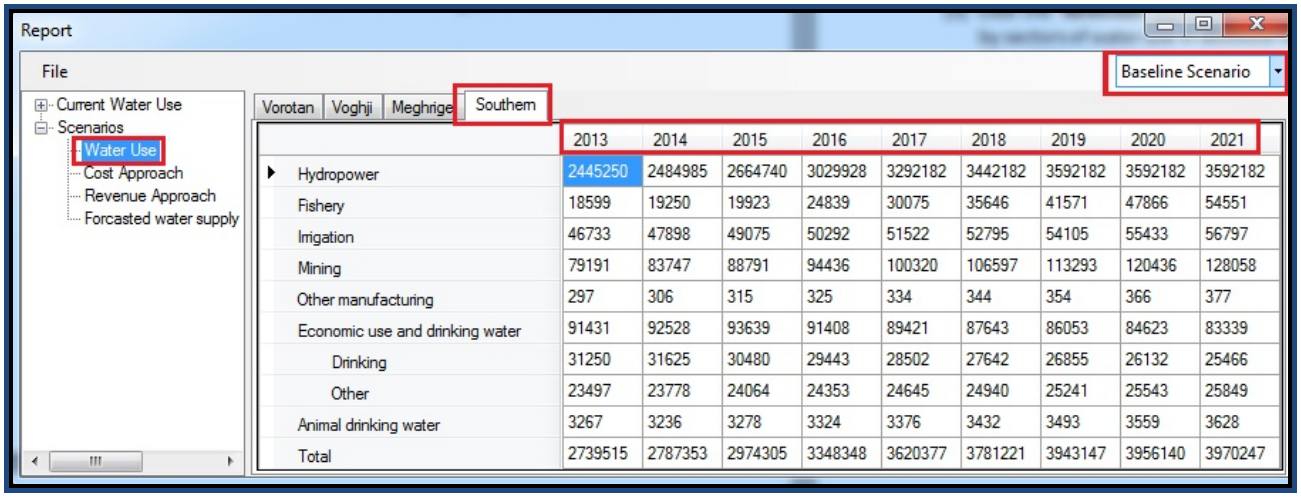


Any of the resulted report tables can be exported to a Ms Excel spreadsheet by clicking the “File” menu and selecting the “Export” command.

6.3.4. Main outputs

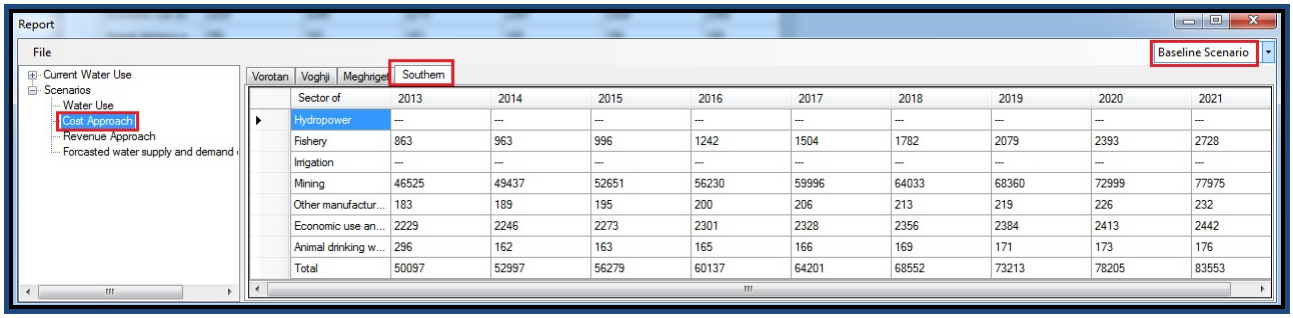
The outputs of the Water use development scenarios component are presented on the example of the Southern BMA of Armenia.

(1) Table showing the forecasted water use amount by sectors of economy of the Southern BMA and for each river basin (Vorotan, Meghriget, Voghji) separately for the period of 2014-2021



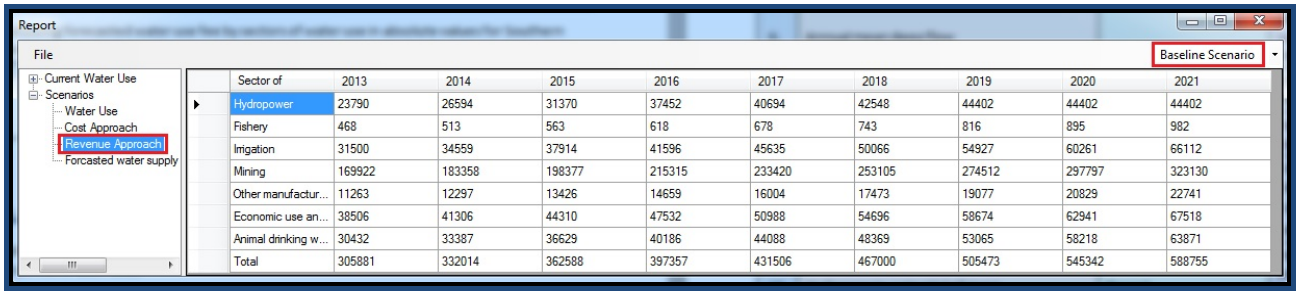
	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hydropower	2445250	2484985	2664740	3029928	3292182	3442182	3592182	3592182	3592182
Fishery	18599	19250	19923	24839	30075	35646	41571	47866	54551
Irrigation	46733	47898	49075	50292	51522	52795	54105	55433	56797
Mining	79191	83747	88791	94436	100320	106597	113293	120436	128058
Other manufacturing	297	306	315	325	334	344	354	366	377
Economic use and drinking water	91431	92528	93639	91408	89421	87643	86053	84623	83339
Drinking	31250	31625	30480	29443	28502	27642	26855	26132	25466
Other	23497	23778	24064	24353	24645	24940	25241	25543	25849
Animal drinking water	3267	3236	3278	3324	3376	3432	3493	3559	3628
Total	2739515	2787353	2974305	3348348	3620377	3781221	3943147	3956140	3970247

(2) Table showing forecasted water use fee by sectors of water use in absolute values for the Southern BMA and for each river basin (Vorotan, Meghriget, Voghji) separately for the period of 2014-2021.



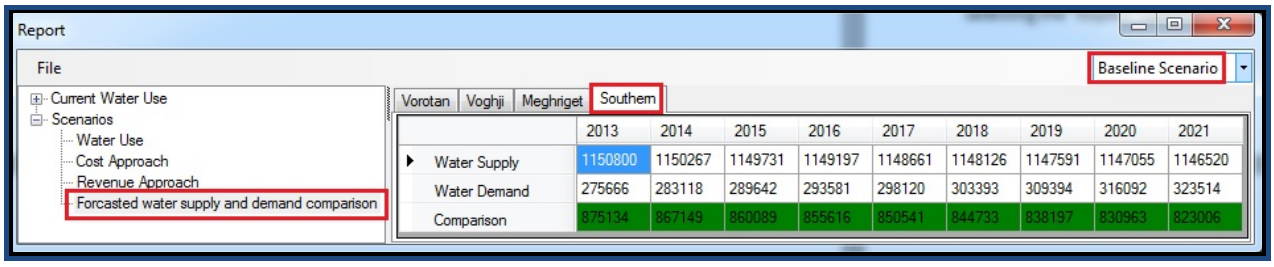
Sector of	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hydropower	---	---	---	---	---	---	---	---	---
Fishery	863	963	996	1242	1504	1782	2079	2393	2728
Irrigation	---	---	---	---	---	---	---	---	---
Mining	46525	49437	52651	56230	59996	64033	68360	72999	77975
Other manufactur...	183	189	195	200	206	213	219	226	232
Economic use an...	2229	2246	2273	2301	2328	2356	2384	2413	2442
Animal drinking w...	296	162	163	165	166	169	171	173	176
Total	50097	52997	56279	60137	64201	68552	73213	78205	83553

(3) Table showing water use added value by sectors of water use in absolute values for the Southern BMA for the period of 2014-2021



Sector of	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hydropower	23790	26594	31370	37452	40694	42548	44402	44402	44402
Fishery	468	513	563	618	678	743	816	895	982
Irrigation	31500	34559	37914	41596	45635	50066	54927	60261	66112
Mining	169922	183358	198377	215315	233420	253105	274512	297797	323130
Other manufactur...	11263	12297	13426	14659	16004	17473	19077	20829	22741
Economic use an...	38506	41306	44310	47532	50988	54696	58674	62941	67518
Animal drinking w...	30432	33387	36629	40186	44088	48369	53065	58218	63871
Total	305881	332014	362588	397357	431506	467000	505473	545342	588755

(4) Comparison table on forecasted water supply/demand for the Southern BMA and for each river basin (Vorotan, Meghriget, Voghji) separately for the period of 2014-2021



	2013	2014	2015	2016	2017	2018	2019	2020	2021
Water Supply	1150800	1150267	1149731	1149197	1148661	1148126	1147591	1147055	1146520
Water Demand	275666	283118	289642	293581	298120	303393	309394	316092	323514
Comparison	875134	867149	860089	855616	850541	844733	838197	830963	823006

7. SUMMARY OF OUTPUT RESULTS

7.1. Hydrological Model

Table below summarizes the main output results of the Hydrological Model:

#	Output	Type/Coverage	Data Source
1.	Annual mean precipitation pattern	One raster image for each year interpolated for the given river basin	Meteorological stations
2.	Annual mean evaporation pattern		Meteorological stations
3.	Annual mean natural flow		Precipitation and evaporation raster images for the given year
4.	Annual mean natural surface flow		Hydrological observation posts
5.	Annual mean surface runoff		Precipitation raster image CN_DEM
6.	Annual mean deep flow		Natural flow and natural surface flow raster images for the given year
7.	Annual mean water balance equation	Report	Values of the above mentioned parameters
8.	Values of ecological flow at the junction points of the rivers for the given year	Point GIS layer	Hydrological observation posts
9.	Annual water supply and demand balance equation	Report	Values of water balance parameters Values of ecological flow Water use permit data
10.	Hydroenergy potential of rivers	Report	Hydrological observation posts Values of ecological flow DEM
11.	Trends of surface water quality changes	Reports, charts	Surface water quality monitoring data Surface water quality norms
12.	Surface water quality assessment	Surface water quality assessment maps	

7.2. Climate Change Model

Table below summarizes the main output results of the Climate Change Model:

#	Output	Type/Coverage	Data Source
1.	Annual mean precipitation trends for the period of 1961-2011.	Graphical illustration with trend lines, equations and reports of deviations against baseline period values.	Meteorological stations
2.	Annual mean precipitation trends with two separations - for the periods of 1961-1990 and 1991-2011 with a report on deviation against the baseline average value.		Meteorological stations
3.	Annual mean temperature trends for the period of 1961-2011.		Meteorological stations
4.	Annual mean temperature trends with two separations - for the periods of 1961-1990 and 1991-2011 with a report on deviation against the baseline average value.		Meteorological stations
5.	Annual mean snowfall trends for the period of 1961-2011.		Meteorological stations
6.	Annual mean snowfall trends with two separations - for the periods of 1961-1990 and 1991-2011 with a report on deviation against the baseline average value.		Meteorological stations
7.	Annual mean natural flow trends for the period of 1961-2011.		Hydrological observation posts
8.	Annual mean natural flow trends with two separations - for the periods of 1961-1990 and 1991-2011 with a report on deviation against the baseline average value.		Hydrological observation posts
9.	Simulated natural flow for each catchment of a river basin for: Short-term projections: 2021, 2027, 2033 Long-term projections: 2040, 2070, 2100 under IPCC A2 and B1 scenarios	Vulnerability maps based on catchment areas and a report on the established regression equations; including simulated natural flow in mm and m3.	Meteorological stations Hydrological observation posts DEM

7.3. Economic Analysis Model

Table below summarizes the main output results of the Economic Analysis Model:

#	Output	Type/Coverage	Data Source
1.	Water use structure by sectors of water use and estimated water use fee figures generated by each sector of economy.	Table report on base year	Water Use Permits Number of inhabitants in each river basin Animal headcount in each river basin Normative water use figures per capita Normative Water use figures per type of animal Ratio of uncounted water in the water supply network Water use fees Water use calculation mechanism
2.	Water use structure by sectors of water use, revenue of the sector and estimated water use added value of the sector.	Table report on base year	Water Use Permits Number of inhabitants in each river basin Animal headcount in each river basin Normative water use figures per capita Normative Water use figures per type of animal Ratio of uncounted water in the water supply network Revenue of the sector Water contributing factor of each sector
3.	Comparison of revenue and cost approach assessment per cubic meter of water use	Table report on base year	Water Use Permits Number of inhabitants in each river basin Animal headcount in each river basin Normative water use figures per capita Normative Water use figures per type of animal Ratio of uncounted water in the water supply network Water use fees Water use calculation mechanism Revenue of the sector Water contributing factor of each sector
4.	Forecasted water use amounts by sector of economy by river basins	Table report on forecasted years	Water Use Permits New HPPs construction permits authorised by Public Service Regulatory Commission of RA Number of inhabitants in each river basin Animal headcount in each river basin Normative water use figures per capita Normative Water use figures per type of animal Ratio of uncounted water in the water supply network Planned growth rates for the sectors Arable land amount Target growth figures for the mining industry
5.	Comparison table on forecasted water supply/demand amounts	Table report on forecasted years	Forecasted water use amounts by sector of economy by river basins Forecasted water supply figures
6.	Forecasted water use fee by sectors of water use	Table report on forecasted years	Forecasted water use amounts by sector of economy by river basins; water use fees Water use calculation mechanism

#	Output	Type/Coverage	Data Source
7.	Water use added value by sectors of water use	Table report on forecasted years	Forecasted water use amounts by sector of economy by river basins Real output growth rates of the sector Consumer price index forecast for each sector Water contributing factor of each sector