Food and Agriculture Organization
of the United Nations

SDG 6.4 MONITORING SUSTAINABLE
USE OF WATER RESOURCES PAPERS

Water stress plugin for Water Evaluation and Planning system (WEAP)

Using the water evaluation and planning tool for the calculation of Sustainable Development Goal indicator 6.4.2

SEI Stockholm
Environment
Institute

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Abbreviations and acronyms

CSV	comma separated values
EFR	environmental flow requirement
EMC	environmental management class
FAO	Food and Agriculture Organization of the United Nations
FDC	Flow duration curve
GIS	geographic information system
IWMI	International Water Management Institute
MCM	million cubic meter
SB	sub-basin
SDG	Sustainable Development Goal
SEI	Stockholm Environment Institute
SMM	Soil moisture method
TFWW	Total freshwater withdrawals
TRWR	Total renewable freshwater resources
WEAP	Water evaluation and planning
WHO	World Health Organization

Foreword

The Food and Agriculture Organization of the United Nations (FAO) is supporting the 2030 Agenda for Sustainable Development through the transformation to MORE efficient, inclusive, resilient and sustainable agri-food systems for better production, better nutrition, a better environment, and a better life. The transformation of agri-food systems is at the heart of FAO's mandate.

Water is the essence of life and central to agri-food systems. The path to reduce water stress passes through sustainable agri-food systems. To ensure sustainable management of water resources for all, it is essential to look at the water cycle in its entirety, including all uses and users.

FAO is the custodian agency responsible for monitoring Sustainable Development Goal (SDG) target 6.4 that addresses water use and scarcity to "*Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity by 2030*". In FAO, the data collection, management and reporting of target 6.4 indicators at the global level takes place through the FAO Global Information System on Water Resources (AQUASTAT).

In 2015 FAO joined the Integrated Monitoring Initiative for SDG 6 coordinated by UN-Water. The Initiative aims at accelerating the achievement of the SDG targets on sustainable water and sanitation through the establishment of a coherent monitoring framework for water and sanitation and by supporting countries to achieve progress through well-informed decision-making on water. Such a framework will help countries achieve progress through well-informed decision-making on water, based on harmonized, comprehensive, timely and accurate information.

This report presents the new water stress plugin developed by FAO in collaboration with the Stockholm Environment Institute's U.S. Center (SEI) for the calculation of the SDG indicator 6.4.2 *"Level of water stress: freshwater withdrawal as a proportion of available freshwater resources"* by river basin.

Since the indicator was introduced in 2015, it has been used widely to estimate the level of water stress experienced at the country or regional level. With this new plugin countries will be able to assess SDG 6.4.2 at basin and sub-basin level providing a different and more hydrologically sound view on the dynamics of water resources and their use. The plugin allows for the exploration of the spatial and interannual trends of the level of water stress within a basin avoiding any multiple counting of its freshwater resources and taking into consideration the needs of water supply of the different sections of the basin. By supporting the improvement of water monitoring and management, this report contributes to the achievement of SDG 6.

In coordination and collaboration with other stakeholders, FAO will continue supporting Members to achieve this target by providing scientific and technical assistance.

Lifeng Li

Director of Land and Water Division, FAO


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Water stress plugin

Introduction and development of the water stress plugin

SDG indicator 6.4.2 is a measure of the level of water stress that assesses the amount of freshwater that is being withdrawn compared to the total freshwater resource available for some defined region. It takes into account freshwater supplies and withdrawals as well as environmental flow requirements and is expressed numerically using the following equation.

$$\text{Water Stress} = \frac{TFWW}{TRWR - EFR} * 100$$

Where TFWW is the total freshwater withdrawn, TRWR is the total renewable freshwater resources, and EFR is the environmental flow requirement. This expression suggests that a water stress value of one hundred indicates that all freshwater supplies in excess of EFR are being diverted for consumptive use, which suggests a high level of water stress. Conversely, low water stress is experienced when TFWW is small compared to the available water supply, in which case values of water stress approach zero.

Since the indicator was introduced in 2015, it has been used widely to estimate the level of water stress experienced at the country or regional level. While this has been a useful tool to assess water stress on a large scale, it has not accounted for much of the spatial and temporal trends that dictate how water stress is experienced at the local level. Specifically, some basins within a country may have plenty of water relative to water demands, while other areas experience regular periods of water shortage.

The water stress plugin was developed by FAO in collaboration with SEI's U.S. Center to let countries calculate the level of water stress (SDG 6.4.2) at basin level providing a different and more hydrologically sound view on the dynamics of water resources and their use. The water stress plugin was developed to allow decisionmakers to better visualize and understand the temporal and spatial trends of water stress within countries. The first version of the plugin, developed in 2022, calculates water stress on an annual basis. Future updates may include the ability to calculate water stress seasonally.

The **plugin** is available for download with this link:

https://storage.googleapis.com/fao-aquastat.appspot.com/SDG642/Water%20Stress.WEAPPlugin

The plugin was applied for the first time during the training on WEAP for SDG 6.4.2 developed by FAO in collaboration with SEI in 2022. A complete package of WEAP for SDG 6.4.2 training materials were developed that cover: building a WEAP model from scratch, hydrologically and operationally calibrating the WEAP model, structuring of scenarios including climate change, as well as use of the WEAP water stress plugin.

The **WEAP for SDG 6.4.2 training materials** are available for download with this link:

https://storage.googleapis.com/fao-aquastat.appspot.com/SDG642/WEAP_SDG642_EN.zip

Summary of the water stress plugin

The water stress plugin was developed to be used along with WEAP's soil moisture method (SMM) hydrology module, because the calculation relies on estimates of annual precipitation, evapotranspiration, and groundwater recharge for each sub-basin. As such, the SMM hydrology routines should be calibrated before using the water stress plugin.

To prepare your model for using the WEAP Plugin, be sure that your EFRs have been calculated including future dates, and that all EFRs have been assigned the highest priority so that they are always met, as the calculation of the SDG requires that EFRs be met.

The plugin allows exploring the spatial and temporal trends of the level of water stress (SDG 6.4.2) within a basin taking advantage of the existing features of the WEAP system to calculate water stress for a set of user-defined sub-basins (SB's). With this plugin the user will be able to assess the level of water stress at basin scale, avoiding any double counting of its freshwater resources because, for each sub-basin, the water supplies will be calculated taking into account the water demands of their neighbouring hydrological units. It was designed as a portable module that can be applied in any basin with some requirements that are summarized below.

The WEAP model uses a collection of several objects to simulate water movement throughout a basin, where each object contributes in some way to the overall water balance at the basin scale and the water balance within smaller sub-basins. Thus, calculating each of the terms used in the equation above involves an accounting of the stocks and flows associated with each WEAP object. For example, to calculate the total freshwater withdrawals (TFWW) we need to know for each sub-basin direct river abstractions, groundwater pumping, and changes in reservoir storage. Similarly, to estimate the total renewable freshwater resources (TRWR) we need to know cumulative precipitation and evapotranspiration – which defines the overall freshwater supply – and how water resources are distributed between soil water storage, flows to rivers, and groundwater recharge.

As the WEAP model can, and often does, include dozens or even hundreds of model objects, the calculation of water stress can become quite complicated.

For this reason, a plugin was created that automates the process of calculating water stress. As we will discover, the plugin includes the use of generalized scripts that delineate sub-basins based on user input and that calculate water stress based on WEAP results.

Approach

Environmental flow requirement (EFR)

The WEAP software includes a flow requirement object that behaves much the same as a demand object, except that it is non-consumptive. Like a demand object it must be assigned a demand priority, which determines the order in which WEAP will allocate water to various water uses. These flow requirements can represent different water management objectives, include supporting aquatic/riparian habitat, maintaining flows for navigation, or various operational rules (e.g. flood control, inter-basin transfers, etc). In fact, WEAP applications commonly include flow requirements representing a mix of these objectives.

When using the water stress plugin it is important to identify the flow requirements that are intended to be used within the calculation of water stress. These flow requirements represent the flows required to support environmental objectives within each sub-basin. As such, the first thing that must be done once the plugin has been installed is to indicate which flow requirements will be used in the calculation of water stress. You may need to insert and calculate new environmental flow requirements specifically for the purpose of delineating sub-basins for which to calculate water stress.

There are two points to make about the EFR that is used to calculate water stress. First, it is important that each sub-basin has an EFR at its most downstream point. Doing so keeps the calculation of water stress consistent with the intent of the equation. For example, if an EFR were placed upstream of demands within a sub-basin, then the same water could be used to meet both the EFR and the water demands (TFWW), which is inconsistent with the equation for water stress. Secondly, EFR’s should be given the highest priority for water, because the water stress equation estimates the volume of water available for TFWW assuming EFR is fully met.

Your basin may have locally-defined environmental flow requirements. If not, and you are interested in using the flow-duration curve shift method, WEAP has a built in function that you can use to calculate environmental flow requirements at each EFR location. See Appendix C. Whatever method is used to define the EFR's, there should be enough water in the system to meet them. For example, if we specify that EFR's are equal to the Q90 flows[1] then we would expect that unregulated flows at that location will be lower than the EFR ten percent of the time. If we were to calculate water stress in periods when flow is less than the EFR, then it is likely that the denominator in Equation 1 will become negative, leading to a negative water stress. For this reason, it is suggested to use either a percentage of unregulated (i.e. natural) flows or the FDC shift function.

Total renewable freshwater resources

The TRWR for any given SB is equal to the freshwater generated within a SB plus the water transferred into the SB. The freshwater generated within the SB is equal to the total annual rainfall minus losses to the atmosphere (i.e. evaporation from open water and evapotranspiration from non-irrigated areas). This water is either stored in soil, contributes to groundwater recharge, or flows directly to rivers and streams.

When calculating TRWR at the SB scale, we must consider that upstream SB's may forgo using supplies and leave water in the river for use downstream. Similarly, they could transfer water to downstream SB's via a canal or pipeline. In either case, these transfers are subtracted from TRWR of the upstream SB and added to the TRWR of the downstream SB. This approach assures that this water is not double counted and has the effect of increasing water stress in the upstream SB, because it decreases its TRWR, while simultaneously reducing water stress in the downstream SB, because it increases the value of the denominator (i.e. TRWR – EFR) in the water stress equation.

Total freshwater withdrawn

The TFWW for any given SB is equal to the volume of water taken from the river plus the amount of water pumped from the groundwater.

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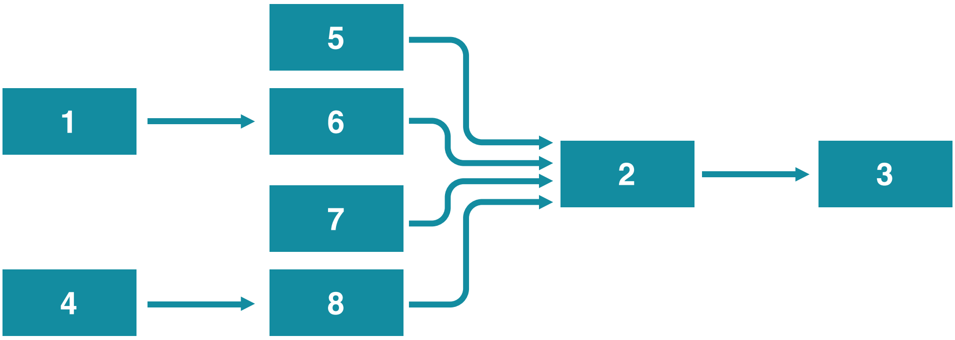
[1] Q90 flow is the flow rate that is exceeded 90 percent of the time.

Connectivity of sub-basins

The water stress plugin includes a script that assesses the location of each SB relative to each other, which is run in Step #3 above. The script produces a square matrix whose dimension (i.e. number of rows and columns) is determined by the number of EFR's that are used to define the downstream location for each SB.

Table 1 shows an example of a connectivity matrix for a basin with eight SB's. The connections between the basins shown in this matrix is illustrated in Figure 1. When read across for a single row, the matrix indicates which SB is downstream. There should be zero downstream SB's for the SB at the basin outlet and only one downstream SB for all others. When read vertically, the sum of the values indicates the number of SB's that are immediately upstream of a single SB. Headwater SB's should have zero upstream SB's, while other SB's may have many SB's that are directly upstream. The SB numbers are not assigned based on their location within the basin. Rather they are arranged alphabetically by WEAP. The script that creates the connectivity matrix also assigns each WEAP object (i.e. demand nodes, catchments, reservoirs, groundwater node) to one of the SB's. These values appear in WEAP in the variable 'SubBasin Number' and should be checked for accuracy.

Figure 1: Schema of sub-basin connections



Source: Authors' own elaboration.

Table 1. Matrix showing position of each sub-basin relative to its neighboring sub-basin(s). (This information is saved in the file SBConnectivity.csv)

	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	Number of SB's Immediately Downstream
SB1	0	0	0	0	0	1	0	0	1
SB2	0	0	1	0	0	0	0	0	1
SB3	0	0	0	0	0	0	0	0	0
SB4	0	0	0	0	0	0	0	1	1
SB5	0	1	0	0	0	0	0	0	1
SB6	0	1	0	0	0	0	0	0	1
SB7	0	1	0	0	0	0	0	0	1
SB8	0	1	0	0	0	0	0	0	1
Number of SB's immediately upstream	0	4	1	0	0	1	0	1	

Source: Authors' own elaboration.

This connectivity matrix is key to the calculation of water stress at the SB level, because it is later used to calculate how water is transferred between SB's.

Water transfers

Water can be transferred between SB's either by diverting water from one SB into a canal/pipeline and conveying it to another SB or by leaving water in the river so that it may be used further downstream. Both methods of transfer are considered in the calculation of water stress. In the first case, the water transfer is explicit and clear. The second case, where water is left in the river, is less clear, because the excess water that remains in the river may be greater than the water requirements downstream. For this reason, we need to evaluate the water surpluses and deficits within each SB and use the connectivity matrix to assess how the surplus water from one SB may be used to satisfy deficits in downstream SB's.

Once the WEAP model is run, we can access results to calculate annual water surplus or deficit within each SB. To do this, we use the following equation to assess the water balance of each SB:

Water Balance = Flow to river + Groundwater recharge + Imported water[2] *– River withdrawals – Groundwater pumping – Exported water*[3] *– EFR increase*[4]

A positive water balance indicates that there was more water available than was needed to satisfy the consumptive use and EFR increase within the SB – i.e. a water surplus. A negative water balance indicates that the SB relied on water flowing into the SB from upstream sources – i.e. a water deficit. Thus, a SB can either have a water surplus or a water deficit, but not both.

Once water surpluses and deficits have been calculated, we use the connectivity matrix to evaluate how water can be transferred between SB's. The connectivity matrix shown in Table 1 is used to create a similar matrix that shows the connection of all SB's (Table 2). For example, if we read across a single row, we can see which SB's can receive transfers for the SB of that row. Similarly, if we read vertically for a single column, we can see which SB's can be called upon to transfer water to the SB of that column.

---

[2] Imported water is water conveyed into a SB by way of a canal or pipeline

[3] Exported water is water conveyed out of a SB by way of a canal or pipeline

[4] EFR increase is equal to the EFR at the downstream point of the SB minus the sum of all EFR's upstream. This indicates how much the total EFR increases as a result of water that is generated within the SB under consideration.

Table 2. Matrix showing the position of each sub-basin relative to all other sub-basins. (This information is saved in the file ConnectAll.csv)

		SB2	SB3	SB4	SB5	SB6	SB7	SB8	Total Number of SB's Downstream
SB1	0	1	1	0	0	1	0	0	3
SB2	0	0	1	0	0	0	0	0	1
SB3	0	0	0	0	0	0	0	0	0
SB4	0	1	1	0	0	0	0	1	3
SB5	0	1	1	0	0	0	0	0	2
SB6	0	1	1	0	0	0	0	0	2
SB7	0	1	1	0	0	0	0	0	2
SB8	0	1	1	0	0	0	0	0	2
Total Number of SB's Upstream	0	6	7	0	0	1	0	1	

Source: Authors' own elaboration.

This matrix is used as the basis for calculating "in-river" water transfers. Immediately, we see that all zero entries within the matrix indicate that there is no connection between the two SB's, so there can be no water transferred. We then need to calculate the amount of water transferred for the entries with values of 1. Let's take an example of a case where we have calculated the water balance for each SB and found that the total surplus exceeds the total deficit (Table 3).

Table 3. Sample water balance for 8x8 matrix

	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	Total Surplus or Deficit
Water surplus	50	0	0	10	25	25	25	0	135
Water deficit	0	40	50	0	0	0	0	10	100

Source: Authors' own elaboration.

The first thing that we do is to add this information to the matrix, with the surplus water added as a final column on the right and the water deficit added as a final row. Next, we can zero out any entry within the matrix that aligns with a zero surplus or deficit. For example, in row two of the matrix below (Table 4), we know that SB2 could theoretically transfer some of its surplus to SB3. However, SB2 has no surplus to share, so the entry must be zero. Similarly, in column six of the matrix, we know that SB6 can receive water from SB1. However, SB6 has no deficit, so that entry must also be zero.

Table 4. Water transfers matrix (with unknown transfer values)

	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	Total surplus available
SB1	0	?	?	0	0	0	0	0	50
SB2	0	0	0	0	0	0	0	0	0
SB3	0	0	0	0	0	0	0	0	0
SB4	0	?	?	0	0	0	0	?	10
SB5	0	?	?	0	0	0	0	0	25
SB6	0	?	?	0	0	0	0	0	25
SB7	0	?	?	0	0	0	0	0	25
SB8	0	0	0	0	0	0	0	0	0
Total deficit	0	40	50	0	0	0	0	10	

Source: Authors' own elaboration.

To fill in the rest of the matrix, we consider the matrix one column at a time, starting with the columns that have only one upstream SB, continuing with columns that indicate two upstream SB's, and so forth until we reach the outlet of the basin (in this case SB3). In our example, SB6 and SB8 each have only one upstream SB, but only SB8 has a deficit. Because only SB4 is upstream, all of the deficit in SB8 must have come from SB4. The water is allocated as such and if SB4 had any remaining surplus that would be made available to other downstream SB's (i.e. SB2 and SB3). Since SB8 took all of the available surplus water from SB8, no additional transfers can be made out of SB4.

In this example, the next SB with a deficit that is encountered is SB2, who has six upstream SB's (Table 2). We have already seen, though, that it cannot receive water from SB4 or SB8, so only four upstream SB's can send it water. To calculate how much water is transferred, we look at the total surplus available (125 = 50 + 25 + 25 + 25) and allocate the transfers according to their proportion of that total. In this case, SB1 sends a total of 16 units, which is equal to 40 * 50 / 125. The other SB's each have a surplus of 25 and will send equal amounts to SB2 (i.e. 8 = 40 * 25 / 125). These transfer amounts are deducted from the total surplus to know how much water is then available to any SB's downstream. In this case SB3. So, when the routine proceeds to SB3 (who has seven upstream SB's), it knows that the total available water for transfer is now 85 units (125 – 40) and it continues to allocate water transfers in the same fashion. In the end, there are an additional 35 units of water that are not considered as transferred water.

Table 5. Water transfers matrix (with transfer values)

	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	Total downstream reserve
SB1	0	16	20	0	0	0	0	0	36
SB2	0	0	0	0	0	0	0	0	0
SB3	0	0	0	0	0	0	0	0	0
SB4	0	0	0	0	0	0	0	10	10
SB5	0	8	10	0	0	0	0	0	18
SB6	0	8	10	0	0	0	0	0	18
SB7	0	8	10	0	0	0	0	0	18
SB8	0	0	0	0	0	0	0	0	0
Total upstream request	0	40	50	0	0	0	0	10	

Source: Authors' own elaboration.

The values in Table 5 are used in the calculation of water stress and are referred to as ‘downstream reserve’ from the perspective of the upstream SB and as ‘upstream request’ from the perspective of the downstream SB.

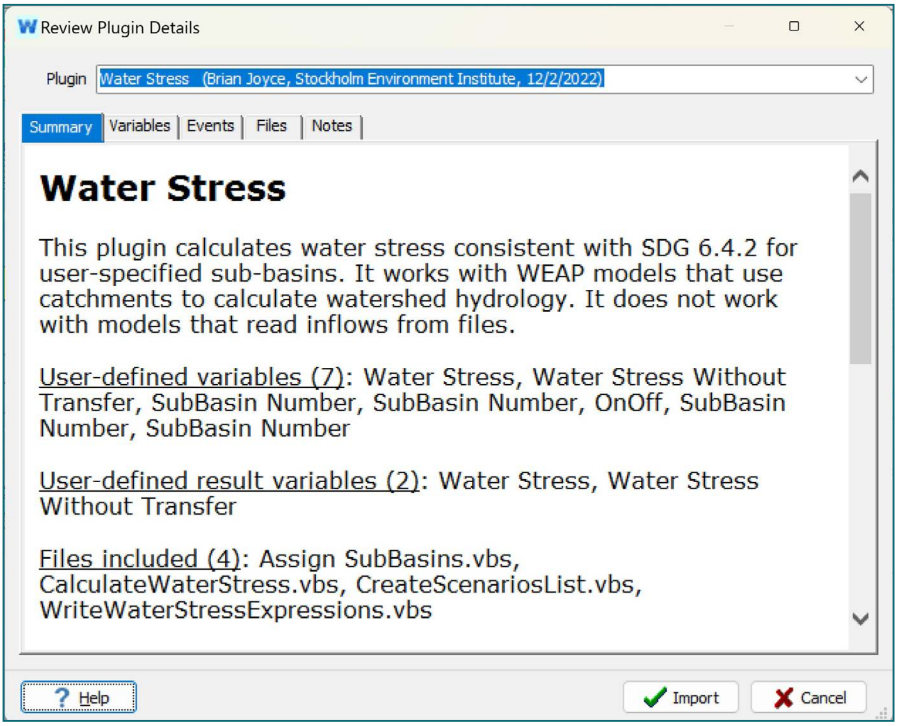
Quick Start

As a quick start to using the water stress plugin, the user can follow these steps:

Step 1: Import Water Stress plugin for water evaluation and planning tool

The water stress plugin must be imported into an existing WEAP application. To do this, open the WEAP area into which you want to install the plugin. Then navigate to the directory on your computer containing the file “Water Stress. WEAPPlugin” and double click the file and follow the prompts. Once this is installed, you can review the details of the plugin by going to the Advanced menu at the top of WEAP and selecting ‘Plugins’. This will bring up a window that summarizes details of the plugin.

Once the plugin is installed a screen will appear that summarizes contents of the plugin. This indicates that the plugin is intended to calculate water stress values consistent with SDG 6.4.2. and that currently it only works with WEAP models that use catchments to calculate watershed hydrology. The screen also indicates the seven user-defined variables, two user-defined result variables, and four files that will be added to the model.



Plugin: Water Stress (Brian Joyce, Stockholm Environment Institute, 12/2/2022)

Water Stress

This plugin calculates water stress consistent with SDG 6.4.2 for user-specified sub-basins. It works with WEAP models that use catchments to calculate watershed hydrology. It does not work with models that read inflows from files.

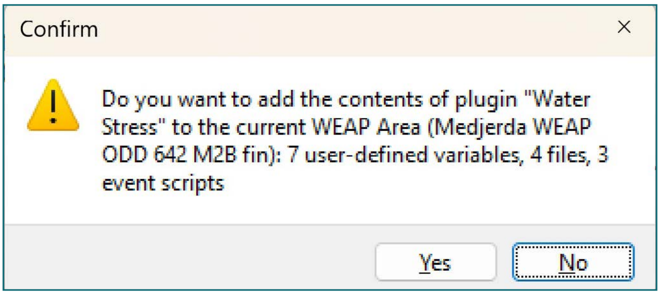
User-defined variables (7): Water Stress, Water Stress Without Transfer, SubBasin Number, SubBasin Number, OnOff, SubBasin Number, SubBasin Number

User-defined result variables (2): Water Stress, Water Stress Without Transfer

Files included (4): Assign SubBasins.vbs, CalculateWaterStress.vbs, CreateScenariosList.vbs, WriteWaterStressExpressions.vbs

Source: Water Evaluation and Planning Tool, modified by the authors.

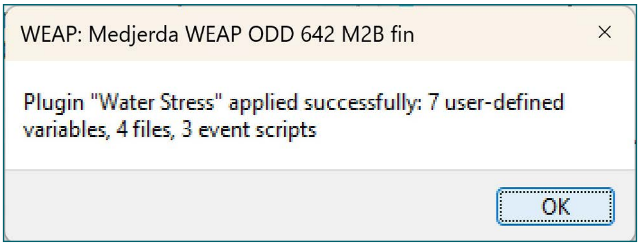
Select the ‘Import’ option and you will be prompted to confirm the installation of the plugin. Click on "Yes"



Do you want to add the contents of plugin "Water Stress" to the current WEAP Area (Medjerda WEAP ODD 642 M2B fin): 7 user-defined variables, 4 files, 3 event scripts

Source: Water Evaluation and Planning Tool, modified by the authors.

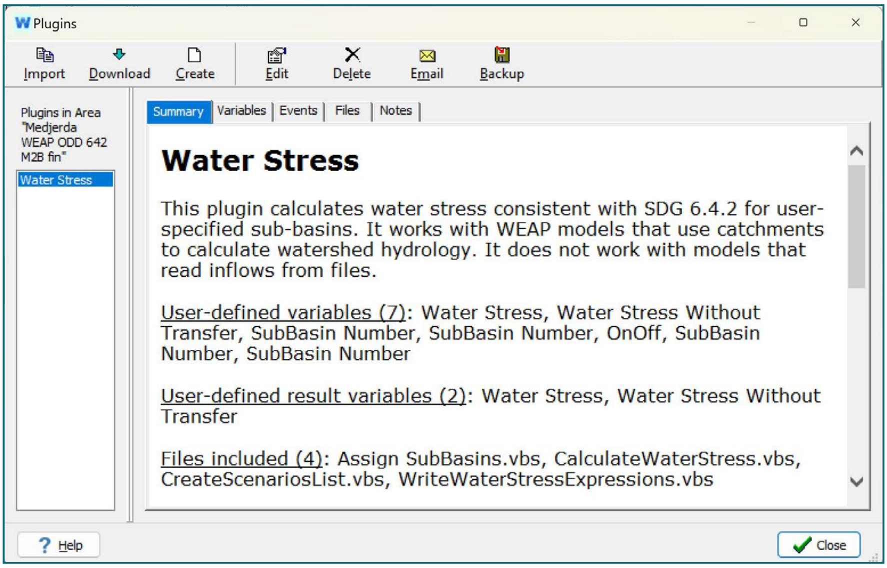
You will also be prompted to let you know that the installation was successful.



Plugin "Water Stress" applied successfully: 7 user-defined variables, 4 files, 3 event scripts

Source: Water Evaluation and Planning Tool, modified by the authors.

Once the plugin has been installed, you will see another screen that allows you to manage plugins. While you do not need to use any of these features for the water stress plugin, you can use this screen to edit, delete, backup, or share plugins. You can return to this screen by selecting ‘Plugins’ under the ‘Advanced menu’ at the top of the main WEAP screen. For now, we will close this window to complete the installation of the plugin.



Water Stress

This plugin calculates water stress consistent with SDG 6.4.2 for user-specified sub-basins. It works with WEAP models that use catchments to calculate watershed hydrology. It does not work with models that read inflows from files.

User-defined variables (7): Water Stress, Water Stress Without Transfer, SubBasin Number, SubBasin Number, OnOff, SubBasin Number, SubBasin Number

User-defined result variables (2): Water Stress, Water Stress Without Transfer

Files included (4): Assign SubBasins.vbs, CalculateWaterStress.vbs, CreateScenariosList.vbs, WriteWaterStressExpressions.vbs

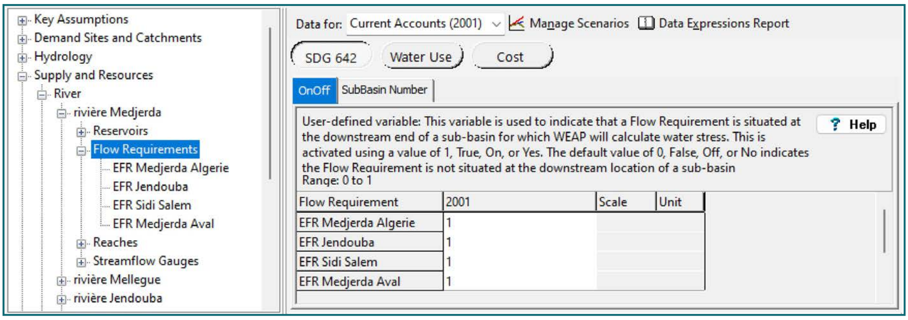
Source: Water Evaluation and Planning Tool, modified by the authors.

Step 2: Indicate which flow requirements will be used to define downstream locations for sub-basins

This is the step that requires the most user input. The equation for water stress includes an environmental flow requirement, which is deducted from the total water supply to determine the total available water for consumptive demands. As such, flow requirements are the one constant in each sub-basin and are, thus, used to define the downstream location of each sub-basin.

In WEAP's Data view, go to each flow requirement that will be used in the calculation of sub-basin water stress (note: only one per sub-basin) and select the 'SDG 642' button. Enter a value of 1 for the variable 'OnOff'. This sets the downstream point of the sub-basin.

For example, let's select the flow requirements on the Medjerda river (as shown below). Within the new tab, SDG 642, there are two new variables: 'OnOff' and 'SubBasin Number'. We will use the 'OnOff' variable to indicate which flow requirements we will use to define our sub-basins, where a value of one indicates that it is the downstream location of a sub-basin. In this case, we've entered values of 1 for each flow requirement.



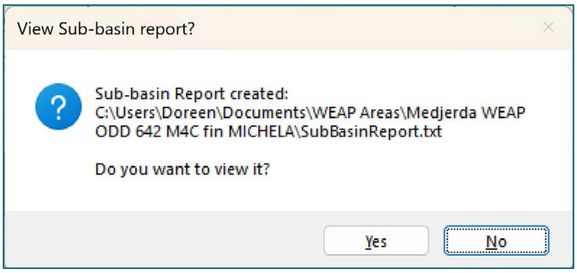
User-defined variable: This variable is used to indicate that a Flow Requirement is situated at the downstream end of a sub-basin for which WEAP will calculate water stress. This is activated using a value of 1, True, On, or Yes. The default value of 0, False, Off, or No indicates the Flow Requirement is not situated at the downstream location of a sub-basin
Range: 0 to 1

Flow Requirement	2001	Scale	Unit
EFR Medjerda Algerie	1		
EFR Jendouba	1		
EFR Sidi Salem	1		
EFR Medjerda Aval	1		

Source: Water Evaluation and Planning Tool, modified by the authors.

Step 3: Run 'Assign SubBasins.vbs' script to assign WEAP objects to sub-basins

In order to calculate water stress for each sub-basin, WEAP must associate any object not directly on a river (i.e. catchment, demand node, and groundwater objects) to one of the sub-basins defined in Step 2. This is done by going to the 'Advanced menu' at the top of the WEAP screen and selecting Advance -> Scripting -> Run -> Area Scripts -> Assign SubBasins.vbs.[5] When the script finishes running, you will be prompted to review a file (SubBasinReport.txt) that summarizes the assignment of all WEAP nodes to sub-basins.


View Sub-basin report?

Sub-basin Report created:
C:\Users\Doreen\Documents\WEAP Areas\Medjerda WEAP ODD 642 M4C fin MICHELA\SubBasinReport.txt

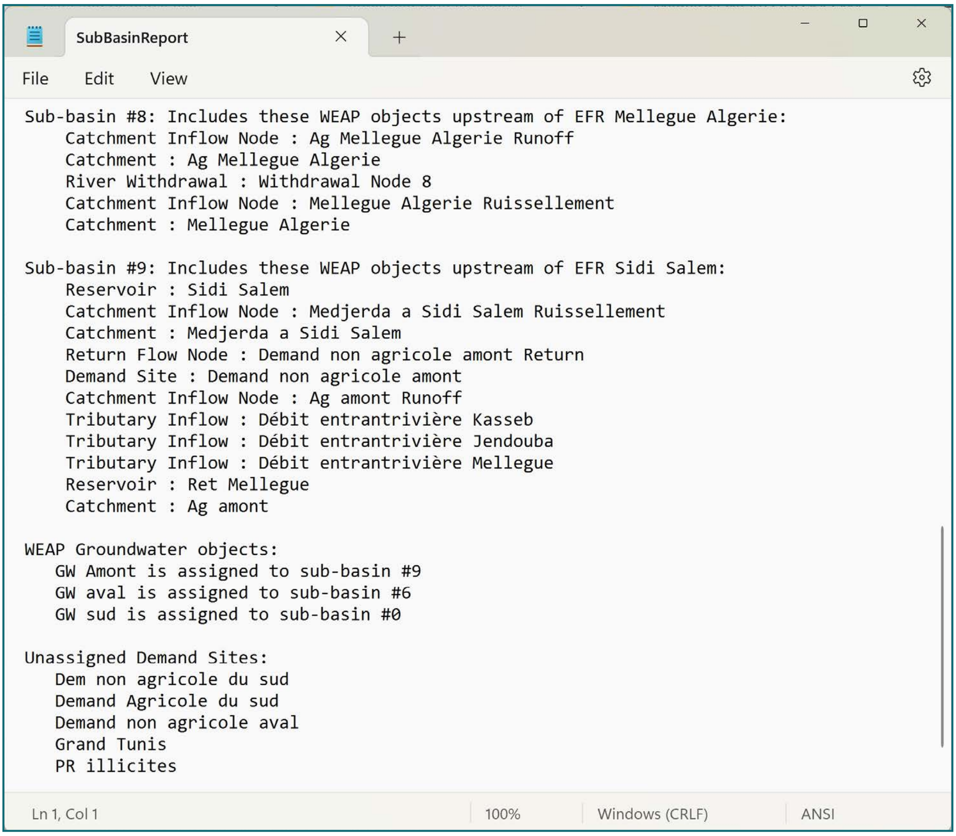
Do you want to view it?

Source: Water Evaluation and Planning Tool, modified by the authors.

---

[5] There is a known issue that this script occasionally returns an error reporting that a "Subscript is out of range". If you encounter this, you should restart WEAP. In every instance, the error has not reappeared after a restart.

Each sub-basin is given a subbasin number, which WEAP determines by the alphabetical order of the flow requirement names. If errors are discovered upon review of the file, the sub-basin assignment can be manually overridden by re-entering values in the ‘SubBasin Number’ variable.



```
Sub-basin #8: Includes these WEAP objects upstream of EFR Mellegue Algerie:
    Catchment Inflow Node : Ag Mellegue Algerie Runoff
    Catchment : Ag Mellegue Algerie
    River Withdrawal : Withdrawal Node 8
    Catchment Inflow Node : Mellegue Algerie Ruissellement
    Catchment : Mellegue Algerie

Sub-basin #9: Includes these WEAP objects upstream of EFR Sidi Salem:
    Reservoir : Sidi Salem
    Catchment Inflow Node : Medjerda a Sidi Salem Ruissellement
    Catchment : Medjerda a Sidi Salem
    Return Flow Node : Demand non agricole amont Return
    Demand Site : Demand non agricole amont
    Catchment Inflow Node : Ag amont Runoff
    Tributary Inflow : Débit entrantrivière Kasseb
    Tributary Inflow : Débit entrantrivière Jendouba
    Tributary Inflow : Débit entrantrivière Mellegue
    Reservoir : Ret Mellegue
    Catchment : Ag amont

WEAP Groundwater objects:
   GW Amont is assigned to sub-basin #9
   GW aval is assigned to sub-basin #6
   GW sud is assigned to sub-basin #0

Unassigned Demand Sites:
   Dem non agricole du sud
   Demand Agricole du sud
   Demand non agricole aval
   Grand Tunis
   PR illicites
```

Source: Water Evaluation and Planning Tool, modified by the authors.

Step 4: Run water evaluation and planning tool and explore results

Once the sub-basins are defined and WEAP nodes are assigned to sub-basins, then water stress can be calculated. Run the WEAP model (click on results), and another Visual Basic script (CalculateWaterStress.vbs) will run automatically at the end of the WEAP simulation (refer to Appendix A for more details). If the script does not run automatically, try pressing the CTRL key while you click on results. When the script has finished running, you will be prompted to open a summary file. You may choose to open if you wish to review the variables that were used in the calculation of water stress for each sub-basin.

The script creates text files that are read into WEAP and can be viewed in both the Data view and the Results view. In the Data view, the results can be seen by selecting the 'Water Stress' variable associated with WEAP catchment objects. These same values can be viewed in Results view by selecting 'Water Stress' from the set of results offered under 'Catchments'.

To visualize how water stress varies spatially across the sub-basins and temporally across the simulation years, select the Map tab at the top of the Results view. Then select Catchments from the Result Layer options at the top right of the screen. Finally, choose 'Water Stress' from the list of result options at the top left of the screen. This will display a map of the sub-basins coloured according to their water stress. To see how these values change over time, drag the slider at the bottom of the screen.

[Note: Visualizing water stress across the basin within the Map tab is only possible when a shapefile of the sub-basins is present. WEAP creates this automatically when catchments are added using WEAP's catchment delineation feature. Otherwise, the shapefile must be added to the schematic and linked to the catchments. This approach is described in Appendix B]

Step 5 (optional): Create scenarios to explore vulnerability under anticipated future conditions and/or to identify promising mitigation strategies

The water stress plugin can be used to explore spatial and temporal trends, but its main utility lies in the exploration of different scenarios to see first how these trends might change in the future and then to identify promising interventions that may help to alleviate water stress in key locations. Note that if a scenario variable (such as precipitation) has an impact on unimpeded streamflows, you will need to re-calculate EFRs for that scenario.

Calculating water stress for each sub-basin

Once the ‘in-river’ water transfers are calculated we have all the information needed to calculate the terms used in Equation 1, where the terms are:

TFWW = River Withdrawals + Groundwater Pumping

TRWR = Flow to River + Groundwater Recharge +Imported Water -Exported Water + Upstream Request - Downstream Reserve

EFR = EFR Increase

By discounting the downstream reserve from the TRWR, this configuration of water stress implies that the transfer represents a transaction occurring between parties in both the source and receiving SB’s. That is, the upstream SB is foregoing its use of that water in a way that increases its water stress. It may be that the upstream SB simply lacks the means to capture or use that water, in which case the water is simply flowing freely downstream. Accounting for this as part of TRWR artificially increases the water stress of the upstream SB. As such, a second water stress metric is calculated that removes downstream reserve from the TRWR of the upstream SB, while continuing to account for that water as part of the downstream users TRWR. Thus, the two water stress metrics can be viewed as bookends depending upon the contractual agreements within the basin.

Viewing and interpreting results

Once we have set up the water stress plugin we can then run the model and assess the water stress values calculated for each sub-basin. The plugin will calculate annual water stress values at the sub-basin level for each scenario that is run in WEAP. For now, we have selected only one scenario: 2020 population.

A prompt will appear at the conclusion of running the water stress script asking if you’d like to view a summary report of the water stress calculations. This report shows the aggregated variables used in the calculation of water stress for each SB in each year of the simulation. We can use this to gain a deeper understanding of the water balance within each SB. For example, the summary below indicates that SB1 reserved 1.11 MCM for downstream use from a total of 3.168 MCM of surplus water. This transfer increased the water stress in SB1 from 80 to 86 percent in the first year of the simulation (2001).

Figure 2. Example calculation of annual water stress for a single sub-basin

```
Sub-basin Report, 21/06/2023

This file shows the values used to calculate annual water stress for each sub-basin

Water Stress = TFWW/(TRWR - EFR)
where
TFWW = River Withdrawals + Groundwater Pumping

TRWR = Flow to River + Groundwater Recharge +Imported Water -Exported Water + Upstream Request -
Downstream Reserve

EFR = EFR Increase

Water Stress (without transfer) assumes that Downstream Reserve is equal to zero and all other terms are the
same as above.

***************************************************************************************************************************************************
Scenario:     Current Accounts
***************************************************************************************************************************************************
Year: 2001
***************************************************************************************************************************************************
SB1: above EFR Ben Metir
     Flow to River                   = 17.07 (MCM)
     Groundwater Recharge            = 0 (MCM)
     River Withdrawals               = 0.064 (MCM)
     Groundwater Pumping             = 0 (MCM)
     Exported Water                  = 12.376 (MCM)
     Imported Water                  = 0 (MCM)
     EFR Increase                    = 1.463 (MCM)
     EFR Total                       = 1.463 (MCM)

     Local Surplus                   = 3.168 (MCM)
     Local Deficit                   = 0 (MCM)
     Downstream Reserve              = 1.11 (MCM)
     Upstream Request                = 0 (MCM)

     TRWR                            = 15.96 (MCM)
     TFWW                            = 12.44 (MCM)
     EFR Increase                    = 1.463 (MCM)
     Water Stress                    = 86%
     Water Stress (without transfer) = 80%
```

Source: Water Evaluation and Planning Tool, modified by the authors.

Please note that this file will be created each time WEAP updates results and will only include results for the scenarios that were most recently run. Therefore, if you would like to keep the information from previous model runs you should rename the file so that it is not overwritten.

After reviewing the water stress calculations, we are prompted again to review a summary of the water transfers. This file contains a matrix for each year of the simulation that shows how water is being transferred from one SB to another. For example, we can see that the 1.11 MCM of downstream reserve in SB1 is all going to meet a deficit in SB9, which also receives water from SB2, SB4, SB5, SB7, and SB8 in the year 2001.

Figure 3. Example summary of water transfers between sub-basins

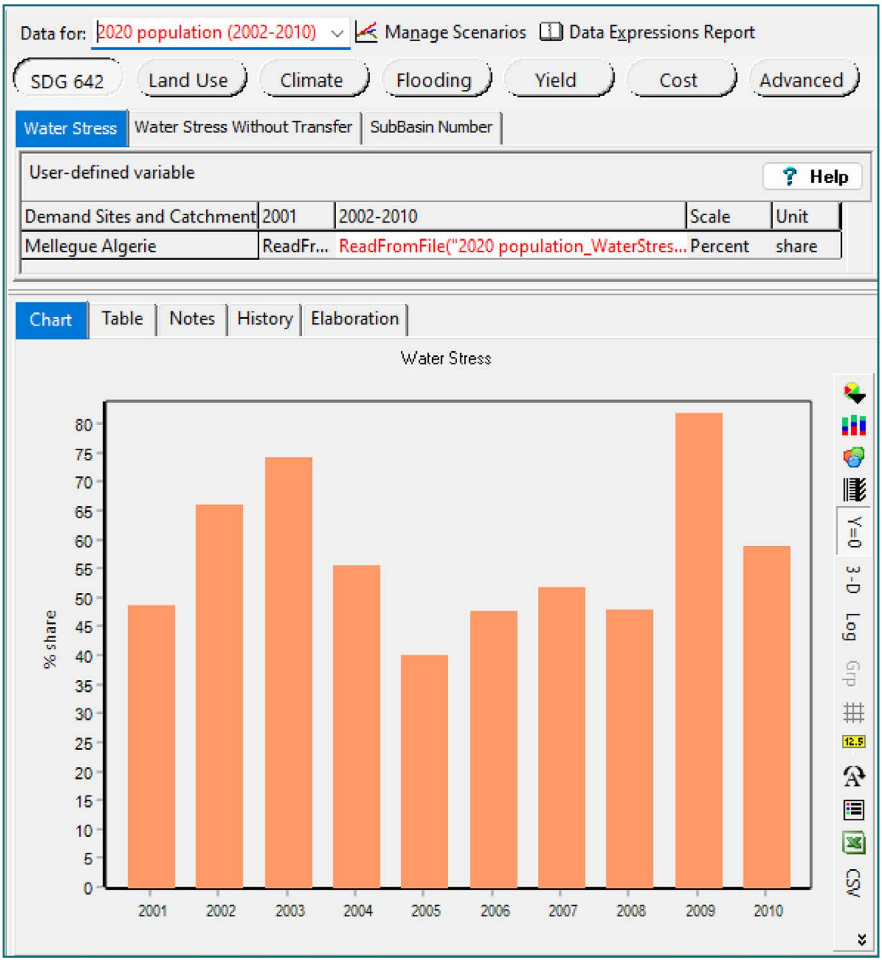
This file summarizes annual water transfers between sub-basins, where each year in the simulation is presented as a matrix. Within the matrix, rows represent the source (from) sub-basin and columns represent the receiving (to) sub-basin. For example, to understand the total water coming into SB2 from all upstream SBs, sum the entries for column SB2.

```
**************************************************************************************************************************************************************
Scenario:   Current Accounts
**************************************************************************************************************************************************************
Year: 2001
**************************************************************************************************************************************************************
       SB1      SB2     SB3     SB4     SB5     SB6     SB7     SB8     SB9        Total
                                                                                   (Sent to Downstream SBs)
SB1    0        0       0       0       0       0       0       0       1.11        1.11
SB2    0        0       0       0       0       0       0       0       4.219       4.219
SB3    0        0       0       0       0       0       0       0       0           0
SB4    0        0       0       0       0       0       0       0       3.177       3.177
SB5    0        0       5.487   0       0       0       0       0       17.08       22.568
SB6    0        0       0       0       0       0       0       0       0           0
SB7    0        0       0       0       0       0       0       0       31.21       31.21
SB8    0        0       0       0       0       0       0       0       66.308      66.308
SB9    0        0       0       0       0       0       0       0       0           0
Total  0        0       5.487   0       0       0       0       0       123.104
(Received from Upstream SBs)
```

Source: Water Evaluation and Planning Tool, modified by the authors.

Once we've reviewed the calculations, we can explore the water stress results in both the Data view and in the Results view. Let's explore this first in the Data view. In the graphic below, we are looking at water stress for the catchment object Mellegue Algerie for the scenario '2020 Population', which we ran for the period 2001-2010. This indicates that the water stress can be quite high in this part of the basin, ranging between 45 and 80 percent.

Figure 4. Viewing water stress for a single sub-basin in the Data view



Data for: 2020 population (2002-2010)

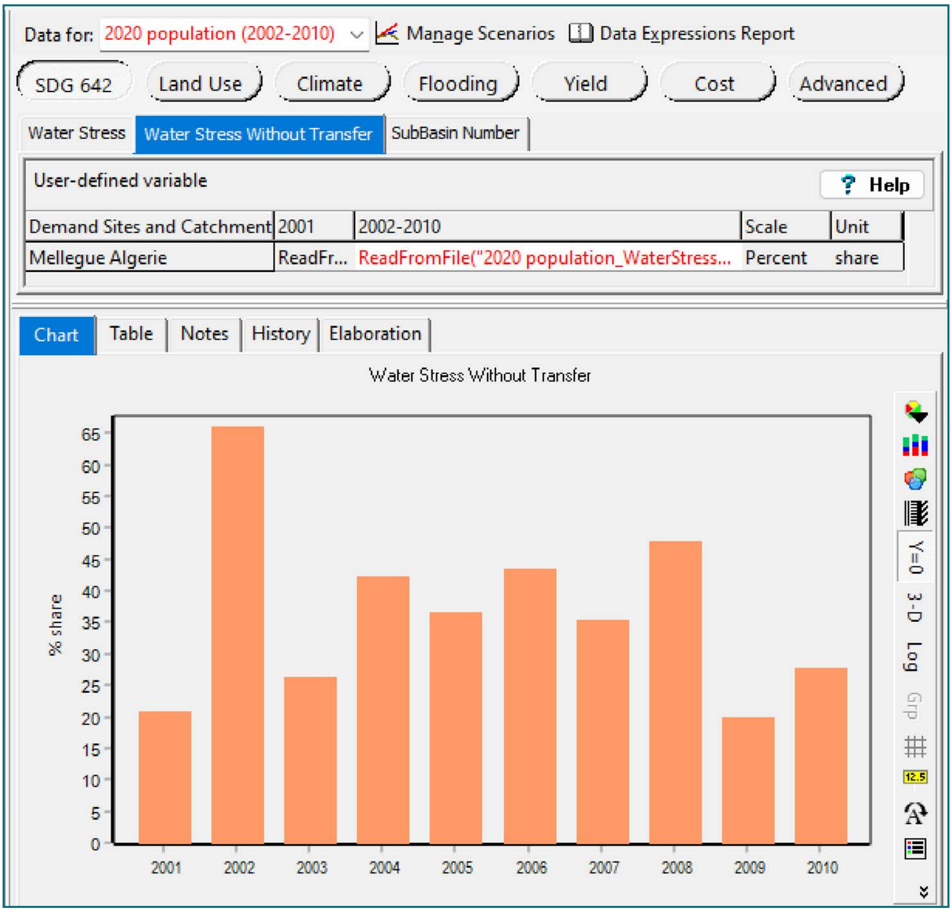
User-defined variable

Demand Sites and Catchment	2001	2002-2010	Scale	Unit
Mellegue Algerie	ReadFr...	ReadFromFile("2020 population_WaterStres...	Percent	share

Source: Water Evaluation and Planning Tool, modified by the authors.

However, if we then look at ‘Water Stress Without Transfer’ we can see that the average stress is quite a bit lower. This suggests that the water stress is high only if the SB is foregoing using the water so that it can be accessed downstream. If that is not a deliberate choice on the part of ‘Mellegue Algerie’ and it is simply letting excess water stay in the river, then its water stress is on the order of 20 to 65 percent.

Figure 5. Viewing water stress without transfers for a single sub-basin within the Data view



Data for: 2020 population (2002-2010)

User-defined variable

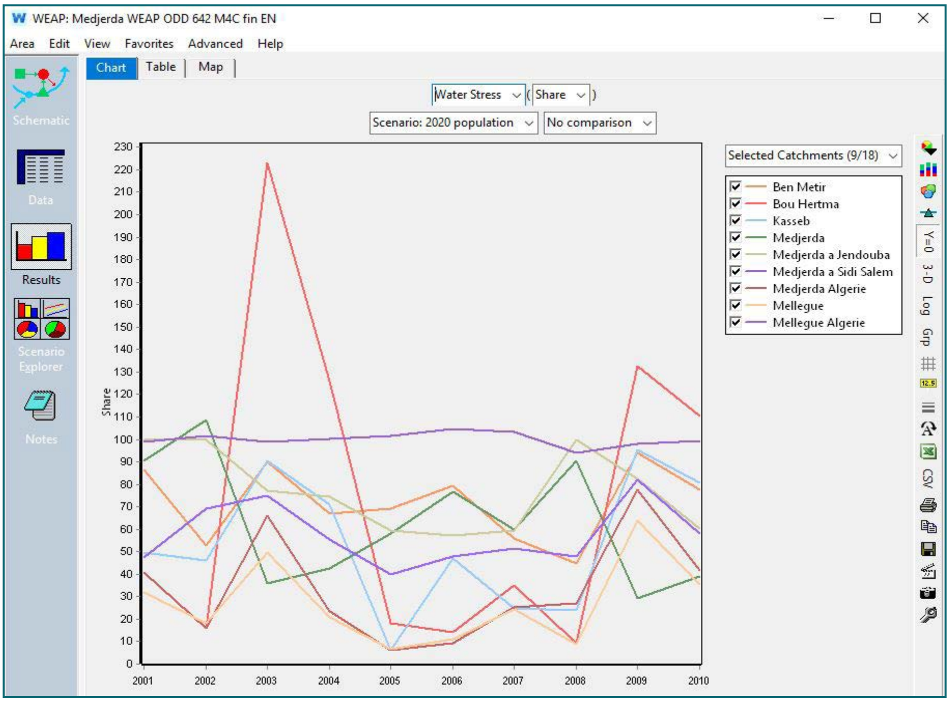
Demand Sites and Catchment	2001	2002-2010	Scale	Unit
Mellegue Algerie	ReadFr...	ReadFromFile("2020 population_WaterStress...	Percent	share

Source: Water Evaluation and Planning Tool, modified by the authors.

If we want to view water stress for many SB's at the same time so that we can see how SB's compare, then we have to go to the Results View. In the graphic below, we have chosen the result Catchments -> Water Stress. This shows that most SB's have water stress that range from around 10 to 220 percent.

When we look at the water stress without transfers we notice that water stress in most SB's decreases substantially. The difference between these two result values suggests how much water transfers are contributing their overall water stress. We notice too that the water stress in SB9 (Medjerda à Sidi Salem), which relies on water transfers to meet demands, remains the same, because its overall water balance does not change.

Figure 6. Viewing timeseries of water stress for all sub-basins in Results view



Water Stress (Share)

Scenario: 2020 population

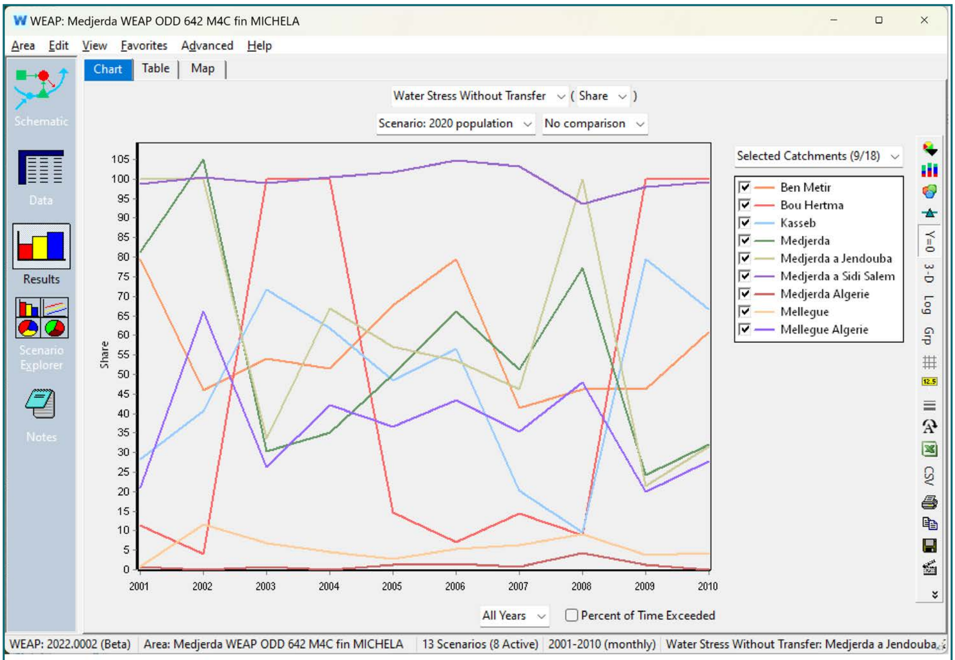
No comparison

Selected Catchments (9/18)

- ☑ Ben Metir
- ☑ Bou Hertma
- ☑ Kasseb
- ☑ Medjerda
- ☑ Medjerda a Jendouba
- ☑ Medjerda a Sidi Salem
- ☑ Medjerda Algerie
- ☑ Mellegue
- ☑ Mellegue Algerie

Source: Water Evaluation and Planning Tool, modified by the authors.

Figure 7. Viewing timeseries of water stress without transfers for all sub-basins in Results view



Water Stress Without Transfer (Share)

Scenario: 2020 population

No comparison

Selected Catchments (9/18)

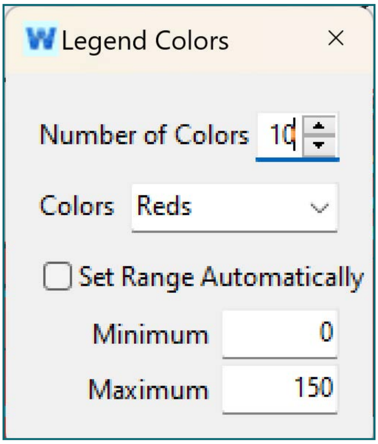
All Years

☐ Percent of Time Exceeded

WEAP: 2022.0002 (Beta) | Area: Medjerda WEAP ODD 642 M4C fin MICHELA | 13 Scenarios (8 Active) | 2001-2010 (monthly) | Water Stress Without Transfer: Medjerda a Jendouba,

Source: Water Evaluation and Planning Tool, modified by the authors.

Lastly, we will look at a map of water stress with and without water transfers. In the Results view, go to the Map tab and select 'Catchments' as the Result layer. Select 'Water Stress' from the results options on the left side of the screen. Then adjust the display by selecting the colour legend on the right hand side of the screen and choosing 'Reds' as the colour option and 10 as the number of bins.


Legend Colors

Number of Colors 10

Colors Reds

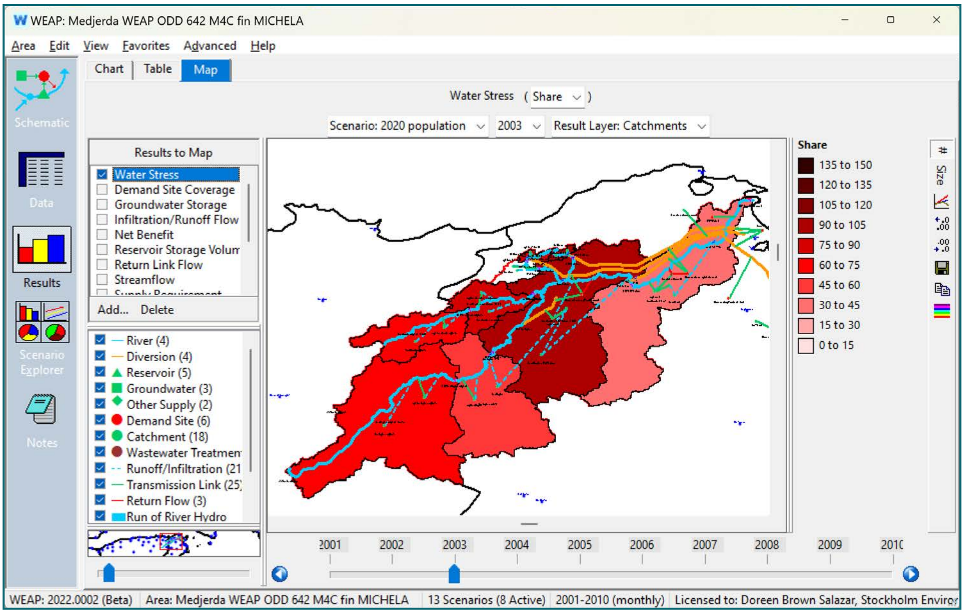
☐ Set Range Automatically

Minimum 0

Maximum 150

Source: Water Evaluation and Planning Tool, modified by the authors.

Figure 8. Viewing map of water stress for a single year in Results view



WEAP: Medjerda WEAP ODD 642 M4C fin MICHELA

Water Stress (Share)

Scenario: 2020 population

2003

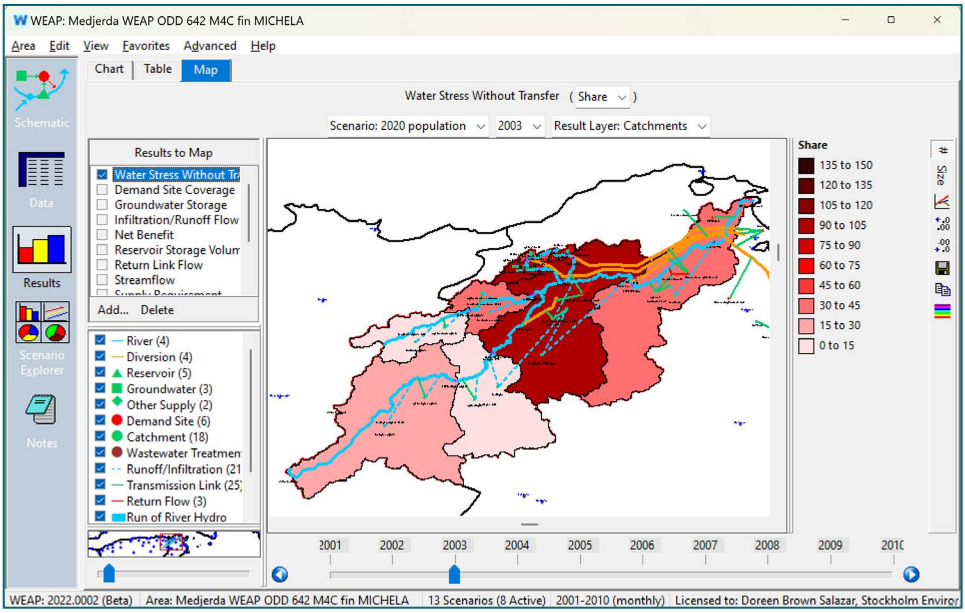
Result Layer: Catchments

WEAP: 2022.0002 (Beta) | Area: Medjerda WEAP ODD 642 M4C fin MICHELA | 13 Scenarios (8 Active) | 2001-2010 (monthly) | Licensed to: Doreen Brown Salazar, Stockholm Enviro

Source: Water Evaluation and Planning Tool, modified by the authors.

This map shows us how water stress varies across the basin for each year of the simulation. We can then use the slider at the bottom to choose which year to view. We can also toggle between the result values ‘Water Stress’ and ‘Water Stress without Transfers’ to see how water transfers affect the overall water stress.

Figure 9. Viewing map of water stress without transfers for a single year in Results view


WEAP: Medjerda WEAP ODD 642 M4C fin MICHELA

Water Stress Without Transfer (Share)

Scenario: 2020 population | 2003 | Result Layer: Catchments

Results to Map: ☑ Water Stress Without Tr

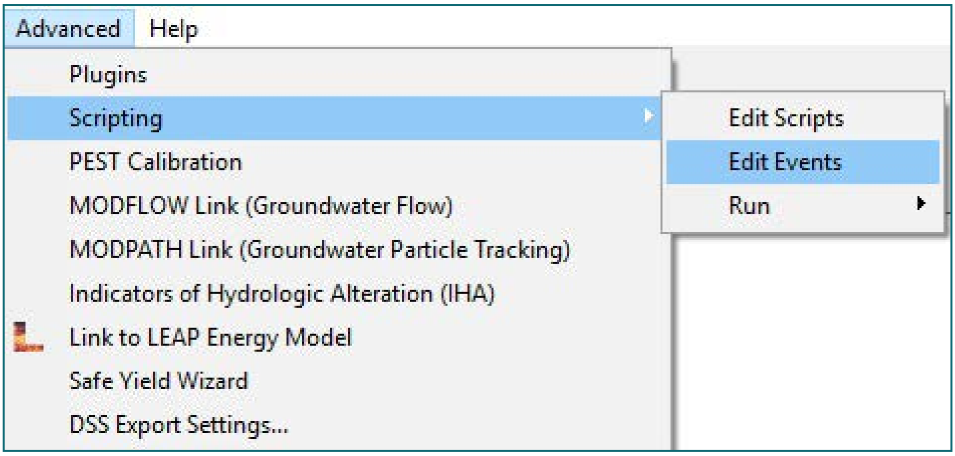
WEAP: 2022.0002 (Beta) | Area: Medjerda WEAP ODD 642 M4C fin MICHELA | 13 Scenarios (8 Active) | 2001-2010 (monthly) | Licensed to: Doreen Brown Salazar, Stockholm Enviro

Source: Water Evaluation and Planning Tool, modified by the authors.

So far, we have focused on viewing and interpreting water stress results for sub-basins in WEAP. It is important to understand that this is a measure of environmental water stress that considers how much of the available renewable water supplies within a sub-basin are being withdrawn on an annual basis.

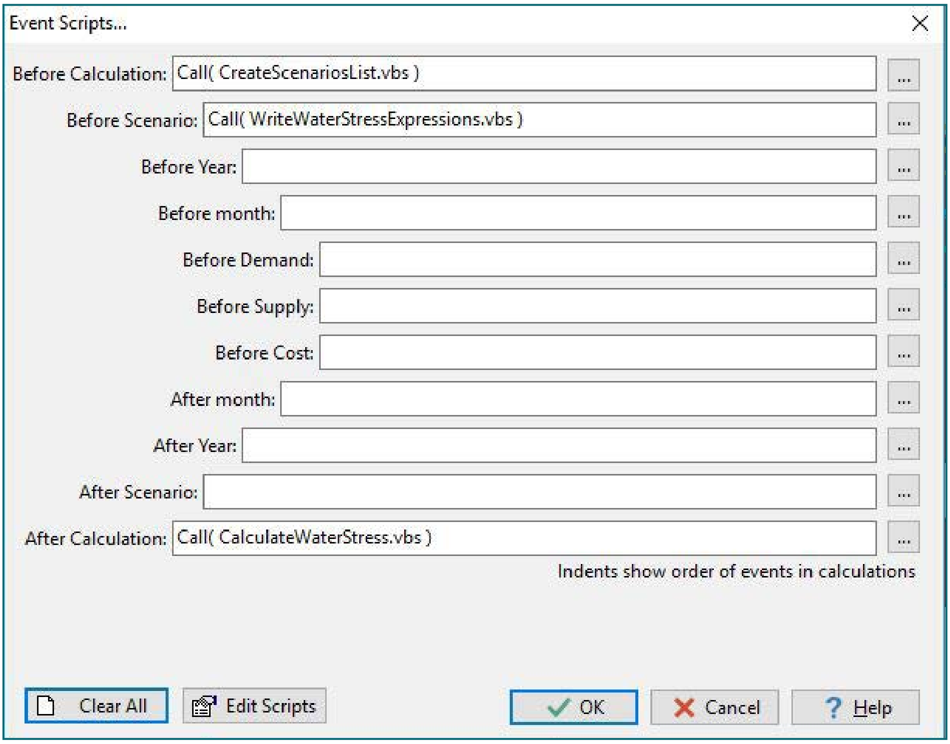
Appendix A: Event scripts

Event scripts are routines that are run outside of the standard WEAP simulation that can perform different tasks at selected points within the running of WEAP. To access the events scripts screen select Advanced -> Scripting -> Edit Events.



Source: Water Evaluation and Planning Tool, modified by the authors.

From the event scripts screen, notice that there are several places where scripts can be inserted before, during, or after WEAP's standard calculations. For the water stress plugin, WEAP runs three scripts: 1) 'CreateScenariosList.vbs' that runs before any calculations are performed by WEAP; 2) 'WriteWaterStressExpressions.vbs' that runs before each scenario; and 3) the script 'CalculateWaterStress.vbs' that runs after WEAP has completed calculations, which suggests that the reported values of water stress are post-processed from WEAP results, which indeed they are.



Event Scripts...

Before Calculation: Call(CreateScenariosList.vbs)

Before Scenario: Call(WriteWaterStressExpressions.vbs)

Before Year:

Before month:

Before Demand:

Before Supply:

Before Cost:

After month:

After Year:

After Scenario:

After Calculation: Call(CalculateWaterStress.vbs)

Indents show order of events in calculations

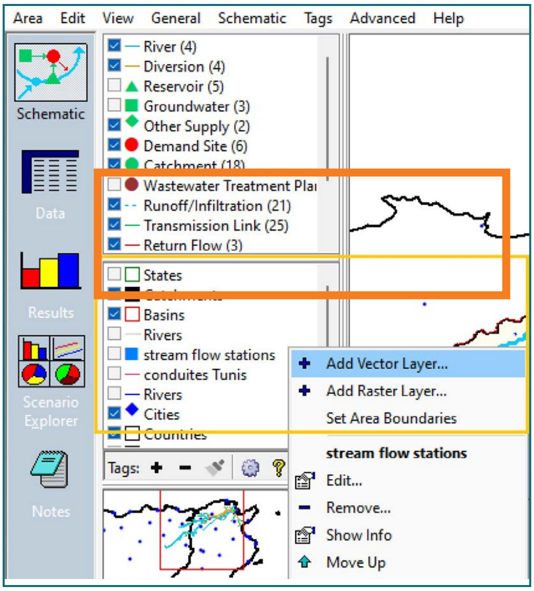
Source: Water Evaluation and Planning Tool, modified by the authors.

Appendix B: linking catchments to a shapefile

If you did not use WEAP catchment delineation feature to create catchment objects in WEAP, then it is necessary to link to a geographic information system (GIS) shapefile of catchments in order to visualize water stress as a map within WEAP Result view. This can be done following these steps:

Step 1: Import a shapefile into WEAP

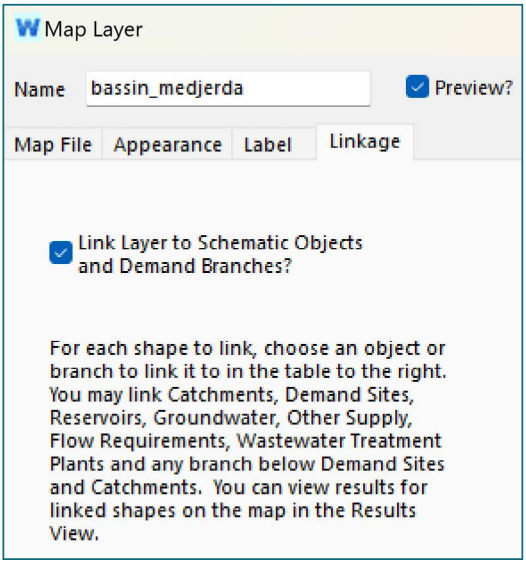
- First go to the Schematic view
- Right click on the pane containing background GIS layers
- Select 'Add Vector Layer'
- Navigate to where the file is located on your computer and click OK
- [Please note that the shapefile will need to have the same projection as the ones already within the WEAP model. WEAP's default projection is WGS 84 Geographic]



Source: Water Evaluation and Planning Tool, modified by the authors.

Step 2: Link catchments to polygons within the shapefile

- Double click on the name of the shapefile you just imported into WEAP
- Select the Linkage tab
- Click on “Link layer to schematic objects and demand branches
- At the bottom of the screen use the button “Guess linkages by location”
- Using the table, double click on Branch name to edit any linkages that are missing or incorrect
- Click OK to finish



Name: bassin_medjerda

☑ Preview?

☑ Link Layer to Schematic Objects and Demand Branches?

For each shape to link, choose an object or branch to link it to in the table to the right. You may link Catchments, Demand Sites, Reservoirs, Groundwater, Other Supply, Flow Requirements, Wastewater Treatment Plants and any branch below Demand Sites and Catchments. You can view results for linked shapes on the map in the Results View.

Source: Water Evaluation and Planning Tool, modified by the authors.

Appendix C: using the flow duration curve method to calculate environmental flows

C.1 The flow duration curve method for determining environmental flows

Please refer to the FAO Guidelines for Incorporating environmental flows into "water stress" indicator 6.4.2 (FAO, 2019). In those guidelines, environmental flows (EF) are defined following the Brisbane Declaration of 2017, as "… the quantity and timing of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being", adapted from (Arthington, *et al.*, 2018).

EFRs are often reported as a percentage of long-term mean flows, on an annual or on a monthly basis. For the purpose of EFR definitions, Enviromental management classes (EMC), as suggested by Kleynhans & Louw (2008) are used. Each class corresponds to the extent to which the original ecological condition of a river has been altered from its natural reference condition.

- **Class A = natural (unmodified);** protected rivers and basins, reserves and national parks with minor modification of in-stream and riparian habitat, where no new dams or diversions allowed.
- **Class B = largely natural conditions;** slightly modified and/or ecologically important rivers where small water supply development schemes are allowed.
- **Class C = moderately modified**; where the modifications are such that they generally have a limited impact on the ecosystem integrity, although sensitive species are impacted.
- **Class D = largely modified ecosystems;** where sensitive biota in particular are reduced in numbers and expanse and where community structure is substantially but acceptably changed.

- **Class E = Seriously modified ecosystems;** in poor condition where most of the ecosystem's functions and services are lost. This class is considered unacceptable from a management perspective as it represents ecosystems that are being used unsustainably.

Note that the EFR required to support the present-day EMC is used to calculate the water stress index in SDG 6.4.2. It is therefore necessary to know in advance the EMC of the day and to use this EMC as a framework to fix the EFR.

Flow duration curve (FDC) shift is one of several possible approaches to calculating environmental flows. If local environmental flow requirement have been defined, for example based on studies that take into account local species and habitat conditions, the environmental flow requirements of these studies can be used in WEAP. The justification for the FDC methodology is described in: Smakhtin, V. and Anputhas, M. (2006). The International Water Management Institute (IWMI) developed a software package for rapid assessment of environmental flows, the global environmental flow calculator (GEFC)[6]. The same method used by this software package is included in the FDCShift function of WEAP.

In concept, the FDC shift is calculated according to the following procedure:

1. Unregulated (no withdrawals) multi-annual streamflow time series for a point along a river are obtained or simulated. These series may be daily, weekly or monthly.
2. Multi-annual average unregulated flow values are calculated for each day/week/month of the years modeled.
3. A flow duration curve is developed for the unregulated streamflow. These time series are used to construct a flow duration curve, a plot that shows percentage of time the flow in a river is likely to equal or exceed a given flow value. For each flow value Q in the original streamflow time series, its percentile P in the FDC: P = 100 * Rank / (N + 1) is calculated, where N is the number of data points and Rank is the rank order (from 1-N) of Q in the flow duration curve (flows in

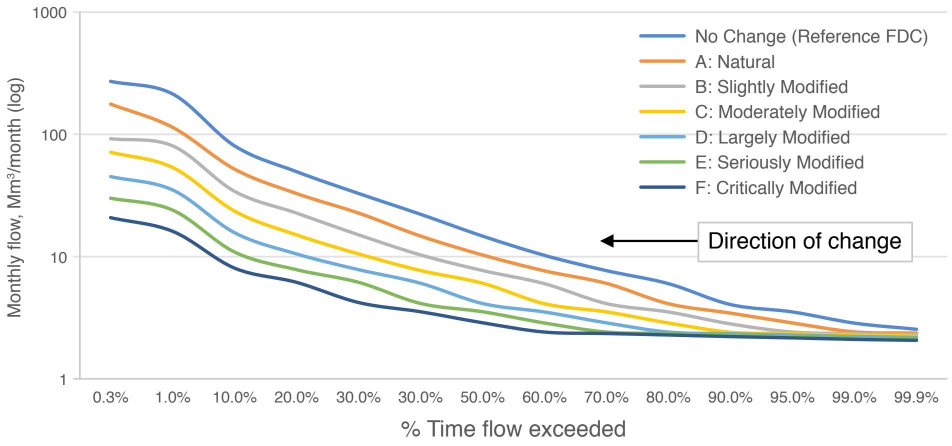
---

[6] For more information about GEFC, see **Smakhtin, V., Eriyagama N.** 2008. Developing a software package for global desktop assessment of environmental flows. Environmental Modelling and Software 23: 1396-1406. https://doi.org/10.1016/j.envsoft.2008.04.002

decreasing order). Rank = 1 is the highest flow; Rank = N is the lowest flow.

4. A new percentile P’ by shifting P the number of steps according to the EMC parameter (A-F, corresponding to a shift of 1-6 steps). A shift of one step corresponds to moving from one number to the next larger number in the following list of percentiles: 0.01 percent, 0.1 percent, 1 percent, 5 percent, 10 percent, 20 percent, 30 perent, 40 percent, 50 percent, 60 percent, 70 percent, 80 percent, 90 percent, 95 percent, 99 percent, 99.9 percent and 99.99 percent. For example, a shift of 2 places (B: Slightly modified) would mean that a 60 percent flow would be reduced to a 80 percent flow, and a 90 percent flow would be reduced to a 99 percent flow. Percentiles between the specified values, e.g., 85 percent, are calculated by a linear interpolation. For example, P = 85 percent is halfway between 80 percent and 90 percent; when shifted 2 places, it will be halfway between 95 percent and 99 percent, so P’ = 97 percent.
5. the EFR is calculated by applying the shift value to the multi-annual unregulated flow values, creating an EFR time series for each day/week/month of the year.

In other words, for Class A rivers, the environmental flow requirement will be equal to the multi-annual mean flow for the given time period (day, week or month of the year).



Source: **Smakhtin, V., & Anputhas, M.** 2006. *An assessment of environmental flow requirements of Indian river basins.* Colombo, Sri Lanka: International Water Management Institute. 42p. (IWMI Research Report 107). https://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB107/RR107.pdf

Estimation of environmental FDCs for different environmental management classes (EMCs) by lateral shift (Smakhtin & Anputhas, 2006)

C.2 Using the flow duration curve shift function to calculate environmental flows in the Water Evaluation And Planning Tool

To use the FDC shift method in WEAP, begin with a WEAP model that has been hydrologically calibrated, and be sure that flow requirement objects have been inserted in the model.

Note about placement of flow requirement objects in relation to reservoir objects in WEAP

Remember that flow requirement objects are recognized by WEAP as a demand which must be met and have two purposes in this WEAP model: simulation of operations and calculation of water stress. For water stress calculations, increases in reservoir storage are considered as withdrawals (part of TFWW) and releases as part of TRWR.

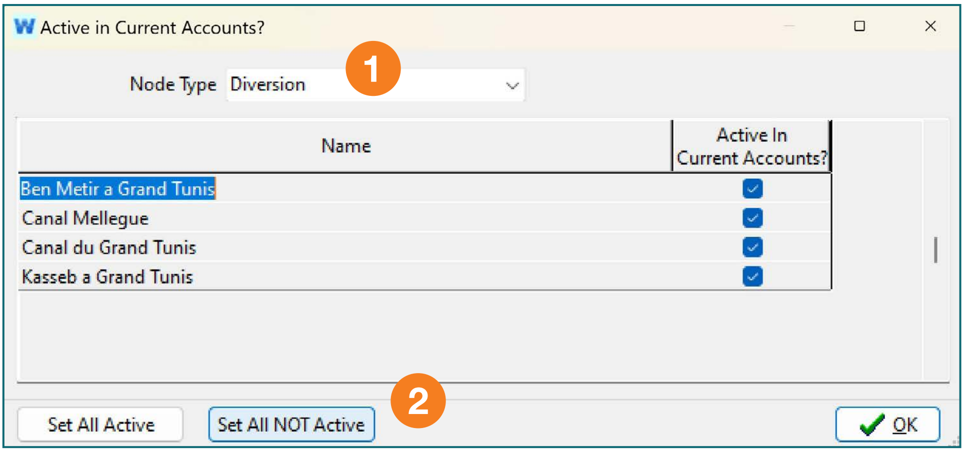
If you place flow requirement objects just downstream of the reservoirs, that will instruct the WEAP algorithms to maintain a minimum flow in the river just downstream of the reservoir for operational simulation, but use of an EFRs to mark the boundaries of sub-basins for the purpose of water stress calculations downstream of a reservoir will imply that reservoir releases will be included in the calculation of water stress for the upstream sub-basin.

If you believe that these releases should be included in the calculation of water stress for the downstream sub-basin, then a flow requirement for the purpose of SDG 6.4.2 calculation should be placed upstream of the reservoir object. It may be that you will include a flow requirement object upstream of the reservoir object for the purpose of calculating water stress and another downstream of the reservoir object for operations simulation.

Once your model is hydrologically calibrated and all required EFR objects for water stress calculations have been inserted, **generate simulated unimpaired flows** by first inactivating diversion arcs, transmission links and reservoirs by selecting

Schematic -> Set active in current accounts.

Then “Set All NOT Active” for those three “Node Type”s.



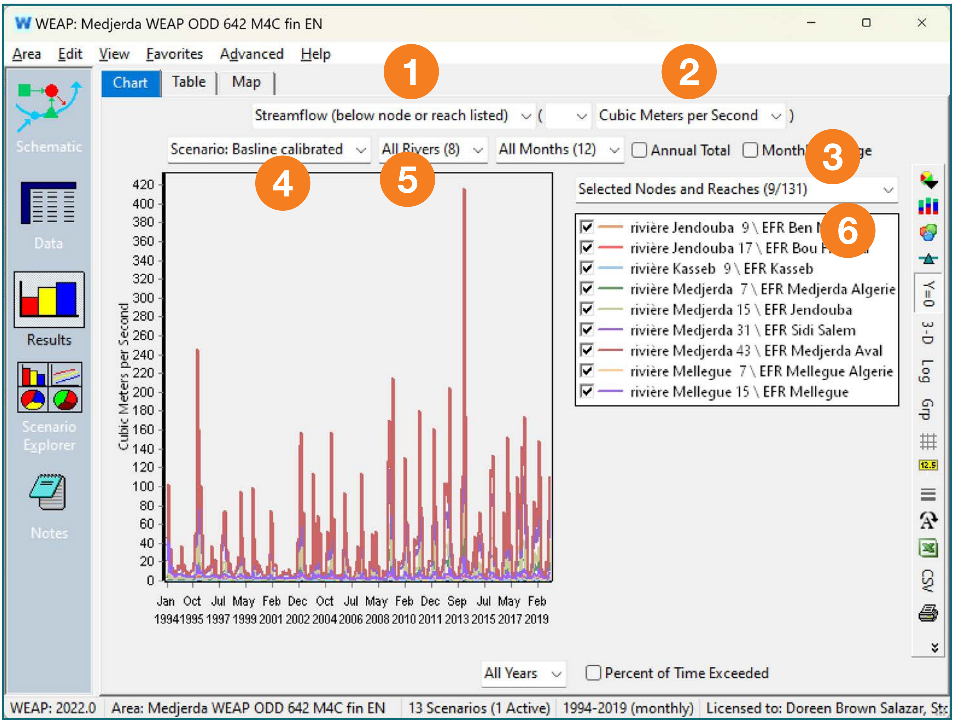
Active in Current Accounts?

Node Type: Diversion

Name	Active In Current Accounts?
Ben Metir a Grand Tunis	☑
Canal Mellegue	☑
Canal du Grand Tunis	☑
Kasseb a Grand Tunis	☑

Source: *Water Evaluation and Planning Tool, modified by the authors.*

Run the model, then select results for streamflows calculated by WEAP at all EFR locations. These are unimpaired flows. Be sure that you have selected flow units for the results. See example below.



WEAP: Medjerda WEAP ODD 642 M4C fin EN

Streamflow (below node or reach listed) (Cubic Meters per Second)

Scenario: Basline calibrated | All Rivers (8) | All Months (12) | ☐ Annual Total | ☐ Monthly Average

Selected Nodes and Reaches (9/131)

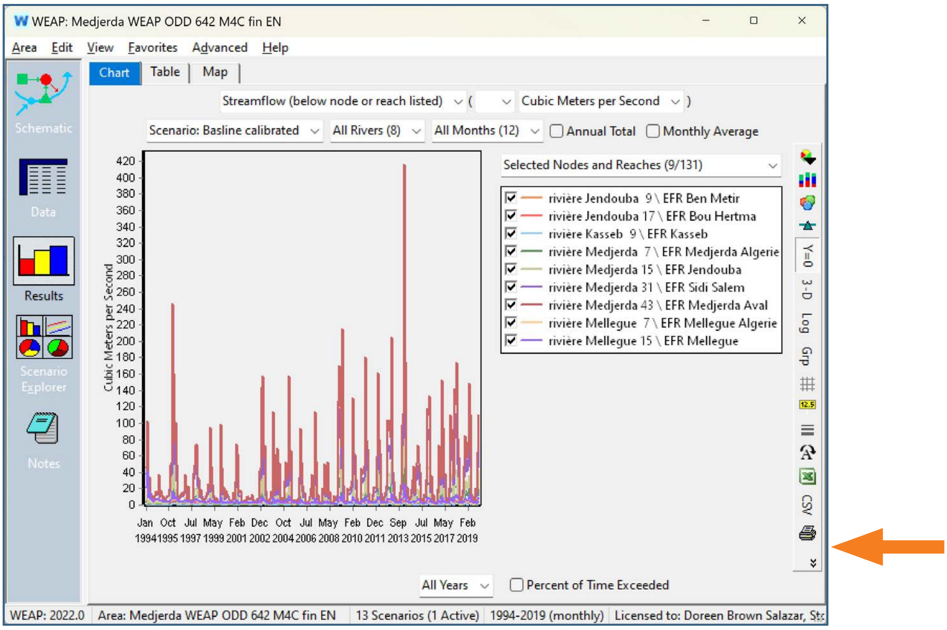
- ☑ rivière Jendouba 9 \ EFR Ben M
- ☑ rivière Jendouba 17 \ EFR Bou H
- ☑ rivière Kasseb 9 \ EFR Kasseb
- ☑ rivière Medjerda 7 \ EFR Medjerda Algerie
- ☑ rivière Medjerda 15 \ EFR Jendouba
- ☑ rivière Medjerda 31 \ EFR Sidi Salem
- ☑ rivière Medjerda 43 \ EFR Medjerda Aval
- ☑ rivière Mellegue 7 \ EFR Mellegue Algerie
- ☑ rivière Mellegue 15 \ EFR Mellegue

All Years | ☐ Percent of Time Exceeded

WEAP: 2022.0 | Area: Medjerda WEAP ODD 642 M4C fin EN | 13 Scenarios (1 Active) | 1994-2019 (monthly) | Licensed to: Doreen Brown Salazar, St

Source: *Water Evaluation and Planning Tool, modified by the authors.*

Now click on csv to **export a csv file with these unimpaired flows.** This file will be used by WEAP to calculate environmental flows using the FDC shift function. If you do not see the csv option on the right, click the down arrow.



Streamflow (below node or reach listed) (Cubic Meters per Second)

Scenario: Basline calibrated | All Rivers (8) | All Months (12) | ☐ Annual Total ☐ Monthly Average

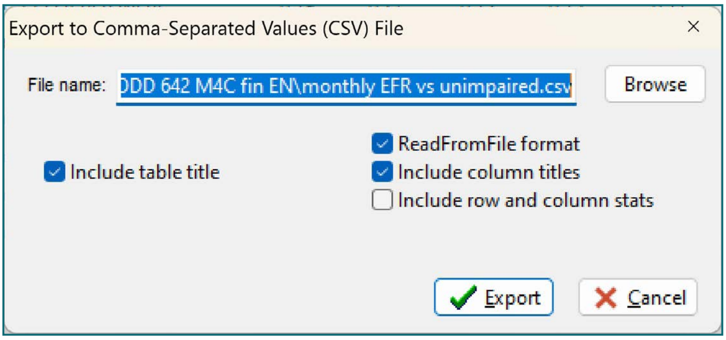
Selected Nodes and Reaches (9/131)

- ☑ rivière Jendouba 9 \ EFR Ben Metir
- ☑ rivière Jendouba 17 \ EFR Bou Hertma
- ☑ rivière Kasseb 9 \ EFR Kasseb
- ☑ rivière Medjerda 7 \ EFR Medjerda Algerie
- ☑ rivière Medjerda 15 \ EFR Jendouba
- ☑ rivière Medjerda 31 \ EFR Sidi Salem
- ☑ rivière Medjerda 43 \ EFR Medjerda Aval
- ☑ rivière Mellegue 7 \ EFR Mellegue Algerie
- ☑ rivière Mellegue 15 \ EFR Mellegue

All Years | ☐ Percent of Time Exceeded

Source: Water Evaluation and Planning Tool, modified by the authors.

Remember to specify the location where you are saving your csv file and the name of the file. We recommend placing your file in the folder of the WEAP Area that you are working in.



File name: DD 642 M4C fin EN\monthly EFR vs unimpaired.csv

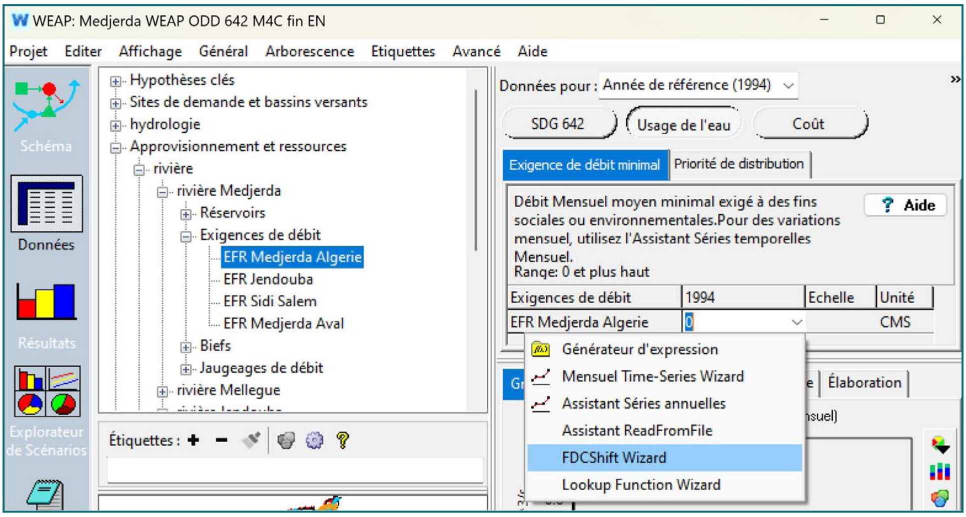
☑ Include table title

☑ ReadFromFile format
☑ Include column titles
☐ Include row and column stats

Source: Water Evaluation and Planning Tool, modified by the authors.

Use the FDC shift function; The FDC shift function in WEAP is similar to the ReadFromFile Wizard, with the modification that you can select an environmental management class.

For each of the EFRs used to define catchments for water stress, in the data tree mode, in the minimum flow tab of the flow requirement, select FDCShift Wizard, then browse for and select your csv file of unimpaired flows.



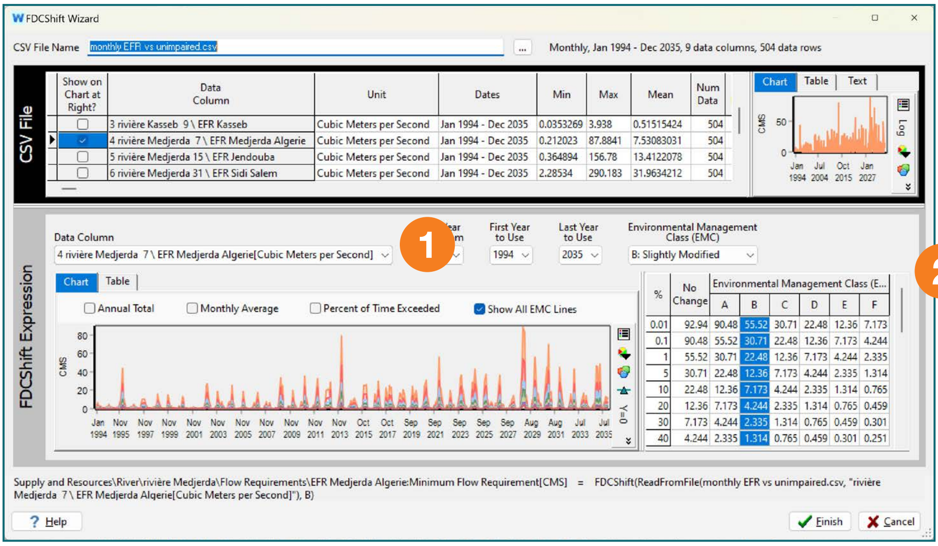
Données pour : Année de référence (1994)

Débit Mensuel moyen minimal exigé à des fins sociales ou environnementales.Pour des variations mensuel, utilisez l'Assistant Séries temporelles Mensuel.
Range: 0 et plus haut

Exigences de débit	1994	Echelle	Unité
EFR Medjerda Algerie	0		CMS

Source: Water Evaluation and Planning Tool, modified by the authors.

The two selections you must make are the unimpaired flow curve location (point 1 in the figure below) and the environmental management class (point 2 in the figure below). If you do not select an environmental management class, then the environmental flow requirement will be 100 percent of unimpaired flows.



CSV File Name monthly EFR vs unimpaired.csv ... Monthly, Jan 1994 - Dec 2035, 9 data columns, 504 data rows

Show on Chart at Right?	Data Column	Unit	Dates	Min	Max	Mean	Num Data
☐	3 rivière Kasseb 9 \ EFR Kasseb	Cubic Meters per Second	Jan 1994 - Dec 2035	0.0353269	3.938	0.51515424	504
☑	4 rivière Medjerda 7 \ EFR Medjerda Algerie	Cubic Meters per Second	Jan 1994 - Dec 2035	0.212023	87.8841	7.53083031	504
☐	5 rivière Medjerda 15 \ EFR Jendouba	Cubic Meters per Second	Jan 1994 - Dec 2035	0.364894	156.78	13.4122078	504
☐	6 rivière Medjerda 31 \ EFR Sidi Salem	Cubic Meters per Second	Jan 1994 - Dec 2035	2.28534	290.183	31.9634212	504

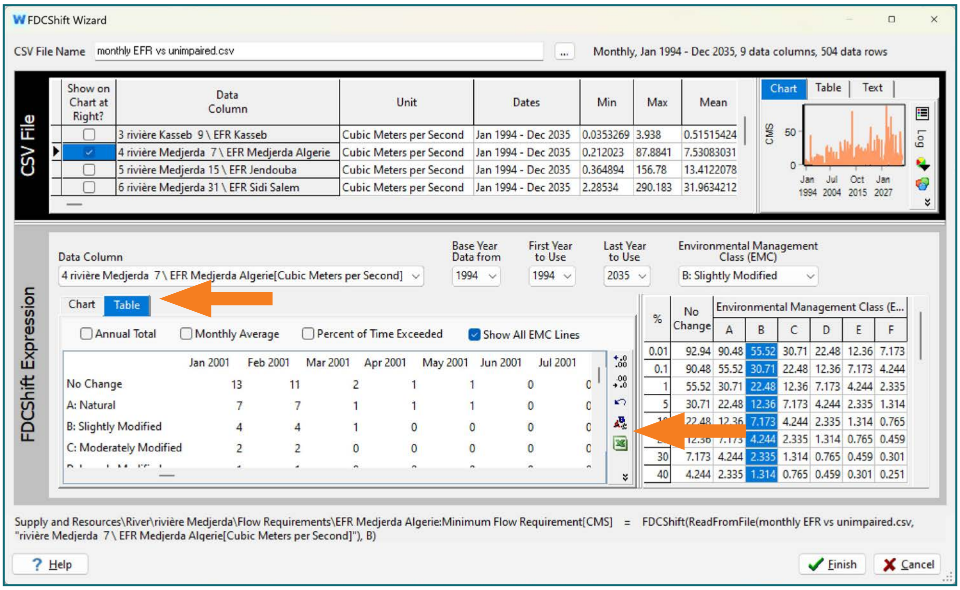
Data Column: 4 rivière Medjerda 7 \ EFR Medjerda Algerie[Cubic Meters per Second]
First Year to Use: 1994
Last Year to Use: 2035
Environmental Management Class (EMC): B: Slightly Modified

%	No Change	Environmental Management Class (E...					
		A	B	C	D	E	F
0.01	92.94	90.48	55.52	30.71	22.48	12.36	7.173
0.1	90.48	55.52	30.71	22.48	12.36	7.173	4.244
1	55.52	30.71	22.48	12.36	7.173	4.244	2.335
5	30.71	22.48	12.36	7.173	4.244	2.335	1.314
10	22.48	12.36	7.173	4.244	2.335	1.314	0.765
20	12.36	7.173	4.244	2.335	1.314	0.765	0.459
30	7.173	4.244	2.335	1.314	0.765	0.459	0.301
40	4.244	2.335	1.314	0.765	0.459	0.301	0.251

Supply and Resources\River\rivière Medjerda\Flow Requirements\EFR Medjerda Algerie:Minimum Flow Requirement[CMS] = FDCShift(ReadFromFile(monthly EFR vs unimpaired.csv, "rivière Medjerda 7 \ EFR Medjerda Algerie[Cubic Meters per Second]"), B)

Source: Water Evaluation and Planning Tool, modified by the authors.

To review in more detail how changes in management classes affect environmental flows, you can select the table view while showing all EMC lines, then export the data to Excel.


FDCShift Wizard

CSV File Name: monthly EFR vs unimpaired.csv

Monthly, Jan 1994 - Dec 2035, 9 data columns, 504 data rows

Show on Chart at Right?	Data Column	Unit	Dates	Min	Max	Mean
☐	3 rivière Kasseb 9 \ EFR Kasseb	Cubic Meters per Second	Jan 1994 - Dec 2035	0.0353269	3.938	0.51515424
☑	4 rivière Medjerda 7 \ EFR Medjerda Algerie	Cubic Meters per Second	Jan 1994 - Dec 2035	0.212023	87.8841	7.53083031
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☐	6 rivière Medjerda 31 \ EFR Sidi Salem	Cubic Meters per Second	Jan 1994 - Dec 2035	2.28534	290.183	31.9634212

Data Column: 4 rivière Medjerda 7 \ EFR Medjerda Algerie[Cubic Meters per Second]

Base Year Data from: 1994

First Year to Use: 1994

Last Year to Use: 2035

Environmental Management Class (EMC): B: Slightly Modified

☐ Annual Total ☐ Monthly Average ☐ Percent of Time Exceeded ☑ Show All EMC Lines

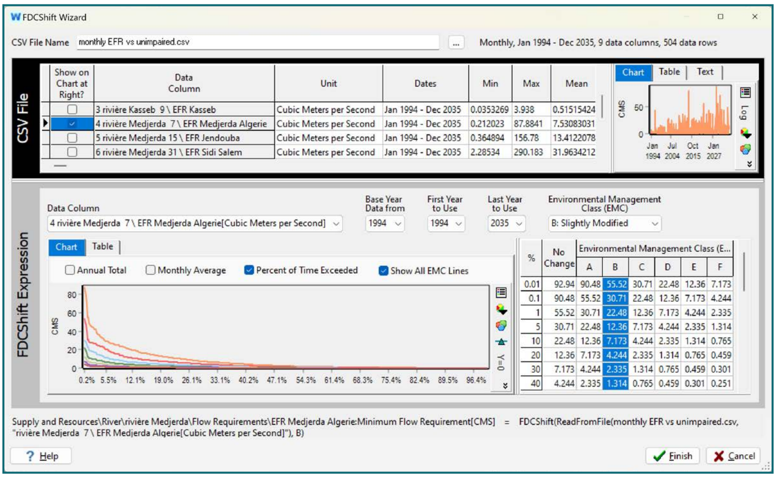
	Jan 2001	Feb 2001	Mar 2001	Apr 2001	May 2001	Jun 2001	Jul 2001
No Change	13	11	2	1	1	0	
A: Natural	7	7	1	1	1	0	
B: Slightly Modified	4	4	1	0	0	0	
C: Moderately Modified	2	2	0	0	0	0	

%	No Change	Environmental Management Class (E...					
		A	B	C	D	E	F
0.01	92.94	90.48	55.52	30.71	22.48	12.36	7.173
0.1	90.48	55.52	30.71	22.48	12.36	7.173	4.244
1	55.52	30.71	22.48	12.36	7.173	4.244	2.335
5	30.71	22.48	12.36	7.173	4.244	2.335	1.314
10	22.48	12.36	7.173	4.244	2.335	1.314	0.765
20	12.36	7.173	4.244	2.335	1.314	0.765	0.459
30	7.173	4.244	2.335	1.314	0.765	0.459	0.301
40	4.244	2.335	1.314	0.765	0.459	0.301	0.251

Supply and Resources\River\rivière Medjerda\Flow Requirements\EFR Medjerda Algerie:Minimum Flow Requirement[CMS] = FDCShift(ReadFromFile(monthly EFR vs unimpaired.csv, "rivière Medjerda 7 \ EFR Medjerda Algerie[Cubic Meters per Second]"), B)

Source: Water Evaluation and Planning Tool, modified by the authors.

You can use the window to visualize the options you are choosing. For example, if you click on the “percent of time exceeded”, and “show All EMC Lines buttons” you can see the flow exceedance curves generated for all the environmental management classes.


FDCShift Wizard

CSV File Name: monthly EFR vs unimpaired.csv

Monthly, Jan 1994 - Dec 2035, 9 data columns, 504 data rows

Show on Chart at Right?	Data Column	Unit	Dates	Min	Max	Mean
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☐	6 rivière Medjerda 31 \ EFR Sidi Salem	Cubic Meters per Second	Jan 1994 - Dec 2035	2.28534	290.183	31.9634212

Data Column: 4 rivière Medjerda 7 \ EFR Medjerda Algerie[Cubic Meters per Second]

Base Year Data from: 1994

First Year to Use: 1994

Last Year to Use: 2035

Environmental Management Class (EMC): B: Slightly Modified

☐ Annual Total ☐ Monthly Average ☑ Percent of Time Exceeded ☑ Show All EMC Lines

%	No Change	Environmental Management Class (E...					
		A	B	C	D	E	F
0.01	92.94	90.48	55.52	30.71	22.48	12.36	7.173
0.1	90.48	55.52	30.71	22.48	12.36	7.173	4.244
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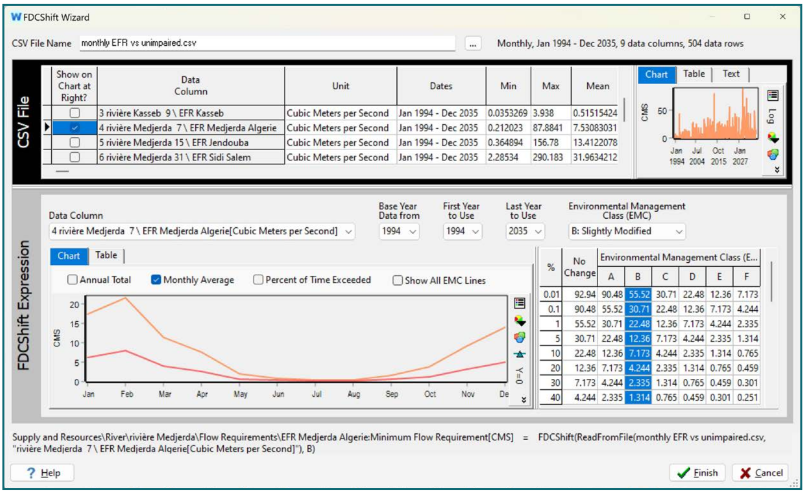
Supply and Resources\River\rivière Medjerda\Flow Requirements\EFR Medjerda Algerie:Minimum Flow Requirement[CMS] = FDCShift(ReadFromFile(monthly EFR vs unimpaired.csv, "rivière Medjerda 7 \ EFR Medjerda Algerie[Cubic Meters per Second]"), B)

Source: Water Evaluation and Planning Tool, modified by the authors.

You can also compare the EFR that will be generated for the EMC that you have chosen with the unimpeded flow curve by unchecking “Show All EMC Lines” and selecting an EMC.



CSV File Name: monthly EFR vs unimpaired.csv

Monthly, Jan 1994 - Dec 2035, 9 data columns, 504 data rows

Show on Chart at Right?	Data Column	Unit	Dates	Min	Max	Mean
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Data Column: 4 rivière Medjerda 7 \ EFR Medjerda Algerie[Cubic Meters per Second]

Base Year Data from: 1994

First Year to Use: 1994

Last Year to Use: 2035

Environmental Management Class (EMC): B: Slightly Modified

☐ Annual Total ☑ Monthly Average ☐ Percent of Time Exceeded ☐ Show All EMC Lines

%	No Change	Environmental Management Class (E...					
		A	B	C	D	E	F
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0.1	90.48	55.52	30.71	22.48	12.36	7.173	4.244
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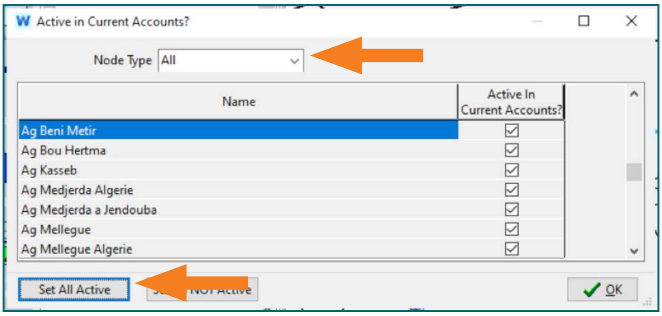
Source: Water Evaluation and Planning Tool, modified by the authors.

For each EFR, use the FDC shift wizard, select the corresponding stream location, and an appropriate environmental management class. For locations upstream of reservoirs or major withdrawals, you will likely choose an environmental management class “B”, while for locations downstream of reservoirs or major withdrawals, you may choose environmental management classes “C” or “D”.

Be sure to activate all inactivated components of the model. In the schematic view, choose Schematic from the dropdown menu, and select all node types and all active.



Node Type: All

Name	Active In Current Accounts?
Ag Beni Metir	☑
Ag Bou Hertma	☑
Ag Kasseb	☑
Ag Medjerda Algerie	☑
Ag Medjerda a Jendouba	☑
Ag Mellegue	☑
Ag Mellegue Algerie	☑

Source: Water Evaluation and Planning Tool, modified by the authors.

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Smakhtin, A. V., & Anputhas, M. 2006. *An assessment of environmental flow requirements of Indian river basins.* Colombo, Sri Lanka: International Water Management Institute. 42p. (IWMI Research Report 107). https://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB107/RR107.pdf

This report presents the instruction manual of the new new water stress plugin developed by FAO in collaboration with the Stockholm Environment Institute's U.S. Center (SEI) for the calculation of the SDG indicator 6.4.2 "*Level of water stress: freshwater withdrawal as a proportion of available freshwater resources*" by river basin.

Since the indicator was introduced in 2015, it has been used widely to estimate the level of water stress experienced at the country or regional level. With this new plugin countries will be able to assess the SDG 6.4.2 at basin and sub-basin level providing a different and more hydrologically sound view on the dynamics of water resources and their use. The plugin allows exploring the spatial and interannual trends of the level of water stress within a basin avoiding any multiple counting of its freshwater resources and taking into consideration the needs of water supply of the different sections of the basin. By supporting the improvement of water monitoring and management, this report contributes to the achievement of SDG 6.

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