Componentized-WEAP RESTful Framework Installation and User Guide*

Version 1.0

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** Point-of-Contact

1. Componentized-WEAP Software Application

The Componentized-WEAP (C-WEAP) is a RESTful framework application [1] written in **NodeJS** for the Water Evaluation and Planning (WEAP) system [2, 3].

2. WEAP Software System

WEAP is a propriety system software supported for the Windows OS. Information on licensing this software is available at WEAP Licensing.

3. Executable Componentized-WEAP Software Application Installation

The executable version of the Componentized-WEAP (C-WEAP) framework is a standalone application to be run on the Windows OS. You just need to download the executables version of the C-WEAP framework from https://acims.asu.edu/software/c-weap/, then unzip the downloaded file in a directory. It contains the "workspace" folder (which uses to manage the required flat files by the C-WEAP framework and WEAP system), the "config.json" file (to set the host and port number of the web-service), the "node-activex.node" (the required third-party packages), and the C-WEAP.exe file. All required libraries and frameworks (NodeJS, Express, etc.) are embedded in this executable file. The unzipped directory should not be installed shared disk drives such as Dropbox.

To run the C-WEAP, double-click on the C-WEAP.exe file. Upon successful execution of the C-WEAP application, the message "`Componentized-WEAP is listening at http://{hostname}:{port}`" appears in the first line of a Command Prompt console such as the one shown in Figure 1.

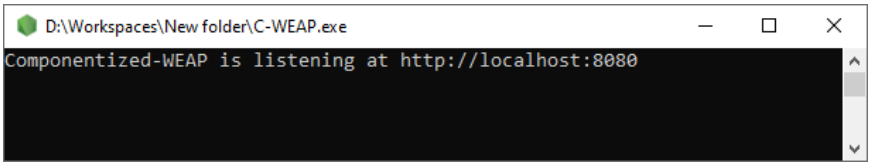


Figure 1. Windows console displaying the successful execution of the C-WEAP.

The C-WEAP can invoke a defined set of WEAP system APIs following the procedure described and exemplified in Section 6.

4. Componentized-WEAP Source Code Installation

The following software frameworks and tools need to be installed to execute the C-WEAP software application from the source code.

4.1. NodeJS

Download the NodeJS framework for the Windows 64-bit OS (MSI or ZIP) from https://nodejs.org/en/download/ (see Figure 2). At the time of preparing this user guide, the latest version of the NodeJS framework is *12.18.1*. It also includes *npm 6.14.5* (Node Package Management). After downloading, use the default choices to install NodeJS.

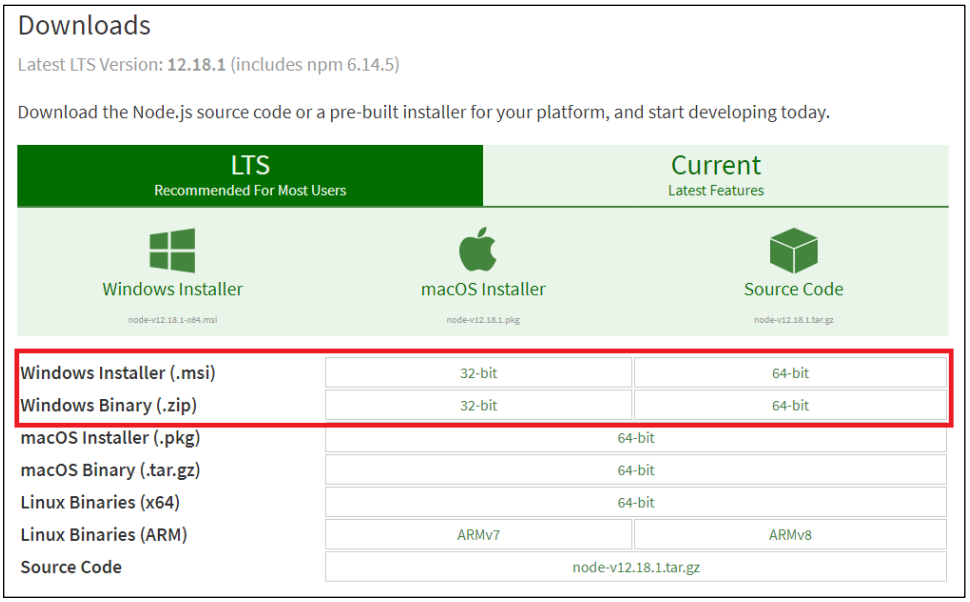


Figure 2. NodeJS download page (https://nodejs.org/en/download/).

4.2. Python

Installing Python requires multiple installations in the order provided below.

Step 1: Choose and click on **Python version *2.7.18*** from https://www.python.org/downloads/.

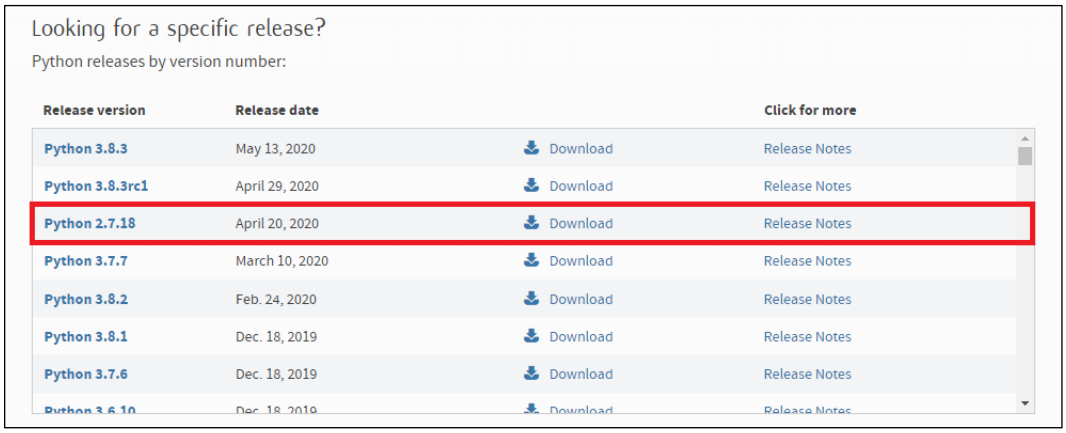
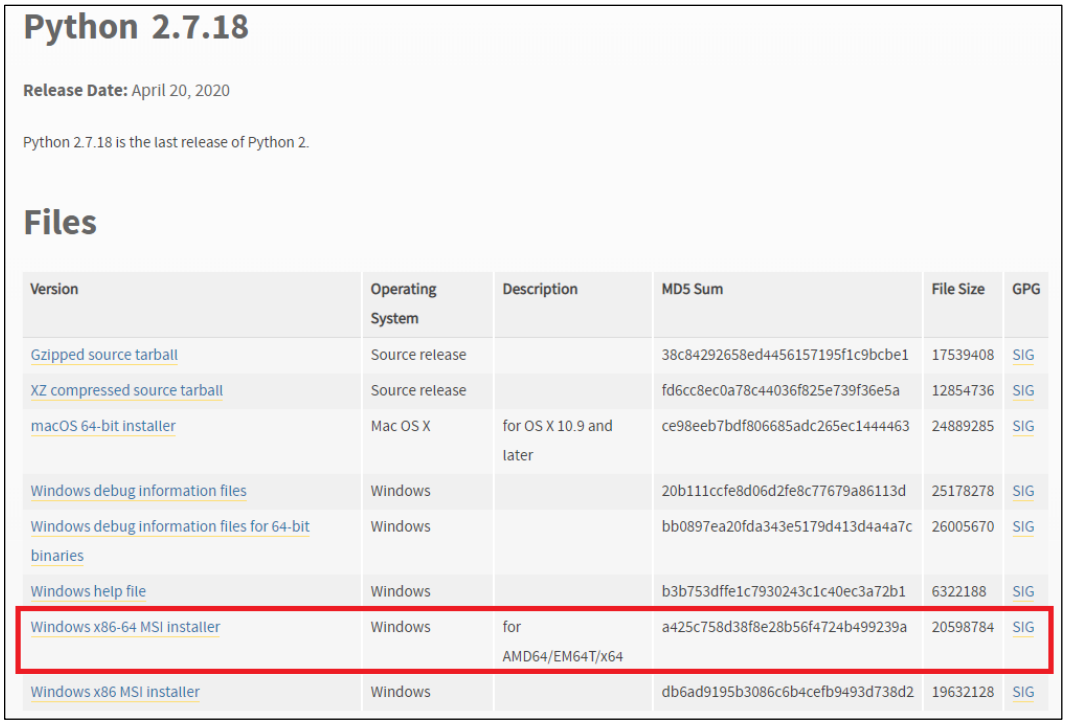


Figure 3. Python download page (https://www.python.org/downloads/).

Step 2: Download the **Windows x86-64 MSI installer** of the python 2.7 (see Figure 4) and install it using the default choices.



Python 2.7.18

Release Date: April 20, 2020

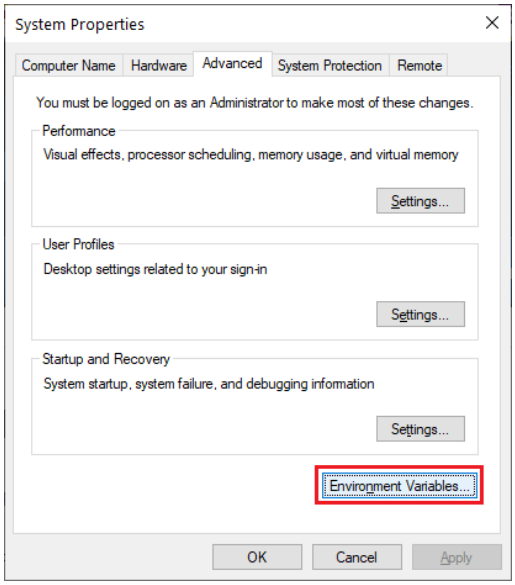
Python 2.7.18 is the last release of Python 2.

Files

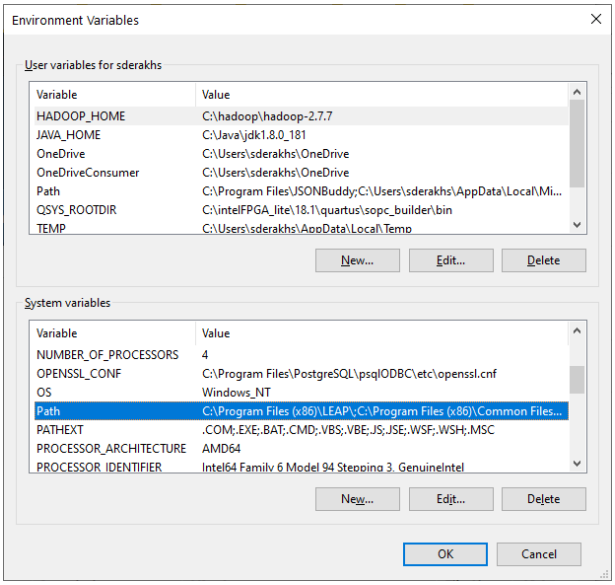
Version	Operating System	Description	MD5 Sum	File Size	GPG
Gzipped source tarball	Source release		38c84292658ed4456157195f1c9bcbe1	17539408	SIG
XZ compressed source tarball	Source release		fd6cc8ec0a78c44036f825e739f36e5a	12854736	SIG
macOS 64-bit installer	Mac OS X	for OS X 10.9 and later	ce98eeb7bdf806685adc265ec1444463	24889285	SIG
Windows debug information files	Windows		20b111ccfe8d06d2fe8c77679a86113d	25178278	SIG
Windows debug information files for 64-bit binaries	Windows		bb0897ea20fda343e5179d413d4a4a7c	26005670	SIG
Windows help file	Windows		b3b753dffe1c7930243c1c40ec3a72b1	6322188	SIG
Windows x86-64 MSI installer	Windows	for AMD64/EM64T/x64	a425c758d38f8e28b56f4724b499239a	20598784	SIG
Windows x86 MSI installer	Windows		db6ad9195b3086c6b4cefb9493d738d2	19632128	SIG

Figure 4. Python 2.7.18 download page (https://www.python.org/downloads/release/python-2718/).

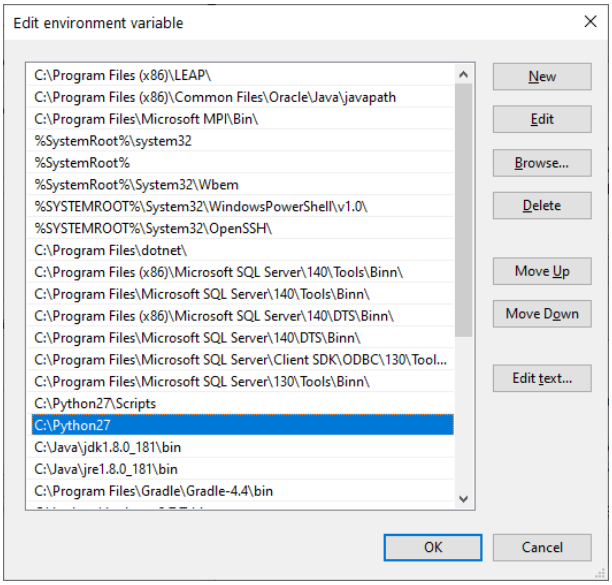
Step 3: Set the environment variable by following the steps shown in Figure 5.



(a) system properties



(b) environments variables



(c) edit environment variables

Figure 5. Add Python path to the Windows Environments Variables.

4.3. TypeScript

Run the following commands using the Windows Command Prompt (cmd) as follows:

Step 1: `npm install typescript --global`

Step 2: `npm install node-gyp --global`

Run the following command using Windows PowerShell (run as administrator)

Step 1: `npm install --global --production windows-build-tools`

Note: Download & Install Visual C++ from here if there is an error in executing the previous step. Also, this step may take a long time (e.g., ~15-30 minutes) and further require multiple runs.

4.4. Git

Download and install the **Git** version control from https://git-scm.com/downloads. At the time of preparing this user guide, the latest version is *2.27.0*. Use the default choices in the installation steps.

Figure 6. Git download page.

4.5. VS-Code

Different IDEs can be used for code development. We recommend the VS-Code editor, and it is used in the rest of this User Guide. Download the Windows version of the VS-Code from https://code.visualstudio.com/Download. Use the default choices in the installation steps.

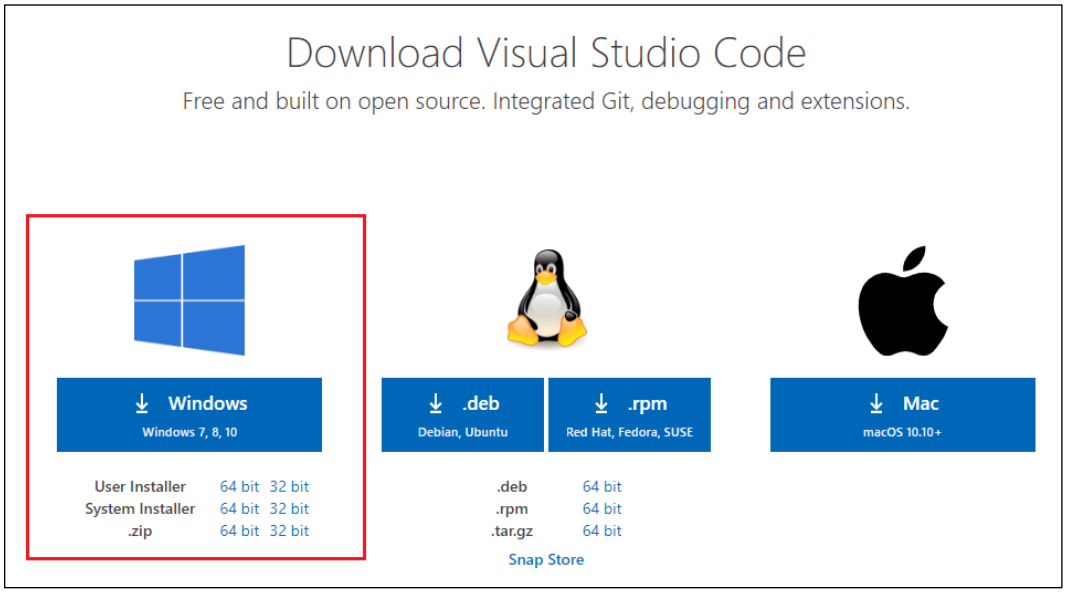


Figure 7. VS-Code Editor download page.

After installing the VS-Code, some extension must be installed (e.g., *TSLint*), and some are recommended to be installed (e.g., *Code Runner*). As shown in Figure 8, open the VS-Code editor, go to the extension page, type **TSLint**, and click on the install button. The same can be done for the **Code Runner** extension.

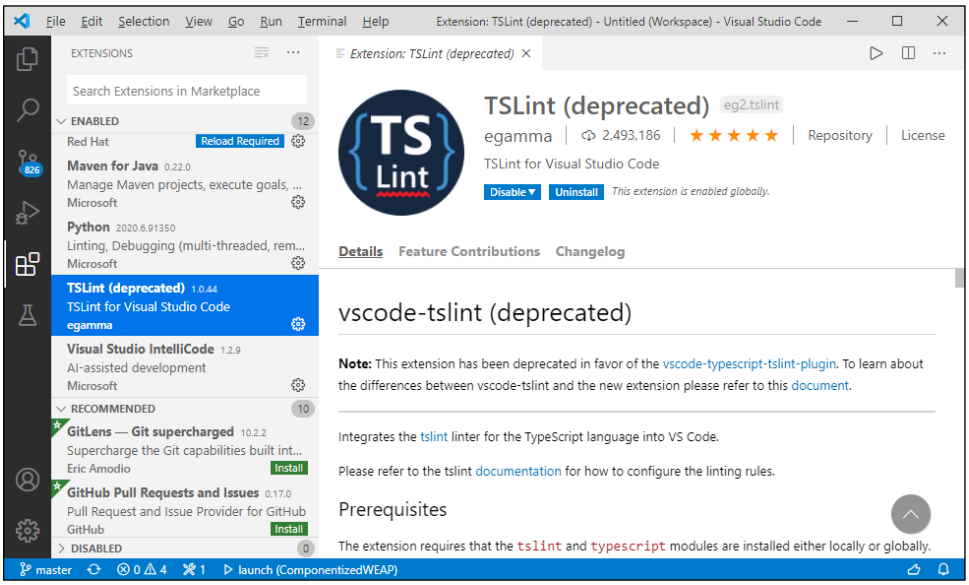


Figure 8. VS-Code editor, extensions page.

Note: The execution policy in the Windows OS Client must be changed to RemoteSigned to be able to run the script. For more information, see About Execution Policy and Set Execution Policy pages. So, open Windows PowerShell (run as administrator), and run:

- `Set-ExecutionPolicy RemoteSigned`

4.6. Download Source Code

To download the C-WEAP framework from the GitHub in the VS-Code editor, follow the following steps:

1) Open VS-Code
2) Press CTRL+SHIFT+P (View/Command Palette...) and type "*`git:Clone`*"
3) Enter the C-WEAP git URL (https://github.com/comses/ComponentizedWEAP.git); contact hss@asu.edu for access.
4) Select a folder for the project to be uploaded

After downloading the source code, you should see the folders similar to Figure 9 in the Explorer window of the VS-Code editor.

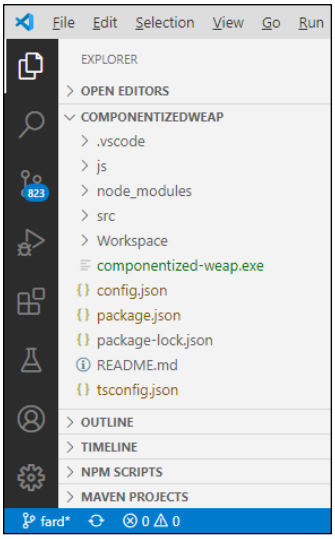


Figure 9. The C-WEAP project directory in the VS-Code editor.

4.7. Update the C-WEAP Packages

After downloading the C-WEAP framework for the first time, or after changing (new updates) any third-party packages (the *dependencies* section of the "**./package.json**" file, see Figure 10), updates to the framework as needed using the following steps:

Step 1: Open VS-Code

Step 2: Right-click on the project folder in the Explorer window (or right clock in the blank area of the project in the Explorer window), and select **Open in Terminal** (as shown in Figure 10).

Step 3: Run the following command in the Terminal (see Figure 10) to update all packages:

- *`npm install`*

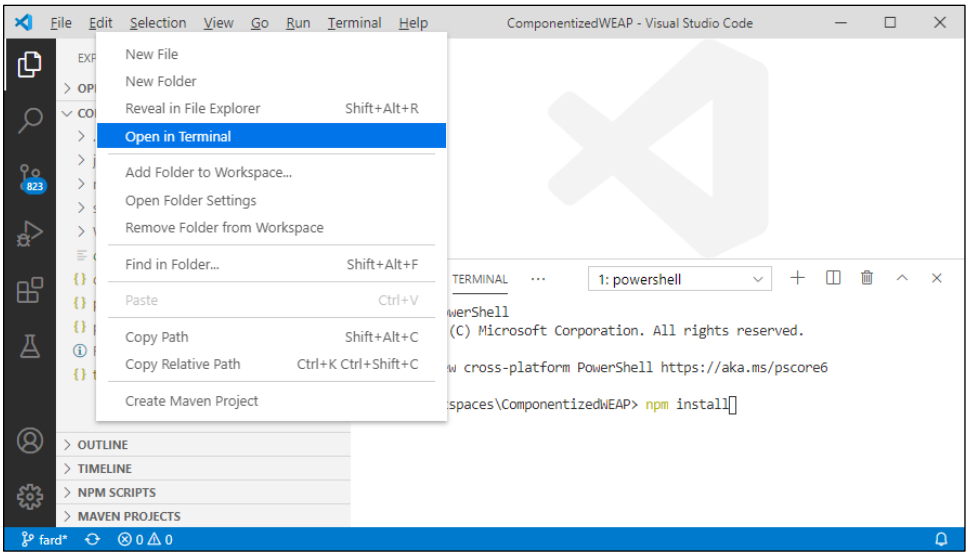


Figure 10. Open Terminal for a project in the VS-Code editor.

4.8. Building the C-WEAP RESTful Framework

The C-WEAP framework is written in TypeScript framework (to have extra facilities which are not available in JavaScript). Finally, the TypeScript files must be converted to the JavaScript files to be able to run on the server using the NodeJS framework. TypeScript does the conversion automatically (using the "**./tsconfig.json**" file) using the following command:

Step 1: Open VS-Code

Step 2: Press CTRL+SHIFT+P (View/Command Palette...) and type "*`tasks:run build task`*"

Step 3: Select "`tsc: build - tsconfig.json`" in the opened list

Note: In the C-WEAP RESTful framework, all the TypeScript files are organized under the "**./src**" folder, and all the generated JavaScript files are under the "**./js**" folder (based on the configuration in the *tsconfig.json* file). Also, the conversion is from TypeScript to ES6.

4.9. Running the C-WEAP RESTful Framework

Be sure that all changes in the TypeScript files are converted to JavaScript before running the C-WEAP framework. The configuration to run the project saves in the "**./.vscode/launch.json**" file. The Run page in the VS-Code editor has a run button to execute the launch file. As can be seen in Figure 11, all open projects in the VS-Code are listed. A project must be selected in the drop-down list (e.g., Componentized-WEAP), then click on the start debugging button (▷) to run it.

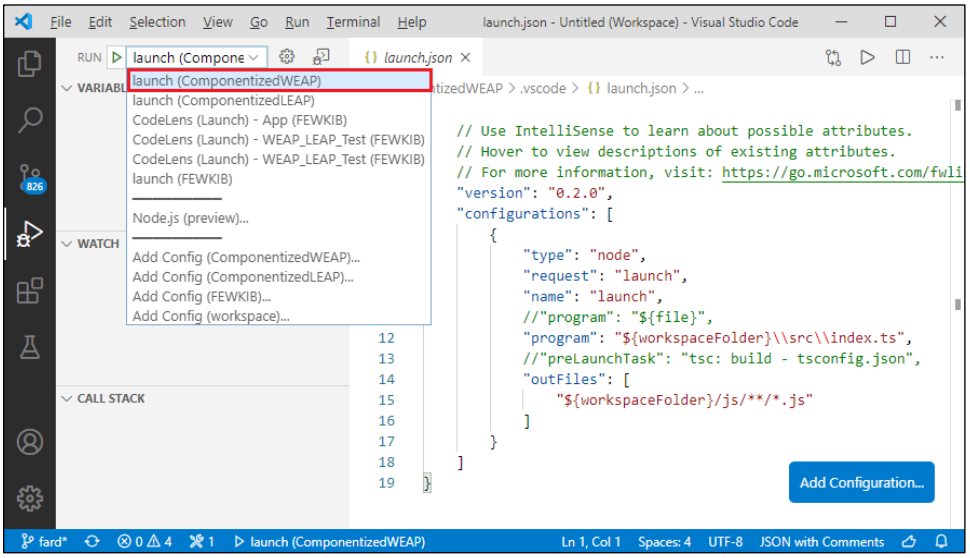


Figure 11. Running a project in the VS-Code editor.

As shown in Figure 12, after running the C-WEAP framework, the "`Componentized-WEAP is listening at http://localhost:8080`" must be displayed in the DEBUG CONSOLE tab of the editor.

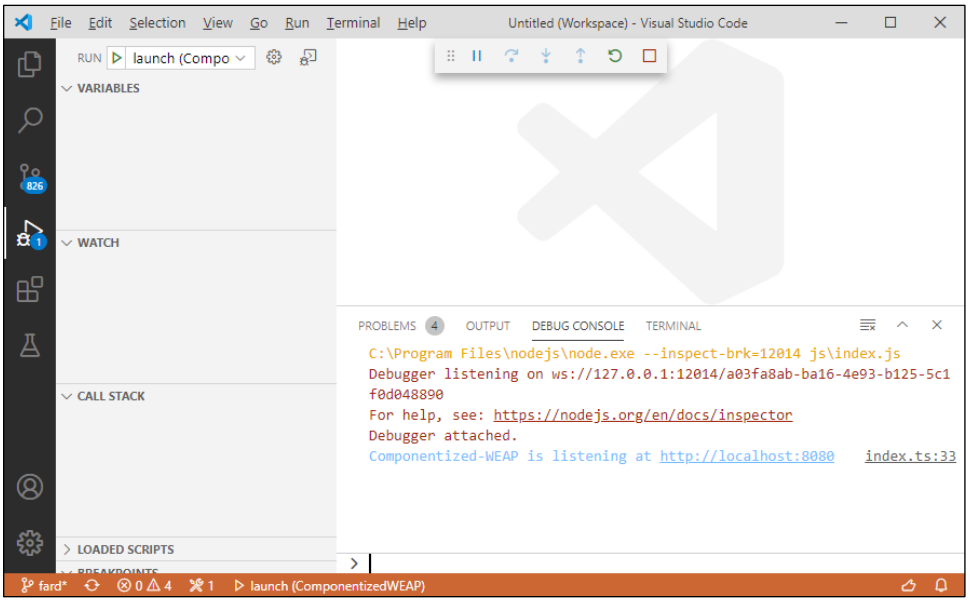


Figure 12. The C-WEAP framework after running in the VS-Code editor.

Note: The WEAP system must be running before running the C-WEAP framework. (Running the C-WEAP prior to running the WEAP system produces unexpected results).

5. Define the C-WEAP Configuration

For each WEAP's project that is going to be used in the C-WEAP framework, the required configuration files must be defined under the "`Workspace`" folder. First, a folder must be defined with the same name as the WEAP's project (called project's folder). The "`Inputs.csv`" and "`Outputs.csv`" files must be defined under the project's folder if we need to set some properties of the input and/or output variables of different components. The "Data Variable Report" form can be used to define the "`Inputs.csv`", automatically. To do that, click on the menu items "`Edit->Data`

`Variable->Report`“ in the WEAP IDE. As shown in Figure 13, use the “`Comma Separated Value (*.csv)`” for the “Save as” property, then store the csv file under the project’s folder. This csv file has a specific structure that the C-WEAP framework will parse it at running time to extract the *Min*, *Max*, *Time Scale*, and *User Defined* properties for the variables of the different components (these variables are definable in the WEAP IDE, but there are not accessible via WEAP’s APIs). The “`Inputs.csv`” file has some extra properties (e.g., Category, Description, etc.), which are not important for the C-WEAP (Just leave them as they are).

The “`Outputs.csv`” file must be defined by the user, and it has six properties. They are six properties that are used in the “`Inputs.csv`” file, as well. The properties are “**Branch**“ to define the entity type, “**Variable**“ to define the variable name, “**Min**” and “**Max**” to define the acceptable range for the variable, “**Time Scale**” to define the time granularity of the variable, and “**User-Defined?**” to show that the variable is defined by user or it is a default variable in the WEAP system. They must be in the presented order (first Branch, then Variable, and so on).

Note: Without defining the inputs.csv/outputs.csv file, all input/output variables will have *Yearly* time-step in the C-WEAP framework.

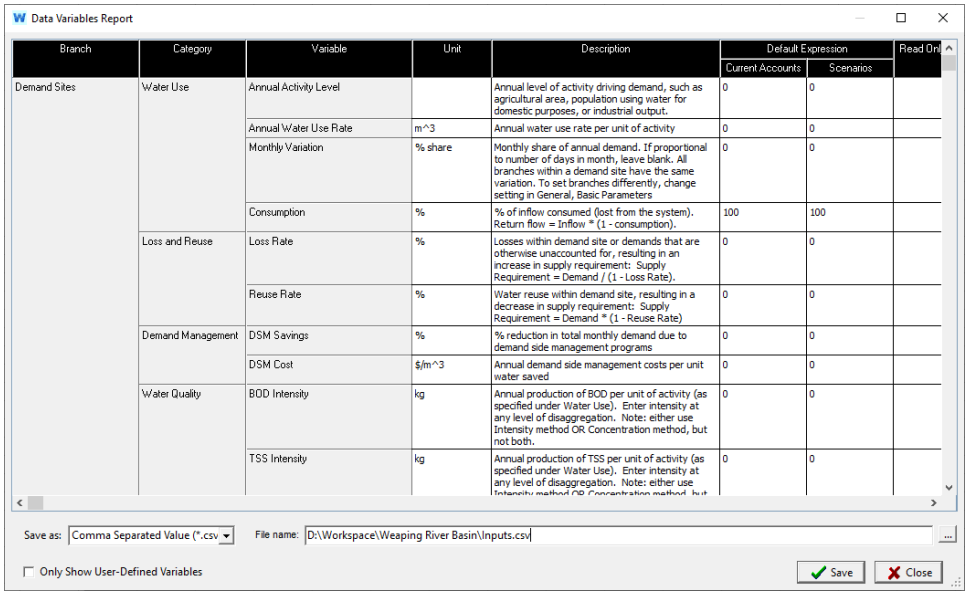


Figure 13. The C-WEAP framework after running in the VS-Code editor.

6. Modules

The C-WEAP APIs are categorized into five modules related to different parts of the WEAP system or subset of WEAP's entities. The modules are *Project*, *Version*, *Node*, *Link*, and *Flow*. Each module has a set of APIs to read/write data from/to the WEAP system. The used WEAP's APIs to develop the C-WEAP RESTful framework is listed in Appendix A.

The URL patterns for five API types are shown in Table 1. The pattern inside each open and close pair bracket is optional. In the pattern of the URLs, constants are written in *PascalCase* style; parameters start with colons and written in *camelCase* style; query parameters (to apply to some filters on returned data) written after the question mark by *Key=Value* (*camelCase* style for the *Key* part). All URLs start with constant "`/Water`". The NodeType, LinkType, FlowType, VariableType, and subNodeType (which are bold) in the patterns, must be replaced by a valid value from Table 2. In the Flow URLs, the `subNodeType` uses to access a specific collection of sub-nodes, and then use *:subNodeName* to select one. For example, the URL "`/Water/demo/DemandSites/phoenix`" returns the *phoenix* demand site's data of the *demo* project. The data of a variable can be retrieved by mentioning the name of the variable and the intended scenario. Query parameters can be used to filter the returned data (the years and time-steps).

Table 1. URL pattern for different types of APIs.

Category	URL Patterns
Project	`/Water[/:projectName[/Run]]`
Version	`/Water/:projectName/Versions[/:versionName/Revert]`
Key	`/Water/:projectName/Keys[/:KeyName/:scenarioName[/Expression]]`
Node	`/Water/:projectName/`**`NodeType`**`[/:nodeName[/`**`VariableType`**`[/:variableName/:scenarioName[/Expression][?startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]]]]`
Link	`/Water/:projectName/`**`LinkType`**`[/:sourceName/:targetName[/`**`VariableType`**`[/:variableName/:scenarioName[/Expression][?startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]]]]`
Flow	`/Water/:projectName/`**`FlowType`**`[/:flowName[/`**`subNodeType`**`[/:subNodeName]][/`**`VariableType`**`[/:variableName/:scenarioName[/Expression][?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]]]]`

Table 2. Type-Values for the patterns of the APIs.

Type	Values
NodeType	Catchments, DemandSites, Groundwaters, Reservoirs, OtherSupplies, WastewaterTreatments
LinkType	Transmissions, Runoffs, ReturnFlows
FlowType	Rivers, Diversions
VariableType	Inputs, Outputs
subNodeType	Reaches, Reservoirs, RunOfRiverHydros, StreamflowGauges, FlowRequirements

All the URLs contain http://(hostname):(port). In our examples, the hostname is "*localhost*", and the port is "*8080*". To test the APIs, the WEAP system and the C-WEAP RESTful framework run, first. Then the APIs are called by the Postman tool. Also, the "*Weaping River Basin*" project is using as the WEAP's project to test the APIs. The Schematic view of this project is presented in Figure 14.

The C-WEAP framework always checks the existence of all parameters (e.g. :projectName, :variableName, etc.) in the URL. For example, the C-WEAP framework first checks the existence of the project "*Weaping River Basin*", then the river "*Nile*", then the input variable "*Headflow*", and finally the scenario "*Current Accounts*" in the URL "`http://localhost:8080/Water/Weaping%20River%20Basin/Rivers/Nile/Inputs/Headflow/Current%20Accounts`". The corresponding error message (with status code 404) will return in the case of not existing a parameter.

Also, for updating APIs, the new values must be set in the body of the request for the URL with PUT methods.

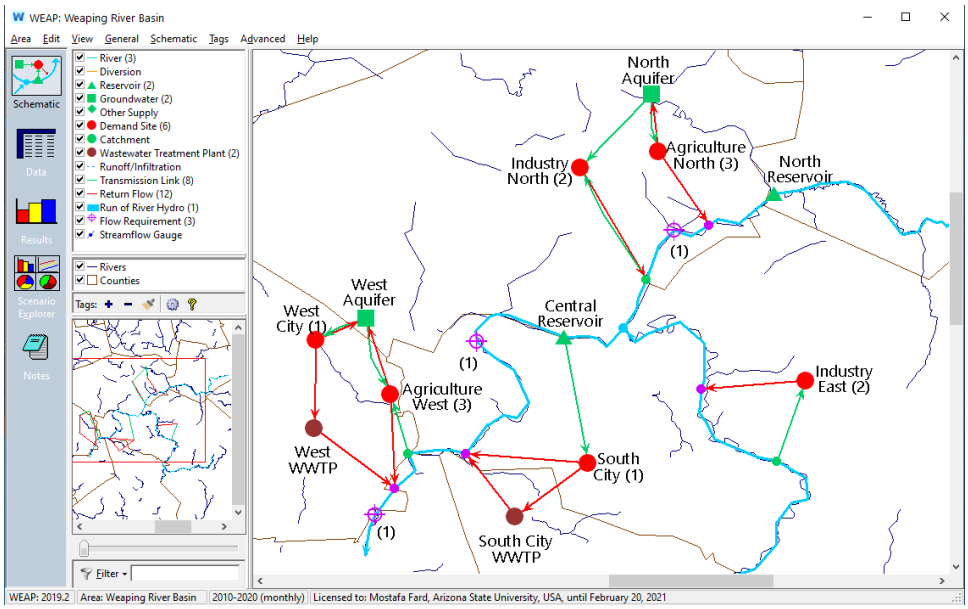


Figure 14. The "*Weaping River Basin*" project in the WEAP system.

Any application can be used to call the APIs (for example, typing a URL in the address bar of a web-browser and hitting the Enter for the GET type requests), but we use the Postman tool (see https://www.postman.com/). As shown in Figure 15, the API method, the URL, the parameters, and the body of the request (for PUT requests) can specify in the Postman (and some other features that we are not going to use them).

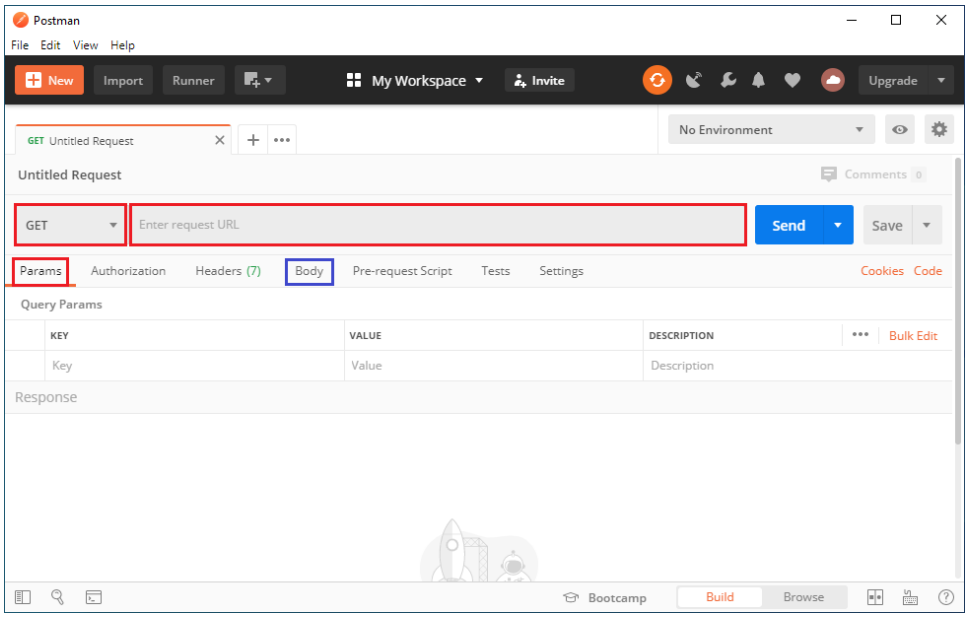


Figure 15. The Postman tool environment.

Note: Using an incorrect URL makes "404 Not Found" response (incorrect hostname, port, constant, etc. in the URL). For example, Figure 16 shows the situation that the URL entered "`http://localhost:8080/Watter`" by mistake. It shows the message "Cannot `GET /Watter`" in the web-browser. Indeed, it is requesting an API that is not defined in the webserver.

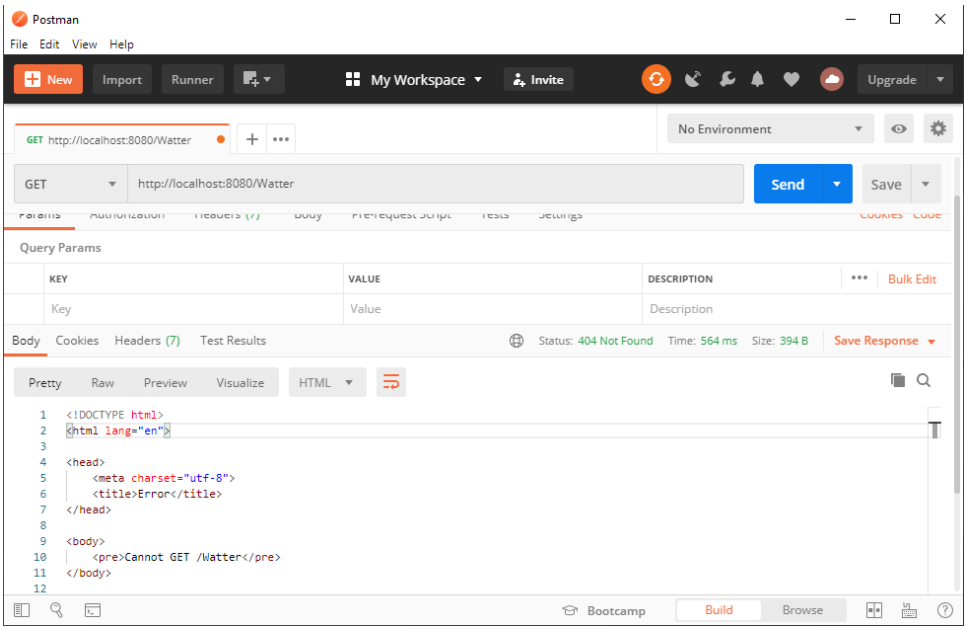


Figure 16. Calling an incorrect URL ("/Watter") in the Postman.

Figure 17 presents individual domain model classes defined in the C-WEAP framework for receiving/sending data from/to the API caller.

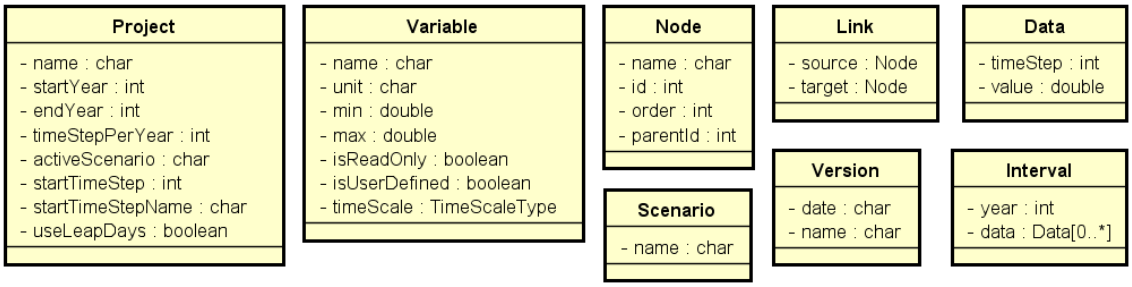


Figure 17. Domain Model classes in the C-WEAP framework.

6.1. Project

The C-WEAP's APIs related to the Project category are listed in Table 3.

Table 3. List of APIs for the Project module.

#	Method	URL	Return Value/s	Description
P1	GET	`/Water`	String[]	Get the name of all projects
P2	GET	`/Water/:projectName`	Project	Get properties of a project
P3	GET	`/Water/:projectName/Run`	Boolean	Run a project
P4	PUT	`/Water/:projectName`	Boolean	Update properties of a project, by setting new values for the Project object in the body of the request

Example: As an example, the API P1 from Table 3 is presented here. Figure 18 shows the available projects in the WEAP system. Calling the URL "`http://localhost:8080/Water`" in Postman (or web browser) returns the project names while the C-WEAP is running (see Figure 19). The list of projects shown in vary depending on the projects

that are available in the WEAP system. It is shown in the Postman that the status of the request is "`200 OK`", the time to get data is "`128 ms`" (which can be different in different calls), and the size of the response is "`361 Byte`". The time and response time measurements can vary depending on the host computer and other factors.

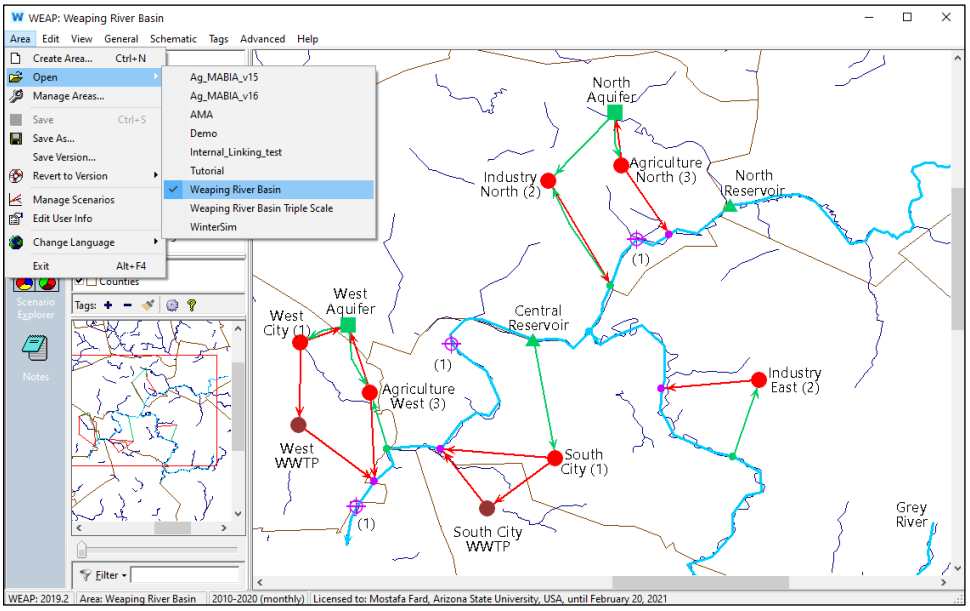


Figure 18. The projects in the WEAP system.

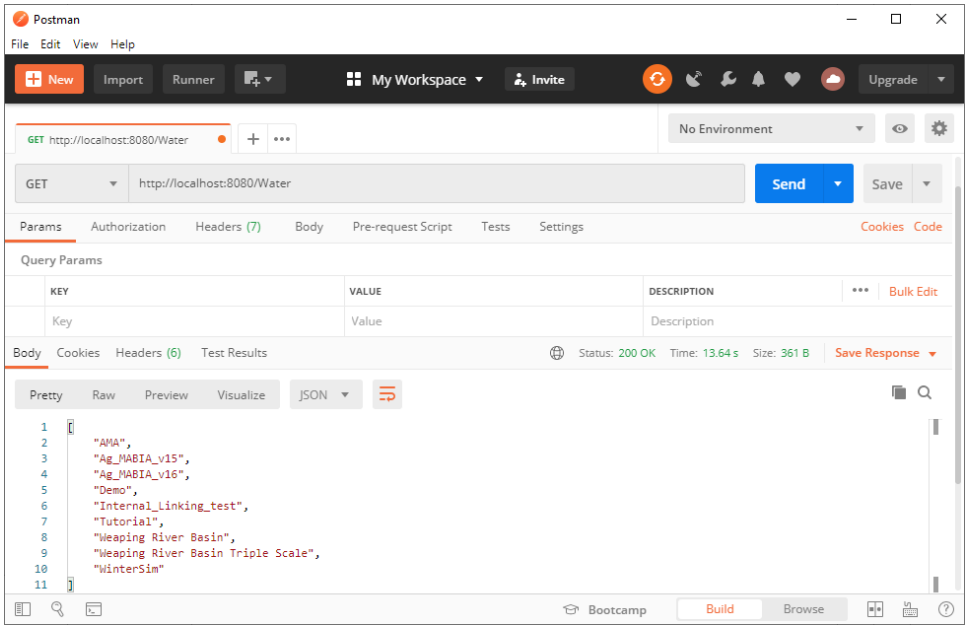


Figure 19. Calling the URL "`/Water`" in the Postman.

6.2. Version

The C-WEAP's APIs related to the Version category are listed in Table 4. The name of the version is the concatenated of the date and name properties of the Version class in Figure 17.

Table 4. List of APIs for the Version module.

#	Method	URL	Return Value/s	Description
V1	GET	`/Water/:projectName/Versions`	Version[]	Get the list of all versions of a project
V2	GET	`/Water/:projectName/Versions/:versionName`	Version	Get a version of a project
V3	PUT	`/Water/:projectName/Versions/:versionName/Revert`	Boolean	Revert to a version for a project

Example: As an example, the API V1 from Table 4 is presented here. Figure 20 shows the available versions defined in the "*Weaping River Basin*" project in the WEAP system. Calling the URL "`http://localhost:8080/Water/Weaping%20River%20Basin/Versions`" in Postman (or web browser) returns the list of versions for the project, ordered by ascending on the date (see Figure 21).

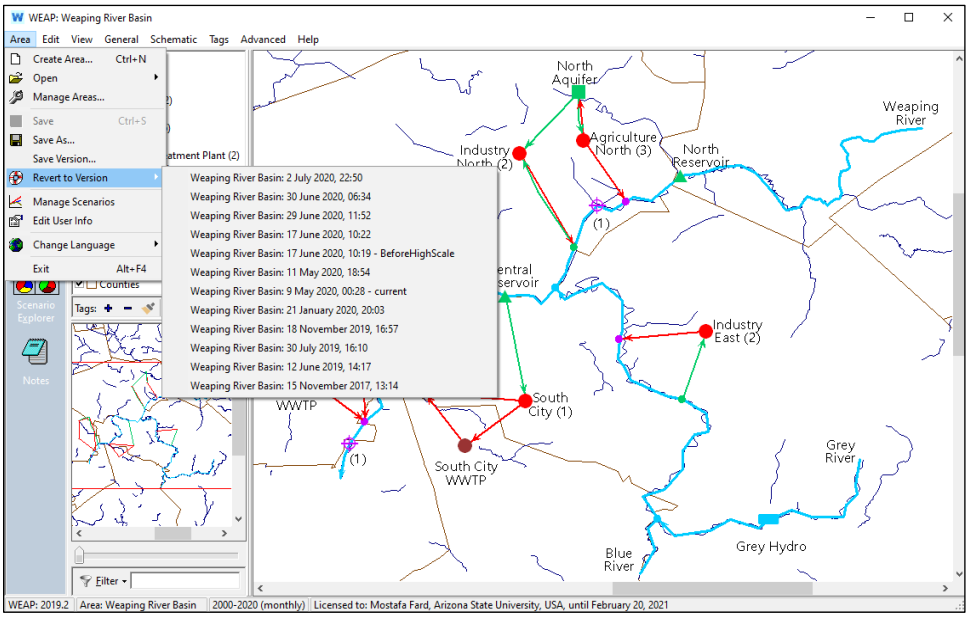


Figure 20. The versions of "*Weaping River Basin*" project in the WEAP system.

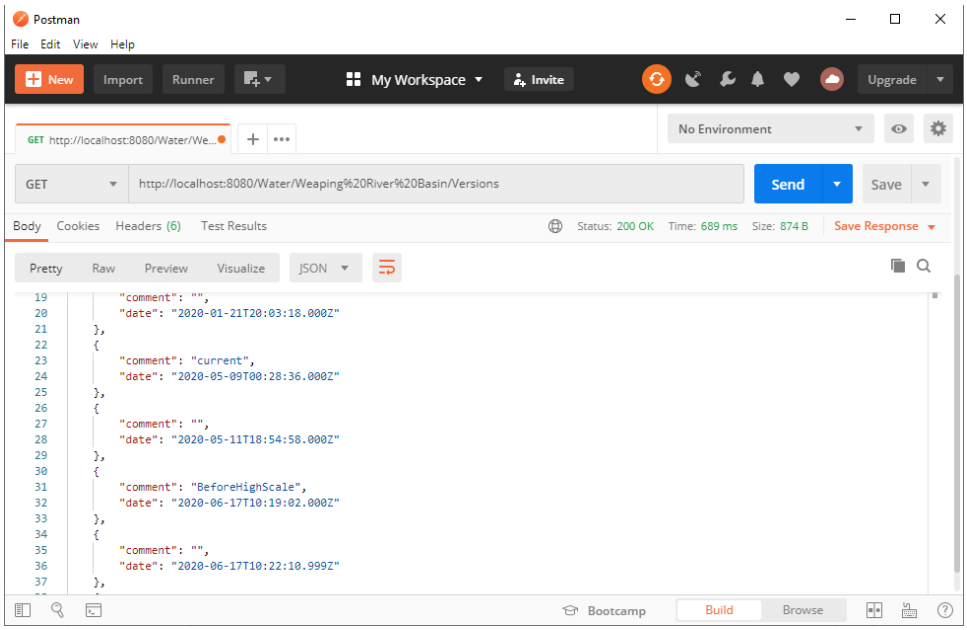


Figure 21. Calling the URL "`/Water/Weaping%20River%20Basin/Versions`" in the Postman.

6.3. Key

The C-WEAP's APIs related to the Key category are listed in Table 5.

Table 5. List of APIs for the Key module.

#	Method	URL	Return Value/s	Description
K1	GET	`/Water/:projectName/Keys`	String[]	Get the list of all keys in a project
K2	GET	`/Water/:projectName/Keys/:keyName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]`	Interval[]	Get a list of all values of a key in a project
K3	GET	`/Water/:projectName/Keys/:keyName/:scenarioName/Expression`	String	Get the expression of a key in a project
K4	PUT	`/Water/:projectName/Keys/:keyName/:scenarioName`	Boolean	Update the values of a key in a project, by setting new values in the body of the request
K5	PUT	`/Water/:projectName/Keys/:keyName/:scenarioName/Expression`	Boolean	Update the expression of a key in a project, by setting new value in the body of the request

Example: As an example, the API K5 from Table 5 is presented here. Figure 22 shows the value of the "Efficiency Improvements" key defined in the "*Weaping River Basin*" project for "*Reference*" scenario in the WEAP system. We sare going to change the value. So, by calling the URL "`http://localhost:8080/Water/Weaping%20River%20Basin/Keys/Efficiency%20Improvements/Reference/Expression`" and set the body of the request to {"value":"3.5"} in Postman (see Figure 23). This URL will change the current value of the Efficiency Improvements to 3.5 (see Figure 24), and returns true if the API executes successfully.

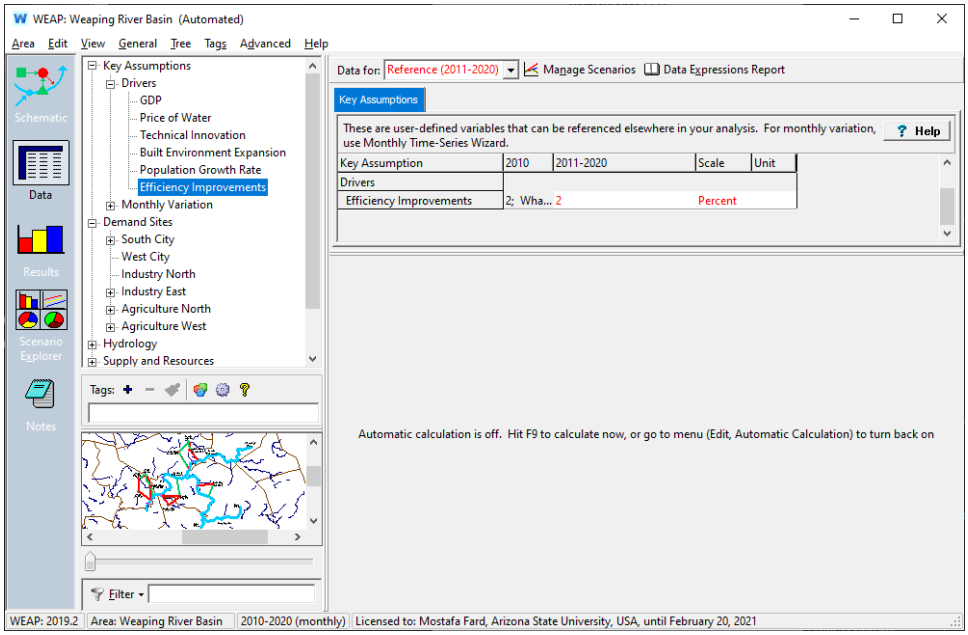


Figure 22. The Efficiency Improvements key in the "*Weaping River Basin*" project in the WEAP system.

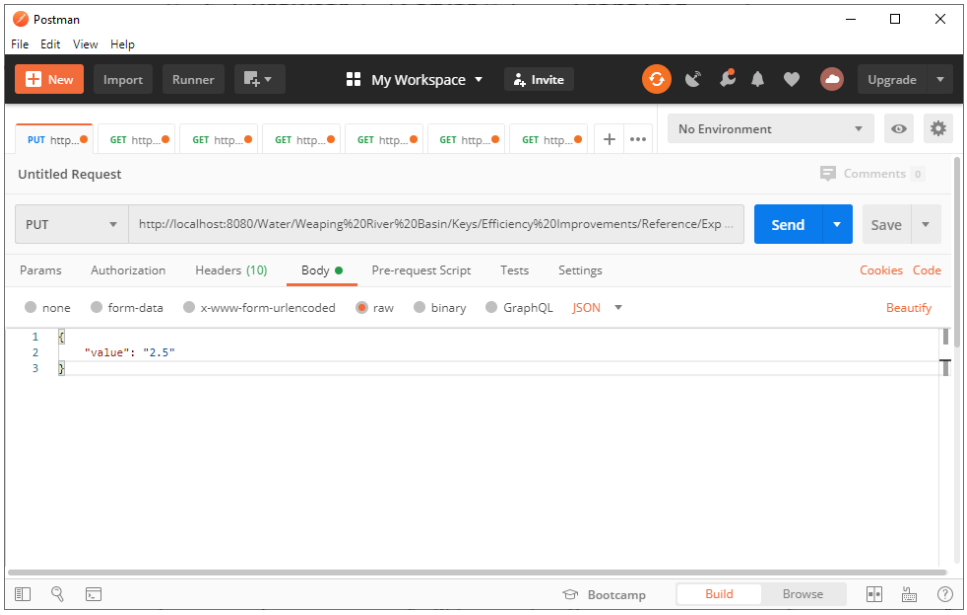


Figure 23. Calling the URL "/Water/Weaping%20River%20Basin/Keys/Efficiency%20Improvements/Reference/Expression " in the Postman.

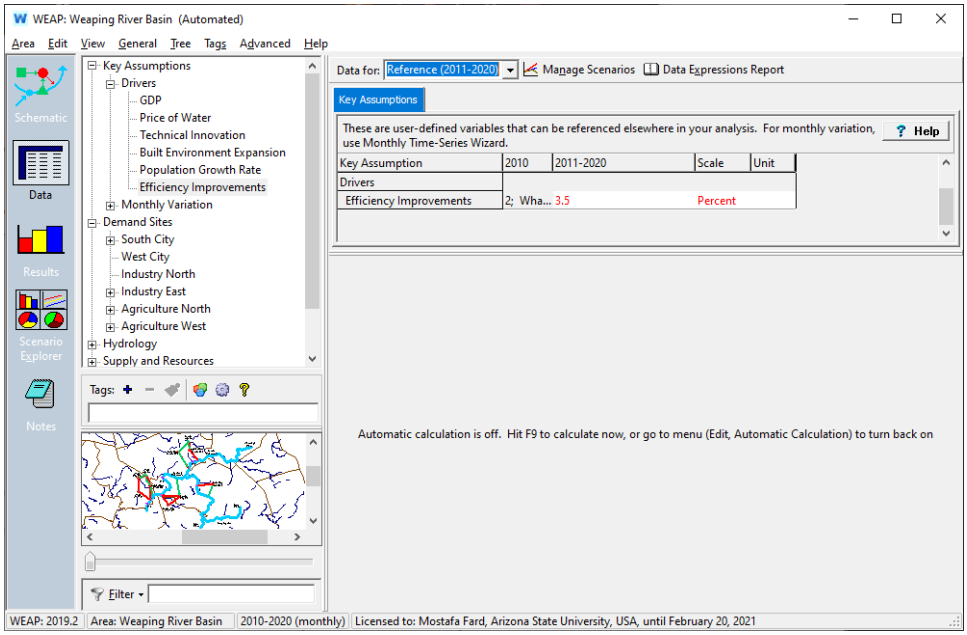


Figure 24. The key changing in the "*Weaping River Basin*" project after using the URL in Figure 23.

6.4. Node

The C-WEAP's APIs related to the Node category are listed in Table 6. As mentioned before, one of the values from Table 2 (Node Type) must be replaced with the **NodeType** in the URLs in Table 6.

Table 6. List of APIs for the Node module.

#	Method	URL	Return Value/s	Description
N1	GET	`/Water/:projectName/NodeType`	Node[]	Get the list of all nodeType components in a project
N2	GET	`/Water/:projectName/NodeType/:nodeName`	Node	Get a nodeType component in a project
N3	GET	`/Water/:projectName/NodeType/:nodeName/Inputs`	Variable[]	Get a list of all input variables of a nodeType component in a project
N4	GET	`/Water/:projectName/NodeType/:nodeName/Inputs/:variableName`	Variable	Get an input variable of a nodeType component in a project
N5	GET	`/Water/:projectName/NodeType/:nodeName/Inputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]`	Interval[]	Get a list of all values of an input variable of a nodeType component in a project
N6	GET	`/Water/:projectName/NodeType/:nodeName/Inputs/:variableName/:scenarioName/Expression`	String	Get the expression of an input variable of a nodeType component in a project
N7	PUT	`/Water/:projectName/NodeType/:nodeName/Inputs/:variableName/:scenarioName`	Boolean	Update the values of an input variable of a nodeType component in a project, by setting new values in the body of the request
N8	PUT	`/Water/:projectName/NodeType/:nodeName/Inputs/:variableName/:scenarioName/Expression`	Boolean	Update the expression of an input variable of a nodeType component in a project, by

				setting new value in the body of the request
N9	GET	`/Water/:projectName/NodeType/:nodeName/Outputs`	Variable[]	Get a list of all output variables of a nodeType component in a project
N10	GET	`/Water/:projectName/NodeType/:nodeName/Outputs/:variableName`	Variable	Get an output variable of a nodeType component in a project
N11	GET	`/Water/:projectName/NodeType/:nodeName/Outputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]`	Interval[]	Get a list of all values of an output variable of a nodeType component in a project

Note: The returned values for APIs N5 and N11 can be filtered using query parameters. It means, adding the "`?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N`" at the end of the URL.

Example: As an example, the API N3 from Table 6 for the DemandSite is presented here. Figure 25 shows the input variables of the "*South City*" demand site in the "*Weaping River Basin*" project in the WEAP system. Calling the URL "`http://localhost:8080/Water/Weaping%20River%20Basin/DemandSites/South%20City/Inputs`" in Postman (or web browser) returns the list of variables (see Figure 26).

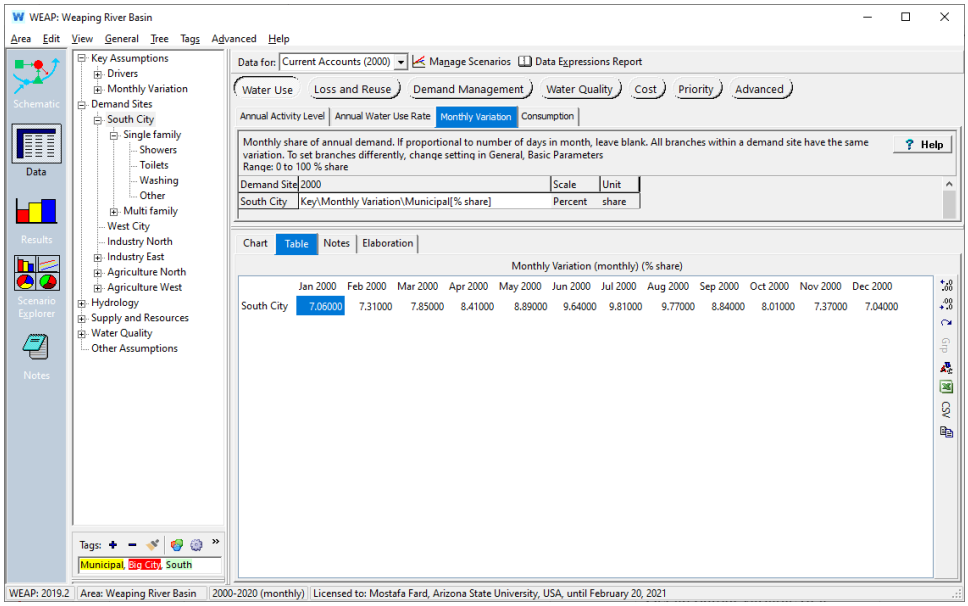


Figure 25. The input variables of the "*South City*" demand site in the "*Weaping River Basin*" project in the WEAP system.

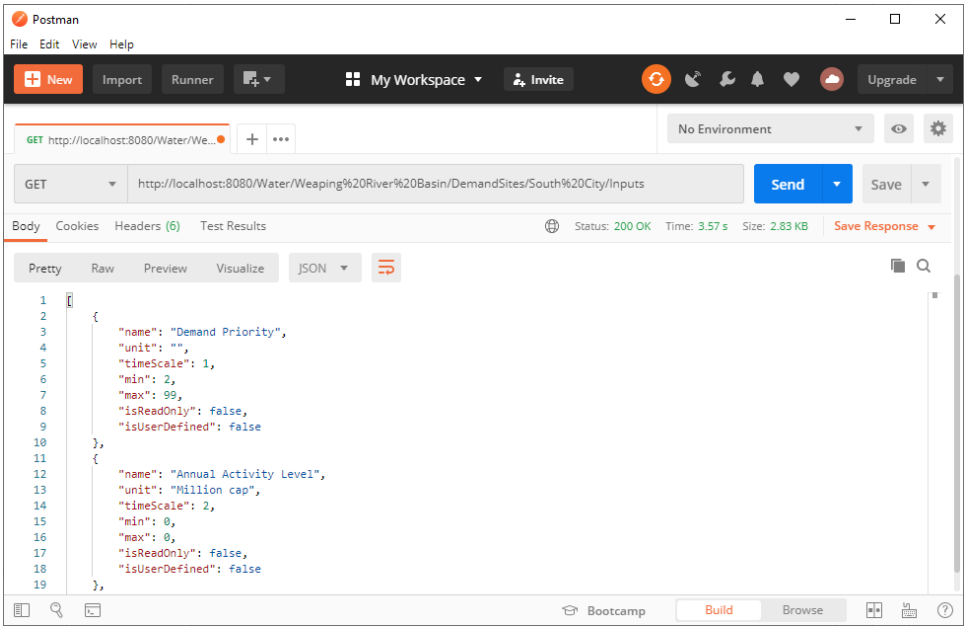


Figure 26. Calling the URL "/Water/Weaping%20River%20Basin/DemandSites/South%20City/Inputs/Monthly%20Variation/Current%20Accounts?&startYear=2000&endYear=2000" in the Postman.

6.5. Link

The C-WEAP's APIs related to the Link category are listed in Table 7. As mentioned before, one of the values from Table 2 (Link Type) must be replaced with the **LinkType** in the URLs in Table 7.

Table 7. List of APIs for the Node module.

#	Method	URL	Return Value/s	Description
L1	GET	`/Water/:projectName/LinkType`	Link[]	Get the list of all linkType components in a project
L2	GET	`/Water/:projectName/LinkType/:sourceName/:targetName`	Link	Get a linkType component in a project
L3	GET	`/Water/:projectName/LinkType/:sourceName/:targetName/Inputs`	Variable[]	Get a list of all input variables of a linkType component in a project
L4	GET	`/Water/:projectName/LinkType/:sourceName/:targetName/Inputs/:variableName`	Variable	Get an input variable of a linkType component in a project
L5	GET	`/Water/:projectName/LinkType/:sourceName/:targetName/Inputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]`	Interval[]	Get a list of all values of an input variable of a linkType component in a project
L6	GET	`/Water/:projectName/LinkType/:sourceName/:targetName/Inputs/:variableName/:scenarioName/Expression`	String	Get the expression of an input variable of a linkType component in a project
L7	PUT	`/Water/:projectName/LinkType/:sourceName/:targetName/Inputs/:variableName/:scenarioName`	Boolean	Update the values of an input variable of a linkType component in a project, by setting new values in the body of the request

L8	PUT	`/Water/:projectName/`**`LinkType`**`/:sourceName/:targetName/Inputs/:variableName/:scenarioName/Expression`	Boolean	Update the expression of an input variable of a linkType component in a project, by setting new value in the body of the request
L9	GET	`/Water/:projectName/`**`LinkType`**`/:sourceName/:targetName/Outputs`	Variable[]	Get a list of all output variables of a linkType component in a project
L10	GET	`/Water/:projectName/`**`LinkType`**`/:sourceName/:targetName/Outputs/:variableName`	Variable	Get an output variable of a linkType component in a project
L11	GET	`/Water/:projectName/`**`LinkType`**`/:sourceName/:targetName/Outputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]`	Interval[]	Get a list of all values of an output variable of a linkType component in a project

Note: Like Node APIs, filtering can be applied to the link APIs L5 and L11 in Table 7.

Example: As an example, the API L11 from Table 7 for the DemandSite is presented here. Figure 27 shows the "*Water Demand*" output variable for the "*Reference*" scenario of the "*Weaping River Basin*" project in the WEAP system. Calling the URL "`http://localhost:8080/Water/Weaping%20River%20Basin/DemandSites/South%20City/Outputs/Water%20Demand/Reference?&startYear=2002&endYear=2002`" in Postman (or web browser) returns the list of intervals filtered for the year 2002 (see Figure 28).

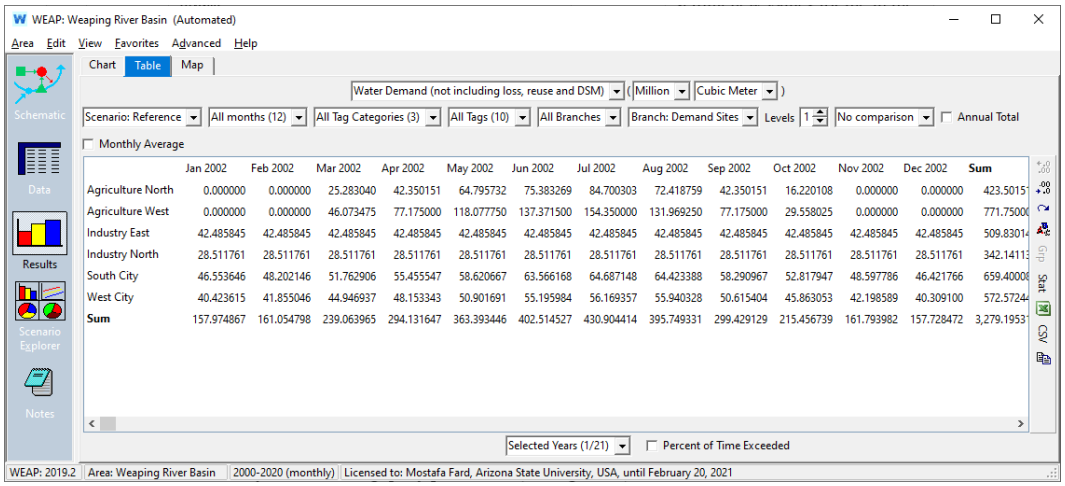


Figure 27. The "*Water Demand*" output variable of the demand sites for the "*Reference*" scenario of the "*Weaping River Basin*" project in the WEAP system.

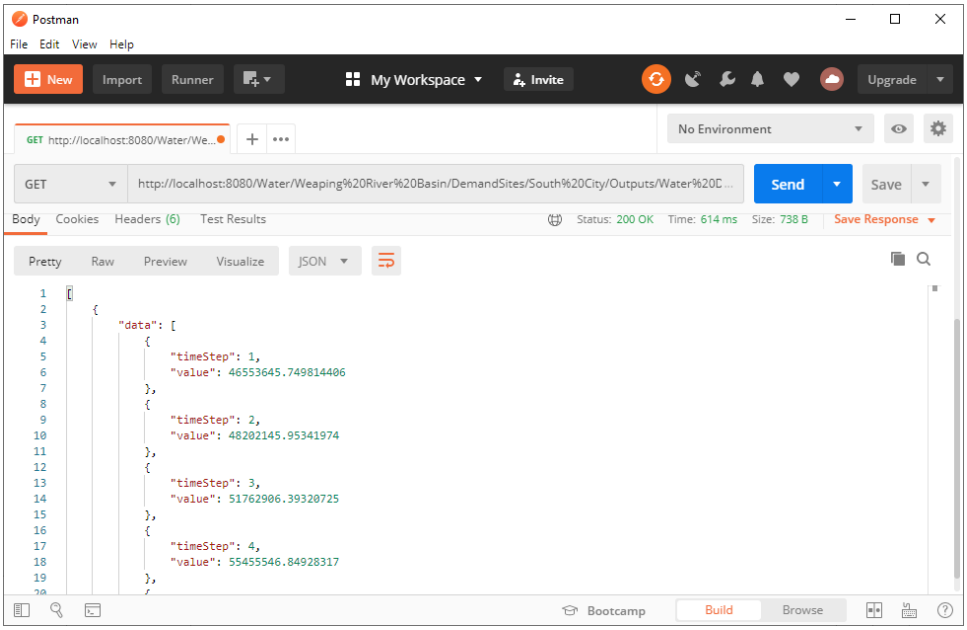


Figure 28. Calling the URL "/Water/Weaping%20River%20Basin/DemandSites/South%20City/Outputs/Water%20Demand/Reference?&startYear=2002&endYear=2002" in the Postman.

6.6. Flow

The C-WEAP's APIs related to the Flow category are listed in . As mentioned before, one of the values from Table 2 (Flow Type) must be replaced with the **FlowType** in the URLs in .

Table 8. List of APIs for the Node module.

#	Method	URL	Return Value/s	Description
F1	GET	`/Water/:projectName/FlowType`	Node[]	Get the list of all flowType components in a project
F2	GET	`/Water/:projectName/FlowType/:flowName`	Node	Get a flowType component in a project
F3	GET	`/Water/:projectName/FlowType/:flowName/Inputs`	Variable[]	Get a list of all input variables of a flowType component in a project
F4	GET	`/Water/:projectName/FlowType/:flowName/Inputs/:variableName`	Variable	Get an input variable of a flowType component in a project
F5	GET	`/Water/:projectName/FlowType/:flowName/Inputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]`	Interval[]	Get a list of all values of an input variable of a flowType component in a project
F6	GET	`/Water/:projectName/FlowType/:flowName/Inputs/:variableName/:scenarioName/Expression`	String	Get the expression of an input variable of a flowType component in a project
F7	PUT	`/Water/:projectName/FlowType/:flowName/Inputs/:variableName/:scenarioName`	Boolean	Update the values of an input variable of a flowType component in a project, by setting new values in the body of the request

F8	PUT	/Water/:projectName/**FlowType**/:flowName/Inputs/:variableName/:scenarioName/Expression	Boolean	Update the expression of an input variable of a flowType component in a project, by setting new value in the body of the request
F9	GET	/Water/:projectName/**FlowType**/:flowName/Outputs	Variable[]	Get a list of all output variables of a flowType component in a project
F10	GET	/Water/:projectName/**FlowType**/:flowName/Outputs/:variableName	Variable	Get an output variable of a flowType component in a project
F11	GET	/Water/:projectName/**FlowType**/:flowName/Outputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]	Interval[]	Get a list of all values of an output variable of a flowType component in a project
F12	GET	/Water/:projectName/**FlowType**/:flowName/**subNodeType**	Node[]	Get the list of all subNodeType components in a flowType components in a project
F13	GET	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName	Node	Get a subNodeType component of a flowType component in a project
F14	GET	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName/Inputs	Variable[]	Get a list of all input variables of a subNodeType component of a flowType component in a project
F15	GET	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName/Inputs/:variableName	Variable	Get an input variable of a subNodeType component of a flowType component in a project
F16	GET	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName/Inputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]	Interval[]	Get a list of all values of an input variable of a subNodeType component of a flowType component in a project
F17	GET	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName/Inputs/:variableName/:scenarioName/Expression	String	Get the expression of an input variable of a subNodeType component of a flowType component in a project
F18	PUT	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName/Inputs/:variableName/:scenarioName	Boolean	Update the values of an input variable of a subNodeType component of a flowType component in a project, by setting new values in the body of the request
F19	PUT	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName/Inputs/:variableName/:scenarioName/Expression	Boolean	Update the expression of an input variable of a subNodeType component of a flowType component in a project, by setting new value in the body of the request
F20	GET	/Water/:projectName/**FlowType**/:flowName/**subNodeType**/:subNodeName/Outputs	Variable[]	Get a list of all output variables of a subNodeType component of a flowType component in a project

F21	GET	`/Water/:projectName/FlowType/:flowName/subNodeType/:subNodeName/Outputs/:variableName`	Variable	Get an output variable of a subNodeType component of a flowType component in a project
F22	GET	`/Water/:projectName/FlowType/:flowName/subNodeType/:subNodeName/Outputs/:variableName/:scenarioName[?&startYear=N&endYear=N&startTimeStep=N&endTimeStep=N]`	Interval[]	Get a list of all values of an output variable of a subNodeType component of a flowType component in a project

Note: Like Node and Link APIs, filtering can be applied on the Flow APIs F5, F11, F16, and F22 in .

Example: As an example, the API F12 from for the *Rivers* FlowType and *Reservoirs* for the subNodeType is presented here. Figure 14 shows the Schematic view for the "*Weaping River Basin*" project in the WEAP system. As can be seen, there are two reservoirs on the "*Weaping River*" river. Calling the URL "`http://localhost:8080/Water/Weaping%20River%20Basin/Rivers/Weaping%20River/Reservoirs`" in Postman (or web browser) returns the list of nodes (shown in Figure 29).

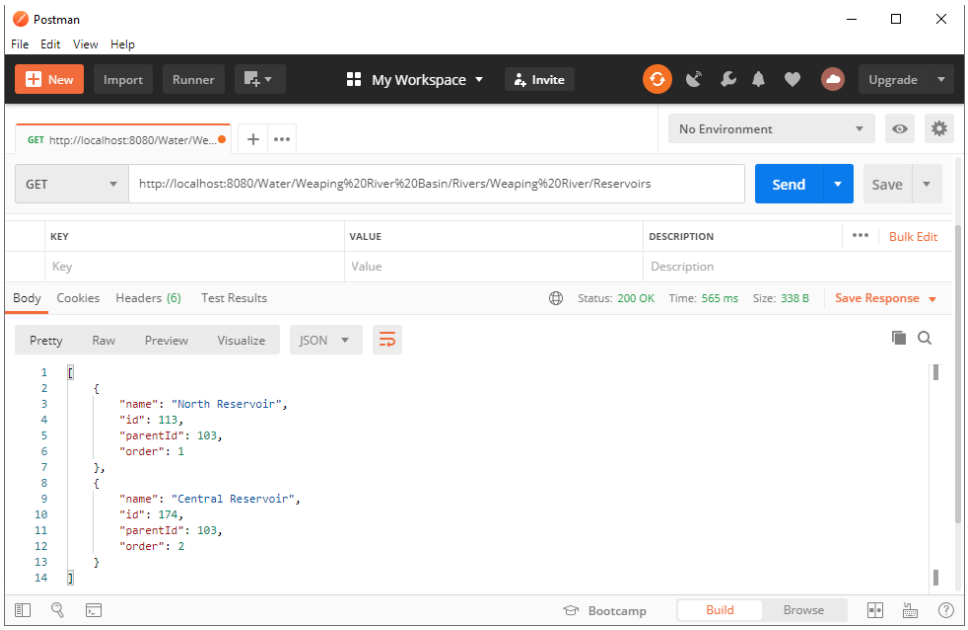


Figure 29. Calling the URL "`/Water/Weaping%20River%20Basin/Rivers/Weaping%20River/Reservoirs`" in the Postman.

6.7. A simple example

The following is an example illustrating using the C-WEAP framework for making changes to the "*Weaping River Basin*" model's configuration, reaching to an optimal solution.

Problem: Given the default "*Weaping River Basin*" project, what is the optimal value for the "*Efficiency Improvements*" key value to have the "*Water Demand*" result for the "*West City*" demand site in the year 2020 between 495,000,000 m^3 and 505,000,000 m^3 (500,000,000 ± 1%).

6.7.1. Model configuration

Based on the WEAP's calculation, the "*Water Demand*" result for a demand site uses the "*Annual Activity Level*" and "*Annual Water Use Rate*" input values. In the "*Reference*" scenario of the project, the "*Annual Water Use Rate*" is using the "*Technical Innovation*" key, and the "*Technical Innovation*" key is using the "*Efficiency Improvements*" key

to define the input data (the default value for the "*Efficiency Improvements*" key is 2). Using these value, the "*Water Demand*" is calculated by changing the "*Efficiency Improvements*" value.

6.7.2. Simulation Execution

The basic algorithm presented in Figure 30 to find the optimal "*Efficiency Improvements*" for the defined problem based on using different APIs from the C-WEAP framework. In step 1, the water demand is to be determined (calculate the optimal range for the "*Water Demand*") for the water demand ranging from 495,000,000 (WD_{lower_bound}) to 505,000,000 (named WD_{upper_bound}) values. In step 2, the default key "*Efficiency Improvements*" value is read from the WEAP system by calling the K3 API from the C-WEAP (`http://localhost:8080/Water/Weaping%20River%20Basin/Keys/Efficiency%20Improvements/Reference/Expression`). In step 3, the WEAP is executed (i.e., simulated) using the P3 (`http://localhost:8080/Water/Weaping%20River%20Basin/Run`). In step 4, the "*Water Demand*" result values for the demand site "*West City*" and scenario "*Reference*" for year 2020 are read using the N11 API from the C-WEAP (`http://localhost:8080/Water/Weaping%20River%20Basin/DemandSites/West%20City/Outputs/Water%20Demand/Reference?StartYear=2020&endYear=2020`). Also, in this step, the sum of the water demand for year 2020 must be calculated (called WD_{2020}), because the return type of calling N11 is an array of the Intervals for all time-steps values.

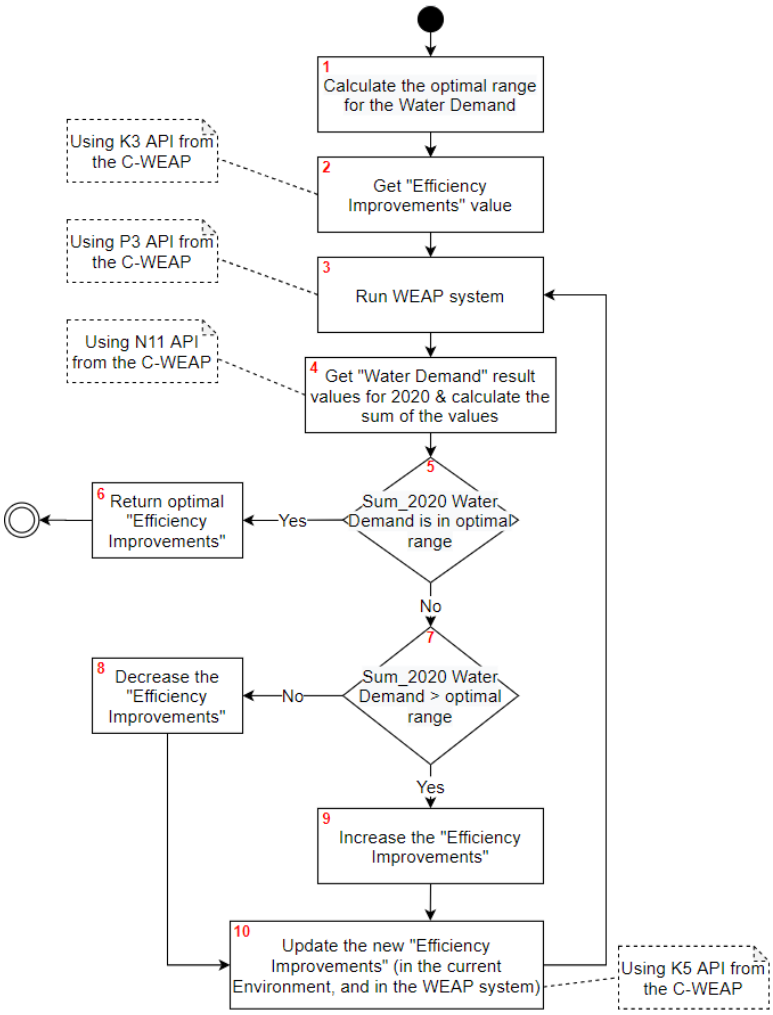


Figure 30. The flowchart to solve the defined problem in section 6.7 to find optimal efficiency.

In step 5, the WD_{2020} is checked to be in the optimal water demand range (between WD_{lower_bound} and WD_{upper_bound}). If the WD_{2020} is in the optimal range, the current "*Efficiency Improvements*" value is returned as the result, in step 6. Otherwise, the "*Efficiency Improvements*" key value must be checked to be decreased/increased using a simple evaluation of the WD_{2020} value to be smaller/larger than the WD_{lower_bound}/WD_{upper_bound} value, in step 7. In steps 8/steps 9, the decrease/increase amounts for the "*Efficiency Improvements*" is calculated. In step 10, the new value for the "*Efficiency Improvements*" updates using the K5 API from the C-WEAP (`http://localhost:8080/Water/Weaping%20River%20Basin/Keys/Efficiency%20Improvements/Reference/Expression`) and then the algorithm returns to step 3. The algorithm is expected to terminate with an optimal value for the "*Efficiency Improvements*".

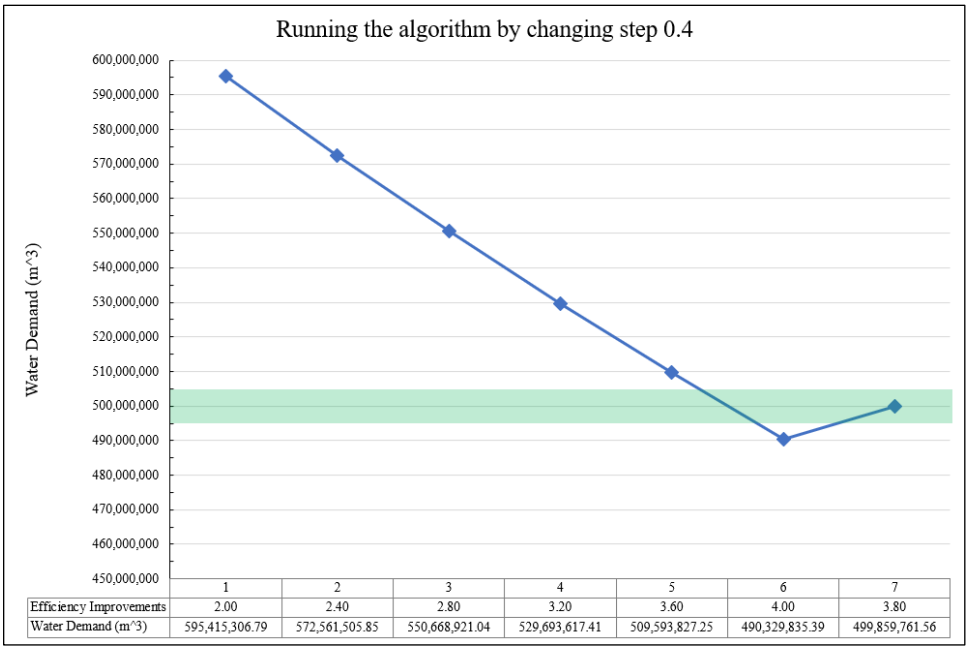
In this simulation execution, a value k for changing the "*Efficiency Improvements*" (if the current DW_{2020} value is out of the acceptance range) is set initially. Then, the k value is divided by 2 if DW_{2020} value is outside the acceptance range defined for the "*Water Demand*". For example, suppose the current DW_{2020} is larger than WD_{upper_bound}, then the value of the "*Efficiency Improvements*" will increase by x and the WEAP system is executed. Now, suppose the DW_{2020} is smaller than WD_{lower_bound}, so the value of "*Efficiency Improvements*" will decrease by $\frac{x}{2}$ and the WEAP system is executed.

6.7.3. Model Implementation

A Java maven application is used to implement the illustrated algorithm in Figure 30. Also, the Jersey framework is used to define the RESTful API for the Java application. The full implementation is presented in Appendix B. In the source code, lines 1 to 84 are the implementation for the algorithm in Figure 30. Lines 85 to 207 are the RESTful API (using Jersey framework) for the Project, Key, and Node categories. Finally, lines 208 to 312 are the classes to define the required domain models.

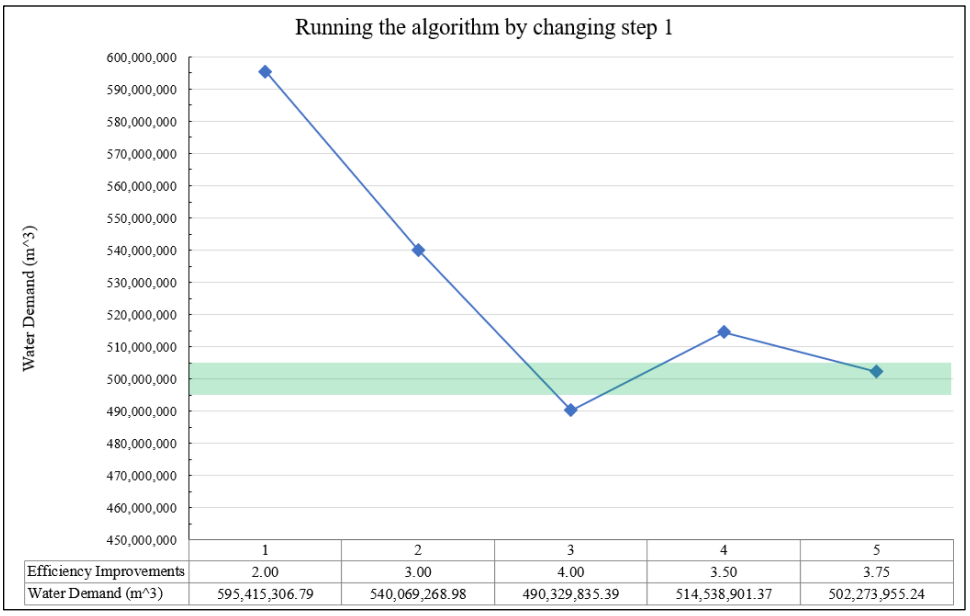
6.7.4. Simulation Results

A set of suitable values should be selected for k, the amounts by which is to be changed as long as the water demand is outside of the desired range. Three changing steps equal to 0.4, 1, and 2 are selected. The results and the trends of water demand to reach the desired ranges for three configurations are shown in Figure 31. The "*Efficiency Improvements*" is initialized to 2 and the WD_{2020} is 595,415,306.79 m^3. In Figure 31(a) the "*Efficiency Improvements*" increases by 0.4 through the sixth simulation cycle for the WD_{2020} to smaller than WD_{lower_bound}. For the seventh simulation cycle, the "*Efficiency Improvements*" decreases by 0.2. The result is the WD_{2020} falls within the acceptance range (499,859,761.56 m^3) with the final efficiency improvement equal to 3.8. Different results are shown in Figure 31(b) and (c) for changing steps 1 and 2, respectively. For both settings, the optimal efficiency improvement is 3.75. The desired range for the "*Water Demand*" values (495,000,000 to 505,000,000) is shown in the green areas in Figure 31(b) and (c).



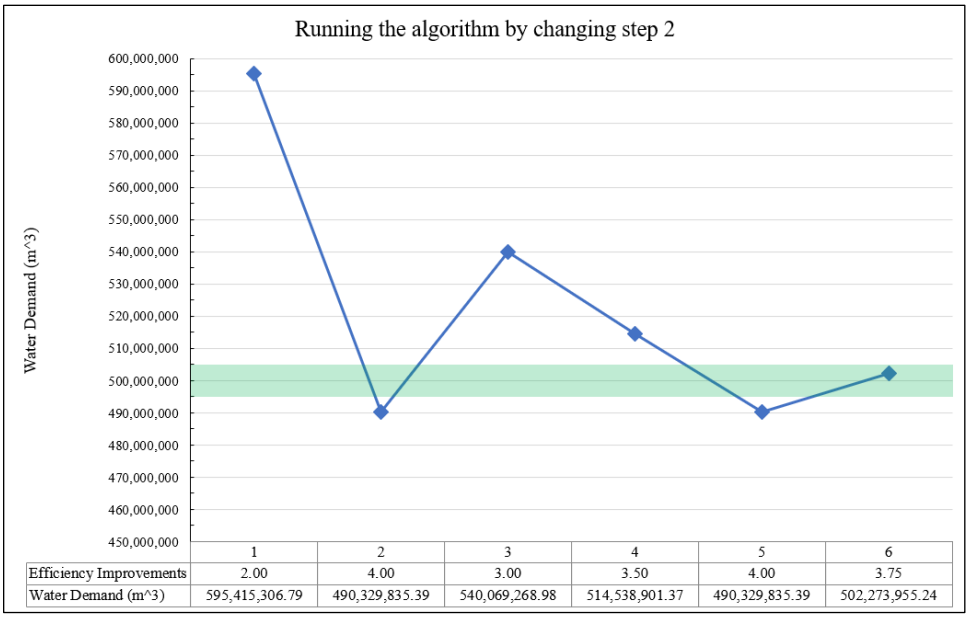
	1	2	3	4	5	6	7
Efficiency Improvements	2.00	2.40	2.80	3.20	3.60	4.00	3.80
Water Demand (m^3)	595,415,306.79	572,561,505.85	550,668,921.04	529,693,617.41	509,593,827.25	490,329,835.39	499,859,761.56

(a)



	1	2	3	4	5
Efficiency Improvements	2.00	3.00	4.00	3.50	3.75
Water Demand (m^3)	595,415,306.79	540,069,268.98	490,329,835.39	514,538,901.37	502,273,955.24

(b)



	1	2	3	4	5	6
Efficiency Improvements	2.00	4.00	3.00	3.50	4.00	3.75
Water Demand (m^3)	595,415,306.79	490,329,835.39	540,069,268.98	514,538,901.37	490,329,835.39	502,273,955.24

(c)

Figure 31. The result of running simulation with different changing step values (a) changing step equals 0.4 unit, (b) changing step equals 1 unit, (c) changing step equals 2 unit.

References

[1] ACIMS, "Componentized-WEAP RESTful Framework," 20 June 2020. [Online]. Available: https://acims.asu.edu/software/c-weap. [Accessed 20 June 2020].

[2] M. D. Fard and H. S. Sarjoughian, "A Web-service Framework for the Water Evaluation and Planning System," *Spring Simulation Conference (SpringSim)*, pp. 1-12, 2019.

[3] M. D. Fard and H. S. Sarjoughian, "Coupling WEAP and LEAP Models using Interaction Modeling," in *SpringSim Conference*, Fairfax, VA, USA, 2020.

Appendix A

The WEAP's APIs used in developing the Componentized-WEAP framework

#	API	Return Object	Category
1	WEAP.ActiveArea	Area	WEAP
2	WEAP.ActiveArea.Name	String	
3	WEAP.WaterYearStart	Integer	
4	WEAP.ActiveScenario	Scenario	
5	WEAP.BaseYear	Integer	
6	WEAP.EndYear	Integer	
7	WEAP.TimeStepName(Id)	String	
8	WEAP.NumTimeSteps	Integer	
9	WEAP.View	String	
10	WEAP.Calculate(LastYear, LastTimestep, AlwaysCalculate)	-	
11	WEAP.ResultValue(BranchName:VariableName, Year, TimeStep, ScenarioName)	Double	
12	WEAP.Areas(Id)	Area[]	Area
13	WEAP.Areas.Count	Integer	
14	WEAP.Versions.Count	Integer	Version
15	WEAP.Versions(Name/Id)	Version	
16	WEAP.Versions.Exist(VersionName)	Boolean	
17	WEAP.SaveVersion(VersionName)	-	
18	WEAP.Versions(VersionName).Revert()	-	
19	WEAP.Scenarios(Id)	Scenario[]	Scenario
20	WEAP.Scenarios.Exists(ScenarioName)	Boolean	
21	WEAP.Scenarios.Add(ScenarioName)	-	
22	WEAP.Scenarios(ScenarioName).Delete()	-	
23	WEAP.Branch(BranchName)	Branch	Branch
24	WEAP.BranchExists(BranchName)	Boolean	
25	WEAP.Branch(BranchName).Children	Branch[]	
26	WEAP.Branch(BranchName).Variables	Variable[]	
27	WEAP.Branch(BranchName).Variables.Exists(VariableName)	Boolean	

Appendix B

```
public class App
{
    public static void main(String[] args) {
        OEIC oeic= new OEIC("Weaping River Basin", 500000000, 5000000, 2);
        oeic.calculate();
    }
}
```

```
// OEIC stands for Optimal Efficiency Improvement Calculator
public class OEIC {
    private String _projectName = null;
    private double _changeEfficiencyValue = 0;

    private double _startWD = 0;
    private double _endWD = 0;

    public OEIC(String projectName, double optimalEfficiency, double efficiencyThreshold, double changeEff
    iciencyValue) {
        this._projectName = projectName;
        this._changeEfficiencyValue = changeEfficiencyValue;

        this._startWD = optimalEfficiency - efficiencyThreshold;
        this._endWD = optimalEfficiency + efficiencyThreshold;
    }

    public double calculate() {
        WaterService waterService = new WaterService();
        waterService.run(this._projectName);

        KeyService keyService = new KeyService(this._projectName);
        NodeService nodeService = new NodeService(this._projectName,ComponentTypes.DemandSite);

        double efficiencyValue = Double.valueOf(keyService.getExpression("Efficiency Improvements", "Refer
        ence"));
        Interval[] waterDemandValues = nodeService.getOutputValues("West City", "Water Demand", "Reference
        ", new FilterParams(2020, 2020));
        double sum2020 = this.getSum(waterDemandValues);

        double changeEfficiency = this._changeEfficiencyValue;
        boolean isBigger = false;
        if (sum2020 > this._endWD)
            isBigger = true;

        while ((sum2020 < this._startWD) || (sum2020 > this._endWD)) {
```

```
            if (sum2020 < this._startWD) {
                if (isBigger) {
                    changeEfficiency /= 2;
                    isBigger = false;
                }

                efficiencyValue -= changeEfficiency;
            }
            else {
                if (!isBigger) {
                    changeEfficiency /= 2;
                    isBigger = true;
                }

                efficiencyValue += changeEfficiency;
            }

            keyService.setExpression("Efficiency Improvements", "Reference", String.valueOf(efficiencyValu
            e));

            waterService.run(this._projectName);

            waterDemandValues = nodeService.getOutputValues("West City", "Water Demand", "Reference", new
            FilterParams(2020, 2020));
            sum2020 = this.getSum(waterDemandValues);
        }

        return efficiencyValue;
    }

    private double getSum(Interval[] values) {
        double result = 0;
        for (Interval interval : values) {
            for (Data data : interval.getData()) {
                result += data.getValue();
            }
        }
        return result;
    }
}
```

```
public abstract class AbstractWebService {
    private static final String SYSTEM = "Water";
    private String projectName = "";
    private ComponentTypes componentType = null;

```

```
89      public AbstractWebService() {
90      }
91
92      public AbstractWebService(String projectName, ComponentTypes componentType) {
93          this.projectName = projectName.replaceAll("\\s", "%20");
94          this.componentType = componentType;
95      }
96
97      private URI getBaseUrl() {
98          UriBuilder uri = UriBuilder.fromUri("http://localhost:8080/" + SYSTEM);
99          if (this.componentType != null)
100             uri.path(this.projectName).path(this.componentType.getTitle());
101         return uri.build();
102     }
103
104     protected <T> T Get(Class<T> type) {
105         return this.Get(type, "", null);
106     }
107
108     protected <T> T Get(Class<T> type, String path) {
109         return this.Get(type, path, null);
110     }
111
112     protected <T> T Get(Class<T> type, String path, FilterParams filters) {
113         path = path.replaceAll("\\s", "%20");
114         if (filters != null) {
115             path += this.getQueryParameters(filters);
116         }
117         String url = this.getBaseUrl() + path;
118         Builder builder = ClientBuilder.newClient().target(url).request(MediaType.APPLICATION_JSON);
119         Response res = builder.get();
120
121         return res.readEntity(type);
122     }
123
124     protected boolean Put(String path, Object values) {
125         String url = this.getBaseUrl() + path.replaceAll("\\s", "%20");
126         Builder builder = ClientBuilder.newClient().target(url).request(MediaType.APPLICATION_JSON);
127         Response res = builder.put(Entity.entity(values, MediaType.APPLICATION_JSON), Response.class);
128
129         return res.readEntity(boolean.class);
130     }
131
132     private String getQueryParameters(FilterParams filters) {
133         String start = "?";
```

```
134         String result = start;
135
136         if (filters.getStartYear() != 0) {
137             if (result == start)
138                 result += "startYear=" + filters.getStartYear();
139             else
140                 result += "&startYear=" + filters.getStartYear();
141         }
142
143         if (filters.getEndYear() != 0) {
144             if (result == start)
145                 result += "endYear=" + filters.getEndYear();
146             else
147                 result += "&endYear=" + filters.getEndYear();
148         }
149
150         if (filters.getStartTimeStep() != 0) {
151             if (result == start)
152                 result += "startTimeStep=" + filters.getStartTimeStep();
153             else
154                 result += "&startTimeStep=" + filters.getStartTimeStep();
155         }
156
157         if (filters.getEndTimeStep() != 0) {
158             if (result == start)
159                 result += "endTimeStep=" + filters.getEndTimeStep();
160             else
161                 result += "&endTimeStep=" + filters.getEndTimeStep();
162         }
163
164         return result;
165     }
166 }
```

```
167 public class WaterService extends AbstractWebService {
168     public WaterService() {
169         super();
170     }
171
172     public boolean run(String projectName) {
173         String path = "/" + projectName + "/Run";
174         return (boolean) super.Get(boolean.class, path);
175     }
176 }
```

```
177 public class KeyService extends AbstractWebService {
178     public KeyService(String projectName) {
```

```
179             super(projectName, ComponentTypes.Key);
180         }
181
182         public String getExpression(String compName, String scenarioName) {
183             String path = "/" + compName + "/" + scenarioName + "/Expression";
184             String temp = super.Get(String.class, path);
185             return (String) temp.substring(1, temp.length() - 1);
186         }
187
188         public boolean setExpression(String compName, String scenarioName, String expression) {
189             String path = "/" + compName + "/" + scenarioName + "/Expression";
190             return super.Put(path, new ExpressionValue(expression));
191         }
192     }
```

```
193     public class NodeService extends AbstractWebService {
194         public NodeService(String projectName, ComponentTypes componentType) {
195             super(projectName, componentType);
196         }
197
198         public Interval[] getOutputValues(String compName, String portName, String scenarioName, FilterParams
199         filters) {
200             String path = "/" + compName + "/Outputs/" + portName + "/" + scenarioName;
201             return (Interval[]) super.Get(Interval[].class, path, filters);
202         }
203     }
```

```
204     public class Interval {
205         private int year;
206         private List<Data> data;
207
208         public Interval() {
209             this.data = new ArrayList<>();
210         }
211
212         public int getYear() {
213             return year;
214         }
215
216         public void setYear(int year) {
217             this.year = year;
218         }
219
220         public List<Data> getData() {
221             return data;
222         }
223
```

```
    public void addData(Data data) {
        this.data.add(data);
    }

    public void addData(List<Data> data) {
        this.data.addAll(data);
    }
}
```

```
public class Data {
    private int timeStep;
    private double value;

    public Data() {
    }

    public Data(int timeStep, double value) {
        this.timeStep = timeStep;
        this.value = value;
    }

    public int getTimeStep() {
        return timeStep;
    }

    public double getValue() {
        return value;
    }

    public void setValue(double value) {
        this.value = value;
    }

    public void setTimeStep(int timeStep) {
        this.timeStep = timeStep;
    }
}
```

```
public class FilterParams {
    private int startYear;
    private int endYear;
    private int startTimeStep;
    private int endTimeStep;

    public FilterParams(int startYear, int endYear) {
        this(startYear, endYear, 0, 0);
    }
```

```
269
270         public FilterParams(int startYear, int endYear, int startTimeStep, int endTimeStep) {
271             this.setStartYear(startYear);
272             this.setEndYear(endYear);
273             this.setStartTimeStep(startTimeStep);
274             this.setEndTimeStep(endTimeStep);
275         }
276
277         public int getStartYear() {
278             return startYear;
279         }
280
281         public void setStartYear(int startYear) {
282             this.startYear = startYear;
283         }
284
285         public int getEndYear() {
286             return endYear;
287         }
288
289         public void setEndYear(int endYear) {
290             this.endYear = endYear;
291         }
292
293         public int getStartTimeStep() {
294             return startTimeStep;
295         }
296
297         public void setStartTimeStep(int startTimeStep) {
298             this.startTimeStep = startTimeStep;
299         }
300
301         public int getEndTimeStep() {
302             return endTimeStep;
303         }
304
305         public void setEndTimeStep(int endTimeStep) {
306             this.endTimeStep = endTimeStep;
307         }
308     }
```