Inter-American Development Bank

Water and Sanitation Division

STEP BY STEP GUIDE

Hydro-BID Manual

Mauro Nalesso
Pedro Coli

Keywords: Water Management, Hydrobid, Water Resources, Latin America, Water and Sanitation, Hydrobid manual, Water Resource Planning, Hydrobid initiative.

Inter-American Development Bank
1300 New York Avenue, NW
Washington, DC 20577

Table of Contents

Introduction.......... 3

1. How to Install the Software of Support for Hydro-BID? 4

   How to Install QGIS? 4

   How to Install SQLite Data Browser? 9

   How to Install Java Runtime Environment? 13

2. Organization of the material 16

3. How to install the navigation AHD-Tool 19

4. Visualization of the AHD-LAC in QGIS 22

5. Visualization of the SQLITE database 25

6. How to use the AHD-TOOL Navigator 28

7. How to use the Hydro-BID Interface to carry out a simulation. 32

8. Model Calibration 42

9. Simulation of Climate Change Scenarios. 52

Introduction

The following manual has been prepared with the idea of facilitating the learning process in the use of the Hydro-BID model and the Analytical Hydrographic Database for Latin America and the Caribbean (*LAC-AHD*). The instructions below are supported by the material distributed in Hydro-BID's installation package and that is based on the simplified case study of Una River basin in the state of Pernambuco, Brazil.

By following the instructions you should be able to understand how to set up a simulation in Hydro-BID, how to proceed for the interpolation of climate data, how to calibrate the model and how to visualize the results obtained.

The technical information relating to the model and the LAC-AHD database can be obtained by downloading the technical notes from our website www.hydrobidlac.org.

The necessary support material for the development of the processes described in this guide are available through the following link: https://code.iadb.org/en/repository/12/hydro-bid

Links to Technical Notes:

- Hydro-BID: An Integrated System for Modeling impacts of Climate Change on Water Resources
- Analytical Hydrology Dataset for LAC (Spanish)
- Hydro-BID: New Functionalities (Reservoir, Sediment and Groundwater Simulation Modules

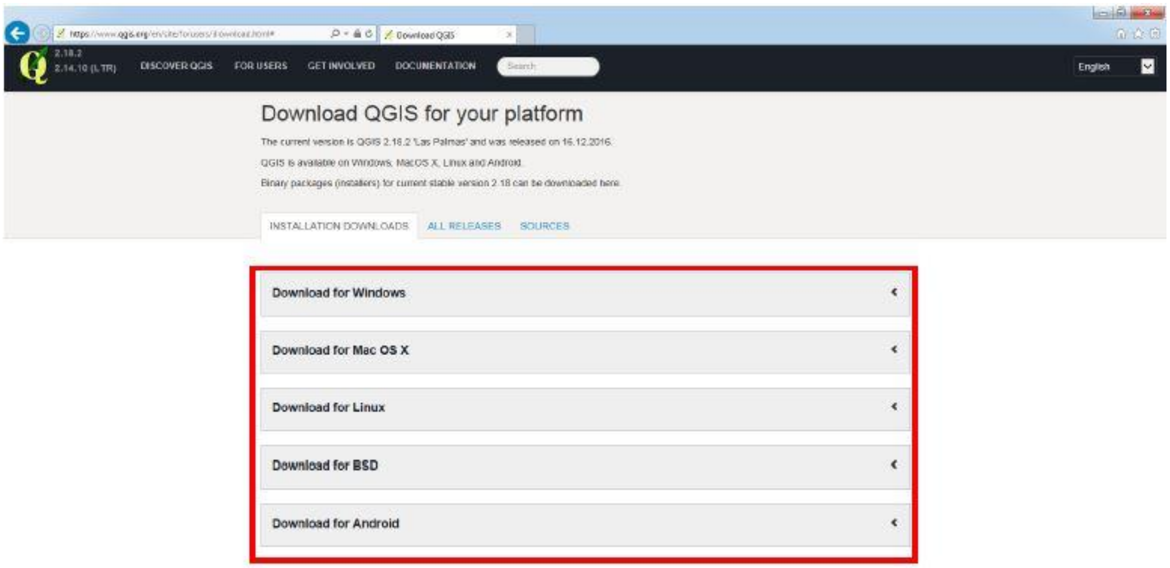
1. How to Install the Software of Support for Hydro-BID?

In this chapter you will find a tutorial of how to install QGIS, SQLite and Java software.

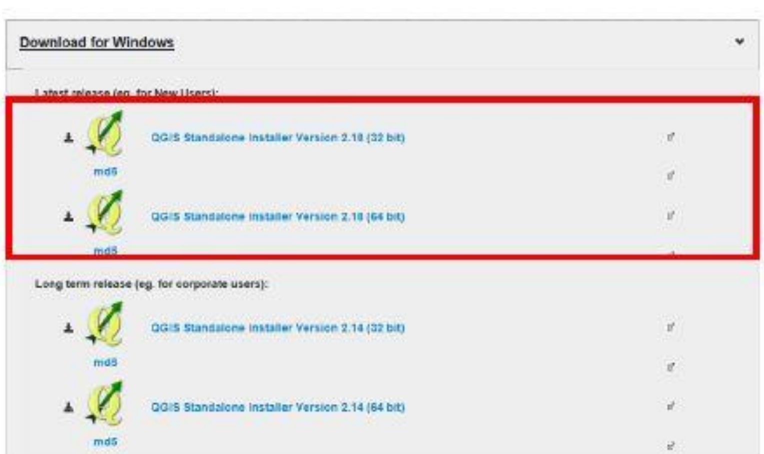
How to Install QGIS?

1. Go to: https://qgis.org/en/site/forusers/download.html

2. Click on the operating system that you use on your computer

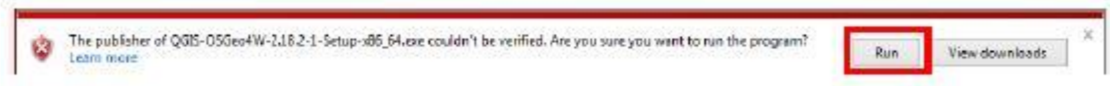


3. Under "**Long term release repository (most stable):**", select "**QGIS Standalone installer version 2.18**" of 32 bit or 64 bit depending on your operating system (version 3.2 is still not recommended).

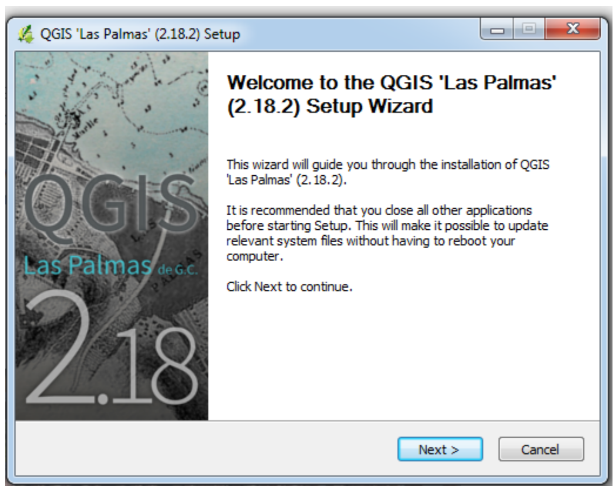


4. Click on "**RUN**" in the message that appears

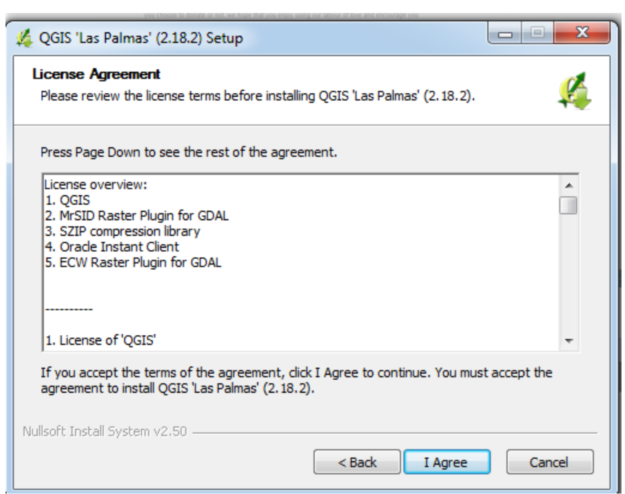
If a warning message appears, click "**Run**" again



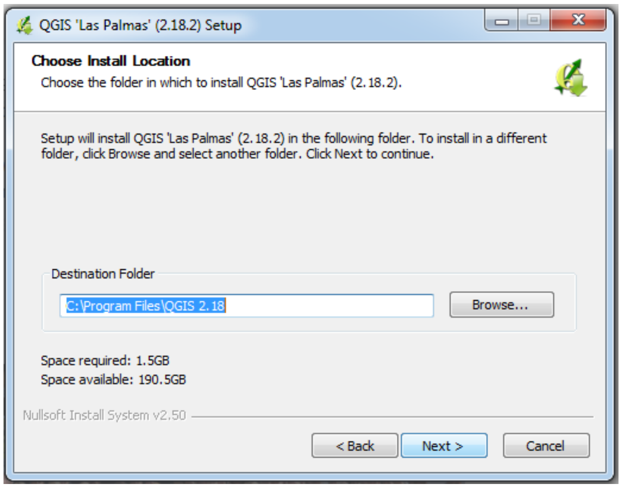
5. In the **Setup** window of QGIS, click on "**Next**"



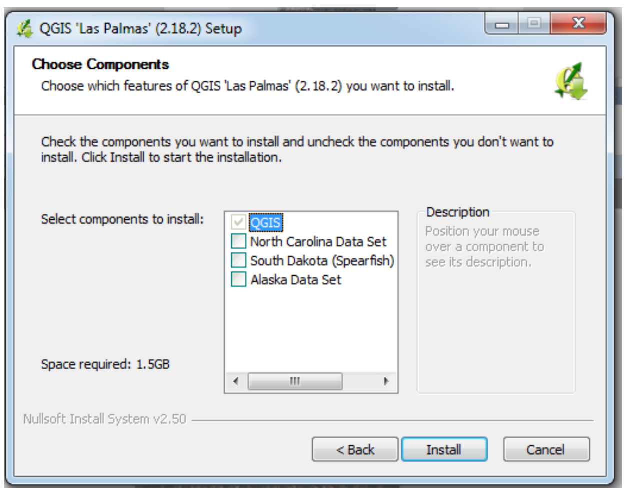
6. Click on "**I Agree**" to accept the license agreement



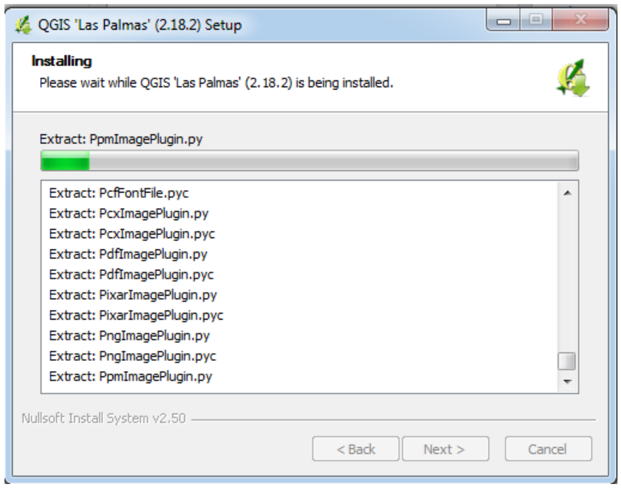
7. Click on "**Browse**" if you want to change the destination folder where the QGIS program will be installed. Then click on "**Next**"



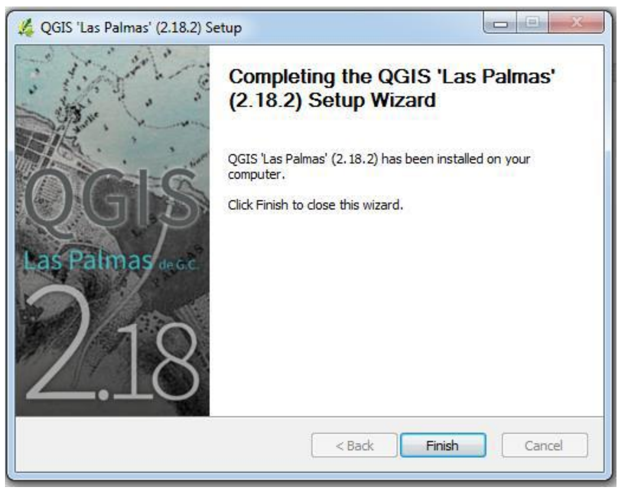
8. In the **Choose Components** window, click on "**Install**"



9. The installation of QGIS will start automatically



10. To complete the installation, click on "**Finish**"

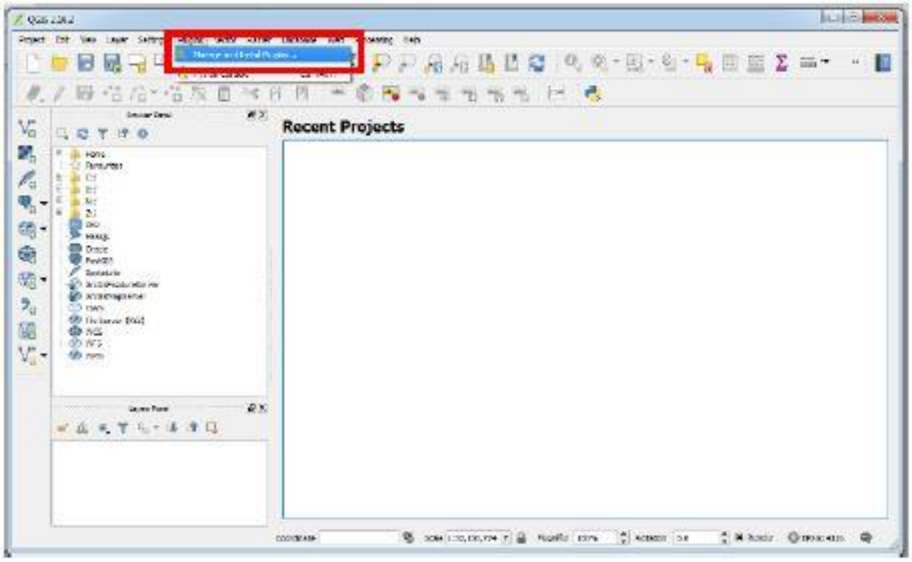


11. How to Install the OpenLayer Plugin:

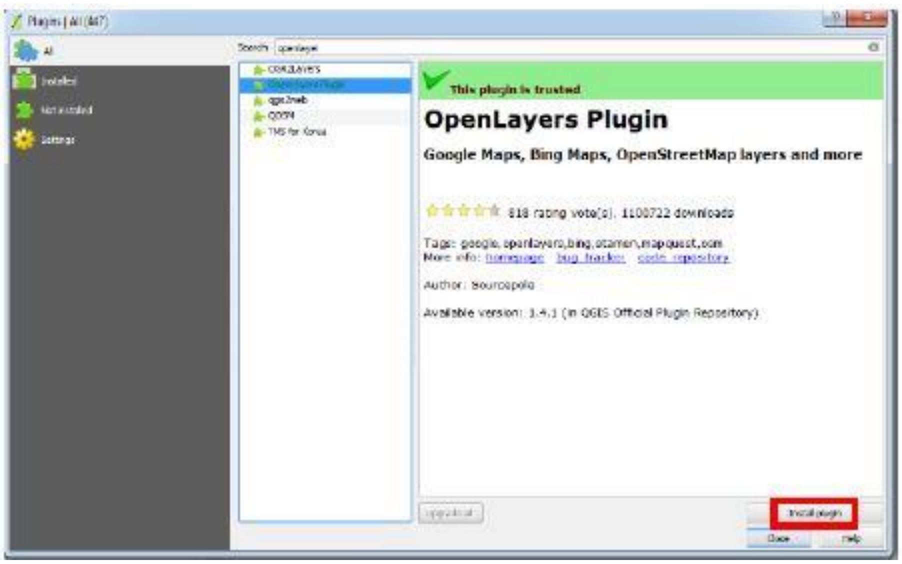
a. Start QGIS by going to the Start menu and typing "**QGIS**" in the search bar. Click on the icon "QGIS Desktop 2.18.2"[1]

[1] The version of QGIS may vary, this will not affect the operation of the AHDTool

b. Within QGIS, select "**Plugins**" and then click on "**Manage and Install Plugins**"



c. In the Search bar, type "**Openlayer**"[2] and click on "**Install Plugin**"



[2] Openlayers do not support printing, if you want to use the QGIS Print Composer you need to install the QuickMapServices Plugin.

How to Install SQLite Data Browser?

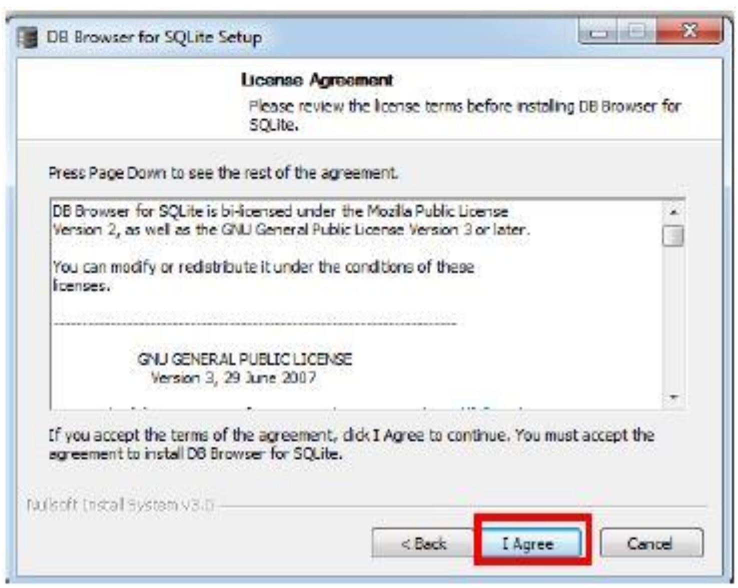
1. Go to: http://sqlitebrowser.org/

2. Click on the operating system that you use on your computer

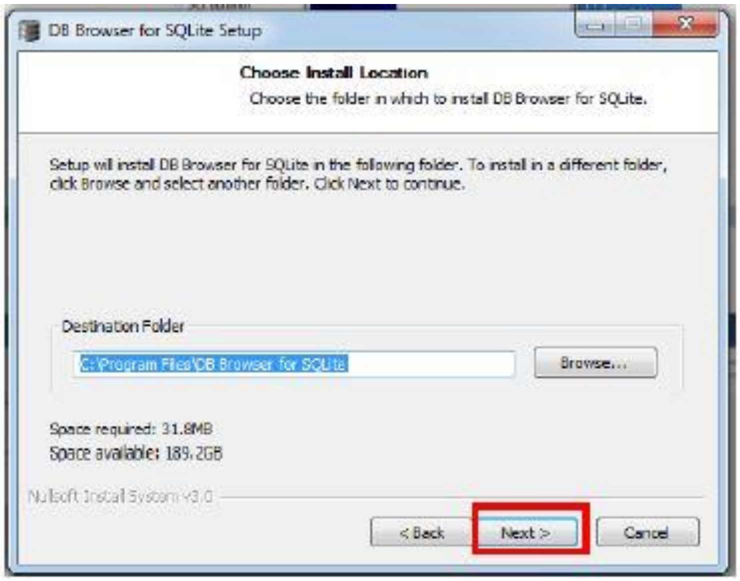
3. Click on "**RUN**" in the message that appears

4. In the **Setup** window, click on "**Next**"

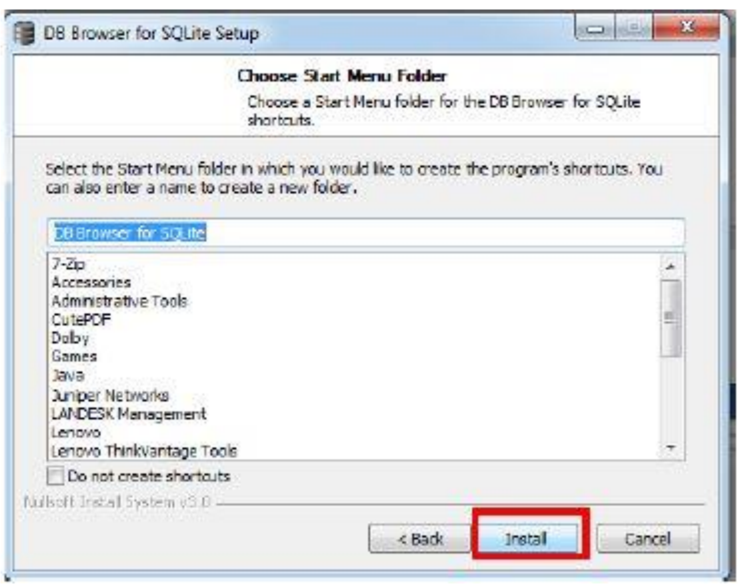
5. Click on "**I Agree**" to accept the license agreement



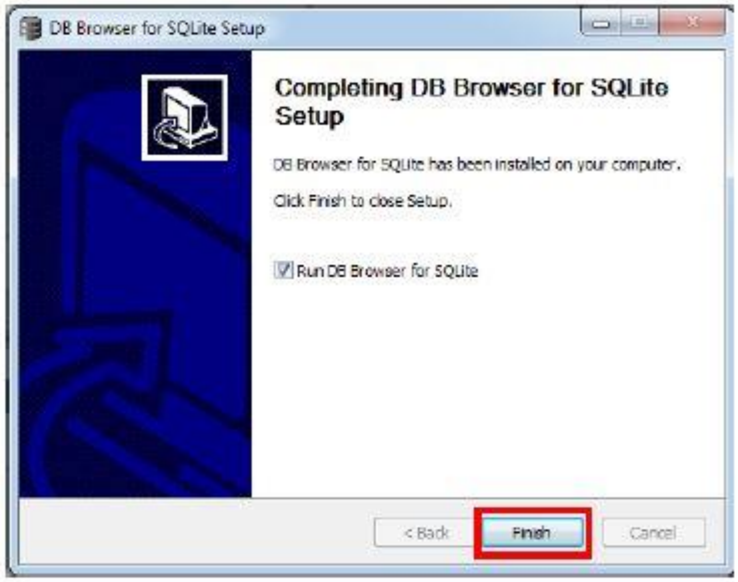
6. Click on "**Browse**" if you want to change the destination folder where the DB Browser program for SQLite will be installed. Then click on "**Next**"



7. In the window "**Choose Smart Folder Menu**", click on "**Install**"



8. Once the installation is complete, click on "**Finish**"



How to Install Java Runtime Environment?

1. Go to: http://www.oracle.com/technetwork/java/javase/downloads/index.html

2. Click on the "**Java Download**" box. You will be installing the latest Java Platform available

3. Click on "**Accept License Agreement**" to accept the license agreement

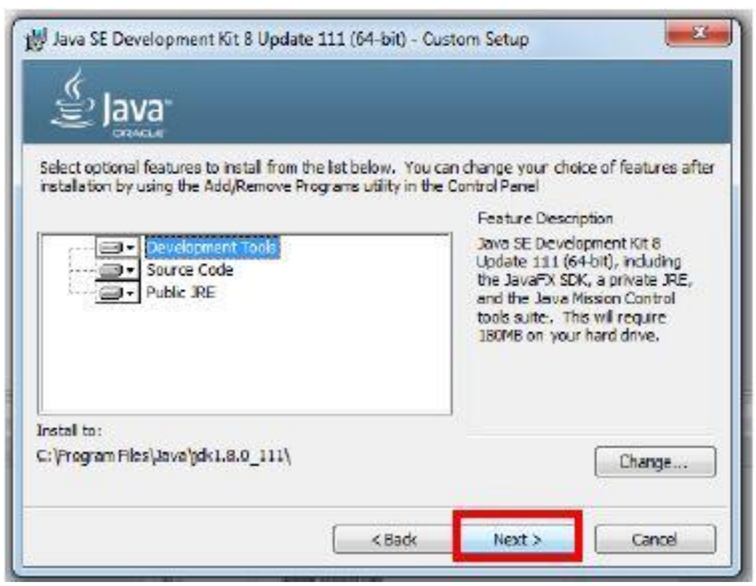
4. From the **Download** column, select the operating system you use on your computer. If your system is Windows and you installed the 32-bit version of QGIS, you should install the version for "**Windows x86**".

Product / File Description	File Size	Download
Linux ARM 32 Hard Float ABI	77.86 MB	jdk-8u121-linux-arm32-vfp-hflt.tar.gz
Linux ARM 64 Hard Float ABI	74.83 MB	jdk-8u121-linux-arm64-vfp-hflt.tar.gz
Linux x86	162.41 MB	jdk-8u121-linux-i586.rpm
Linux x86	177.13 MB	jdk-8u121-linux-i586.tar.gz
Linux x64	159.96 MB	jdk-8u121-linux-x64.rpm
Linux x64	174.76 MB	jdk-8u121-linux-x64.tar.gz
Mac OS X	223.21 MB	jdk-8u121-macosx-x64.dmg
Solaris SPARC 64-bit	139.64 MB	jdk-8u121-solaris-sparcv9.tar.Z
Solaris SPARC 64-bit	99.07 MB	jdk-8u121-solaris-sparcv9.tar.gz
Solaris x64	140.42 MB	jdk-8u121-solaris-x64.tar.Z
Solaris x64	96.9 MB	jdk-8u121-solaris-x64.tar.gz
Windows x86	189.36 MB	jdk-8u121-windows-i586.exe
Windows x64	195.51 MB	jdk-8u121-windows-x64.exe

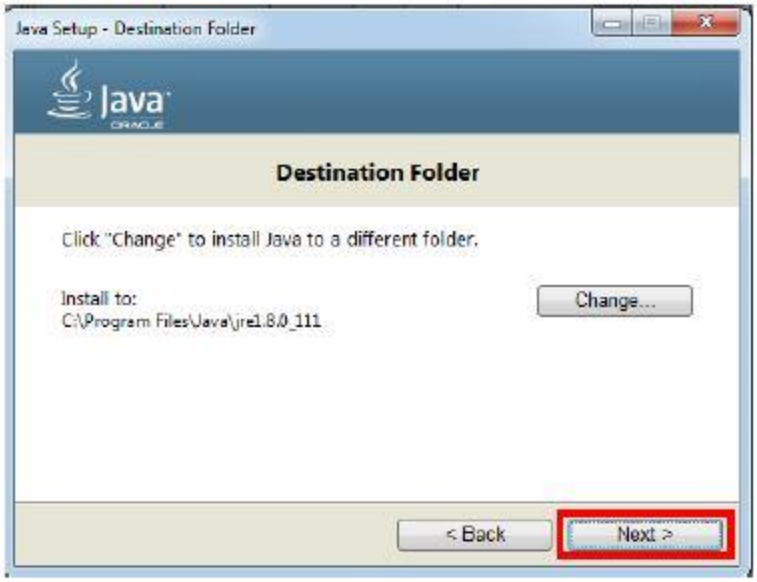
5. Click on "**RUN**" in the message that appears

6. In the **Setup** window, click on "**Next**"

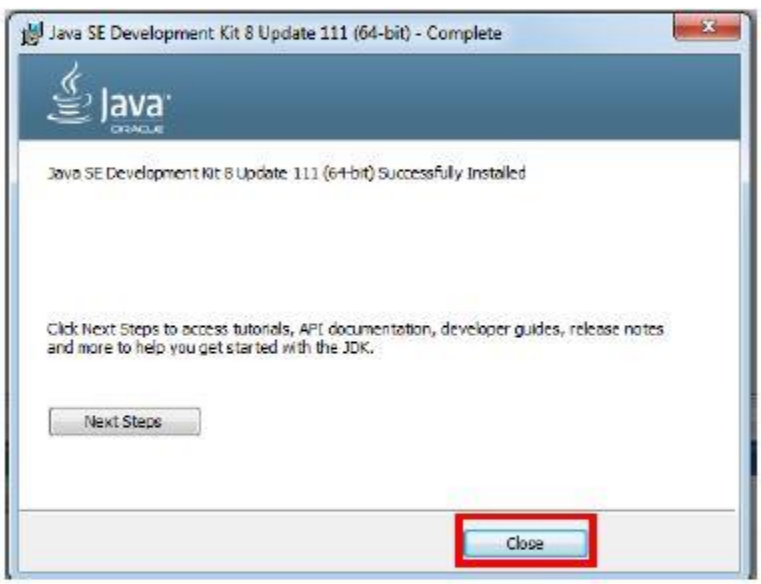
7. In the **Custom Setup** window, click on "**Next**"



8. Click on "**Change**" if you want to change the destination folder where the Java program will be installed. Then, click on "**Next**"



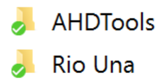
9. Click on "**Close"** to complete the installation process



2. Organization of the material

This step-by-step manual includes supporting materials that are separated into 2 folders, the **GIS_Una** folder and the **Hydro-BID** folder.

The **GIS_Una** folder contains 2 sub-folders: **AHDTool** and **Una River (or Rio Una)**

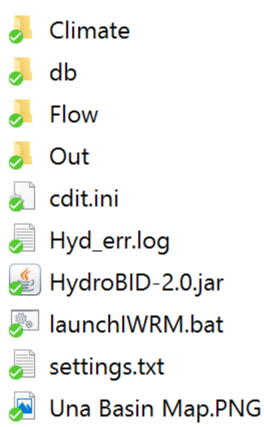


In the **AHDTool** sub-folder you will find the navigation tool of the hydrology dataset for Latin America and the Caribbean (AHD-LAC). The installation procedure for this tool is explained in the next chapter.

In the sub-folder **Una River (or Rio Una)** you will find the shapefiles (files of river basins) relating to the AHD-LAC for the case of the Una River basin (State of Pernambuco, Brazil). The folder contains the following files:

- **Rio Una Example.qgs** (project with the catchments in QGIS)
- **Rio Una_Catchments** (shp file with the delineation of catchments)
- **Rio Una_Streamline** (shp file with the delineation of streamlines)
- **AHDFlow.dbf** (table with the connectivities between catchments and streams)
- **Climate stations** (vector shp file with the locations of weather stations)
- **Flow stations** (vector shp file with the locations of the hydrometric stations)
- **Reservoirs** (vector shp file with the location of the reservoirs)

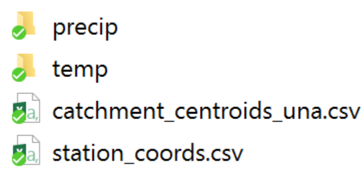
The folder **Hydro-BID**, for its part, contains sub-folders with data files and the executable file[3].



[3] Folder and data file names can be changed by the user without affecting the simulations

The structure of the internal sub-folders is as follows:

1. **"Climate" folder**: This folder contains the climate data and location of weather stations and catchment centroids, and presents the following structure



- **precip** is the folder that contains precipitation historical data
- **temp** is the folder containing temperature historical data
- **catchment_centroids_una.csv** is the file with the coordinates of the catchment centroids
- **stations_coords.csv** is the file with the coordinates of the weather stations

Note: The files in **precip** and **temp** folders should correspond to the same stations and must match in name.

The files are comma separated values "csv" with the following structure:

precip		
Header	Date	Precip
Format/units	DD/MM/YYYY	Cm

temp		
Header	Date	Temp
Format/units	DD/MM/YYYY	Celsius

Catchment_centroids_una.csv			
Header	Centroid_x	Centroid_y	COMID
Format/units	degrees	degree	Catchment Identifier

COMID: is the identifier number unique to each catchment in the AHD-LAC.

Stations_coords.csv			
Header	Name	Lat_deg	Long_deg
Format/units	Station name	rad	rad

2. **"db" folder**: This folder contains the database with the parameters of the catchments.

   You will find the database with the Una catchment parameters in SQLITE format.

   una.sqlite

3. **"Flow" folder:** This folder contains the flow data required for the calibration of the model.

The files are comma separated values "csv" with the following structure:

Station.csv		
Header	Date_format	Flow
Format/units	DD/MM/YYYY	m^3/s

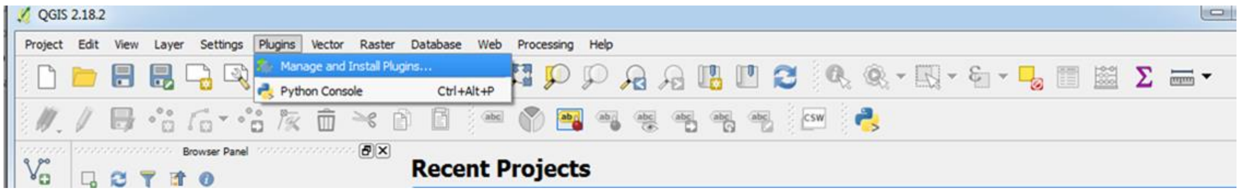
4. **Folder "Out"**: this folder is initially empty and it stores the output files after running the model.
   - **Monthlysummary.csv** (monthly time series of precipitation, temperature, simulated and observed flows)
   - **Outlet.csv** (Simulated time series of output variables by catchment)
   - **Summary.csv** (total number of catchments, drainage area, computational time, and COMID of the outlet catchment)
   - **Spatial_file.csv** (catchment averages of temperature, precipitation, runoff, and sediment load)
   - **Annual_file.csv (**annual time series of precipitation, temperature, runoff, and sediment load)
   - **Settings.txt** (all input parameters and model configuration that correspond to the last simulation performed)
   - **flowDurationObs** (observed data for the duration curve)
   - **flowDurationSim** (simulated data for the duration curve)

5. **"Cdit.ini":** file of the AHD tool
6. **"Hyd_err.log"**: file of the log of simulation errors
7. **Executable file "HydroBID-2.0.jar"**: Hydro-BID executable (double-click to launch the Hydro-BID interface)
8. **"launchIWRM.bat"**: batch file pre-loaded with the files of the case study.
9. **"Settings.txt":** file with the input and model set-up parameters
10. **"Una Basin Map.PNG"**: image of pre-visualization of the catchment (added for reference only)

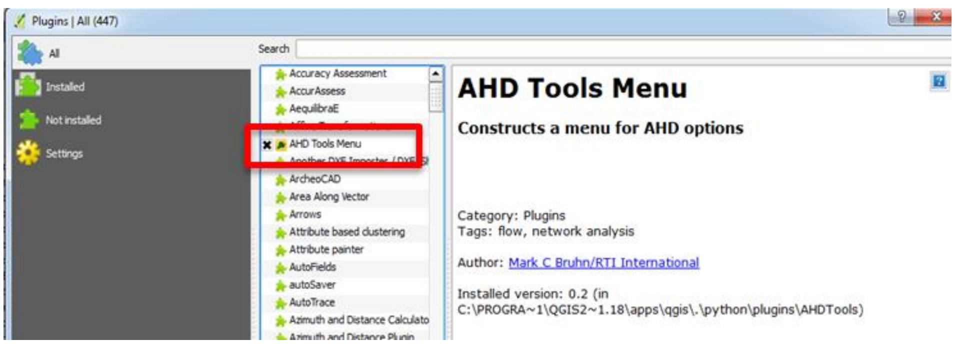
3. How to install the navigation AHD-Tool

1. Copy the folder "**AHDTools**" in the following directory: C:\Program Files\QGIS 2.18\apps\qgis\python\plugin (The directory can vary with respect to the QGIS version installed)

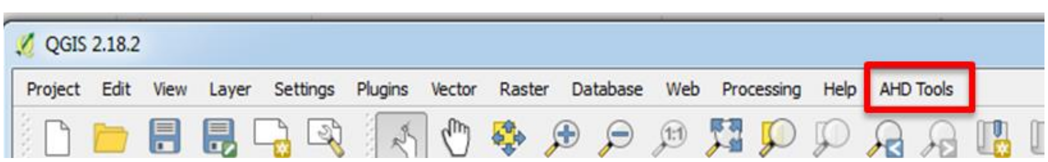
2. In QGIS select "**Plugins**" and then "**Manage and Install Plugins**"



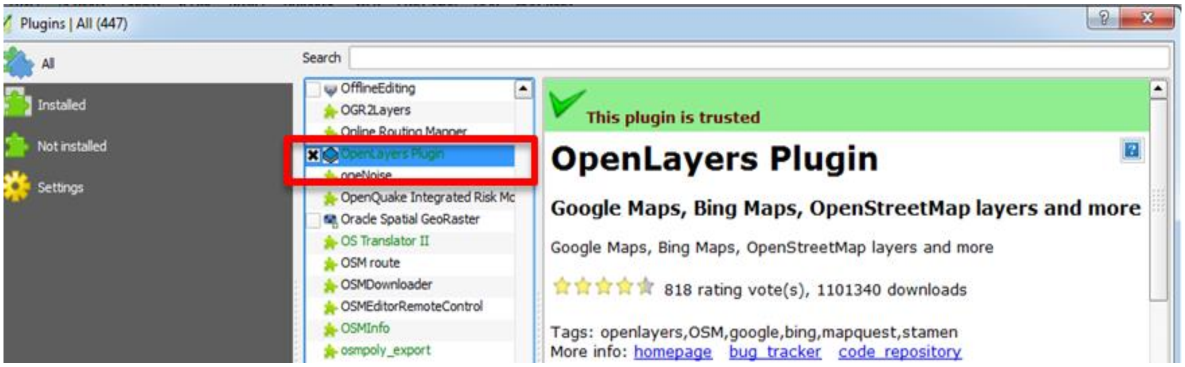
3. Browse and click on "**AHD Tools Menu"** to install the AHD Tool



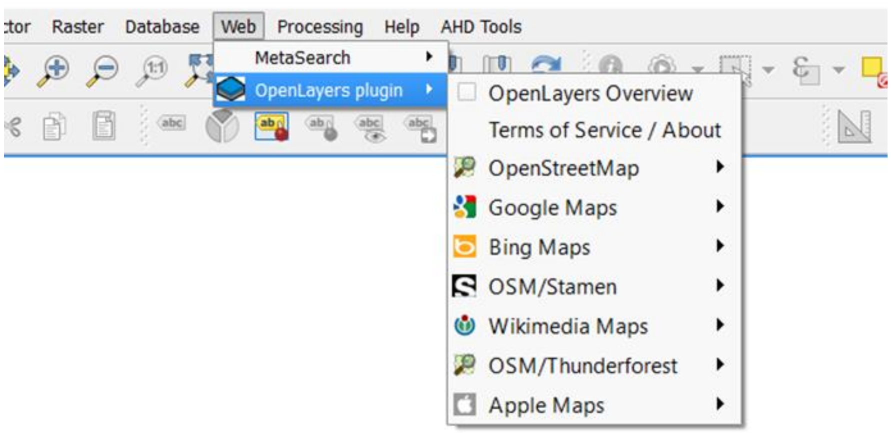
4. Now, the AHD tool will be visible on the toolbar



5. Follow the instructions in point 2, scroll down to "**OpenLayers Plugin**". Click on the plug-in to access Google Earth



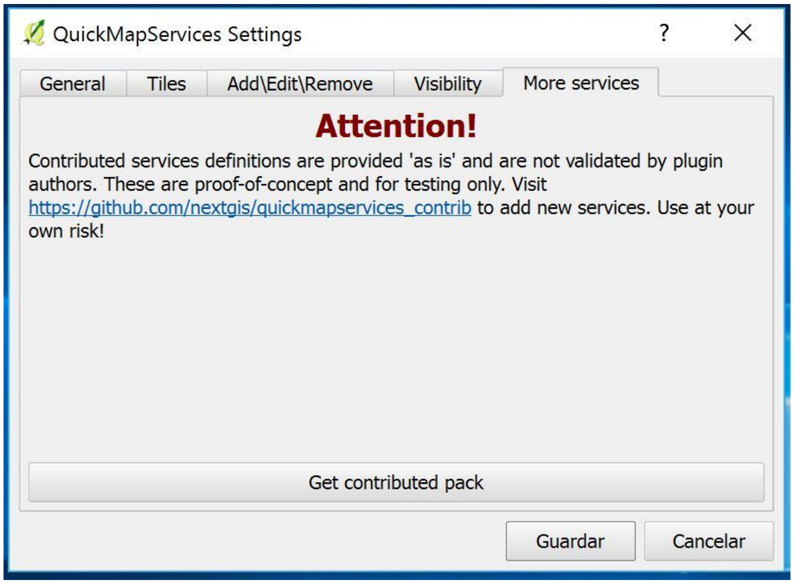
6. OpenLayers Plugin will appear on the “Web” tab of the toolbar and all the support imaging options will appear on the displayable menu



7. Once you select the map type by clicking on it, the map will be automatically loaded into the project

8. OpenLayers Plugin does not support printing of the work area, if you want to make print-outs derived from data processing in QGIS of georeferenced images you must use the procedure explained in point 2 to install **QuickMapServices**

9. Once installed this plugin you should display its menu options, select "**Settings**", go to the "**More Services**" tab and click on "**Get contributed pack**" to access the Google mapping tools.



4. Visualization of the AHD-LAC in QGIS

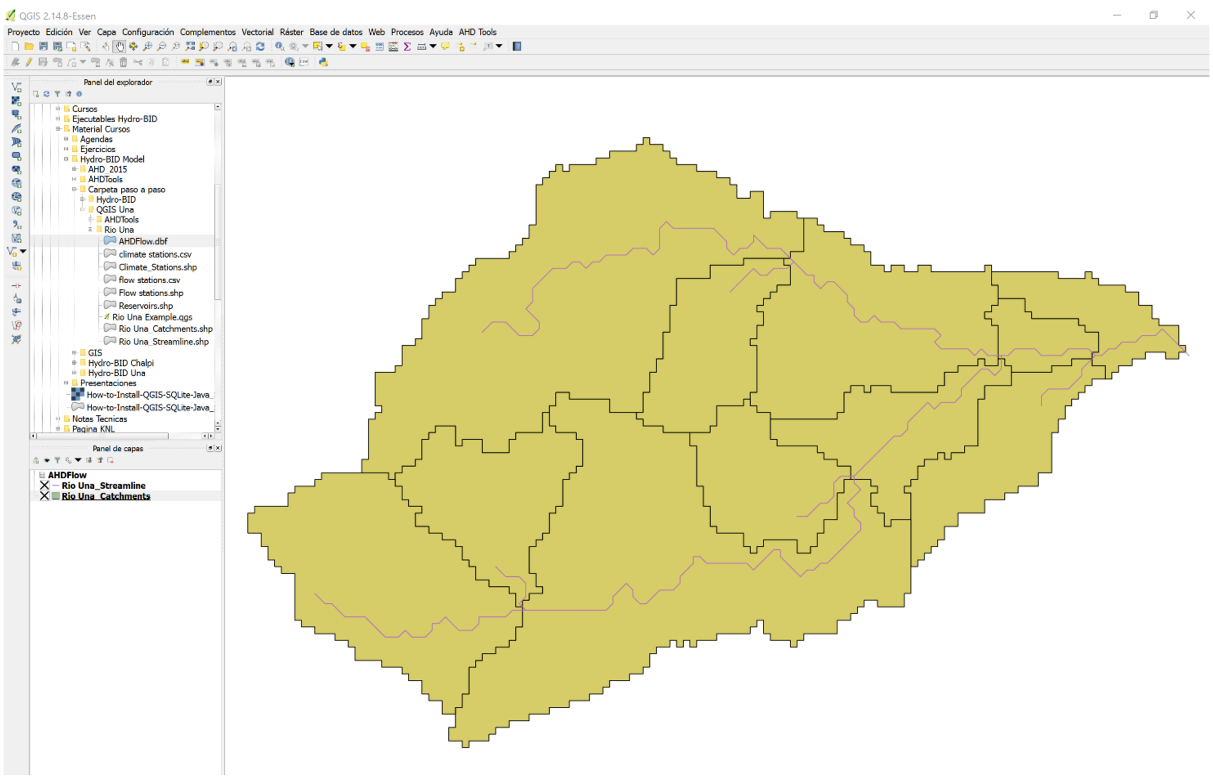
To be able to access the hydrographic databases of the AHD-LAC you must load files in QGIS that characterize the delimitation of catchments, flows and additionally, you will need to upload the file that contains the connectivity between catchments and streamlines (**AHDFlow.dbf**).

To load the files you must simply locate them in the QGIS browser panel and double click on each one.

In the case of the UNA river basin, it is necessary to upload the files located in the Rio Una sub-folder within the QGIS Una folder:

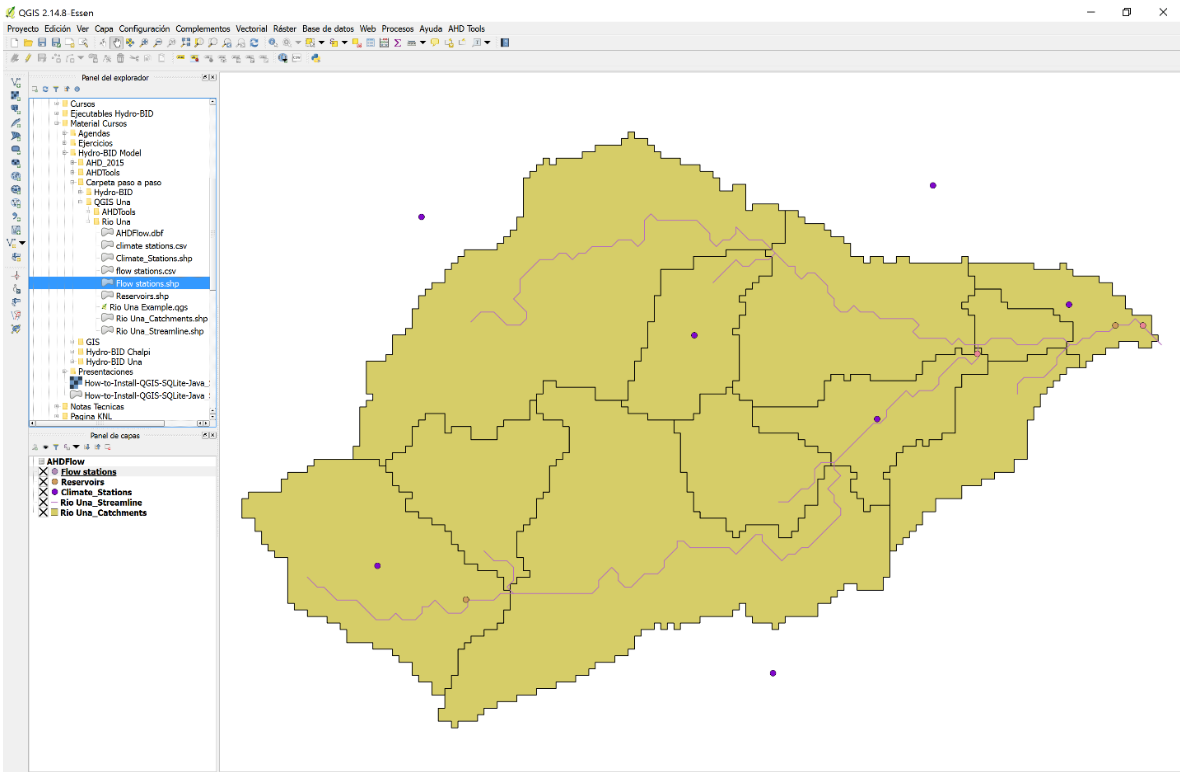
- **Rio Una_Catchments.shp**
- **Rio Una_Streamline.shp**
- **AHDFlow.dbf**

The following image will appear in the QGIS work pane.

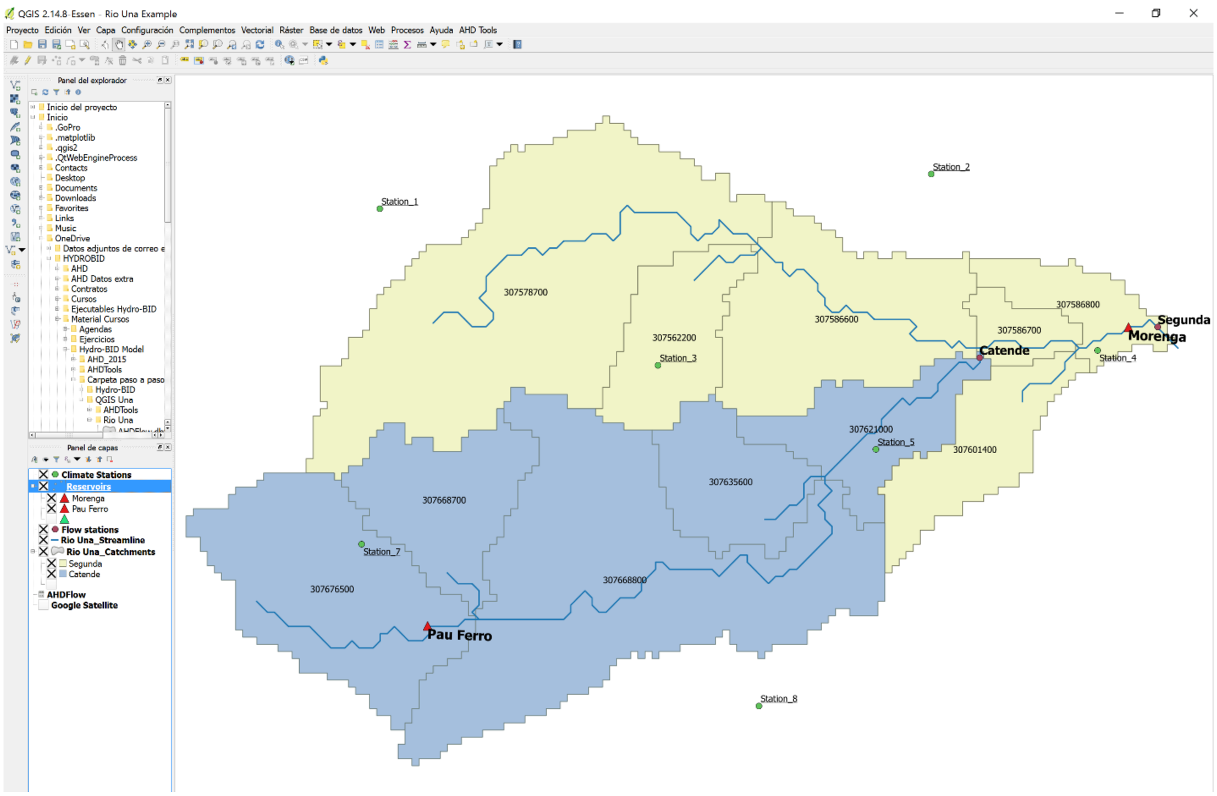


In addition, you must upload the following files which will serve as a reference for the simulations:

- **Climate_Stations.shp**
- **Flow stations.shp**
- **Reservoirs.shp**



You can eventually use the Properties window that appears when you right-click on each of the shapefiles (shp) in order to graphically customize each layer. If you want, this final set-up is already pre-developed in the **Rio Una Example.qgs** project file.



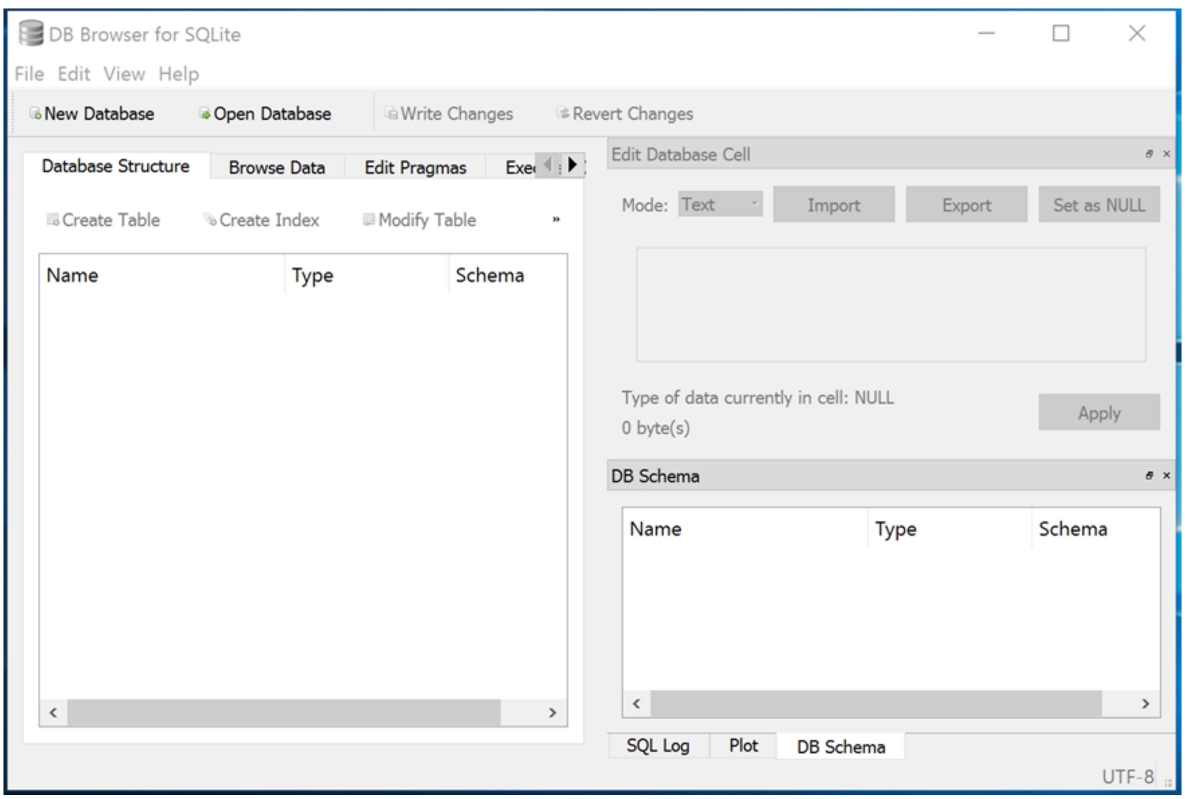
5. Visualization of the SQLITE database

The database with pre-loaded and pre-validated variables is stored in SQLITE format; to view its structure and the values of the variables you can use the **DB Browser for SQLite**. The file for this case study is located inside the **db** folder.

To display the database of the Una river basin you must follow these steps:

1. Open the browser and go to the Start menu and type "**DB Browser for SQLite**" in the search bar. Click on the icon:

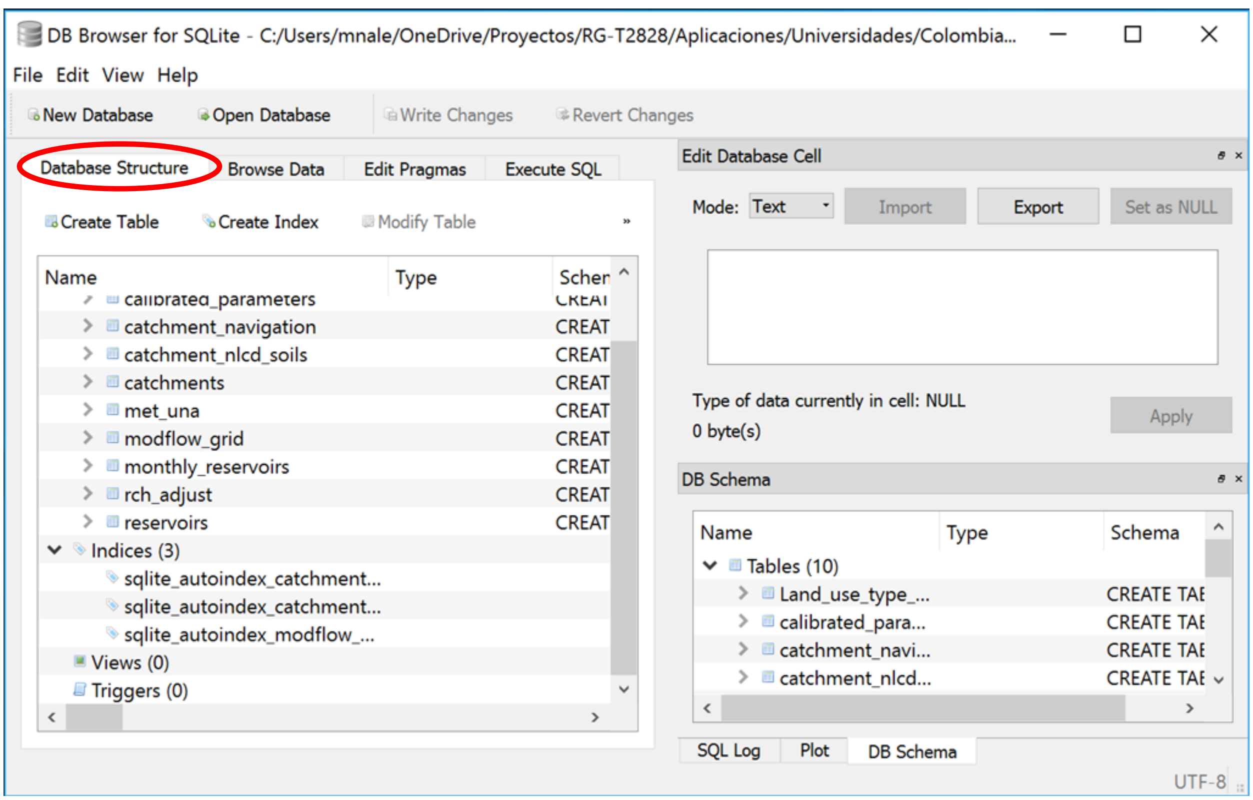
2. The DB Browser will open in its initial window



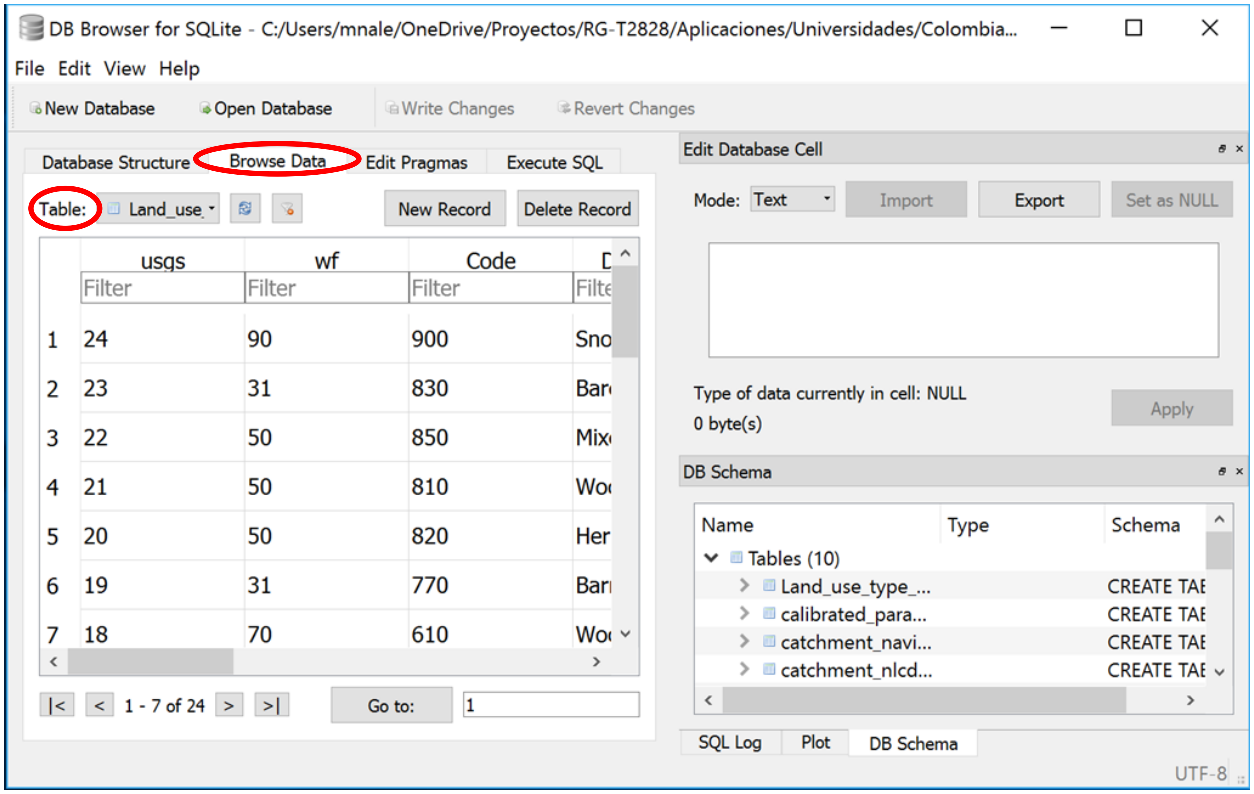
3. To open the database, click on "**File**" and "**Open Database**"

4. Navigate to the SQLite file you want to open, in this case select "**una.sqlite**". All of the input data for this Catchment is stored in this database

5. To visualize the structure of the data, in the "**Database Structure**" tab, expand the tables by clicking on the arrows next to the name



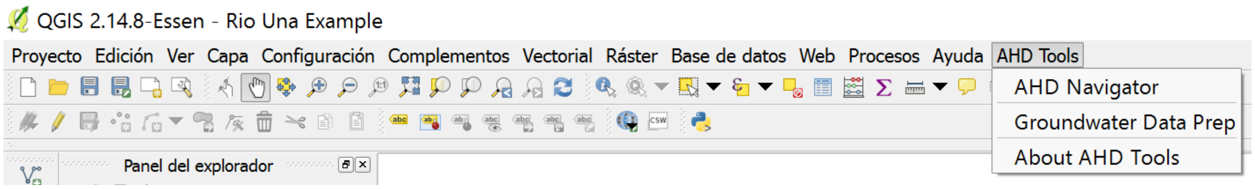
6. To search, view and edit the tables, click on the "**Browse Data**" tab and select the table from the "**Table**" menu



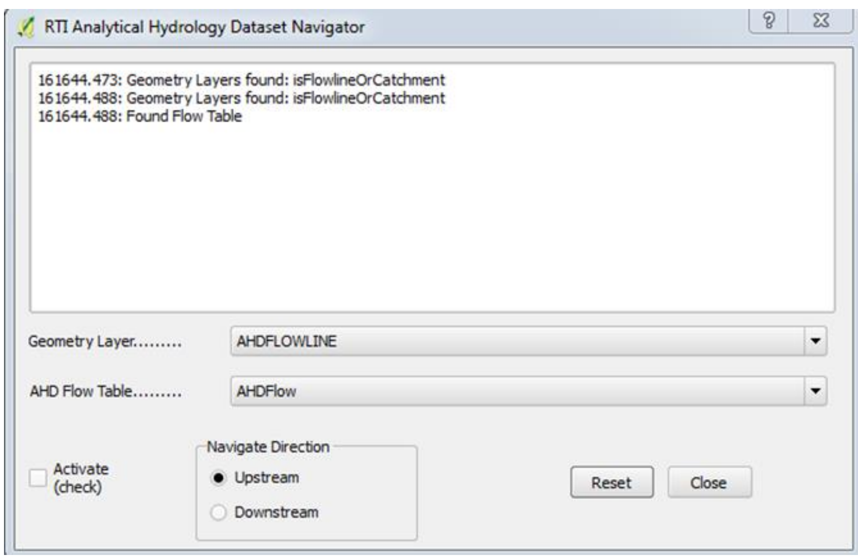
6. How to use the AHD-TOOL Navigator

The navigation AHD-Tool allows you to identify the drainage patterns both upstream or downstream from any of the catchments or streamlines defined in the AHD-LAC.

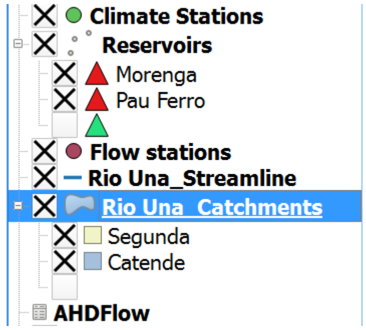
1. Once the project is opened in QGIS the tool opens by clicking on AHD Tools > AHD Navigator



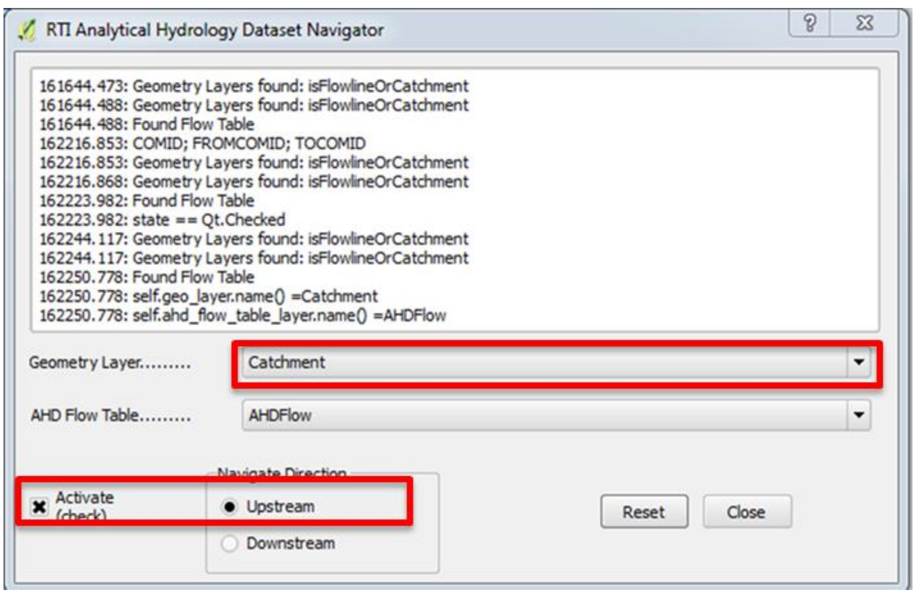
2. The AHD Navigator, after following the connectivities that are stored in the **AHDFlow.dbf** file, will select the catchment or rivers according to the direction of the flow and will provide important statistics



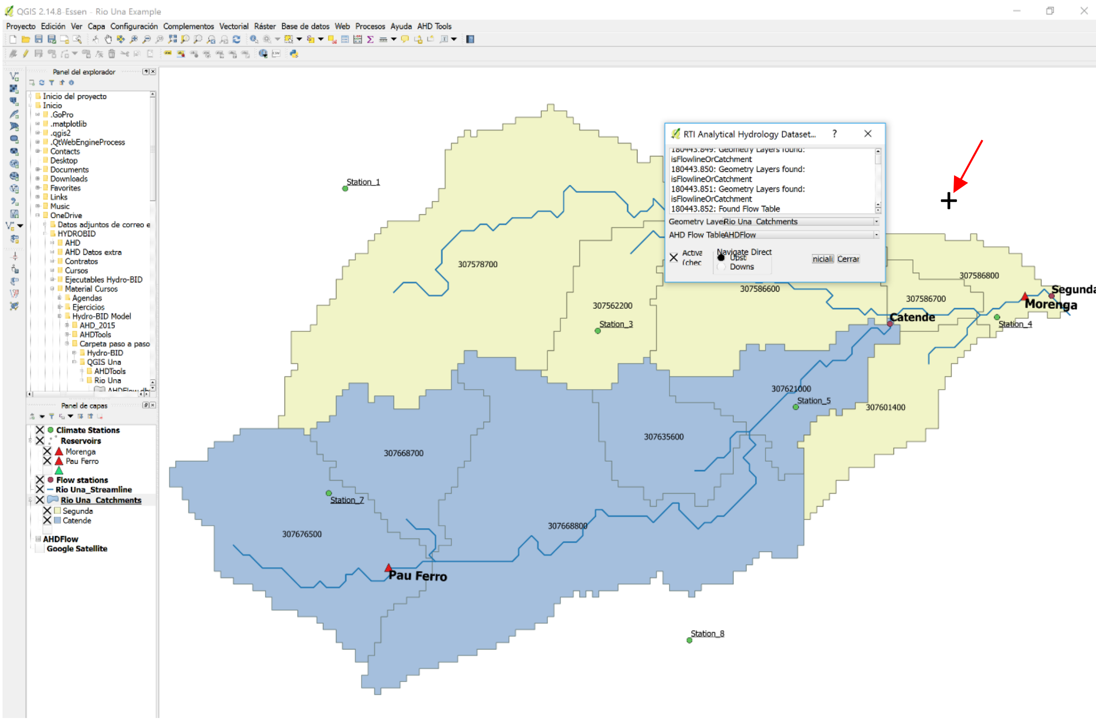
3. Selection of upstream catchments
   a- Active the "**Catchment**" layer by clicking on it



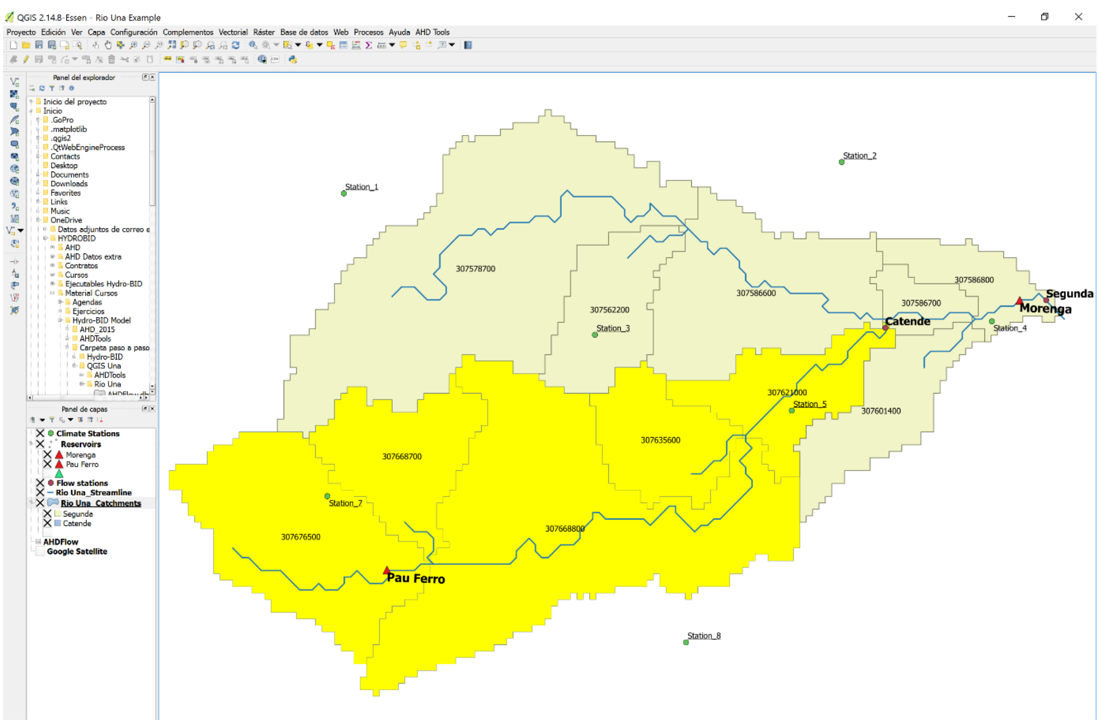
   b- Open the AHD Navigator, select the "**Rio Una Catchments**" from the Geometry Layer menu, make sure that the direction of navigation is set to "**Upstream**" and the "**Activate**" box is enabled



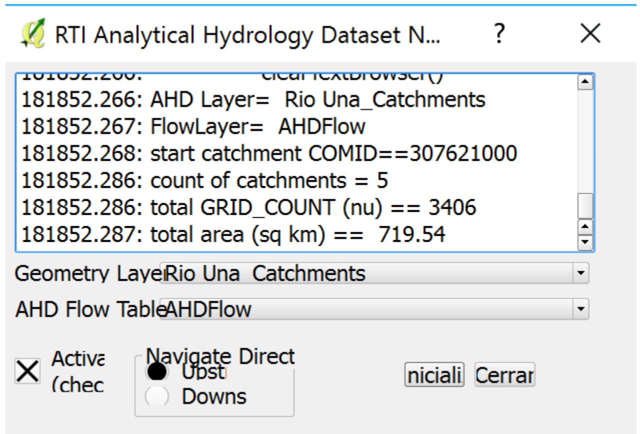
c- Move the cursor over the map, then you will see that it becomes a black cross sign



d- Click on the catchment that contains the "**Catende"** station, the AHD Navigator will select all the sub-basins that drain to the station



e- The AHD Navigator window will show the COMID of the sub-basin that is more downstream, the number of sub-basins selected and the total area of the catchment.



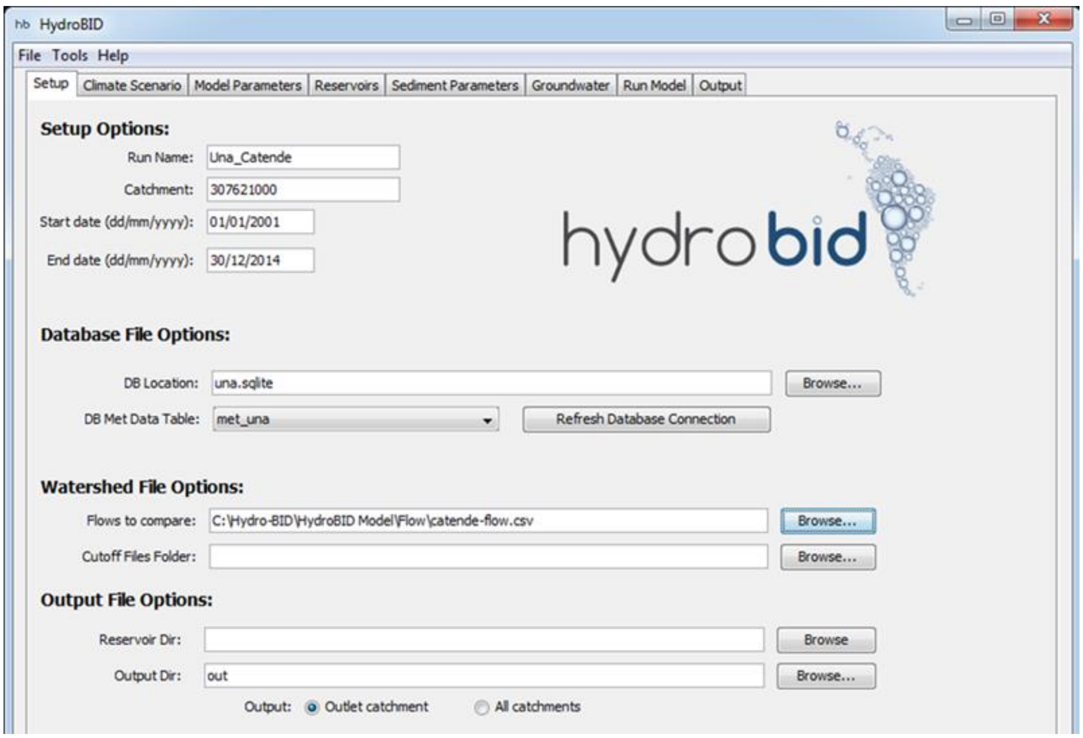
f- The procedure is the same for downstream drainage and for the Geometry Layer of streamlines (flowlines).

7. How to use the Hydro-BID Interface to carry out a simulation.

The AHD-Tool is used not only to display the catchments, view the location of stations and reservoirs and consequently confine the area of study, but it is also important to locate the COMID (unique catchment identifier) of the catchment more downstream of the system subject of analysis. In the Hydro-BID interface, it is vital to identify the COMID of the initial catchment of the study and which will be used to obtain the total water balance.

In this chapter we will be using the files and sub-folders that we find in the **"Hydro-BID"** folder

1. To activate the Hydro-BID interface of the case study, double-click on "**launchIWRM.bat**" file which already has pre-loaded the corresponding data implemented in the file "Settings.txt". If you want to start an analysis from scratch you must use the executable "**Hydro-BID 2.0.jar"**



Note: The .bat file does not use a pattern for saved relative to the folders, therefore you must verify that the pre-loaded directories correspond to the location of these files in your computer, if they do not correspond then use the button "**Browse**" to locate the correct directory.

In the interface's main window you will find the following variables:

a) **Setup Options:**
   - **Run Name**: The name of the simulation
   - **Catchment**: The COMID of the catchment more downstream of the system subject of study. In this case, it corresponds to the sub-basin of the **Catende** hydrometric station identified with the **COMID "307621000"**
   - **Start date**: start date of the simulation
   - **End date**: date of completion of the simulation

   Note: The simulation period must be within the availability of climate data. The first year is considered as a warm-up period.

b) **Database File Options:**

   - **DB Location**: Name of the database for the project. Click the "Browse" button to navigate to the folder where you saved the DB. In this case the name is **Una.sqlite**
   - **DB Met Data Table**: Select the table with the meteorological data to be used. A subsequent chapter will cover the creation of this DB.

   NOTE: Once the path to access the DB is provided, click on "**Refresh Database Connection**" for updating the options of "**DB Met Data Table**"

c) **Watershed File Options:**

   - **Flows to Compare**: input file with the time series of observed flow rates. This file is used to compare the simulated flows. Time series can be daily or monthly.
   - **Cutoff Files Folder**: Contains a list of files with time series of upstream catchment flows (this file is optional).
     <u>This option allows you to add contributions of water to the catchment and/or subtract losses.</u>

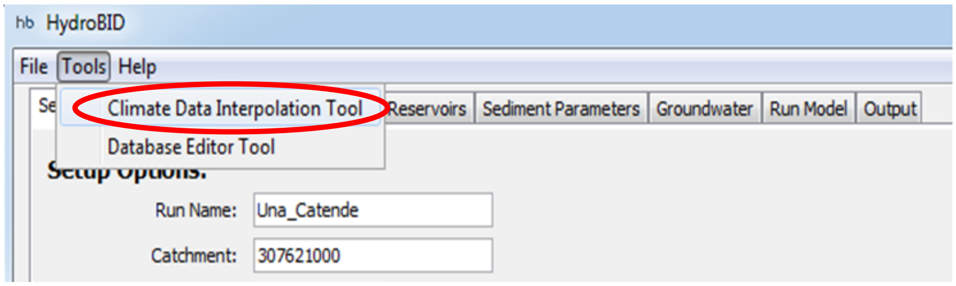
d) **Output File Options:**

   - **Reservoir Dir**: If the reservoirs are included in the model, this directory will include the data of demand, in and out flows of the reservoir.
   - **Output Dir**: Directory where the results of modeling are saved
   - **Outlet Catchments**: Select this option to save the output files only for the catchment more downstream. Use this option for the calibration process.
   - **All Catchments**: Select this option to save the output files of all catchments included in the simulation.

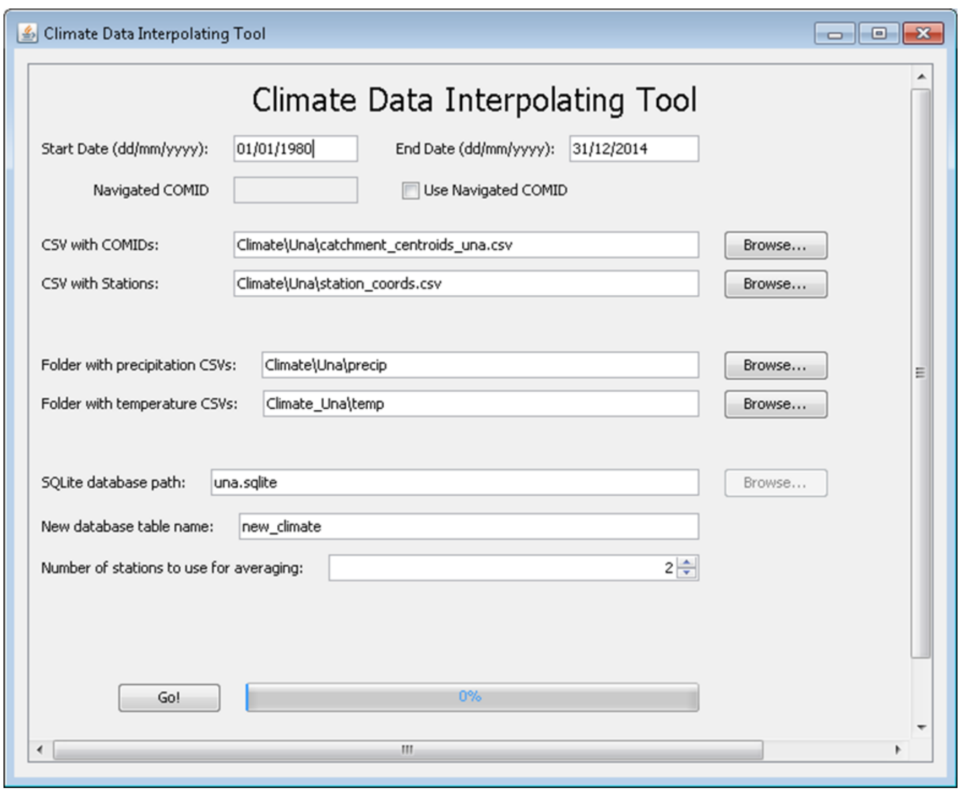
2. The first thing required to perform a simulation is climate data in the centroid of each one of the catchments; for this purpose we will use Hydro-BID's "**Climate Data Interpolation Tool",** a preprocessor that interpolates the daily time series of temperature and rainfall of the

weather stations in each catchment using the weighted average distance method of interpolation.

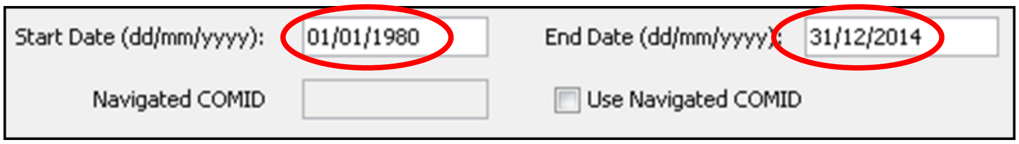
3. In the upper left corner of Hydro-BID, click on "**Tools**", select "**Climate Data Interpolation Tool**".



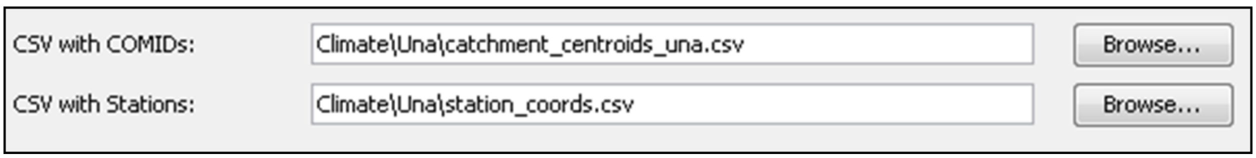
4. Once you click, the pop-up window of the interpolator will appear.



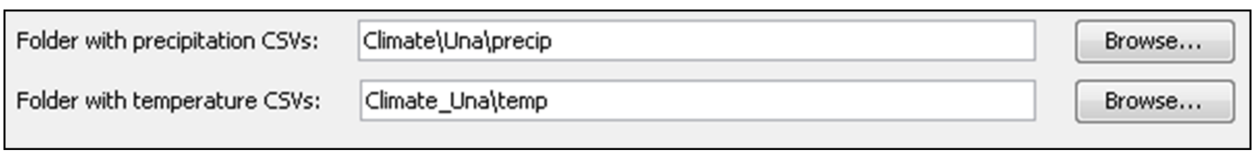
5. Verify that both the Start date and the End date correspond in the period used to perform the simulation (in this case, with the pre-assigned period that you can see in Hydro-BID's main screen).



6. In the option "**CSV with COMIDS**" upload the file "**catchment_centroids.csv**" with the COMIDs of the catchments and their latitude and longitude coordinates, which is located in the "**climate**" folder . Repeat the same operation in the option below, "**CSV with Stations**, uploading the file **"station_coord.csv"** with the weather stations and their latitude and longitude coordinates.

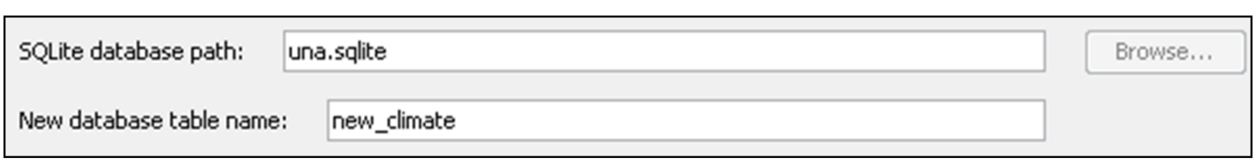


7. In the options "**Folder with precipitation CSVs**" and "**Folder with temperature CSVs**" upload the folders that contain daily data of each station in .csv format (subfolders **Precip** and **Temp** in the **climate** folder).



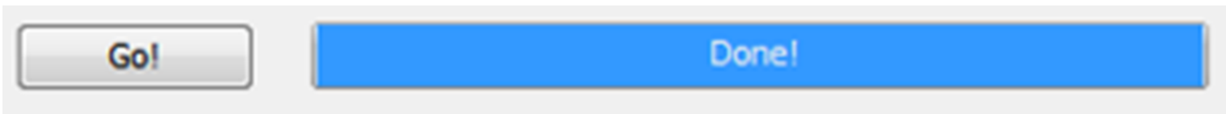
8. The option "**SQLite database path"** contains the path for the database that will be used to run the tool. Here is the place to save the table with the interpolated climate data. The location of the database should automatically match with the one imposed in Hydro-BID's initial screen. However, it is recommended to verify that it is correct, otherwise, to search for the SQLite database, you must find the correct "**.sqlite**" address in the main folder of the exercise.

   In the option of "**New database table name**", you should write the name of the table that will contain the interpolated climate data. When you go run Hydro-BID, from the main screen, this table is then selected in **DB Met Data Table"** for use of the interpolated values. For this exercise we will use the name "**new_climate**".



9. In the window "**Number of stations to use for averaging**" you indicate the number of nearby stations used to calculate the interpolated climate variable. The higher the number it will result in greater accuracy but will make the model run longer. It is recommended that you use a number between 2 and 4 stations.

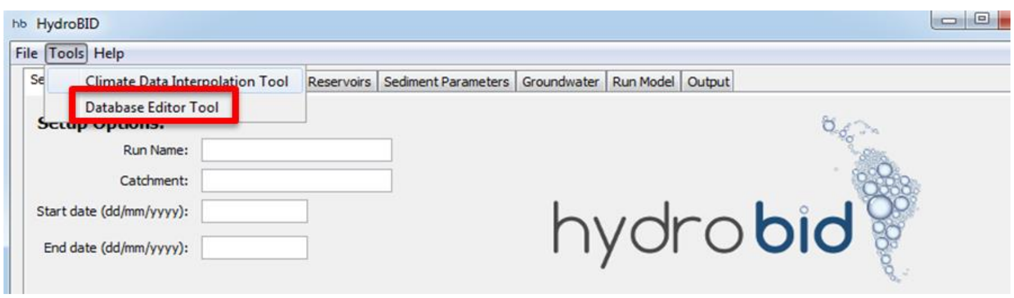
10. Now click on "**Go!**" to run the CDIT tool. Once Hydro-BID ends running successfully, the progress bar turns blue and the message "**Done!**" appears.



11. Once the climate variables have been interpolated you can make your first simulation with Hydro-BID.

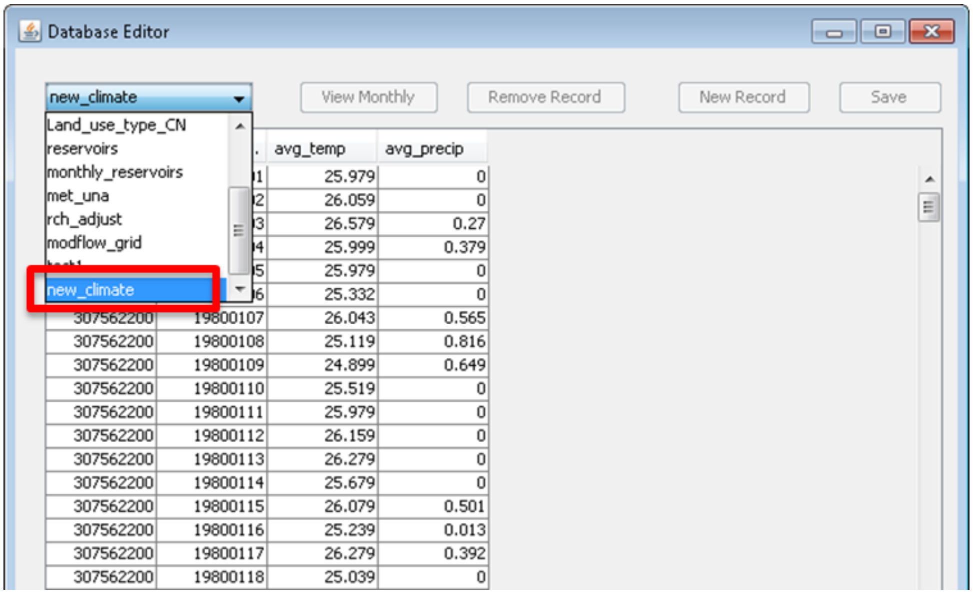
Note: To understand more about the capabilities and limitations of Hydro-BID's climate interpolator we invite you to read the Technical Note: **Hydro-BID: An Integrated System for Modeling Impacts of Climate Change on Water Resources**, which you can download at this link.

If you want to view the interpolated time series for each sub-basin you must click on "**Tools**" at the top left corner and select "**Database Editor Tool**".[4]

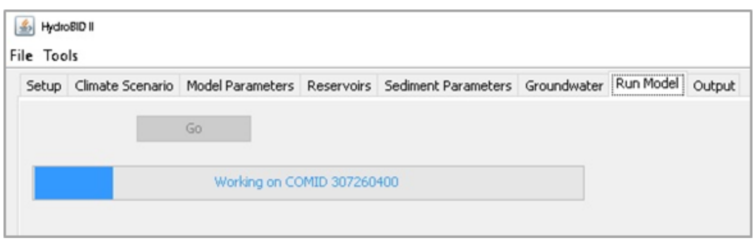


[4] **Note:** you may need to restart Hydro-BID to upload the new table.

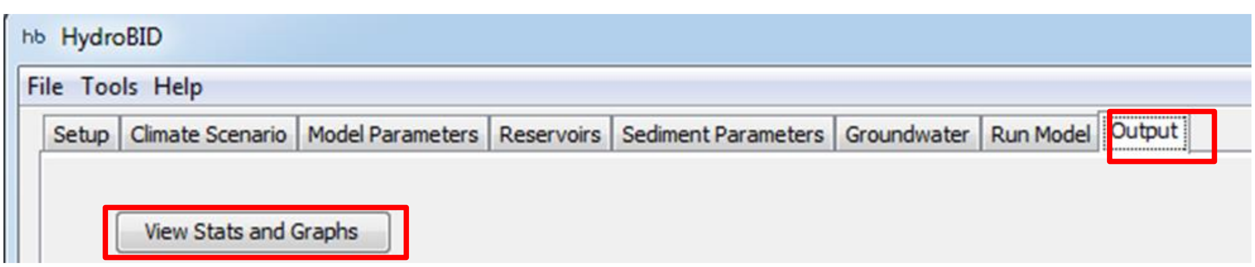
12. Once the pop-up window appears, from the list of tables, select the table you just created. In this case it is "**new_climate"** or any name that you assigned to the table in step 8 of this chapter.



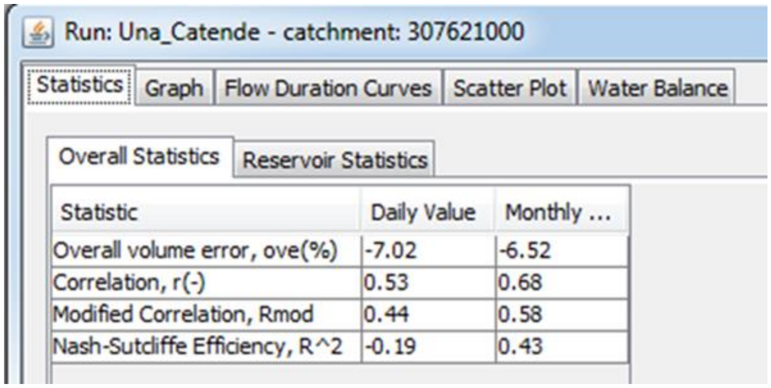
13. Once you are ready to make the first simulation, select the module "**Run Model**" in Hydro-BID's main screen and click on "**GO**". Automatically, the model will start running.



14. To view the results you must click on the "**Output"** tab in Hydro-BID's main screen. Then click on "**View Stats and Graphs**"



15. In the pop-up window, you will see all the options for visualization of the results. In addition, Hydro-BID provides daily and monthly statistics to evaluate the model's performance, such as: **Overall volume error**, **Ove (%), correlation, r (-)**, **modified Correlation**, **Rmod** and **Nash-Sutcliffe Efficiency, R^2**.



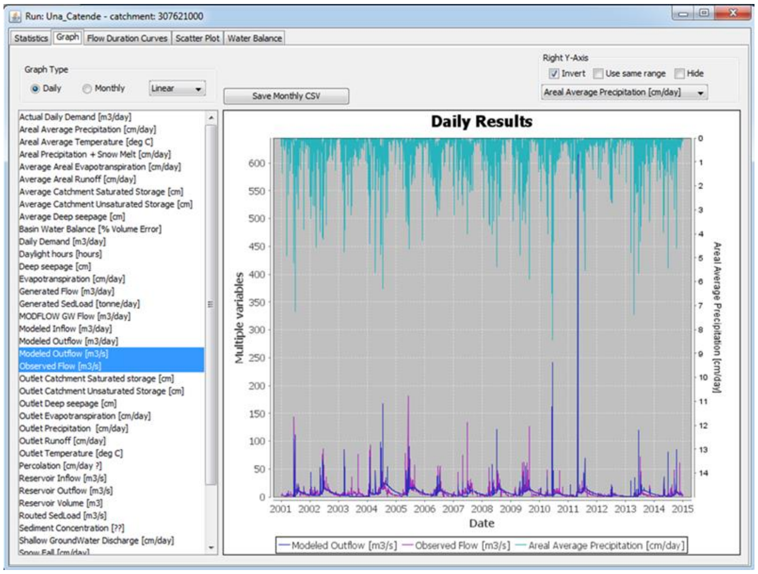
Statistic	Daily Value	Monthly ...
Overall volume error, ove(%)	-7.02	-6.52
Correlation, r(-)	0.53	0.68
Modified Correlation, Rmod	0.44	0.58
Nash-Sutcliffe Efficiency, R^2	-0.19	0.43

16. In addition, errors of monthly and annual volume are provided.

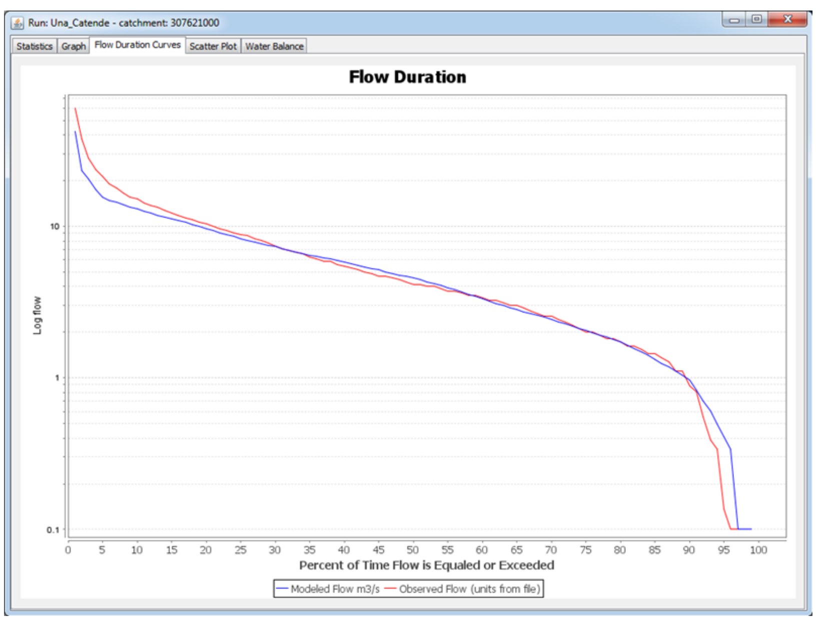
Monthly volume error

Month	Observed Mean (m^3/s)	Simulated Mean (m^3/s)	Ove(%)
January	3.38	4.1	21.4
February	3.72	3.84	3.46
March	3.8	3.41	-10.27
April	5.04	2.74	-45.71
May	9.06	5.81	-35.92

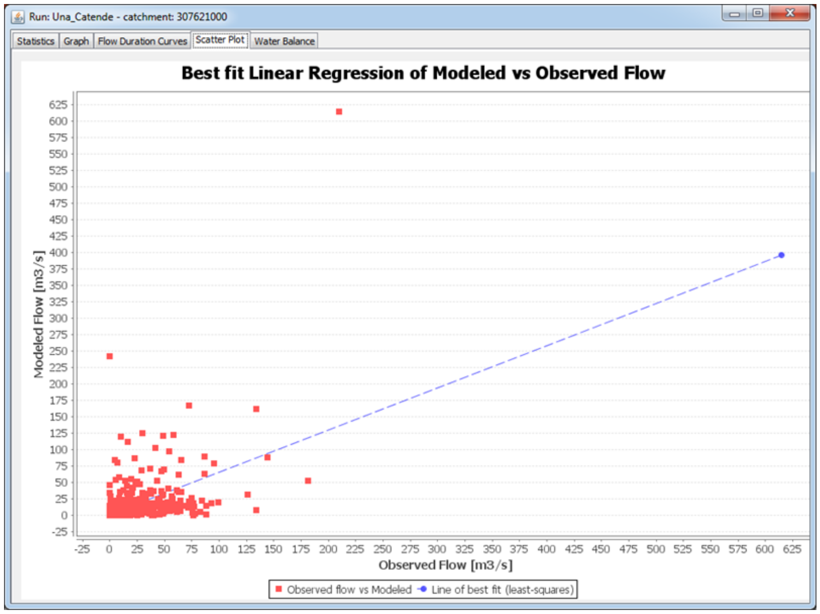
17. The "**Graph"** tab shows a hydrograph and allows other time-series to be displayed in a daily or monthly time scale and with a logarithmic or normal scale.



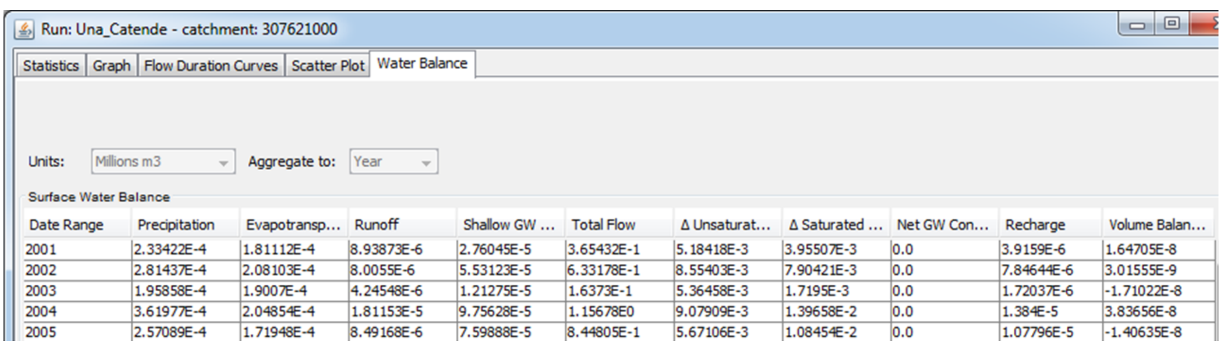
18. **Flow Duration Curve:** A graph to show the percentage of time that a given flow is being matched or exceeded. It is useful to evaluate the model's performance during the calibration.



19. **Scatter Plot:** The pattern of points reveals any correlation between the observed flows and the simulated flows.

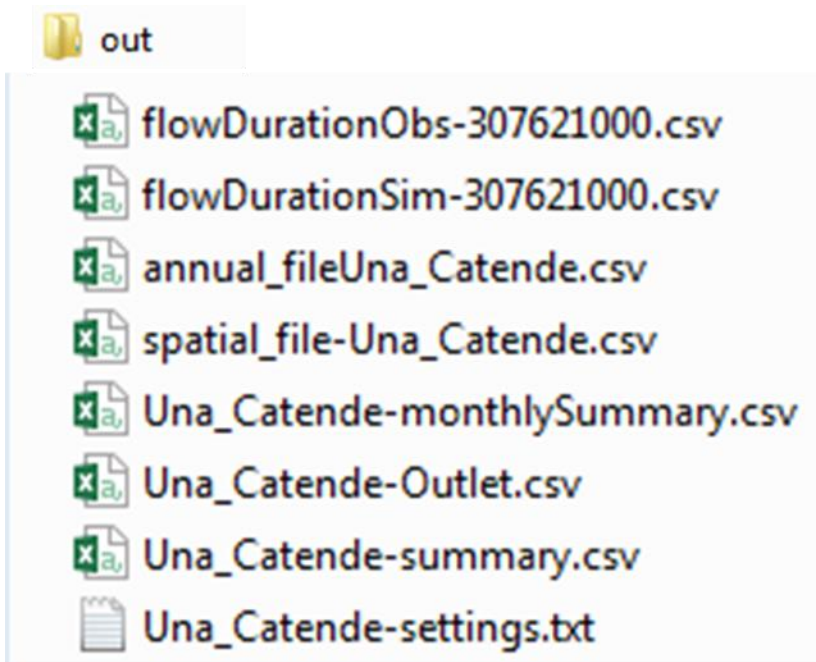


20. **Water Balance :** It provides an annual summary of all of the parameters included in the water balance.



Date Range	Precipitation	Evapotransp...	Runoff	Shallow GW ...	Total Flow	Δ Unsaturat...	Δ Saturated ...	Net GW Con...	Recharge	Volume Balan...
2001	2.33422E-4	1.81112E-4	8.93873E-6	2.76045E-5	3.65432E-1	5.18418E-3	3.95507E-3	0.0	3.9159E-6	1.64705E-8
2002	2.81437E-4	2.08103E-4	8.0055E-6	5.53123E-5	6.33178E-1	8.55403E-3	7.90421E-3	0.0	7.84644E-6	3.01555E-9
2003	1.95858E-4	1.9007E-4	4.24548E-6	1.21275E-5	1.6373E-1	5.36458E-3	1.7195E-3	0.0	1.72037E-6	-1.71022E-8
2004	3.61977E-4	2.04854E-4	1.81153E-5	9.75628E-5	1.15678E0	9.07909E-3	1.39658E-2	0.0	1.384E-5	3.83656E-8
2005	2.57089E-4	1.71948E-4	8.49168E-6	7.59888E-5	8.44805E-1	5.67106E-3	1.08454E-2	0.0	1.07796E-5	-1.40635E-8

21. Each "**run**" or execution of the model, produces four files with the name of the run (**Run Name**) provided by the user in the set-up window (**Set up**). The files are saved in the "**out**" folder. Additionally, files relating to the duration curves are produced.



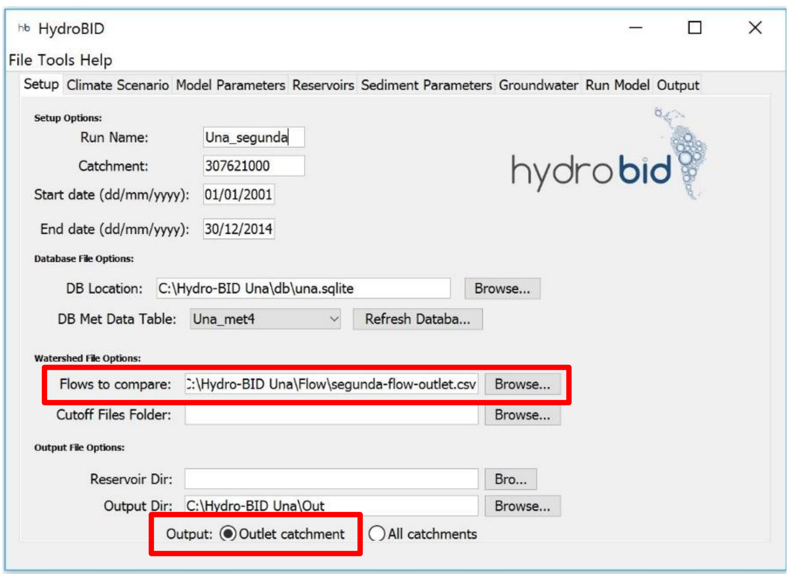
- **MonthlySummary**: monthly time series of precipitation, temperature, simulated flow and observed flow.
- **Outlet**: simulated time series of output variables by catchment.
- **Summary**: The total number of catchments, drainage area, computational time, and the COMID of the outlet catchment.
- **Settings**: All the input parameters and model set-up.

8. Model Calibration

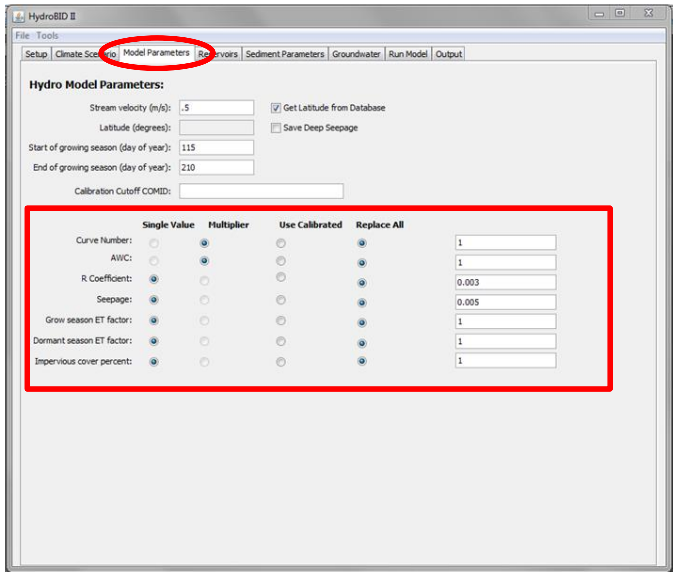
1. The Hydro-BID database is parameterized and pre-calibrated using values from regional databases, for this reason the process of calibration and validation is necessary to ensure that the model represents the reality as correctly as possible.

2. During the calibration, the values of the measured flows that are located in the flow files in the folder **"Flow"** are used to compare with the flows simulated by Hydro-BID.

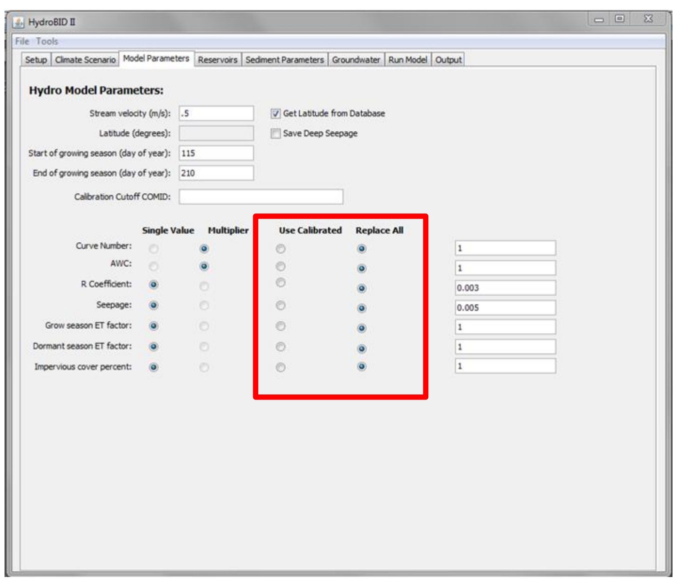
3. First , ensure that the "**Outlet Catchment**" option is enabled in the main screen. Once the process is complete the option "**All Catchment**" option can be activated, if you want detailed information of each sub-basin of the analyzed system. Additionally, verify that the file corresponding to the flow measurement station that you want to calibrate is loaded in the "**Flows to Compare**" option.



4. For the calibration you must click on the "**Model Parameters"** tab in Hydro-BID's main screen and at the bottom you will find all the calibration parameters.



5. To calibrate a particular parameter you need to activate the "**Replace All**" option; once the parameter has been calibrated you must activate the "**Use Calibrated**" option to fix the value and prevent it continue being modified.



6. The parameters to calibrate are the following:

    - **Curve Number**: parameter used to characterize the type of land use and represent the land's hydrology. A curve number is assigned to each sub-basin in the database.
    - **Available Water Content (AWC)**: AWC estimates the amount of water that can be stored in the soil to be used by plants, affecting the infiltration into the groundwater. A value is assigned to each sub-basin in the database.
    - **Coefficient of recession (R)**: The R coefficient characterizes how ground water near the surface contributes to the flow in the rivers after an event of great flows.
    - **Losses (seepage)**: is the exchange between groundwater close to the surface and the deepest groundwater.

7. To verify the simulations of calibrations, you can use the variables of error, the time series graph and the flow duration curve.

8. The variables used in the statistical determination of the errors in Hydro-BID's simulations are the following:

    - **Overall Volume Error**: it indicates the average percent of error between the simulated values and the observed values. Optimum value close to the % of maximum permissible error.
    - **Correlation (r)**: it analyzes the standard deviations of the time series of observed and simulated flows. Optimal value close to 1.
    - **Modified Correlation Coefficient (r_{mod}):** it analyzes the standard deviations of the time series of observed and simulated flows, by applying a factor that relates the maximum and minimum values. Optimal value close to 1.
    - **Nash-Sutcliffe Efficiency Index (R^2):** it analyzes the magnitude of the relation between the variances of the simulated flows and the variances of the observed flows. Optimal value close to 1.

    Note: to understand more about the calibration parameters and the statistics presented for Hydro-BID's simulations, we invite you to read the Technical Note: " **Hydro-BID: An Integrated System for Modeling Impacts of Climate Change on Water Resources**, which you can download at this link.

9. The pre-determined case study is already calibrated, if you want to practice the calibration process you must follow these steps:

    - The initial run corresponds to the sub-basin identified by the "**CATENDE"** hydrometric identified by the **COMID "307621000"** and is used below to illustrate the influence of each parameter in the calibration process.

    - To practice the calibration process, you must use the catchment identified with the hydrometric "**SECOND"**; it is characterized by the **COMID "307586800"**. This is the catchment most downstream of the Una River and it is the one that, once calibrated, allows obtaining the water balances for the entire catchment.

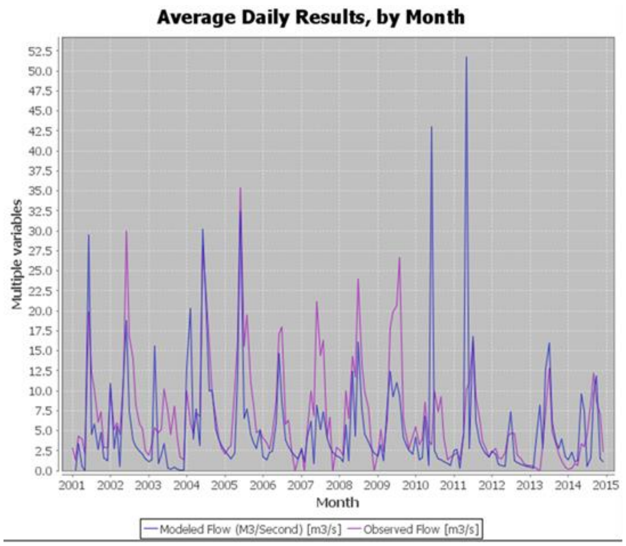
10. The following points illustrate the relevance of each of the parameters used in the calibration process of the catchment identified by the **COMID "307621000"** which is the one that we have been using throughout this tutorial.

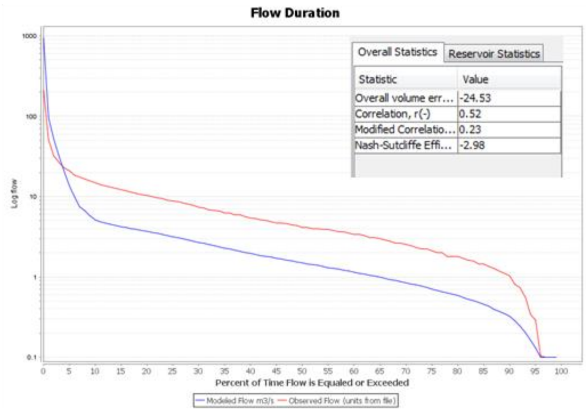
    Note: There is no specific order to calibrate each parameter, this will depend on each simulation to be calibrated depending on the first comparison between observed and simulated values.

    - The following figure shows the initial parameterization of the simulation with their respective graphs and final errors of simulation:

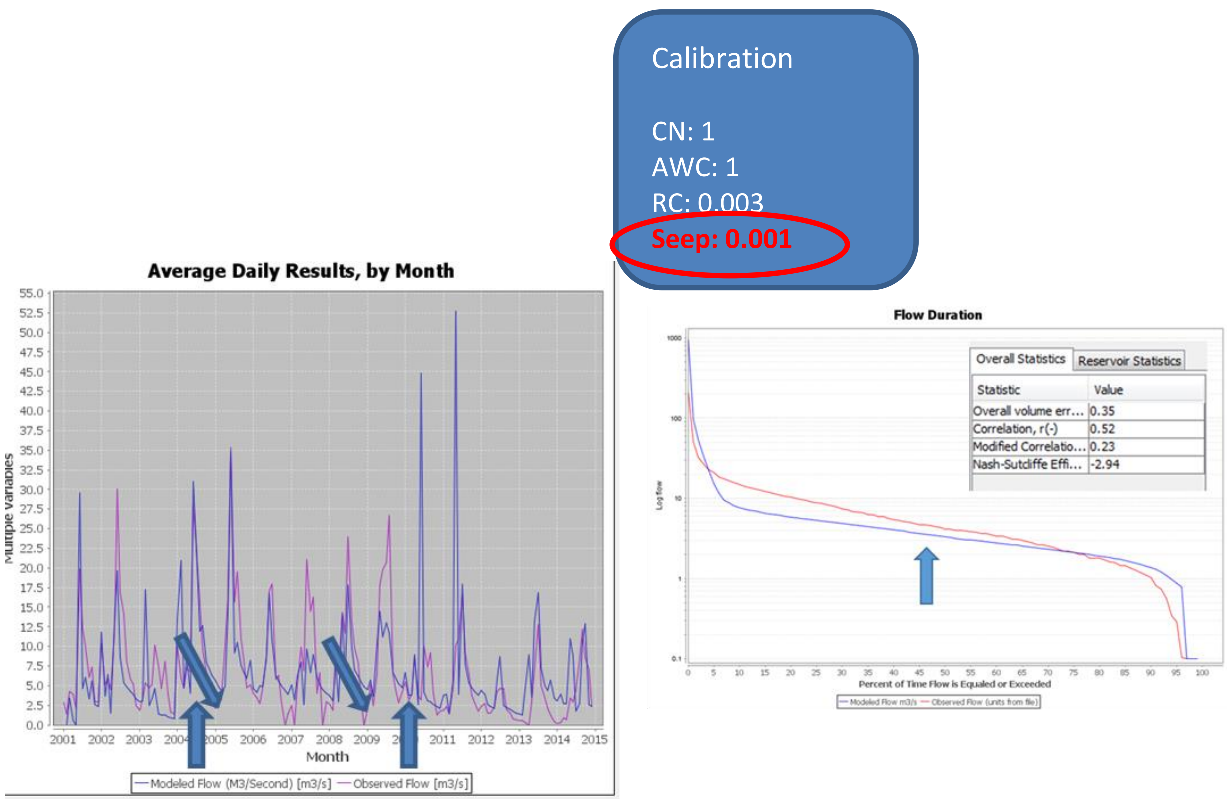
Initial calibration

CN: 1
AWC: 1
RC: 0.003
Seep: 0.005



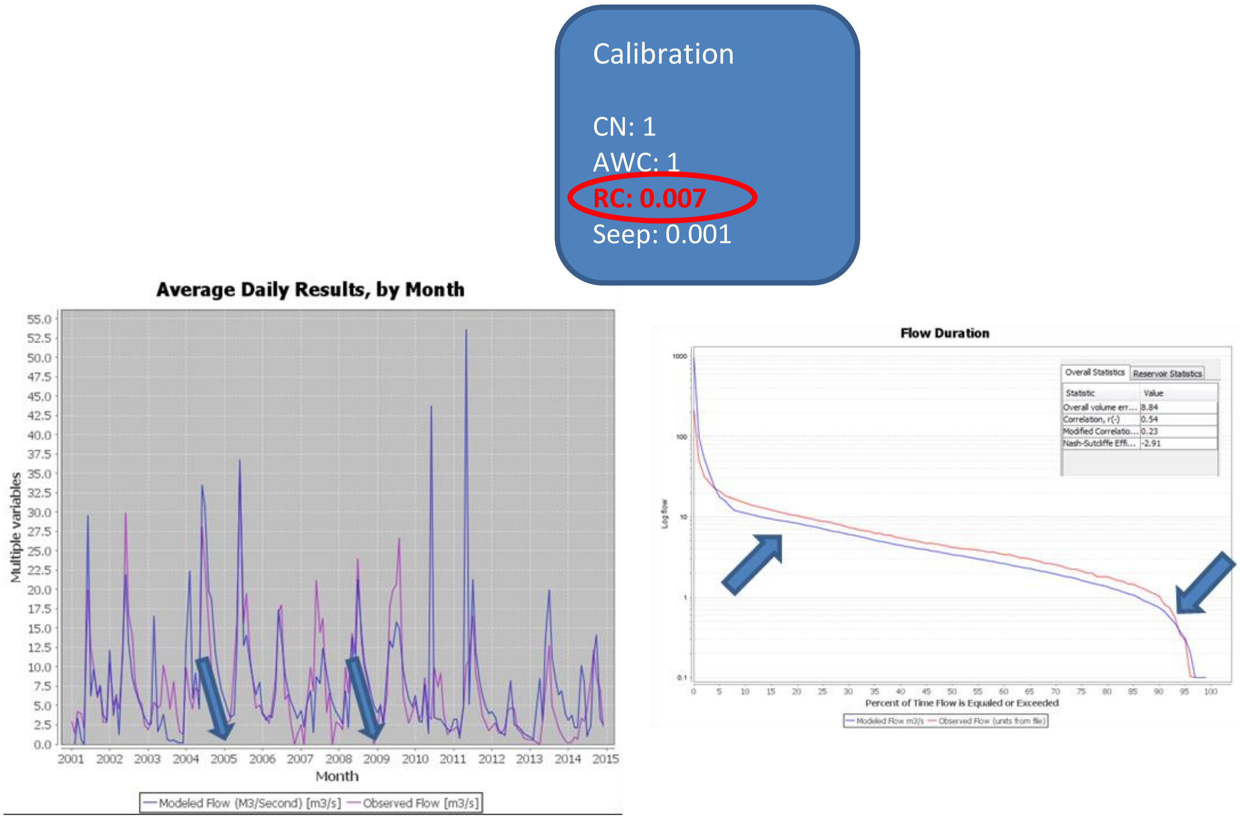


- The graph of flow duration of this initial simulation shows how the simulated volume is less than the observed volume; in addition, you can see the mismatch of the flow peaks in the average monthly hydrograph.
- In this particular case, the first problem to be solved was the total volume. Hence, as a first step the parameter “**SEEPAGE (SEEP)**" was reduced to consequently reduce the infiltration and increase the runoff.
- The new value of "**SEEPAGE**" was reduced from 0.005 to **0.001**.



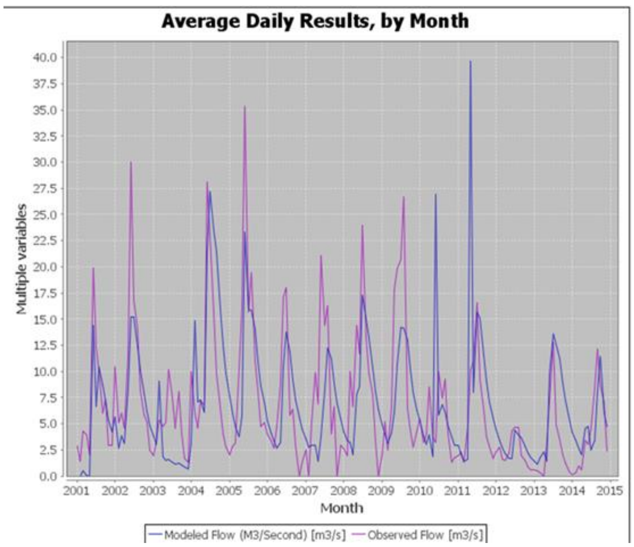
- Although this variation improved significantly the difference in volume, it is noted that the simulation overestimated the values of lower flows and underestimated the values in a higher range.

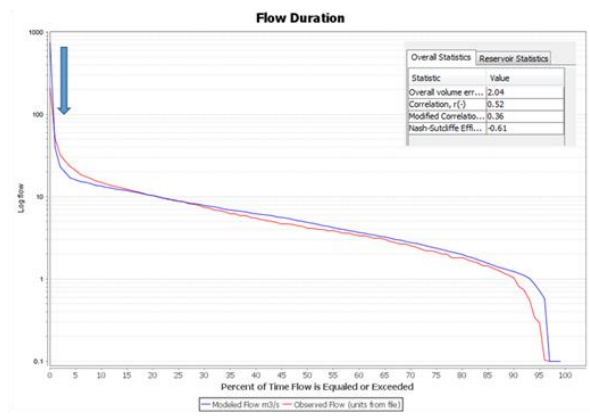
- For this reason, the second step was to increase the "**Coefficient of recession (RC)**" parameter from 0.003 to **0.007**, in order to force the higher flows to have a greater repeatability and similarly to reduce the lower flows. The effect can also be seen in the length of the spikes in the monthly hydrographs.



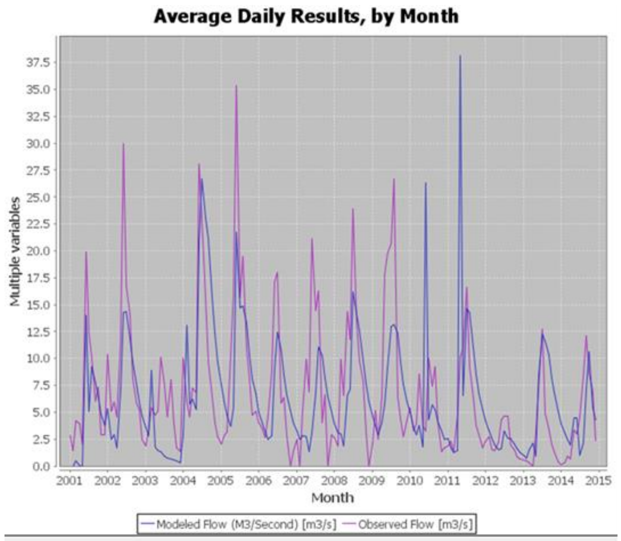
- Once the <u>slope of the flow duration curve</u> was adjusted, first, it became necessary to finish adjusting the overestimated peaks that could be seen both in the curve of the monthly hydrographs as well as in the flow duration curve.

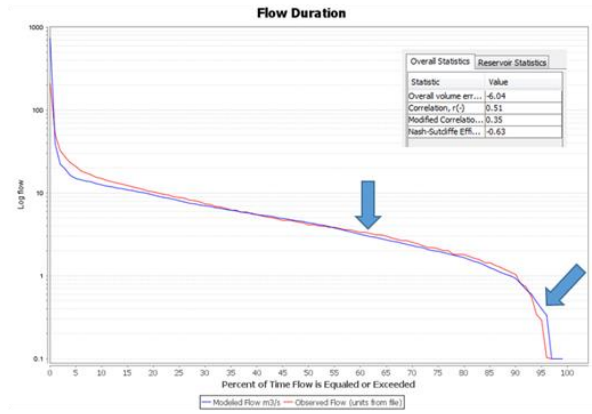
- This is accomplished by reducing the "**Curve Numbers (CN")**, as it reduces the runoff and the sensitivity to precipitation events; in this case it was reduced by 20%, which represents a value of **0.8** once it is included in the interface.





- Finally the **"Available Water Content (AWC)"** was used to adjust the small differences in the ends. In this case, the parameter AWC was increased by 20%, which would mean a value of **1.2** to somewhat reduce the higher flows.





Note: As of this moment, by modifying **AWC** and **Rc** the desired accuracy calibration can be obtained. This will depend on each specialist, the quality of the existing data and the sensitivity pre-established for the study (maximum percent of error allowed).

The following table presents ranges of values "recommended" for each of the variables used in the calibration process:

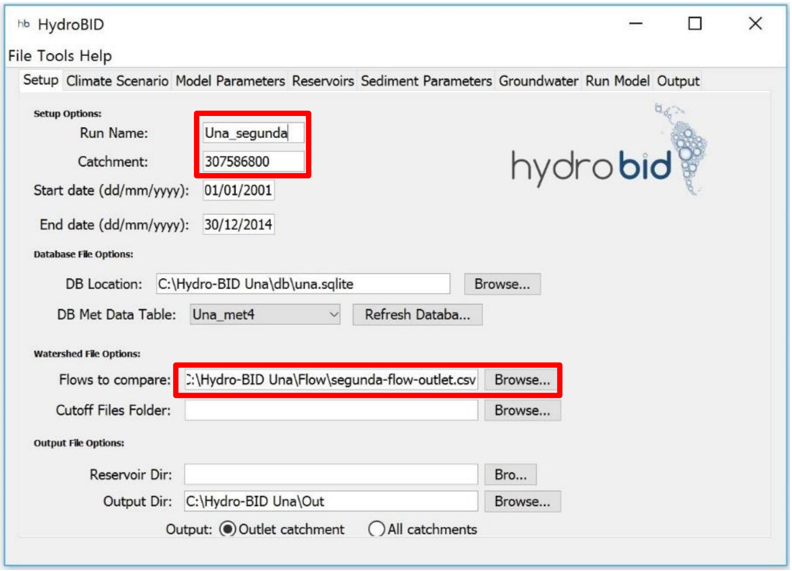
Stream Velocity	Estimated average velocity of the river segments.	0.5 m/s
Curve Number (CN)	Curve number. Controls the initial amount of abstraction used to calculate runoff. The default values are available in the database.	0.8 - 1.2 (multiplier)
Available Water Content (AWC)	Available capacity of water in the soil. It activates the beginning of percolation. The default values are available in the database.	0.2 - 1.2 (multiplier)
Recession Coefficient (r)	Recession Coefficient. Controls the rate of groundwater flow from the saturated storage.	0,001 - 0.75 (day-1)
Seepage Coefficient (S)	Coefficient of percolation. Coefficient that controls the rate of filtration in the underground aquifer	0,005 - 0.1 (day-1)
Grow season ET factor	Evapotranspiration factor during the growing season	0.5 - 1.5
Dormant season ET factor	Factor of evapotranspiration during the dormant season.	0.5 - 1.5
Impervious cover percent	The estimated percent of the impervious portion of the catchment.	1%

11. As indicated, the procedure above is already implemented in the case study that accompanies this manual. Therefore, the procedure that follows will allow to carry out the calibration exercise of the catchment identified by the **COMID "307586800"** and that represents the closing of the total Una River basin:

- In "**Run Name**" change the name to **Una_Second**, and in "**COMID**" place the identifier of the SECOND catchment "**307586800**".

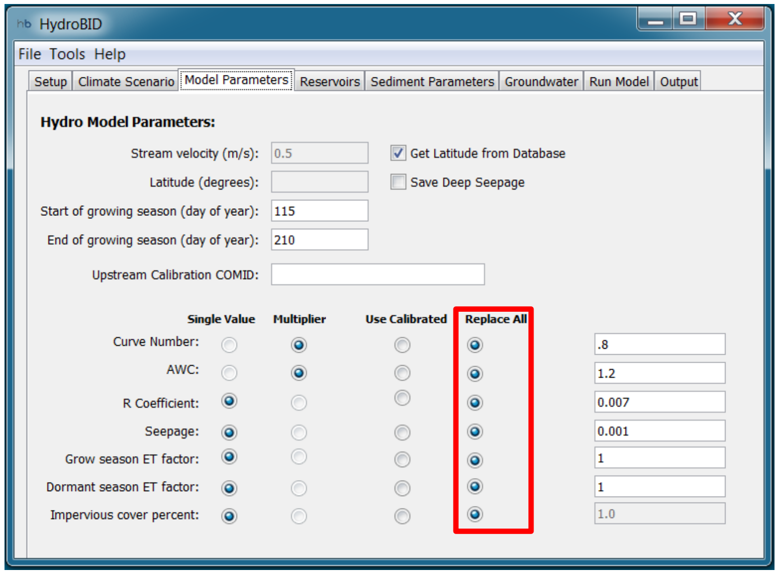
- In "**Flows to Compare**" use "**Browse**" to load the file that corresponds to this station, which you can find in the "**FLOW**" folder.

- The dates **"Start Date"** and **"End Date"** should remain the same because the simulation belongs to the same simulation period.



- In the "**Model Parameters**" window, add the **COMID of the CATENDE catchment, "307621000"**, on the "**Upstream Calibration COMID**" label ; this will prevent the model from modifying the parameters that have been already calibrated for this sub-basin.

- Select the option "**Replace All**" in the parameters you want to calibrate.



- Now you can run Hydro-BID and begin to calibrate the complete model of the Una river basin.

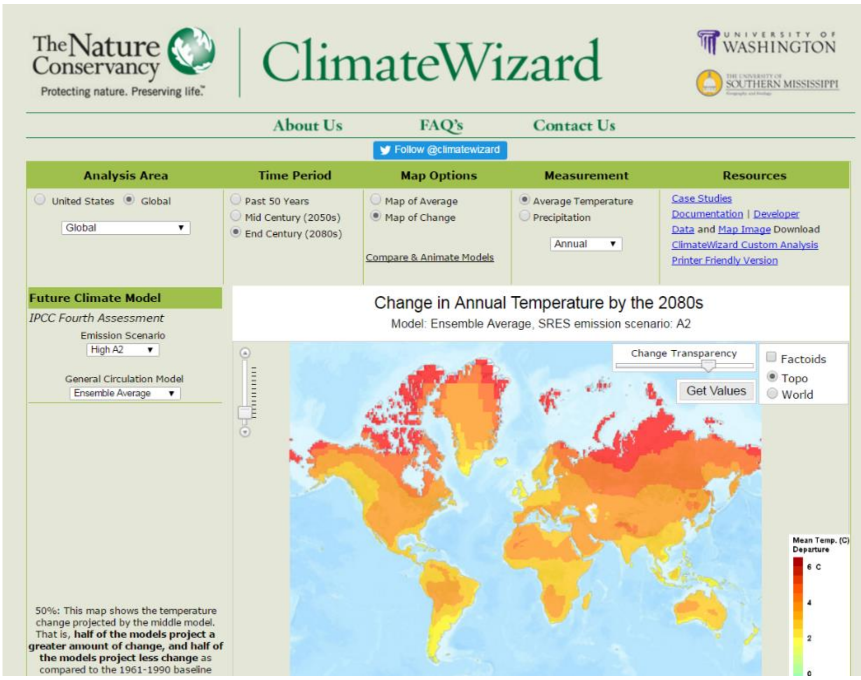
- Once the process is complete, it is not necessary to repeat the calibration unless in the catchments of the study a noticeable alteration in land use occurs, or that the construction of a significant work of infrastructure is planned (reservoir, artificial canal, diversion, etc.)

9. Simulation of Climate Change Scenarios.

Hydro-BID includes a tool to run simulations for the analysis of climate change scenarios; this tool allows for variations of precipitation and temperature on an annual or monthly basis.

Below you will find how to simulate a climate change scenario for the Una River basin.

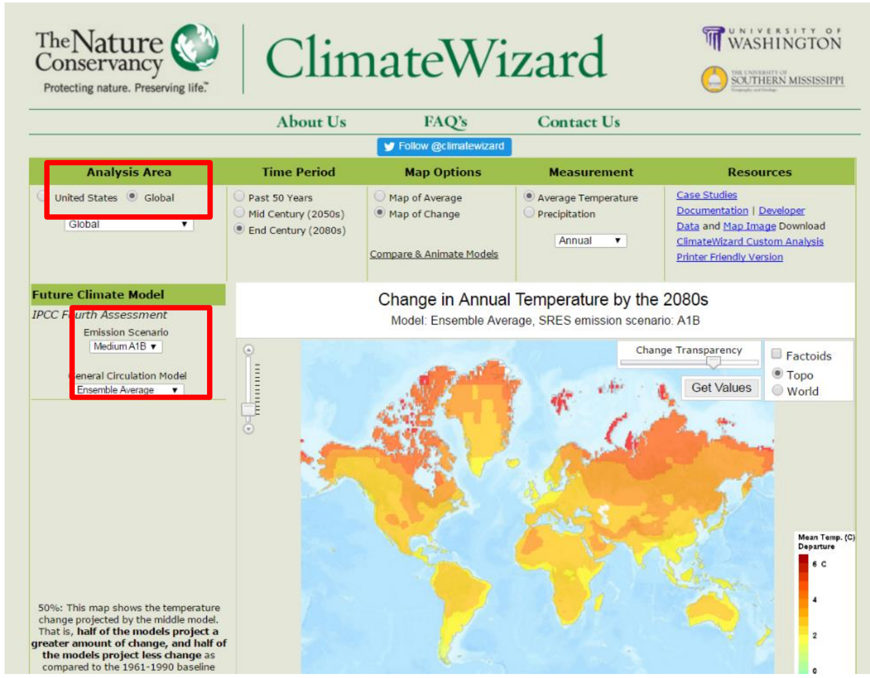
1. To obtain the climate change scenario we will use the information from Climate Wizard (www.climatewizard.org), a platform implemented by The Nature Conservancy (TNC) to access information from global circulation models.



2. Hydro-BID requires the increase of temperature (Celsius) and the change in precipitation (%).

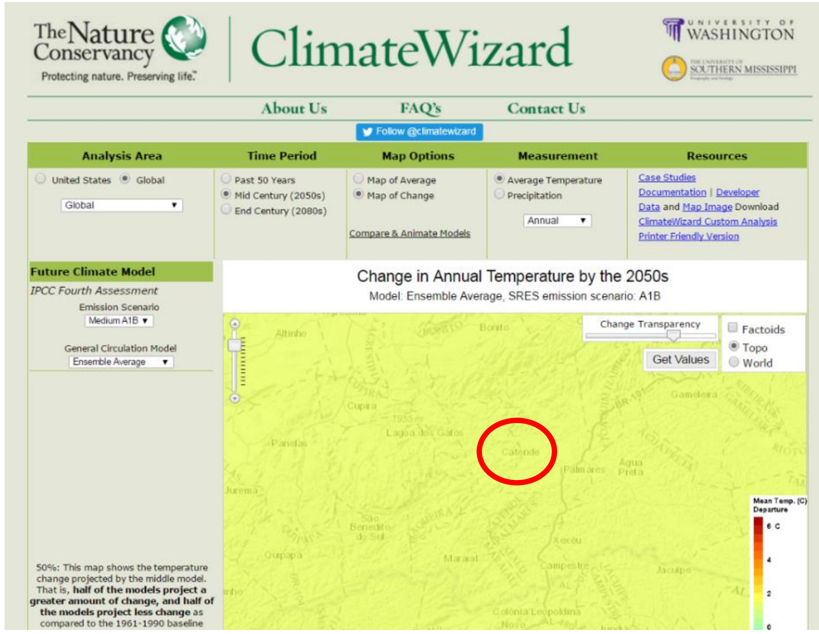
   Note: If you want to use the **"Precipitation"** option, remember the results in Climate Wizard are given in **inches** and these must be converted to **cm**.

3. To obtain the values we will assume the following hypothesis:
   a. In the box of **"Analysis"** select "Global".
   b. In the box of **"Emission Scenario"** select **"Medium A1B"** and in the **"General Circulation Model"** select **"Ensemble Average"**

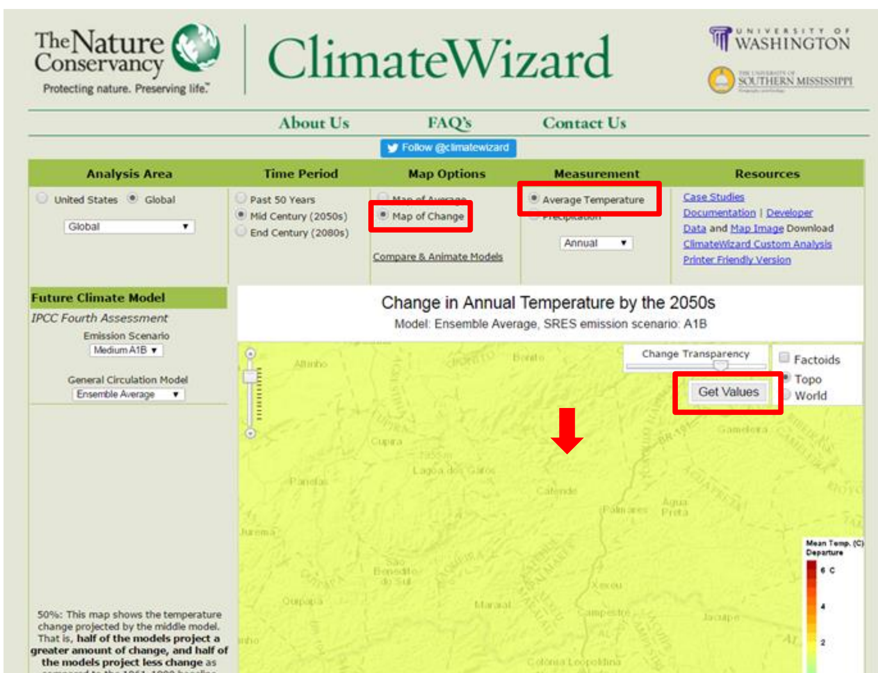


c. In the **"Time Period"** box select **"Mid Century (2050s)"**

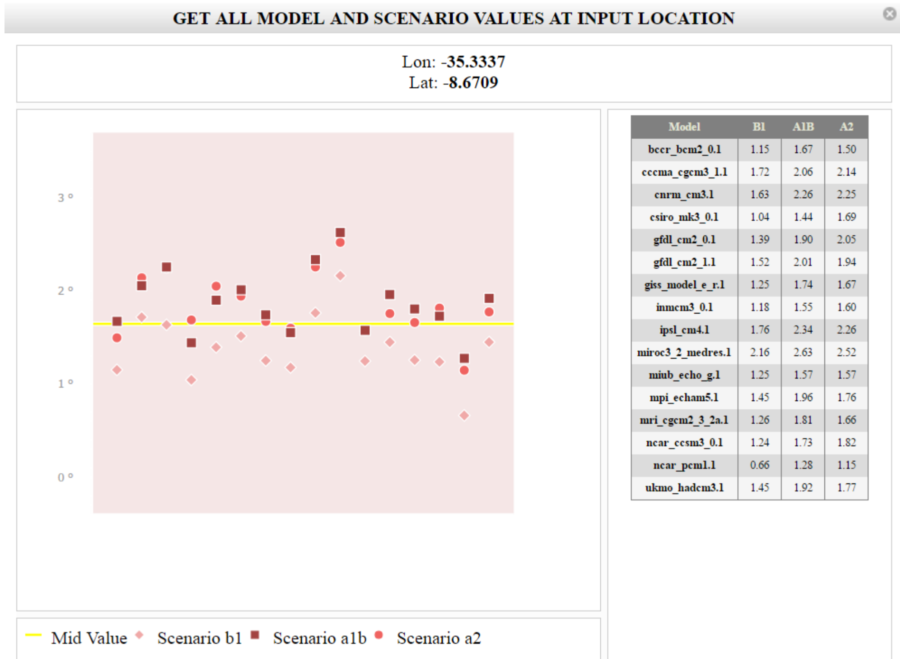
d. "Zoom in" the state of Pernambuco in Brazil and use the point that identifies the location of **"Catende"** (*Lat: -8.67°*, *Lon: -35.69°*) as a reference which is located to the southwest of the city of Recife.



e. To find the value of the temperature, in the **"Map Options"** tab first select **"Map of Change",** then in the **"Measurement"** tab select **"Average Temperature"** and then click on **"Get Values"** and click on the selected zone.



f. In the pop-up window select the value that is on the **"Mid Value";** in this case it could indicate an increase of **1.6 Celsius**

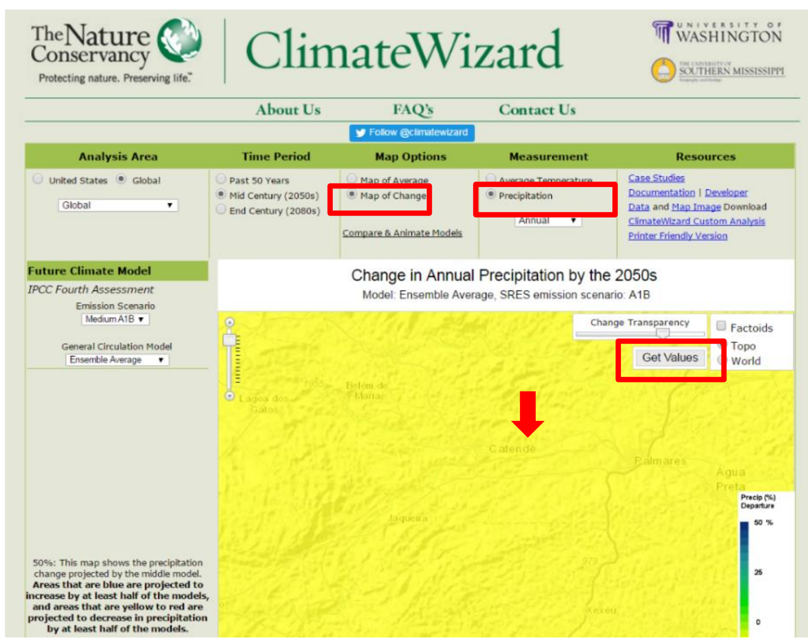


GET ALL MODEL AND SCENARIO VALUES AT INPUT LOCATION

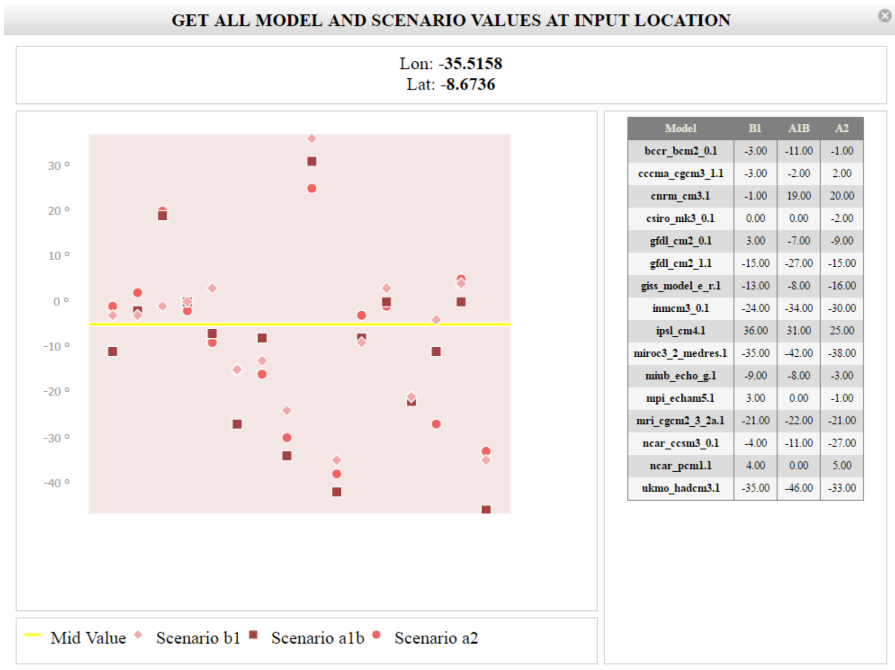
Lon: -35.3337
Lat: -8.6709

Model	B1	A1B	A2
bccr_bcm2_0.1	1.15	1.67	1.50
cccma_cgcm3_1.1	1.72	2.06	2.14
cnrm_cm3.1	1.63	2.26	2.25
csiro_mk3_0.1	1.04	1.44	1.69
gfdl_cm2_0.1	1.39	1.90	2.05
gfdl_cm2_1.1	1.52	2.01	1.94
giss_model_e_r.1	1.25	1.74	1.67
inmcm3_0.1	1.18	1.55	1.60
ipsl_cm4.1	1.76	2.34	2.26
miroc3_2_medres.1	2.16	2.63	2.52
miub_echo_g.1	1.25	1.57	1.57
mpi_echam5.1	1.45	1.96	1.76
mri_cgcm2_3_2a.1	1.26	1.81	1.66
ncar_ccsm3_0.1	1.24	1.73	1.82
ncar_pcm1.1	0.66	1.28	1.15
ukmo_hadcm3.1	1.45	1.92	1.77

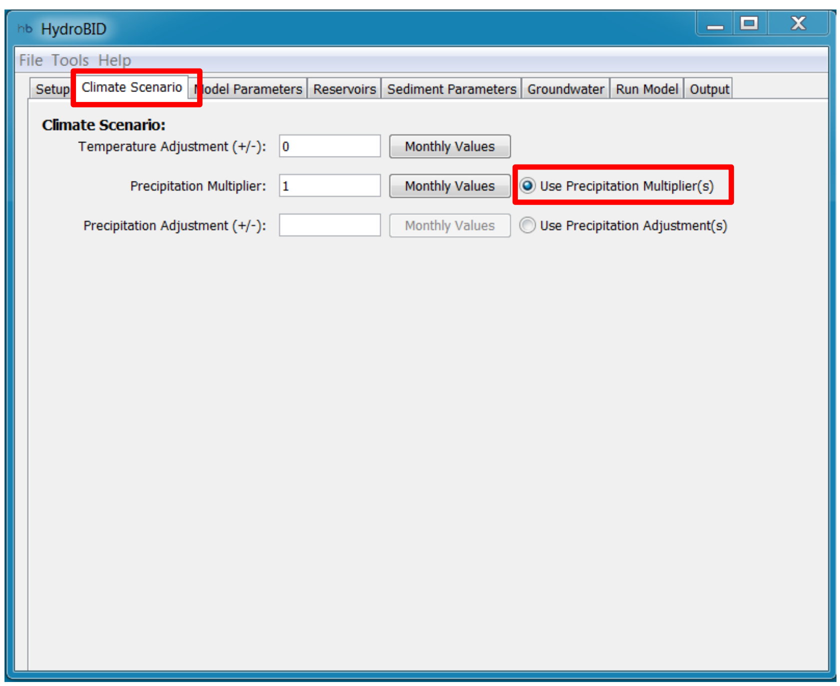
g. To find the value of the precipitation, in the **"Map Options"** tab first select **"Map of Change"** then in the "**Measurement"** tab select **"Precipitation"** and then click on **"Get Values"** and click on the selected zone.



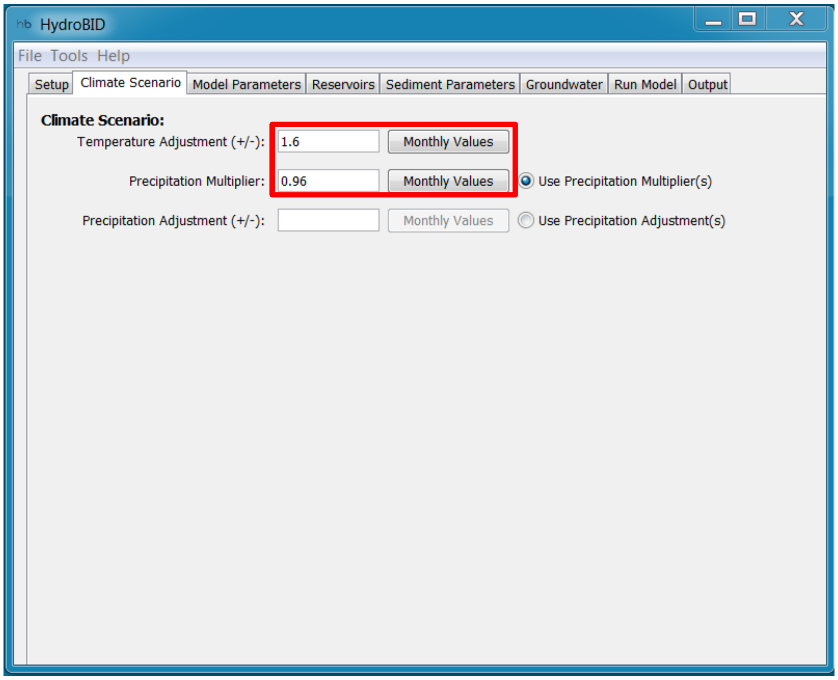
h. In the pop-up window, select the value that is on the **"Mid Value";** in this case it could indicate a decrease of **4%** in precipitation.



4. In the Hydro-BID interface, select **"Climate Scenario"**; in this case we will only make a simulation with total values of change. Check that the option **"Use Precipitation Multiplier"** is active.

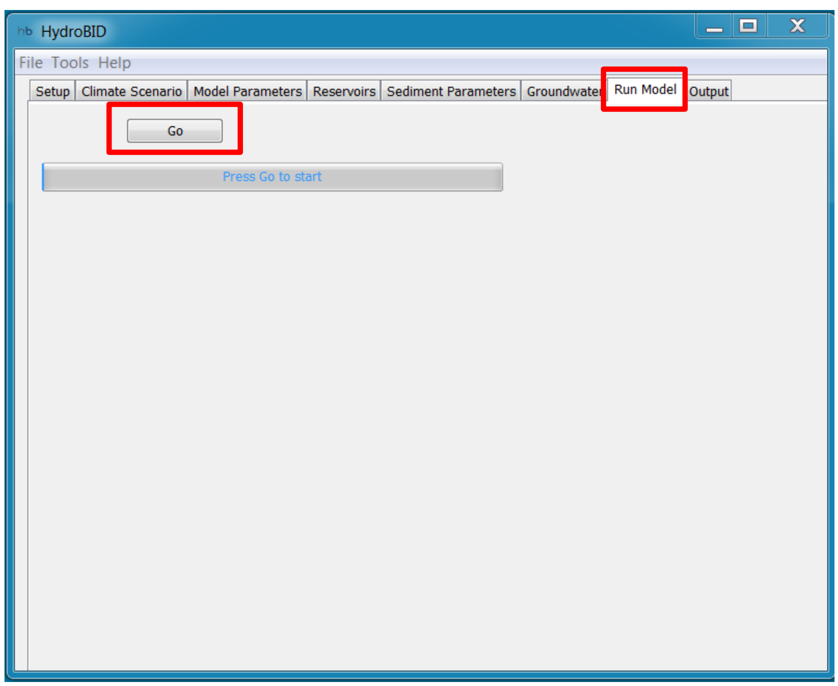


5. Now, we include the value of **1.6** in the **"Temperature Adjustment"** box and we will include **0.96** (representing a reduction of 4%) in the **"Precipitation Multiplier"**



Note: The value that we include in the **"Precipitation multiplier"** box is a multiplier that reflects an increase or decrease in precipitation. For example, if we enter a value of 1, it means that there will be no variation in precipitation. If, on the other hand, we know that the precipitation will increase by 20%, we would enter a value of 1.2.

6. Finally, you can proceed to the **"Run Model"** window to run the simulation and verify changes in the volume available within the climate change scenario that was selected.



7. It is important to understand that Hydro-BID will simulate the same time series that is found in the original simulation but, in this case, the results will represent the same time series but beginning on the year 2050 as the first year and modified with the applied changes. In this case, the values of flow observed, which are used to build the flow duration curve, will help you obtain a good image of the possible change of behavior of the catchment due to the effects of climate change.

IDB

Inter-American
Development Bank