
Ground Water Data Mapper

Release 2.0

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May 08, 2024

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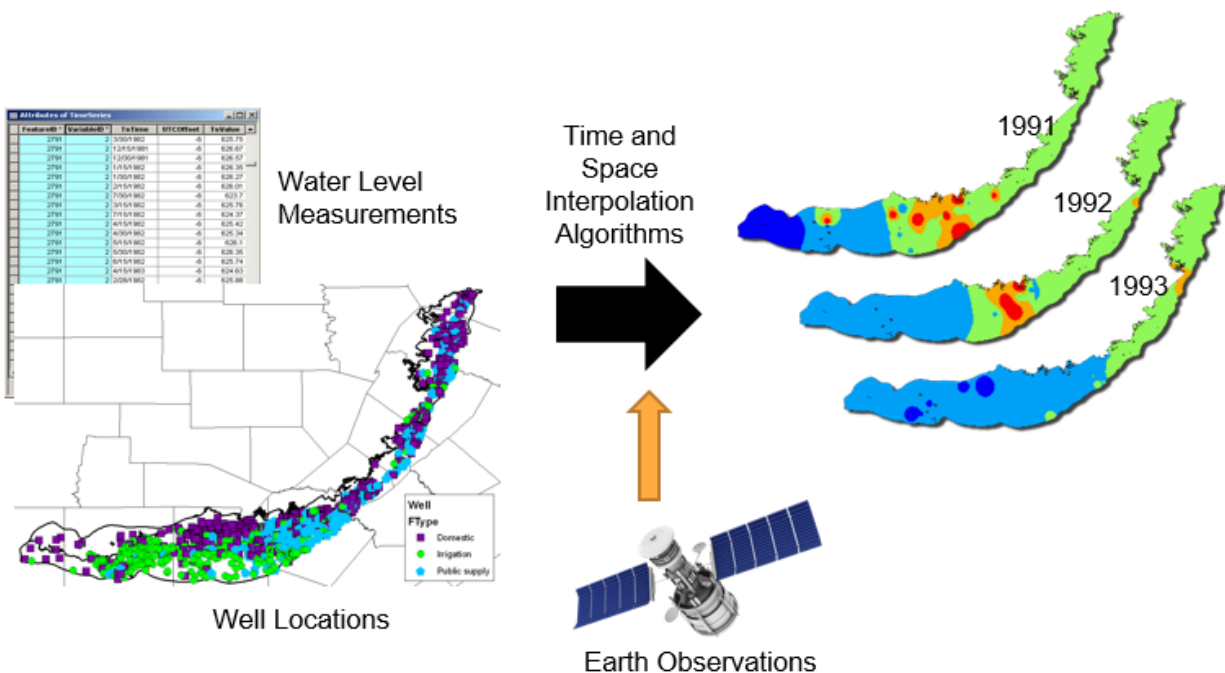
The Groundwater Data Mapper (GWDM) is a Tethys Platform web application and an associated set of Python scripts. The GWDM Tethys app can be used to host and visualize groundwater data in one or more regions. The groundwater data is a set of wells organized by aquifers. For each well, the user can upload a set of measurements (typically groundwater elevations) taken at different points in time. The wells are then displayed on a map in the web interface and the measurement time series can be visualized by clicking on the wells. This documentation describes how to format and organize groundwater data for use in the GWDM app and how to upload and manage the data. Furthermore, the tools include a mapping algorithm that uses a machine learning algorithm to impute gaps in the time series record for all of the wells in an aquifer and it then performs a spatial interpolation of water levels at wells to generate a series of time-varying rasters illustrating how the water levels in the aquifer vary over time. These rasters can be animated in the app. Furthermore, by calculating the volume between subsequent rasters and multiplying by a storage coefficient, the algorithm also generates a time series of groundwater volume storage change over time. Thus the GWDM tools can be used to analyze the sustainability of a aquifer.

These tools were originally developed via funding from the National Aeronautics and Space Administration: 80NSSC20K0155; United States Agency for International Development: Cooperative Agreement with SERVIR West Africa Hub. More details about this project can be found here: <https://hydroinf.groups.et.byu.net/servir-wa/>

OVERVIEW

Water managers in Western Africa and around the world face the daunting task of managing freshwater resources in the face of increased demand from industry, agriculture, climate change, and population growth. As surface water resources become fully allocated, groundwater is increasingly targeted to make up surface water deficits, particularly during periods of drought. As a result, many of our aquifers are not being managed in a sustainable fashion, resulting in reduced water quality, land subsidence, increased pumping costs, and in some cases, the complete exhaustion of an aquifer and the loss of groundwater as a buffer during times of drought.

1.1 Mapping Algorithm



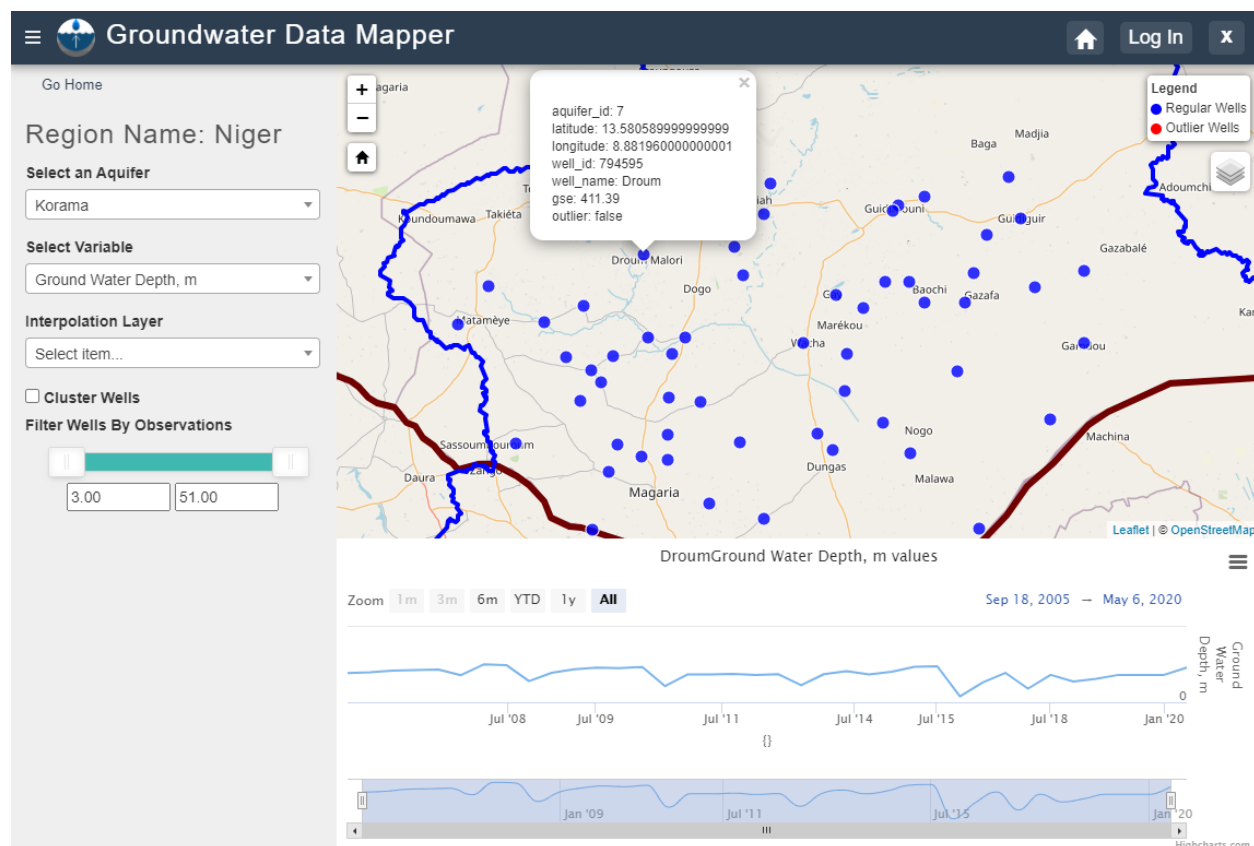
Even when water managers have access to large data sets of historical groundwater level measurements, at any individual well these measurements often exhibit significant time gaps. Aggregating and synthesizing these well measurements to provide information that supports a holistic assessment of aquifer level sustainability can be a challenging task. In partnership with NASA SERVIR, we have developed a series of algorithms that use these existing well measurements combined with Earth Observation data to analyze changes in water tables and characterize aquifer storage over time. Our approach involves collecting data describing well locations and any historical water level measurements in an aquifer. To evaluate aquifer behavior, we need to impute missing data at each well location so that we have data at each time step for analysis. To impute (or estimate) missing measurements at each well, we use a machine learning approach

that trains models to use Earth observation data. Using this approach, we generate a time series for each well and use these data to spatially interpolate the water table at each time step.

These interpolated water table maps can be used to evaluate the sustainability of the aquifer by looking at the changes to aquifer storage over time. We have shown that our approach can deal with gaps resulting from long periods with no measurements at wells. Our machine learning algorithms build correlations between existing water level measurements and Earth observations such as water storage changes from the NASA Gravity Recovery and Climate Experiment (GRACE) mission, soil moisture from the Global Land Data Assimilation System (GLDAS), or the Palmer Drought Severity Index (PDSI). These machine learning methods have shown to be remarkably accurate for data imputation and extrapolation. The product of this process is a series of time-varying rasters that can be animated to allow water managers to visualize how the water levels are changing over time and where the aquifer is being stressed. The rasters can also be analyzed to assess the change in aquifer water volume or storage over time – a key indicator of aquifer health and sustainability.

1.2 Tethys Application

We have incorporated our groundwater level mapping algorithms in a simple, easy-to-use web application created using the Tethys Platform, developed in our hydroinformatics laboratory. In addition to the water level mapping, the system provides a powerful online database of historical groundwater data where users can zoom in to areas of interest, select wells, and view the historical water level record and meta-data about each well.



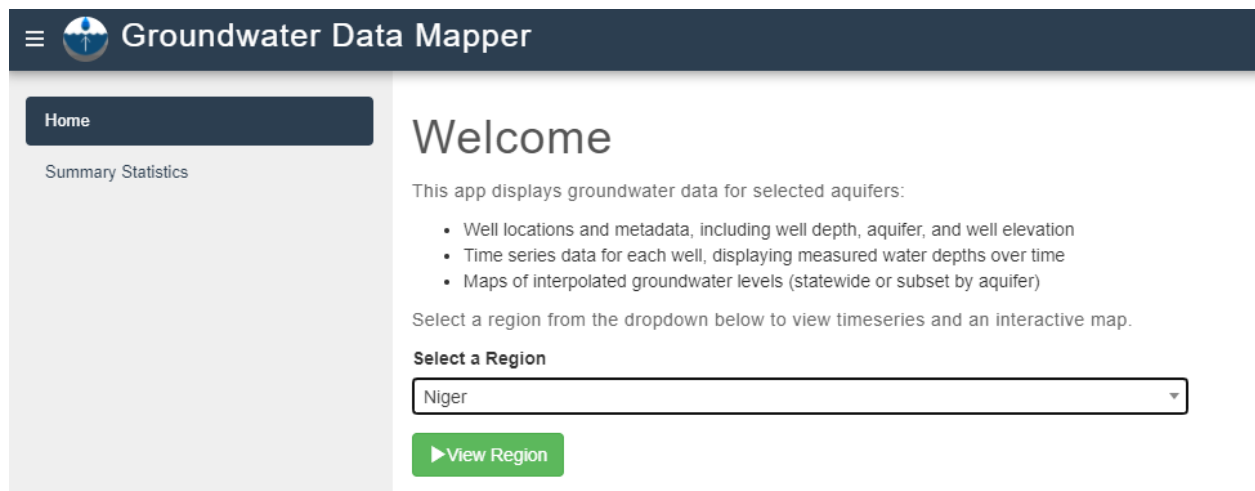
The GWDM app can be accessed in the following locations:

- **Servir West Africa Portal:** Official Tethys portal hosted by the SERVIR Science Coordination Office (SCO) for the West Africa Hub (<https://tethyswa.servirglobal.net/apps/>).

- **BYU Portal:** A Tethys portal hosted by Brigham Young University for all completed apps (<https://tethys.byu.edu>).
- **GEOGloWS Portal:** A portal associated with the GEOGloWS organization (<https://apps.geoglows.org/apps/>).
- **INDRHI GEOGloWS Portal:** A Tethys portal used by INDRHI, the national institute for hydraulics in the Dominican Republic (<https://indrhi.geoglows.org/apps/>).
- **GEOGloWS Portal:** A portal associated with the GEOGloWS organization (<https://apps.geoglows.org/apps/>).

1.3 Regions, Aquifers, and Well Data

For any of the portals, you can access the app by clicking on the Groundwater Data Mapper icon. Once you are in the app, you will see the landing page:



Select a region and then click on the **View Region** button. In the GWDM tool, data are first organized by region and then by aquifer. When you click on the View Region button, you will see a map of the selected region and the corresponding aquifers. To view well data, you need to select an aquifer. Once you select an aquifer, the app will zoom in on the aquifer and display all wells associated with the aquifer. The well data consists of two parts:

- 1) Well locations
- 2) Historical observations at the wells.

The observations are typically water levels that can be represented either as depth to the water table or water table elevations, but any variable is supported and could include water quality data. The regions, aquifers, wells, and measurements are imported through an admin interface that is described in more detail in the subpages associated with the GWDM on this website.

1.4 Controls

On the left side of the map, you will see a set of controls:

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Go Home

Region Name: Niger

Select a Region

Niger

Select an Aquifer

Select an Aquifer

Select Variable

Select a Variable

Interpolation Layer

Select a Layer

Off

Cluster Wells

Off

Multiple Well Select

Filter Wells By Observations

||

||

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Select an Aquifer: This is used to switch between aquifers in the region as described above.

Select Variable: The well data may have historical measurements of different types. You can use this to select the type you'd like to explore.

Interpolation Layer: If the interpolation algorithm has been used to generate aquifer maps, the resulting maps are listed in this drop-down list. These are netCDF files that are displayed as color contours in the map window on the right. See the section below on displaying rasters.

Cluster Wells: For aquifers with large numbers of wells, this feature can be used to simplify the display by grouping sets of adjacent wells into clusters. You can see the individual wells by zooming in or by clicking on the clusters.

Multiple Well Select: This is used to select and display time series plots for multiple wells. See the section below for more details.

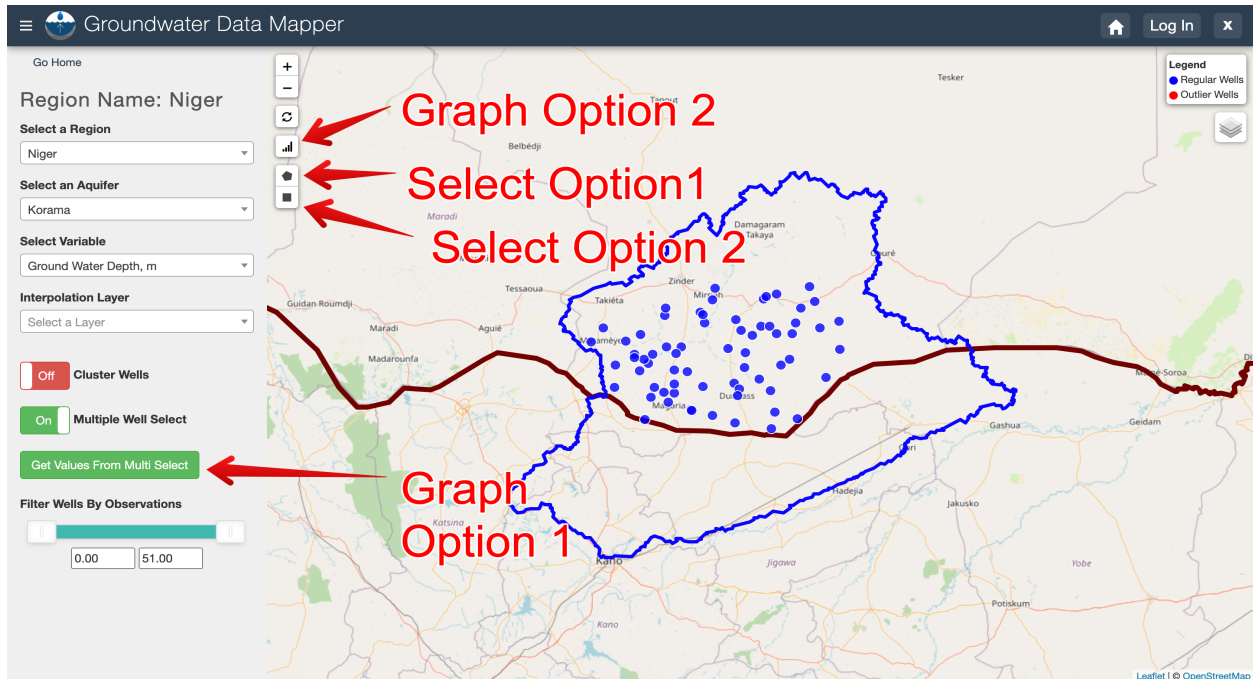
Filter Wells by Observations: These controls show the min and max number of measurements associated with individual wells in the aquifer. By changing the two values, you can filter which wells are displayed. For example, to only show wells that contain at least one measurement, change the min value on the left to something other than zero.

Reset: The reset button is located just above the graphing button to the right of the control panel and is used to return to the region's home

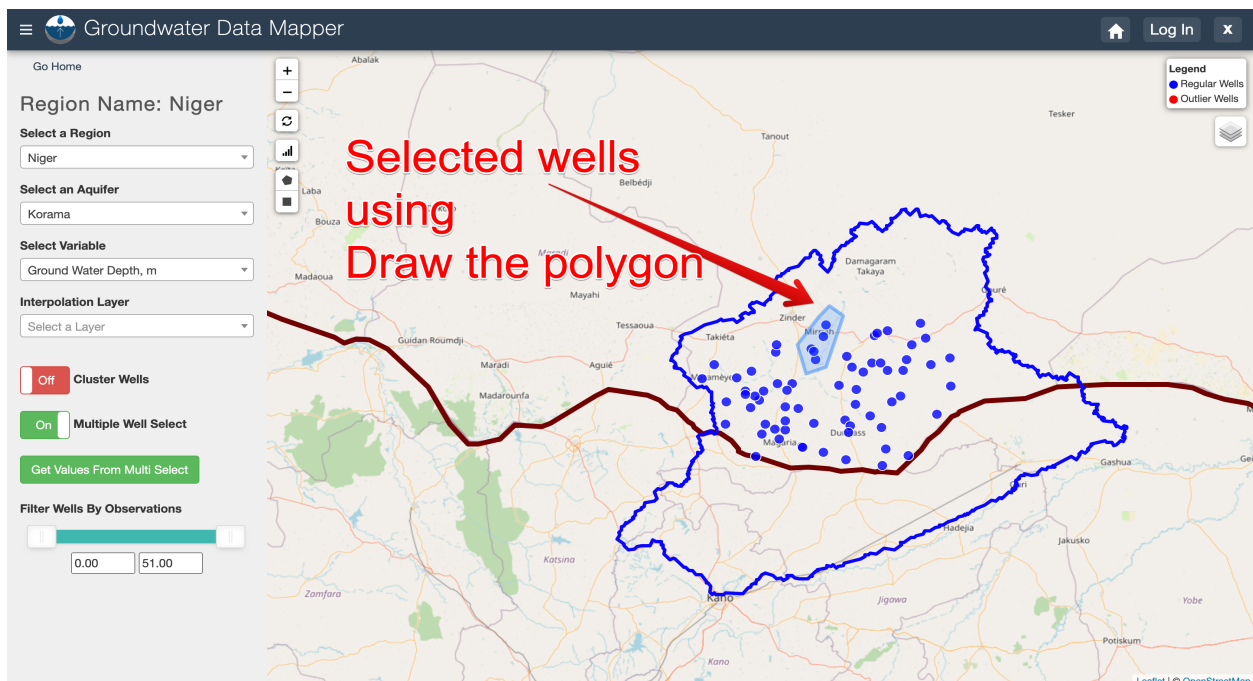
To explore the well data, you can click on individual wells to see metadata about the well. If the well contains historical measurements, they are plotted as a time series graph at the bottom of the screen.

1.5 Selecting and Displaying Multiple Wells

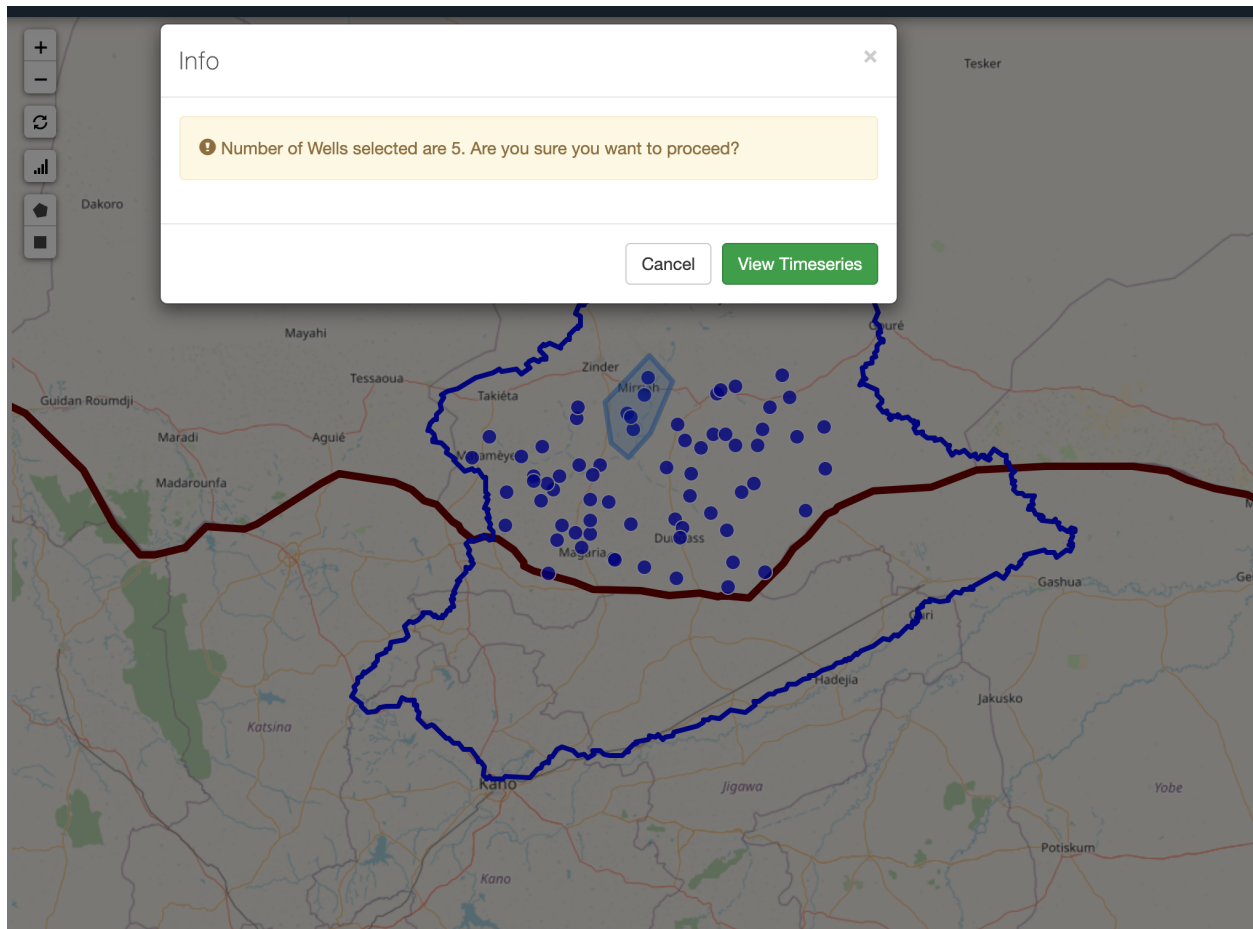
It may be helpful to compare wells within the same aquifer that may not necessarily fall under the same cluster groups. One would need to select which variable to compare before activating the Multi-Well Select. To activate this command, simply click on the button which will then turn green and three more options will be added to the screen. Here is a picture of all the options that will be available once the Multiple Well Select is activated:



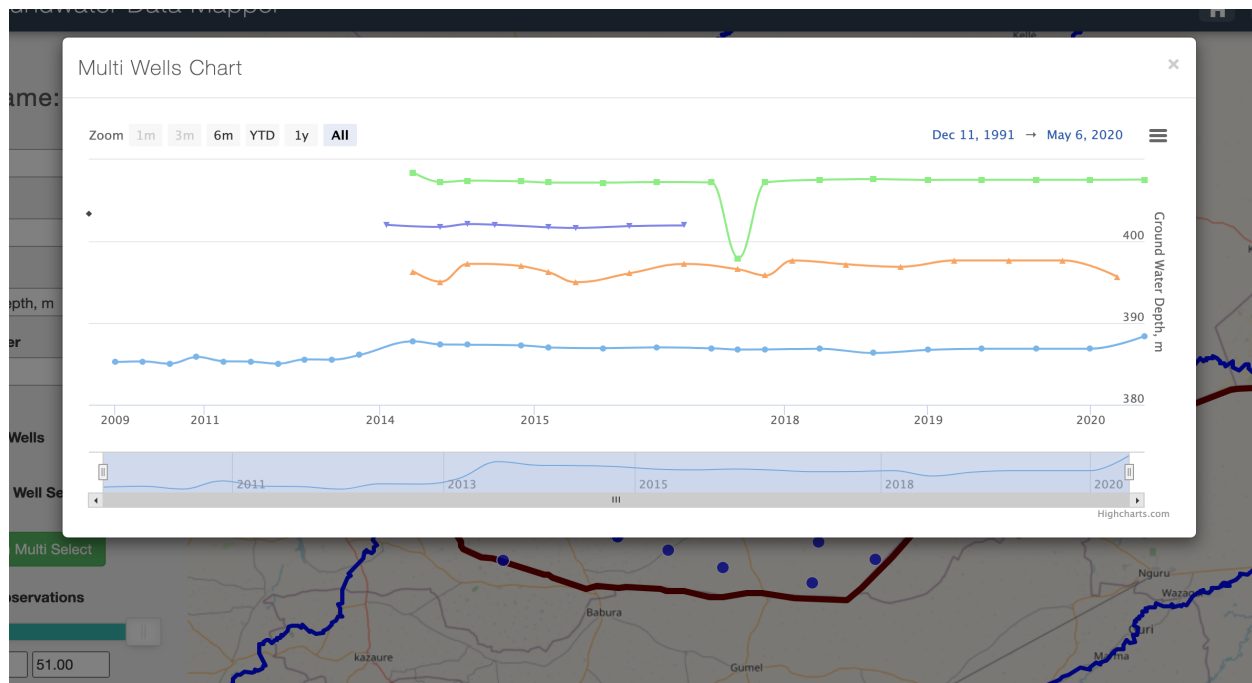
Select Option 1: This select method allows the user to draw a polygon by clicking around the wells interested in. This option allows one to draw any closed polygon around any wells one wishes to visualize.



Once the polygon created is closed, a message box will appear giving you an option to view the time series. When you click on the view time series, a Multi Wells Chart will appear on your screen comparing the time series of the selected wells. If you click cancel, you can still visualize your selected wells by clicking on Graph Option 2 whose icon looks like a bar graph.



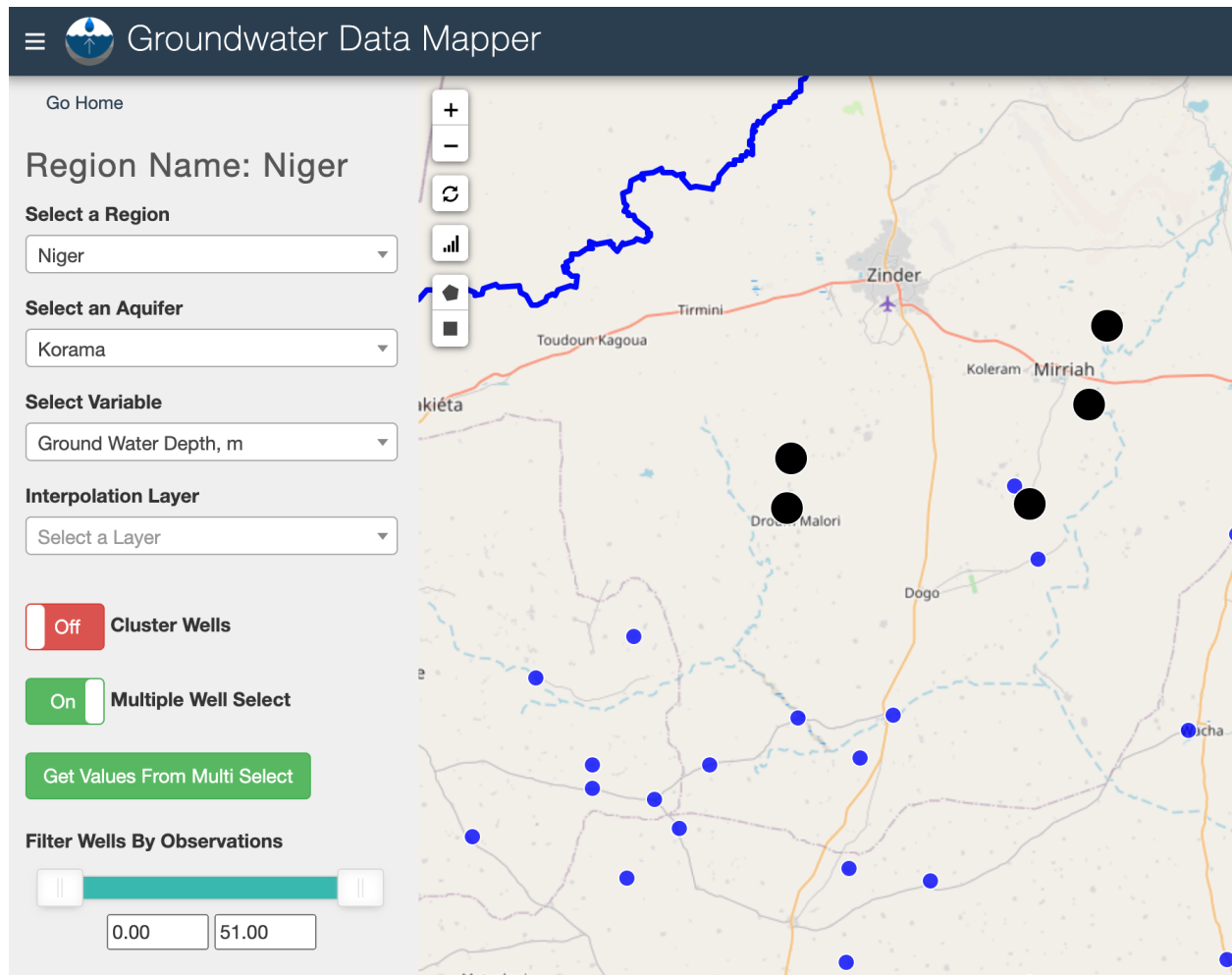
Here is an image of the results from our previous selection. Notice that the chart only shows available data and skips any missing data.



Select Option 2: This option is similar to the first option. The only difference is that this shape is fixed to be a rectangle. You may change the size but not the type. It follows the same procedure as the first option.

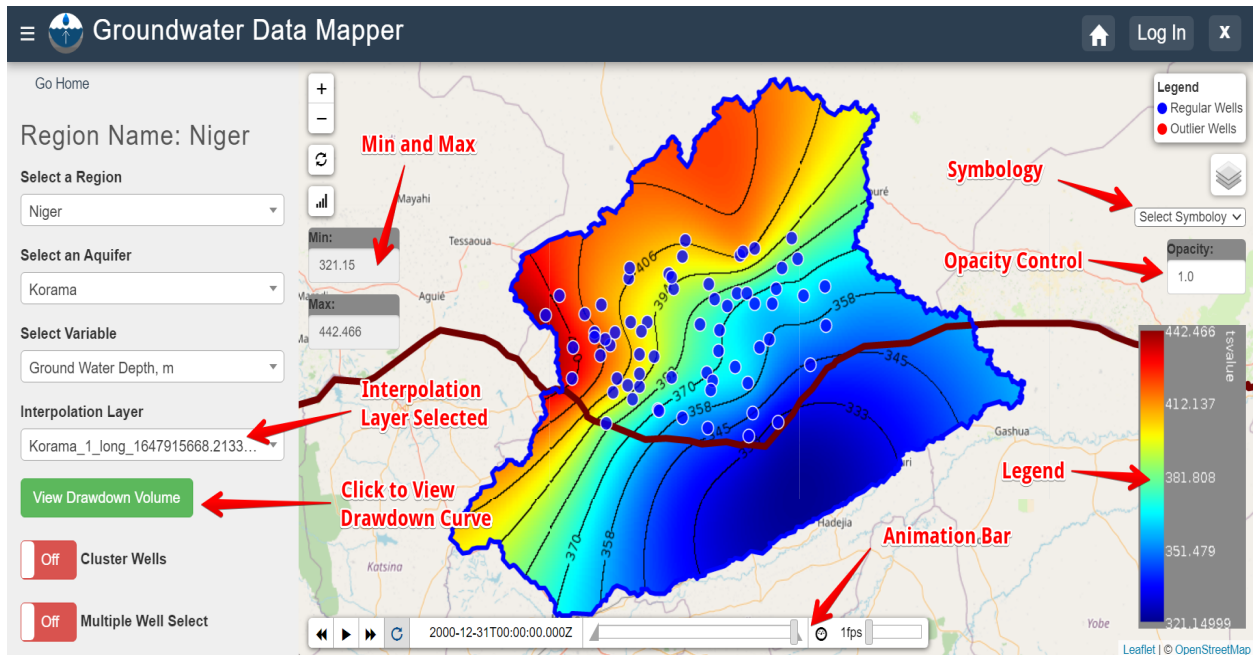
Graph Option 1: This will graph individually selected wells. This is done by individually clicking on individual wells, which will turn black upon selection. This is the only way to graph the selected wells.

Here is a rendering;



1.6 Displaying Rasters

Once you have created an interpolation layer and selected that layer from the control panel on the right, a new set of controls will appear. The figure below points out each of those controls and the following paragraph explains each of them.



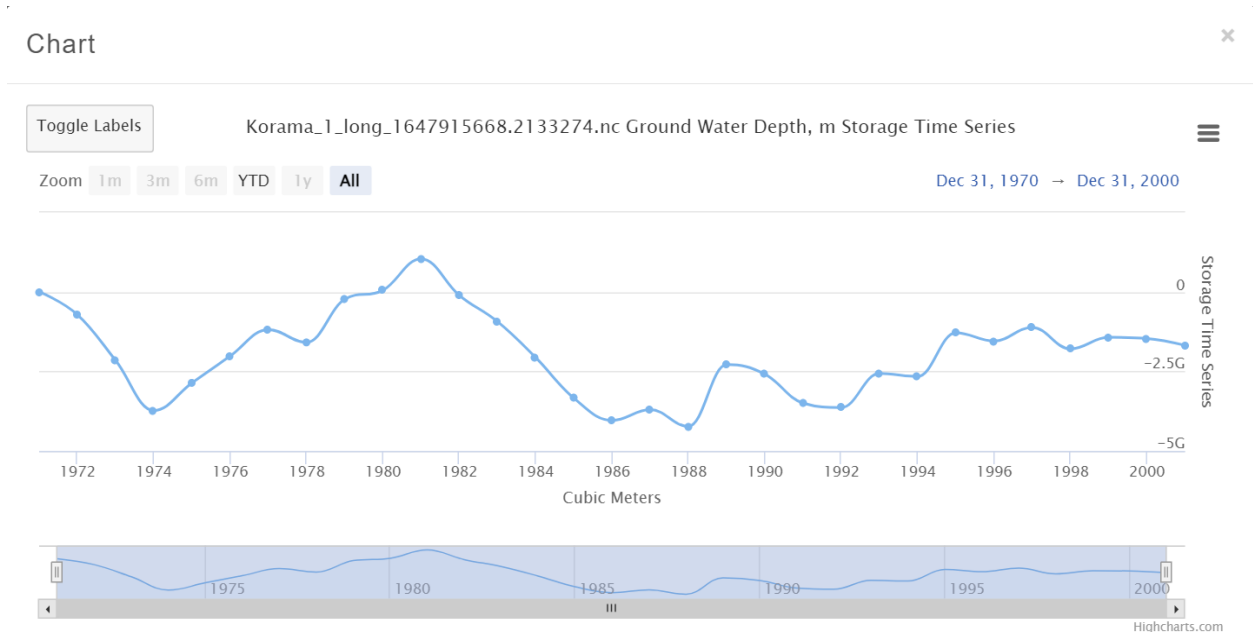
Animation Bar: You can slide the bar to move through the time interpolation or you can hit play to run through the animation automatically. You can change the speed of animation by changing the frames per second (fps). You can also adjust the triangular ends on the slide bar, to animate over a shorter period.

Min and Max: Displays the maximum and minimum water table elevation values for the entire aquifer during the entire interpolation time range.

Symbology: There are several preloaded symbology or raster coloring options which you can choose from the drop-down menu.

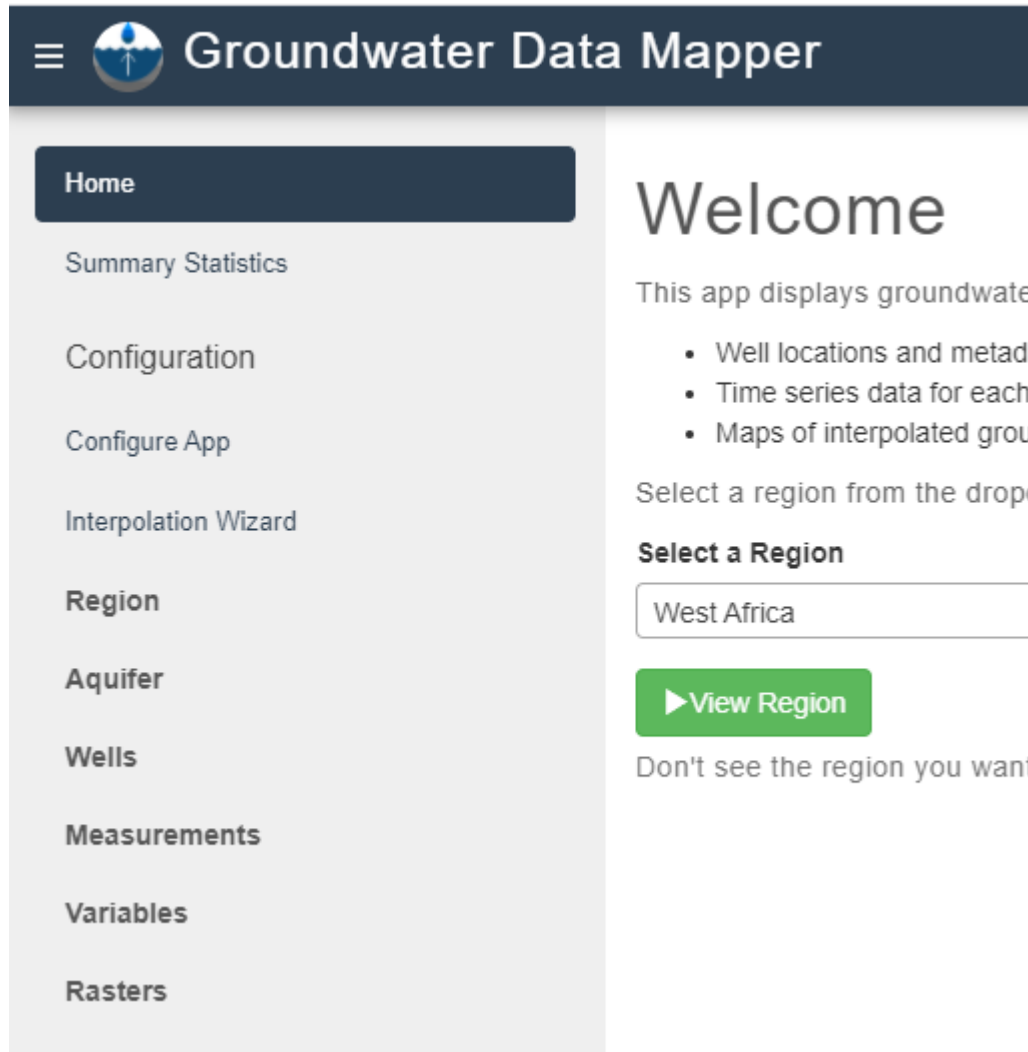
Opacity: Changing the opacity of the raster may be helpful if you wish to see some of the features on the base map.

View Drawdown Volume: The drawdown volume graph converts the water table elevations over time to an increase or decrease in total volume in the aquifer. An example of the drawdown volume curve is included below.



1.7 Admin Control Panel

There is also an admin control panel that is used to import and manage the data used by the app and to perform interpolations:



1.8 Documentation and Tutorials

The table of contents can be used to explore a set of documentation and tutorials associated with the GWDM. The sections are as follows:

Data Preparation. This section describes how the data are organized in the GWDM and how to format your data before importing the data into the app.

Support Scripts. This section describes a set of Python scripts that can be used to process, format, and prepare your data. For example, one of the scripts can be used to generate ground surface elevations using global DEM data if your wells do not have elevation data.

Importing Data. Once your data are organized into properly formatted input files, this section describes how to import the data into the app.

Mapping. This section describes the interpolation algorithms and shows how to generate time-varying rasters of your groundwater data for display and animation.

Installation. This section describes how to install the GWDM app in your own Tethys portal.

DATA PREPARATION

2.1 Introduction

Before importing data into the GWDM app, the following data content needs to be collected and prepared:

- Region Boundary
- Aquifers
- Well locations
- Measurements (Time Series Data)

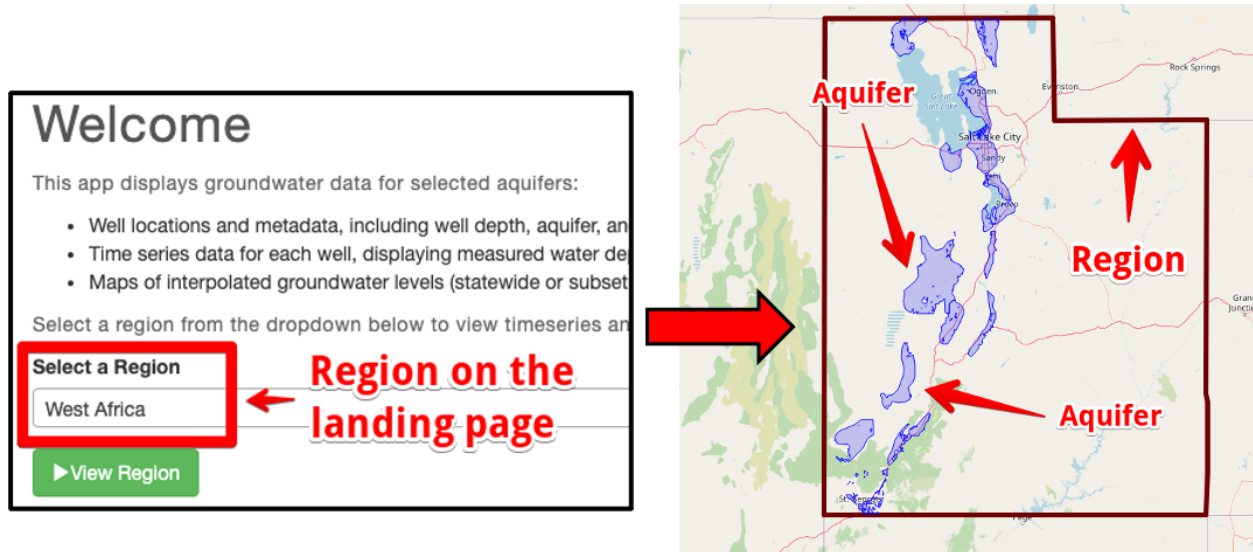
A region is typically a state, country, or water management agency boundary and represents the top of the data hierarchy. In one region, there may be one or more aquifers in which wells are located. Each well may have time series data in one or multiple files that show historical trends of groundwater data such as water table elevations, water quality, etc. The following diagram graphically illustrates the relationship of the different data components:



This page will walk you through how to prepare the appropriate files needed to import data into the app and provide links to complementary tools designed to aid in this data preparation process.

2.2 Regions & Aquifers

The first step of organizing groundwater data in the GWDM app is uploading region and aquifer files where the wells are located. In the app, region is the first “filter” that users see on the landing page. Data are then organized by aquifer in the next page.



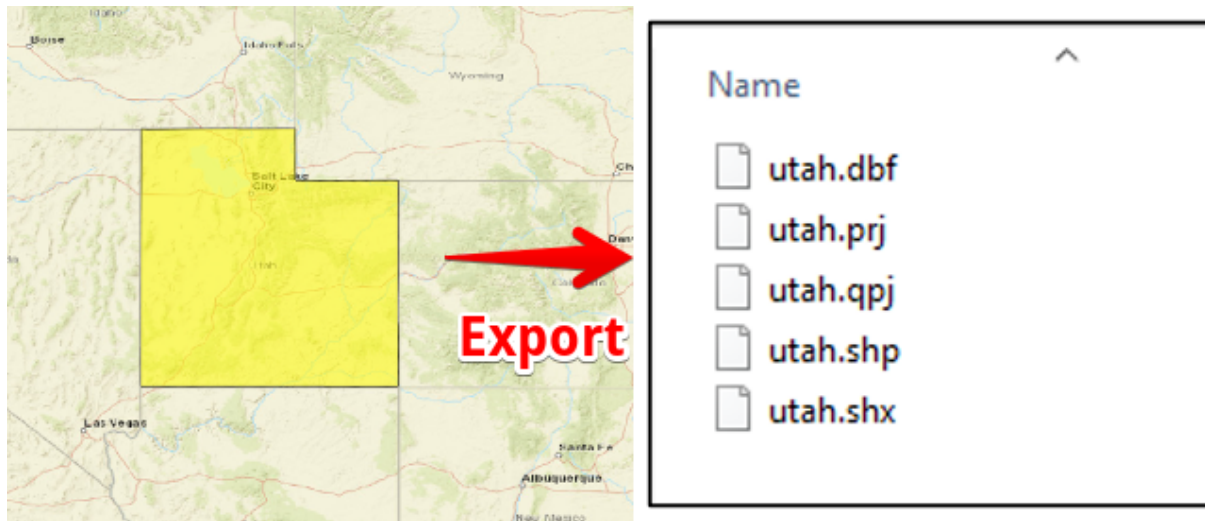
Region and aquifers files have to be one of the following data types:

- Shapefile (.shp, .shx, and .dbf are required)
- GeoJSON file (.geojson)

In the examples used on this page, the state of Utah (USA) was used as a region boundary in a shapefile and Utah's major aquifers were prepared in a .geojson file. When exporting shapefiles from a utility such as Esri ArcGIS or QGIS, the shapefile should be exported as a 2D object, not a 3D object (no Z coordinate). This is because the PostGIS database used to store the objects in the GWDM only supports 2D shapes. Shapefiles with Z coordinates will result in an error message when importing to ArcGIS. In our experience, shapefiles and GeoJSON objects exported from QGIS are more likely to import correctly than shapes exported from ArcGIS.

2.3 Region (State Boundary):

For this example, QGIS was used to export the region boundary (the state of Utah) as a shapefile. You can often find regional shapefiles on the internet. Regardless of where you get your shapefile, the exported files should consist of multiple files as seen below.

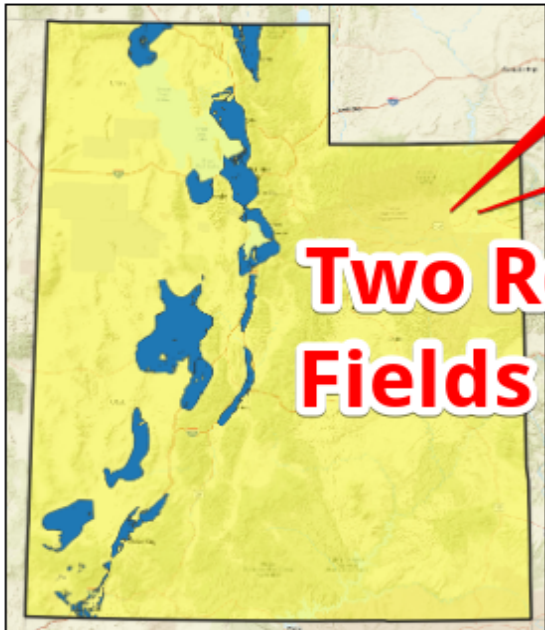


Also, make sure the shapefile does NOT include Z coordinates as this will generate an error when you attempt to import the file. The PostGIS database used by the GWDM to store the region and aquifer boundaries only supports two-dimensional shapes.

2.4 Aquifer:

The aquifers in your region will also need to be organized in either a geojson file or a shapefile. The attribute table for the aquifer file has two fields (columns) that are required to upload the file to the app: an aquifer name representing the unique name of the aquifer and an **aquifer ID**, a unique integer ID.

Field	Type	Description
Aquifer Name	Text	The names should uniquely describe the aquifers
Aquifer ID	Numeric	The integer IDs should be unique (not have duplicate values)



Two Required Fields

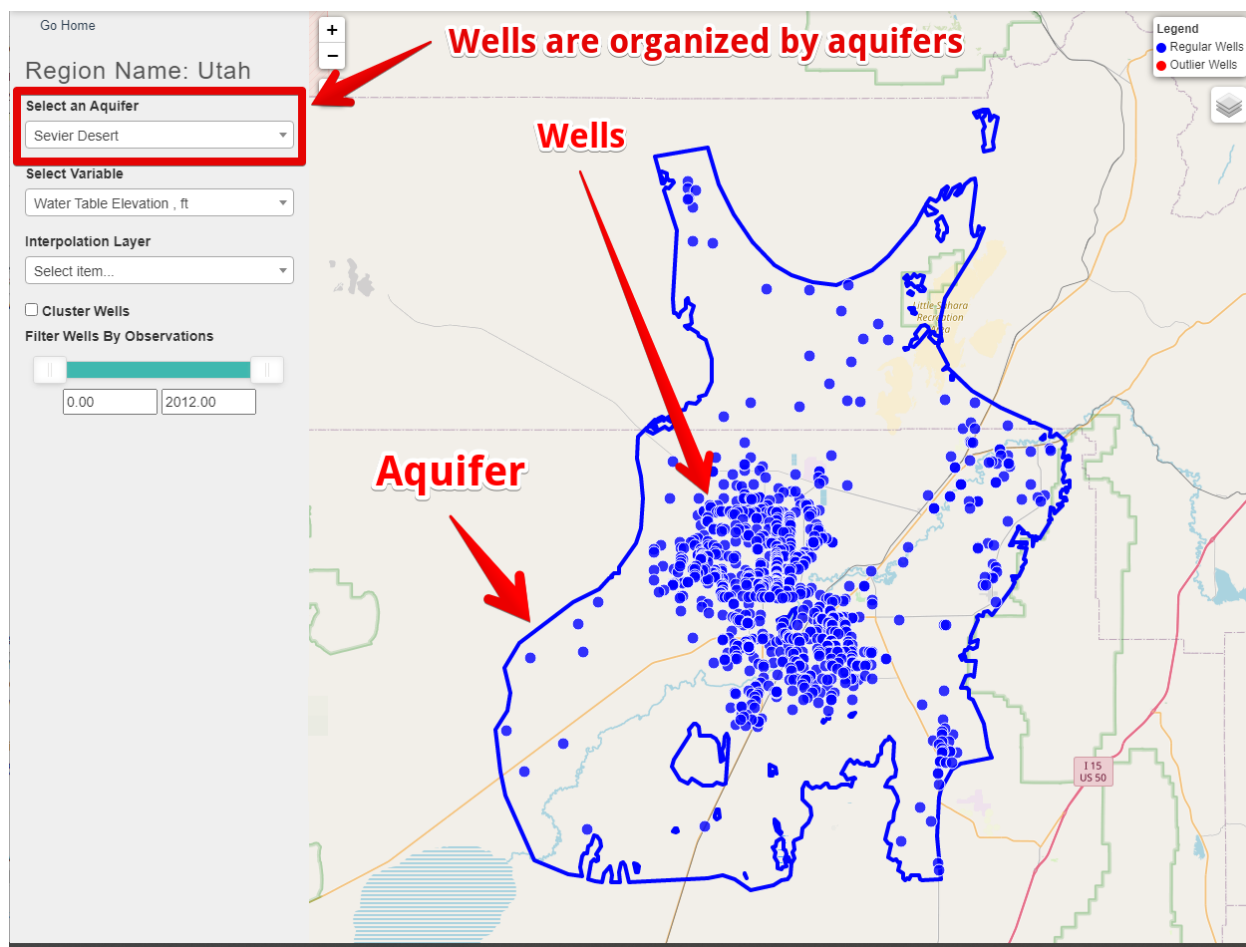
	Aquifer_ID	Aquifer_Name
	0	Curlew Valley
2	1	Cache Valley
5	2	Tooele Valley
4	3	East Shore Ar...
5	4	Northern Uta...
6	5	Northern Uta...
7	6	Salt Lake Vall...

2.5 Well Locations File

Well locations are organized in CSV files where each row represents a well location and the columns represent well attributes. These typically can be exported from Excel or from a well database.

Wells are organized by aquifers in the app. There are two ways to prepare well locations files.

1. Create a single CSV file with all wells and assign each well an aquifer ID corresponding to the aquifer it is located in. This allows the GWDM app to match the aquifer ID attribute from the well location file to the aquifer ID that was input with the aquifer polygons in the previous step. This allows you to import all of the wells associated with your region in a single step. However, it does require that you have aquifer IDs associated with your wells. If you do not have Aquifer IDs, you can use one of the support scripts we have provided to automatically generate the IDs based on the aquifer polygon files and the well coordinates.
2. Create a separate CSV file that contains only wells belonging to a single aquifer. This method does not require an aquifer ID as all of the wells are imported to an assigned aquifer. With this method, you create multiple well files, one per aquifer, and then import the wells one at a time. Each time you import the wells, you explicitly select the aquifer polygon the wells should be assigned to.



A well location file must include the well coordinates (latitude and longitude in a decimal degree format), well names, and well IDs. If you are using method #1 described above, an aquifer ID field is also required.

The required fields (columns) for a wells file are:

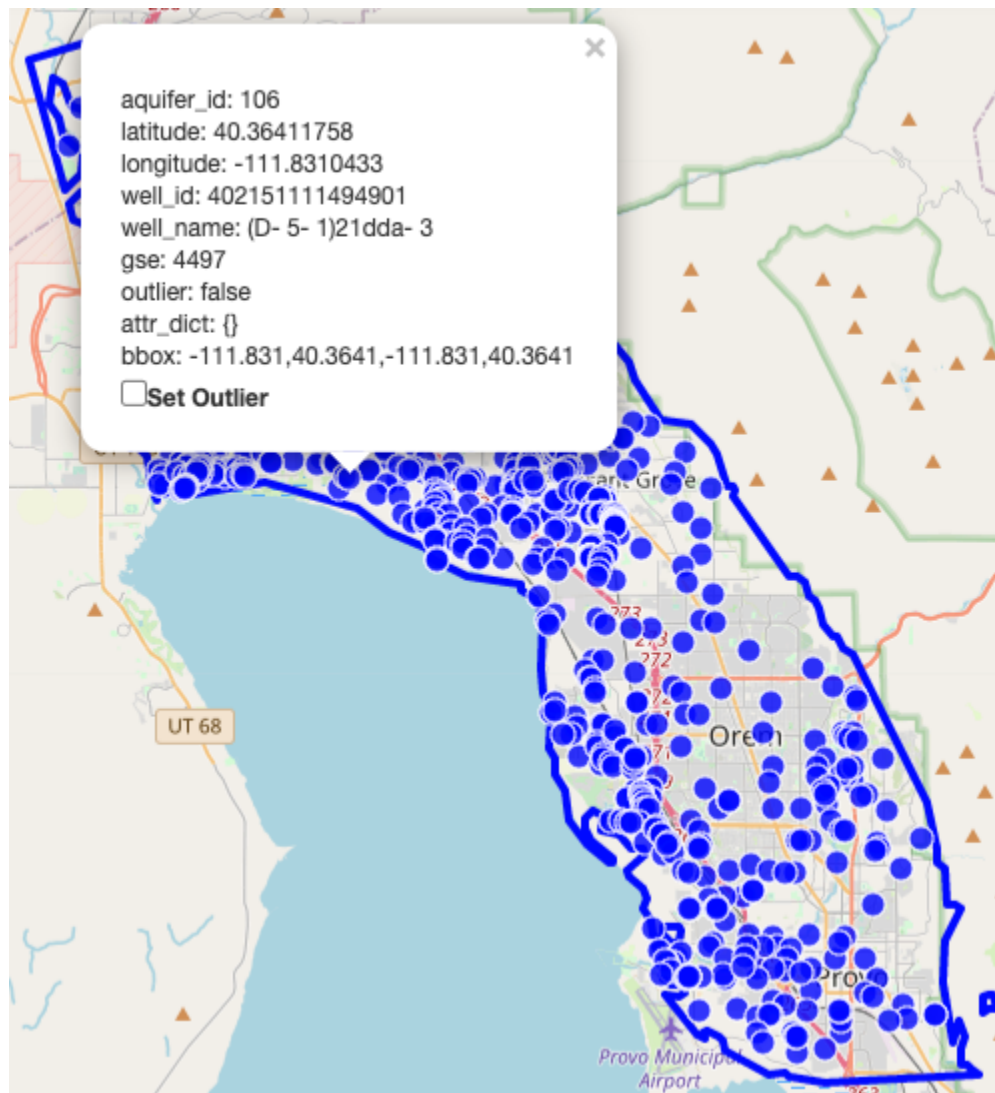
This is a sample well locations file:

Well_ID	Well_Name	lat_dec	long_dec	GSE	AquiferID	Aquifer_Name
370037113281401	(C-43-14)31bab- 1	37.0102604	-113.471340800000000	2830.0	14	Central Virgin River
370045113284201	(C-43-15)25ddd- 1	37.01248259	-113.479118800000000	2795.0	14	Central Virgin River
370125113290401	(C-43-15)24dcc- 1	37.0233158	-113.483285600000000	2850.0	14	Central Virgin River
370201113301701	(C-43-15)23bda- 1	37.03359337	-113.5055084	2760.0	14	Central Virgin River
370204113310701	(C-43-15)23bcb- 1	37.0344265	-113.5193979	2860.0	14	Central Virgin River
370220113263001	(C-43-14)20abb- 1	37.03887159	-113.4424514	3050.0	14	Central Virgin River

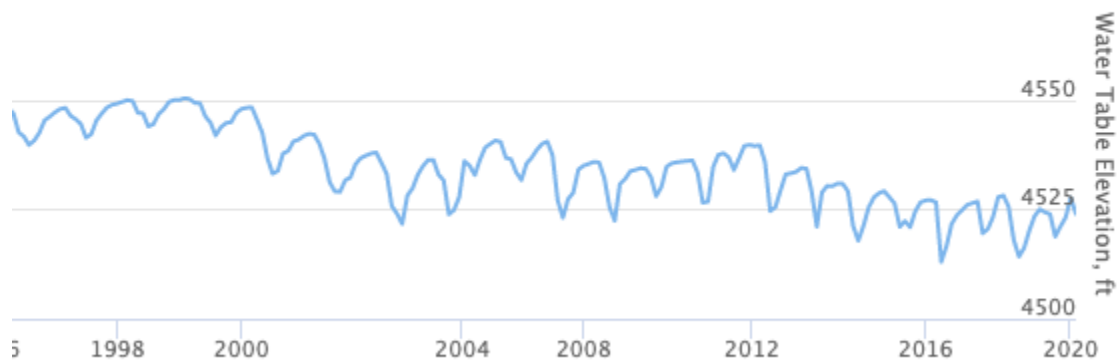
2.6 Measurements File

A measurement file is a CSV file containing the groundwater data measurements. Each measurement has a date, a data value, and a well ID that relates the measurements to the corresponding well. An aquifer ID column is optional depending on how the measurement file is prepared. Like a well locations file, there are two ways to prepare a measurement file.

1. Create a single CSV file with all wells and groundwater measurements and assign each measurement/well an aquifer ID corresponding to the aquifer it is located in. This allows having the same well IDs from different aquifers in a single file (i.e. There can be wells with the same well IDs if they are located in different aquifers). This method allows you to import all of the measurements and wells in a single step. However, it does require that you have aquifer IDs associated with your measurements/wells. We also provided the support scripts to automatically format the uploading file with the well and aquifer IDs.
2. Create a separate CSV file that contains only measurements/wells belonging to a single aquifer. This method does not require an aquifer ID as all of the measurements/wells are imported to an assigned aquifer. With this method, you create multiple well files, one per aquifer, and then import the measurements/wells one at a time. Each time you import the measurements/wells, you explicitly select the aquifer polygon the wells should be assigned to. In the GWDM app, the measurements associated with a well can be displayed as a time series curve as shown below. Measurements are also interpolated in time and space using the Mapping Google Collab Notebook to created time-varying rasters that can be animated or used to compute changes in aquifer storage vs time.



Apr 1, 1947 → Jun 11, 2020



The required fields (columns) for a measurements file are:

This is a sample measurements file. Note that a measurements file can contain extra fields or columns. These columns are ignored when the data are imported. The data import process allows the user to designate which columns contain the required data. In this example, the only fields imported are Well_ID, Date, and WTE (water table elevation). The other fields are ignored. When preparing the measurements file, one should be careful to only include measurements associated with wells that have already been uploaded into the GWDM.

Well_ID	Well_Name	Date	WTE	AquiferID	Aquifer_Name
370037113281401	(C-43-14)31bab- 1	02/24/2003	2656.54	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/25/2004	2653.83	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/24/2005	2652.9	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/24/2006	2652.4	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/23/2007	2651.91	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/20/2008	2651.06	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/24/2009	2653.24	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/23/2010	2654.89	14	Central Virgin River
370037113281401	(C-43-14)31bab- 1	02/23/2011	2656.67	14	Central Virgin River

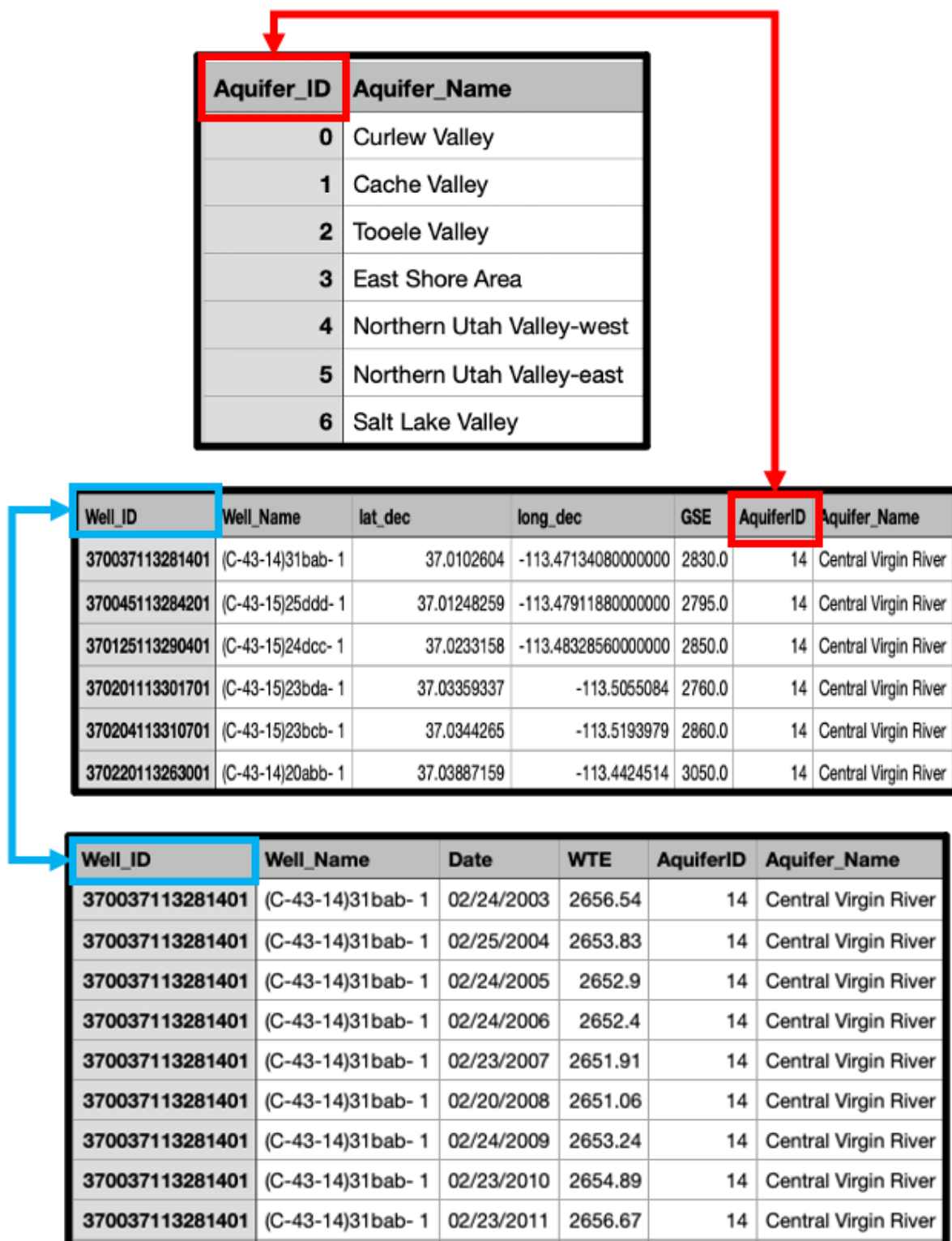
2.7 Support Tools

Collecting, filtering, and formatting well and measurement data can be a complicated process, especially with large datasets. To assist in this process, we have created a set of Python scripts that aid in the generation of ground surface elevations (GSEs), obtaining existing well data from USGS, adding Aquifer IDs, and other formatting options. Each script is contained within a Google Collaboratory notebook. For more information regarding these scripts, go to the Support Scripts page. The scripts include tools for the following tasks:

- Ground surface elevations are necessary to convert depth-to-water-table measurements to water table elevations. If your wells do not include ground surface elevations, the elevations can be sampled from a 30-meter DEM using the **Elevation Generator Tool**.
- For locations in the United States, both well locations and measurements can be downloaded directly from the USGS NWIS database using the **NWIS Data Retriever Tool**.
- You can assign aquifer names and IDs to wells, calculate water table elevations from depth to water table measurements, and clean up your data with other formatting options using the **Data Formatting Tool**.

2.8 Summary

In summary, the app organizes aquifers, wells, and measurements in the relationship presented below under a region. Note how the various feature IDs are used to create relationships between regions, aquifers, wells, and measurements.



DATA PREPARATION SCRIPTS

3.1 Introduction

These scripts can aid in the data preparation process required prior to using the GWDM tool. They have all been created in a cloud-based environment called Google Colaboratory, or Colab for short. Colab is built on Jupyter Notebook, which allows users to write, execute, and visualize Python code quickly and easily.

These notebooks have been shared as GitHub Gists. A gist allows the notebook to be opened, run, and modified by an individual user without affecting the experience of another user.

There is a tool for retrieving elevations at wells that are missing ground surface elevation measurements, a tool for assigning aquifer IDs and names to wells depending on location, a tool for formatting wells and time series files, a tool for retrieving wells and time series files from the USGS NWIS database (U.S. only).

An example set of files has been provided; however, you are welcome to use your own files if you would prefer.

SupportScriptFileSet.zip

3.2 Elevation Generator

This tool can be used to retrieve elevations for wells that are missing ground surface elevations. These ground surface elevations are used for calculating Water Table Elevation (WTE) and are included as well metadata in the app. It samples a global, 30-meter DEM for each well location, providing a reasonable estimate for each missing GSE. Please note that its accuracy is limited and that field-measured GSE measurements are preferable. A file with well locations (lat/long coordinates) is required as input and a file with GSEs generated for each well will be output. To use this tool, you will need to register your Google account with Google Earth Engine to be able to utilize this service. You can do this at: <https://signup.earthengine.google.com/#/> To practice using this script, download and open the attached set of files (top of the page) and locate the ut_2015-2020_wells csv file.

3.3 Aquifer Assignment Tool

This tool can be used for assigning an aquifer name and ID to each well. This requires an aquifers file with aquifer IDs and names assigned to each polygon and a wells file with lat/long locations for each well. Aquifers can also be assigned to a separate time series file with well IDs that correspond to the well IDs in the wells file. To practice using this script, download and open the attached set of files and locate the UtahMajorAquifers json file and the Utah wells and TS (time series) csv files.

3.4 File Formatter

This tool is meant for cleaning and restructuring data files for import into the GWDM app. It accepts a wells file, time series file, and an aquifers file as inputs- each of which are optional, depending on your needs. Options include:

- Dropping unnecessary data
- Reformatting data types
- Accepting different date formats (which Excel sometimes corrupts)
- Calculating water table elevation (WTE) from depth to groundwater measurements

To practice using this script, download and open the attached set of files and locate the UtahMajorAquifers geojson file and the ut_2015-2020_wells and ut_2015-2020_TS csv files.

3.5 NWIS File Retriever

This tool is meant for retrieving groundwater data files from the USGS National Water Information System (NWIS) data repository. The data from NWIS is only available for areas maintained by USGS. This tool:

- Queries the NWIS database for wells and time series measurements that meet the user-specified time and place parameters
- Assigns aquifers to each well
- Drops wells that fall outside the aquifer boundary

The tool requires an aquifers file as input and produces a formatted wells file and time series file (ready for import into the GWDM app). To practice using this tool, download and open the attached set of files and locate the UtahMajorAquifers geojson file.

IMPORTING DATA

4.1 Introduction

To demonstrate the data import process, an example set of data has been provided. Download and unzip the attached files or organize your own files to follow along.

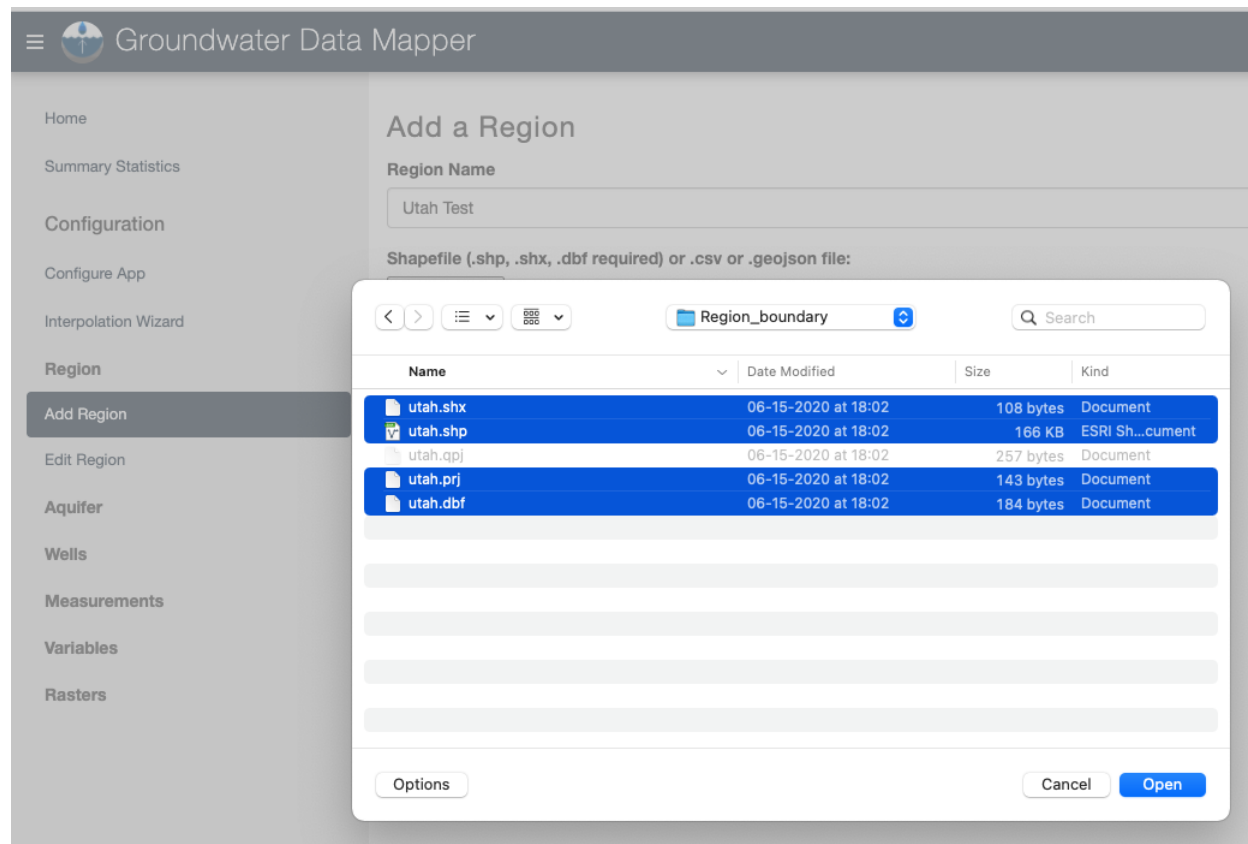
SupportScriptFileSet.zip

4.2 Add Region

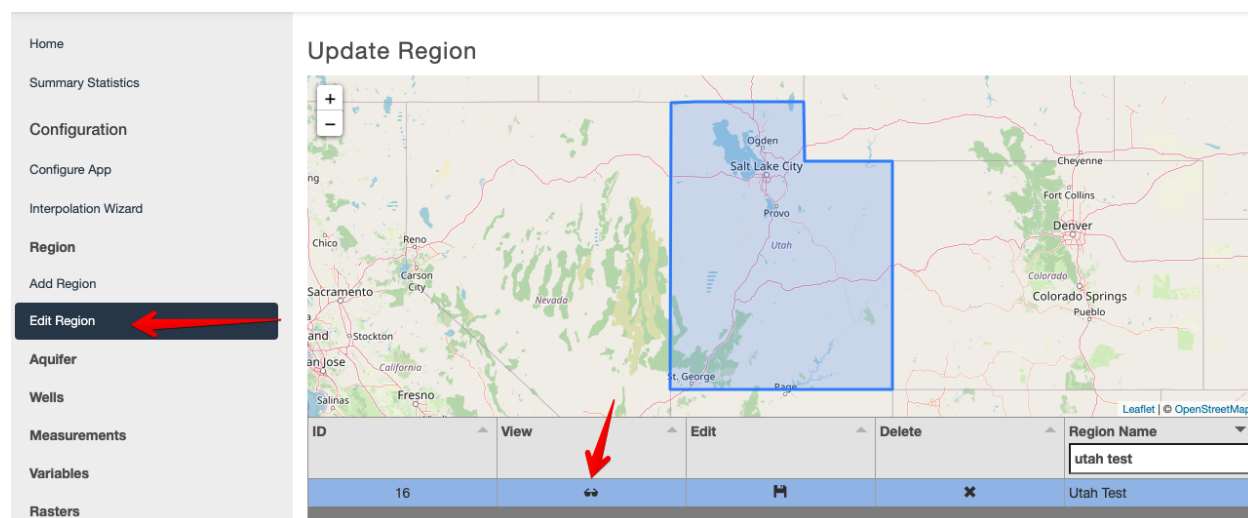
First, we must add a region. To do this, navigate to the main landing page (if you are not logged in with admin privileges, you will need to first obtain these credentials). Select the region tab on the left, then click on the **Add Region** link on the dropdown.

The screenshot shows the 'Groundwater Data Mapper' web application. On the left is a sidebar menu with the following items: Home, Summary Statistics, Configuration, Configure App, Interpolation Wizard, Region (highlighted), Add Region (highlighted), Edit Region, Aquifer, Wells, Measurements, and Variables. The main content area is titled 'Add a Region' and contains a 'Region Name' text input field with the placeholder text 'e.g.: West Africa'. Below this is a label 'Shapefile (.shp, .shx, .dbf required) or .csv or .geojson file:' followed by a 'Choose Files' button and the text 'No file chosen'. At the bottom of the form is a blue button with a plus icon and the text '+ Add Region'.

Type in the name of your region and click the Choose Files button to open a file browser. From there you can select a shapefile set, a csv, or a geojson file. The example file in this demo is a set of shapefile files for the Utah state boundary. Note that shapefiles require .shp, .shx, and .dbf files, although .prj files are also good to include.

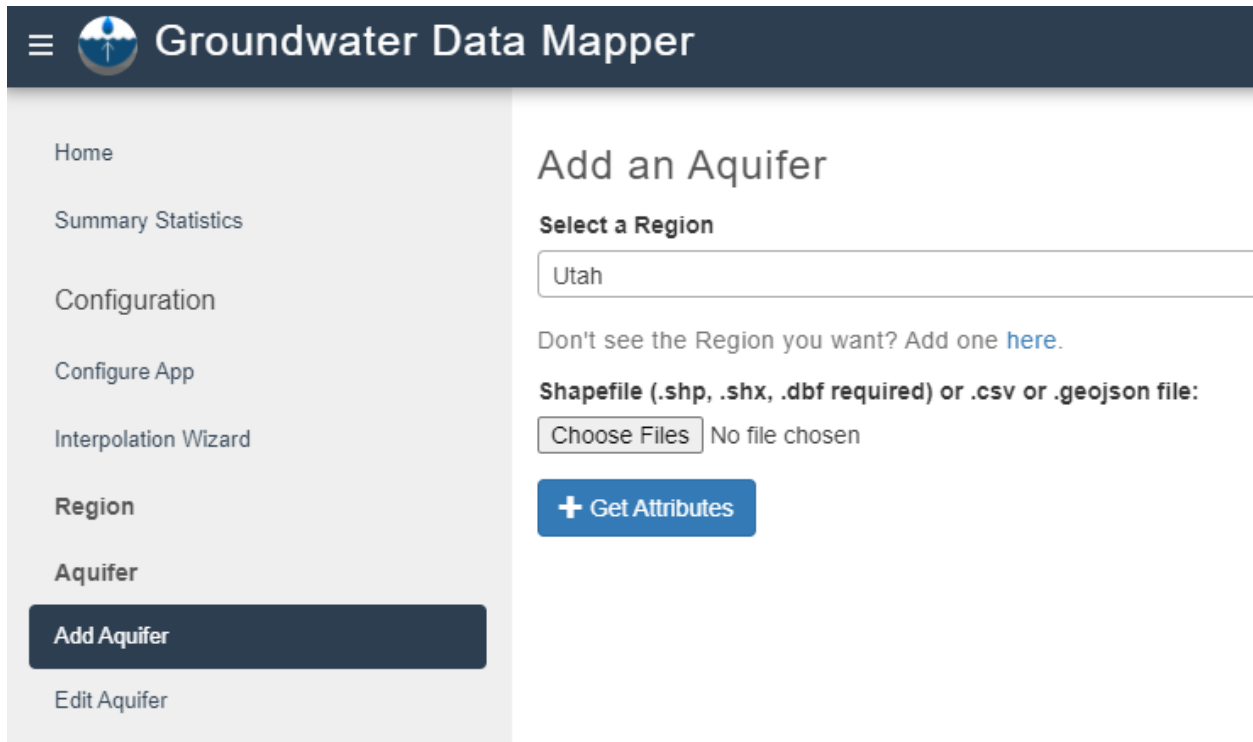


To ensure that your region was loaded properly, you can go to the **Edit Region** tab and click on the **View** icon for your region. This will display your region boundaries on a map. From this page, you can also edit the name of the region or delete a region using the appropriate icons.



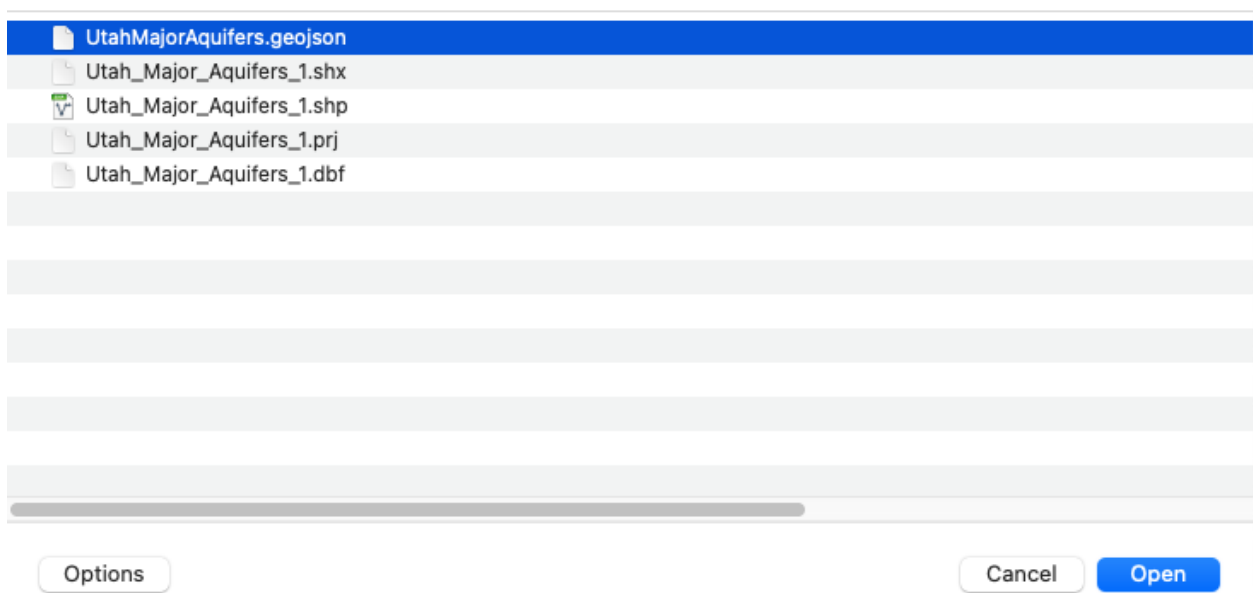
4.3 Add Aquifer

Next, we will add the aquifers. To do this, we will follow a similar process to that of adding a region. First, we select the region where the aquifers are located. The dropdown list will display all previously uploaded regions.



The screenshot shows the 'Groundwater Data Mapper' application interface. On the left is a sidebar menu with options: Home, Summary Statistics, Configuration, Configure App, Interpolation Wizard, Region, Aquifer, Add Aquifer (highlighted), and Edit Aquifer. The main content area is titled 'Add an Aquifer'. It features a 'Select a Region' dropdown menu currently showing 'Utah'. Below this is a link: 'Don't see the Region you want? Add one [here](#).' Further down, it says 'Shapefile (.shp, .shx, .dbf required) or .csv or .geojson file:' followed by a 'Choose Files' button and the text 'No file chosen'. At the bottom of the main area is a blue button labeled '+ Get Attributes'.

After selecting the region, a shapefile must be loaded. This time, we will use a geojson file type that contains aquifers in Utah.



Once the file is added, we click **Get Attributes** to define the aquifer name and ID. An aquifer name and ID should be specified for each aquifer in the file. In the case of the example Utah file, the appropriate attributes are *Aquifer_Name* and *AquiferID* (note that not all files will have intuitive names for these attributes). Finally, we add the aquifer with the

Add Aquifer button. Once the aquifer(s) are loaded, they can be viewed, edited, or deleted on the **Edit Aquifer** tab (editing an aquifer includes an ability to edit its aquifer ID; however, this ID is used to connect wells to aquifers, so be careful with this capability).

Home

Summary Statistics

Configuration

Configure App

Interpolation Wizard

Region

Aquifer

Add Aquifer

Edit Aquifer

Wells

Measurements

Variables

Add an Aquifer

success

Select a Region

Utah Test

Don't see the Region you want? Add one [here](#).

Shapefile (.shp, .shx, .dbf required) or .csv or .geojson file:

Choose Files UtahMajorA...ers.geojson

+ Get Attributes

Select Aquifer Name Column

Aquifer_Name

Select Aquifer ID Column

AquiferID

+ Add Aquifer

4.4 Add Wells

Next, we will add the wells using the **Add Wells** command in the Wells section. These wells have already been assigned to their respective aquifers, so we can add them all at once. If you would like to add wells to a single aquifer at a time, pre-assigning aquifer IDs is unnecessary.

To add a list of wells, we select the region of interest. Since we have pre-assigned aquifer IDs, we will not select a single aquifer from the list; rather, we will leave the field blank. This time, we will use a csv file (although shapefiles can also be used). We again use the **Get Attributes** button to retrieve the column headers from the file. The **Wells Wizard** will automatically open up, wherein we can select the columns for latitude, longitude, aquifer ID (not necessary if a single aquifer was selected previously), well name, well ID, and ground surface elevation (GSE). For this example file, the appropriate headers are lat_dec, long_dec, AquiferID, Well_Name, Well_ID, and GSE, respectively. Finally, we click the **Add Wells** button to add the wells to the app.

Add Wells

✓ success

Select a Region

Utah Test

Don't see the Region you want? Add one [here](#).

Select an Aquifer

Don't see the Aquifer you want? Add one [here](#).

Note: Do not use the Select Aquifer dropdown if you

Shapefile (.shp, .shx, .dbf required) or .csv file:

Choose Files ut_1940-20...aquifers.csv

+ Get Attributes

Wells Wizard

Wells Wizard
✕

Select Lat Column

lat_dec

Select Lon Column

long_dec

Select Aquifer Id Column

AquiferID

Select Well Name Column

Well_Name

Select Well Id Column

Well_ID

Select Ground Surface Elevation Column

GSE

Select Extra Attributes

Cancel

Add Wells

Again, the wells can be viewed or deleted from the **Edit Wells** tab. All wells in an aquifer can also be deleted en masse using the **Delete Wells by Aquifer** tab.

4.5 Add Measurements

Finally, we can add the measurements. Before we can add a measurements file, we need to ensure that our variable is defined. The app is variable agnostic, meaning any variable can be defined and used to label measurements that are uploaded. Variables can be defined using the **Add Variable** tab under **Variables**. A variable name, units, and description needs to be specified and the variable is added with the **Add Variable** button.

Home
Summary Statistics
Configuration
Configure App
Interpolation Wizard
Region
Aquifer
Wells
Measurements
Variables
Add Variable
Edit Variables

Add Variable

Variable Name

Variable Units

Variable Description

+ Add Variable

Measurements are added with the **Add Measurements** tab under **Measurements**. The region and variable that we defined earlier can be selected from the respective dropdown menu. However, just as with the wells, measurements can be added to all aquifers (with AquiferID defined for each measurement) or to an individual well (using the Select an Aquifer dropdown menu).

Our example file includes measurements of water table elevation from wells across Utah, so we will leave the *Select an Aquifer* option blank. We assign the attributes to the appropriate column using the **Get Attributes** button and **Measurements Wizard** window. The headers for our example file are AquiferID, Well_ID, Date, and WTE, as seen below. The date format must be in the Python Date Format, which can be referenced at: <https://strftime.org/>. A list of common date formats can be found below (to determine which date format your file uses, it is strongly recommended to open your file in a text editor, as MS Excel often reformats data). The **Add Measurements** button will add the measurements to the wells in the region.

Measurements Wizard

Select Aquifer Id Column

AquiferID

Select Well Id Column

Well_ID

Select Time Column

Date

Select Measurement Column

WTE

Date Format

%m/%d/%Y

Date Format in the Python Date Format. See the following for reference:
<https://strftime.org/>

The Add Measurements Button will be visible once you enter a valid python date format

Cancel Add Measurements

Table 1: Common Python Date/Time Formats

Date/Time Format	Example	Python Format	Notes
YYYY-MM-DD	2020-01-09	%Y-%m-%d	—
M/D/YY	1/9/20	%m/%d/%Y	Please note that 2-digit years will cause errors if you have dates in your dataset before 1970 (please see Data Prep Section). 4-digit years are best.
D/M/YY	9/1/20	%d/%m/%Y	See above
MM/DD/YY	01/09/20	%m/%d/%Y	—
DD/MM/YY	09/01/20	%d/%m/%Y	—
DD/MM/YY or HH:MM:SS	09/01/20 or 13:35:10	%d/%m/%Y or %H:%M:%S	For groundwater data, the time is generally not recorded and is not normally required for the GWDM app, considering the time scales typically encountered. Therefore, we recommend only using the date portion of the date field.

For a complete description, visit: <https://strftime.org/>.

Warning: If you receive an error while trying to upload measurements, the first thing that you should check is that you specified the correct date format.

Measurements can be deleted by aquifer and variable type through the **Delete Measurements** tab. When adding measurements, care should be taken to only upload measurements associated with wells that have previously been

uploaded to the GWDM. Otherwise, the measurements will be skipped when uploading and after the uploading process is complete, a message similar to this will appear:

☑ Success. Number of observations dropped: 44024. Number of wells dropped: 0

4.6 Rasters

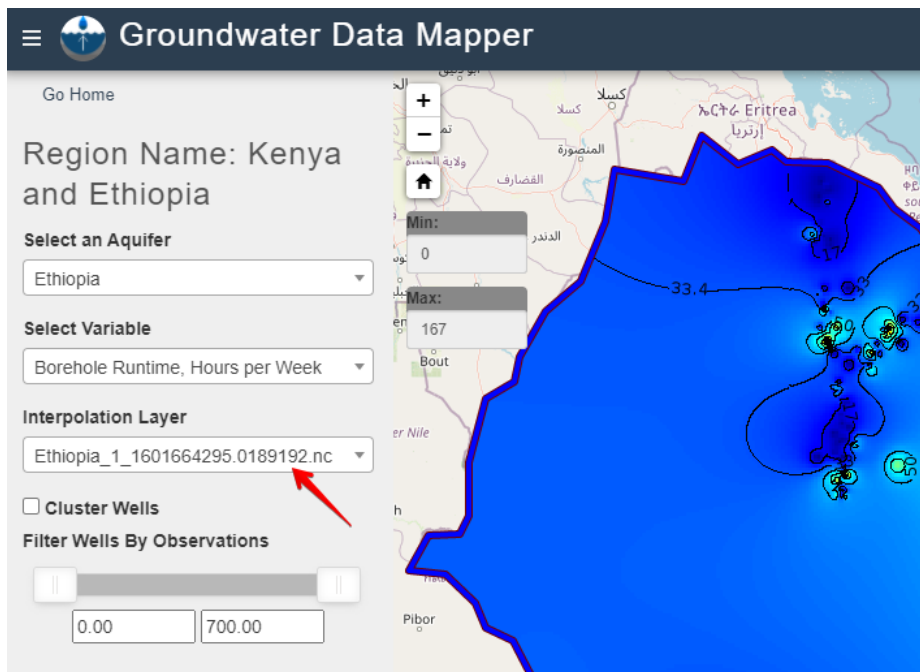
One of the main functions of the GWDM app is to use temporal and spatial interpolation to create time-varying rasters of groundwater data (water level, depth to groundwater, etc). This process is described in the Groundwater Level Mapping section. Interpolated rasters can be animated in the main map window using the Leaflet animation plug-in used by the GWDM.

In some cases, users may elect to use external interpolation algorithms to generate rasters for their aquifers. The Rasters section in the admin control panel can be used to upload and manage these externally generated rasters. Once uploaded, they can be animated and visualized in the GWDM map window.

The **Upload Rasters** command is used to upload raster datasets in netCDF format. The user must first select the region, aquifer, and variable and then choose the netCDF file.

The screenshot shows the 'Groundwater Data Mapper' application interface. On the left is a sidebar menu with options: Home, Summary Statistics, Configuration, Configure App, Interpolation Wizard, Region, Aquifer, Wells, Measurements, Variables, Rasters, Upload Rasters (highlighted), and Delete Rasters. The main content area is titled 'Upload Rasters' and contains three selection fields: 'Select a Region' with 'Kenya and Ethiopia' selected, 'Select an Aquifer' with 'Ethiopia' selected, and 'Select Variable' with 'Borehole Runtime, Hours per Week' selected. Below these is a 'NetCDF file:' section with a 'Choose Files' button and the text 'No file chosen'. At the bottom of this section is a green button with a plus icon and the text '+ Add Rasters'.

Once a raster has been uploaded, it can be selected for visualization by choosing the View Region option, selecting the region, and then selecting the aquifer and variable. The uploaded raster can then be selected using the Interpolation Layer option.



The **Delete Rasters** command is used to delete previously uploaded rasters. The user selects the region, aquifer, variable, and raster and then selects the Delete Rasters button. If the “All Aquifers” option is selected in the “Select an Aquifer” list, all rasters associated with the region are deleted. Likewise, the “Select Variable” and “Interpolation Layer” options both have an “All ____” option to delete all rasters for any variable or all rasters for a selected variable.

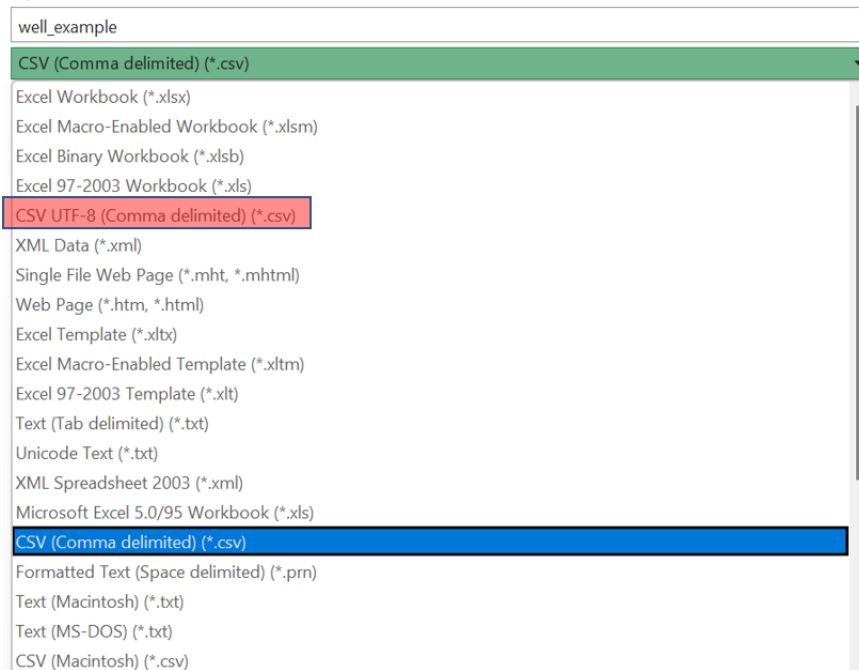
The screenshot shows the 'Groundwater Data Mapper' web application. On the left is a sidebar menu with the following items: Home, Summary Statistics, Configuration, Configure App, Interpolation Wizard, Region, Aquifer, Wells, Measurements, Variables, Rasters, Upload Rasters, and a 'Delete Rasters' button at the bottom. The main content area is titled 'Delete Rasters' and contains four selection fields: 'Select a Region' (with 'Kenya and Ethiopia' selected), 'Select an Aquifer' (with 'Ethiopia' selected), 'Select Variable' (with 'Borehole Runtime, Hours per Week' selected), and 'Interpolation Layer' (with 'Select a Raster(s)' selected). Below these fields is a red button labeled 'Delete Rasters'.

4.7 Trouble Shooting

If you are having trouble getting your data to upload correctly, this section includes several common problems and how to fix them.

CSV Encoding

If your CSV files are encoded (intentionally or accidentally), the app's wizard will not recognize your files' attributes. When you open the wizard, only one attribute will display. To fix this error, save a copy of your file with the option highlighted in blue as opposed to the option highlighted in red in the figure below. If the error persists, copy your data into a new document and save without encoding.



Selecting an Aquifer

! The truth value of a Series is ambiguous. Use `a.empty`, `a.bool()`, `a.item()`, `a.any()` or `a.all()`.

If you have received the error pictured above, you selected an aquifer when you did not need to. If you have organized your data using aquifer IDs then the aquifer option blank must be left blank when you are adding wells and measurements. You will need to refresh the page to make the aquifer option blank again and then leave it blank while you are adding your wells. After you refresh be sure to reselect your region.

Dropped Data

When adding measurements, care should be taken to only upload measurements associated with wells that have previously been uploaded to the GWDM. Otherwise, the measurements will be skipped when uploading and after the uploading process is complete, a message similar to this will appear:

✓ Success. Number of observations dropped: 44024. Number of wells dropped: 0

There are two ways to fix this issue depending on what is causing it. In some cases, the measurements are dropped because the well ID refers to a non-existent well. To fix this you can run our file formatter tool located in the Data Preparation Scripts section. In other cases, the well is assigned to a non-existent aquifer which can be fixed by running our aquifer assignment tool which can also be found on our Data Preparation scripts page.

GROUNDWATER LEVEL MAPPING

5.1 Introduction

In addition to visualizing well and measurement data, the GWDM app and associated tools can generate and display rasters of time varying water levels and time series of aquifer storage change. These groundwater maps are in the form of netCDF rasters at selected intervals (yearly for example) over a selected time range. They are generated using a multi-step process that involves imputing gaps in water level time series at wells using Earth observations and machine learning, spatial interpolation of water levels using kriging, and volumetric analysis of the raster results. While the app supports any kind of groundwater data measurements, the mapping tool is designed for water level data. When using the mapping tool, the user selects a start date and an end date and a time interval for the interpolation process. For example, one could choose start = 1980, end = 2010, step = 5 years and the algorithm would generate a raster for 1980, 1985, 1990, ... 2005, 2010. The rasters are compiled into a netCDF file that can then be uploaded and animated in the map interface. Also, the mapping algorithm calculates the volume between each pair of rasters and multiplies the volume by a user-specified storage coefficient to compute a chart of groundwater storage change vs time. This chart can be especially useful in determining if an aquifer is being used in a sustainable fashion as it can demonstrate groundwater depletion.

In previous versions of the GWDM app, this was accomplished using the Interpolation Wizard that was found in the admin control panel. In order to give the user the ability to monitor each step of the process, we have moved the mapping tool to a standalone Google Colab notebook ([link below](#)).

To launch the mapping tool, please click on this button. The notebook will open in a new tab.

5.2 Overview of Algorithm

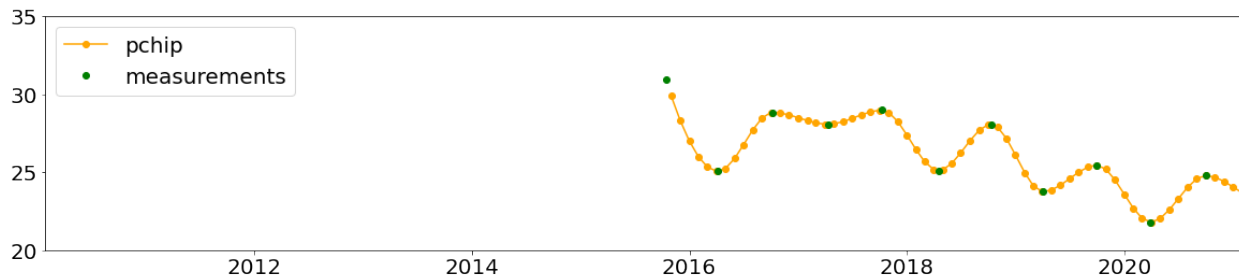
The final aquifer map will include a Water Table Elevation estimate for every point in your aquifer at any time step. Since it is impractical and near impossible to collect all that data, interpolation methods can be applied to fill in for data we do not have. Our interpolation algorithm can be split into two major steps. First, the temporal interpolation of individual well time series. Second, the spatial interpolation between those wells. Each of these is explained in greater detail below.

5.3 Temporal Interpolation

While some wells have a relatively complete dataset over the period of interest, it is very common to have large gaps in the data record. The goal of temporal interpolation is to create a complete time series for each well that can be easily compared to other wells. The final output of this step will be a timeseries with measurements every month during the entire period of interest. Some measurements are close enough together that it is easy to predict the value at the beginning of the month. This can be done using simple PCHIP interpolation. Some measurements are more difficult to predict. We estimate these values using machine learning.

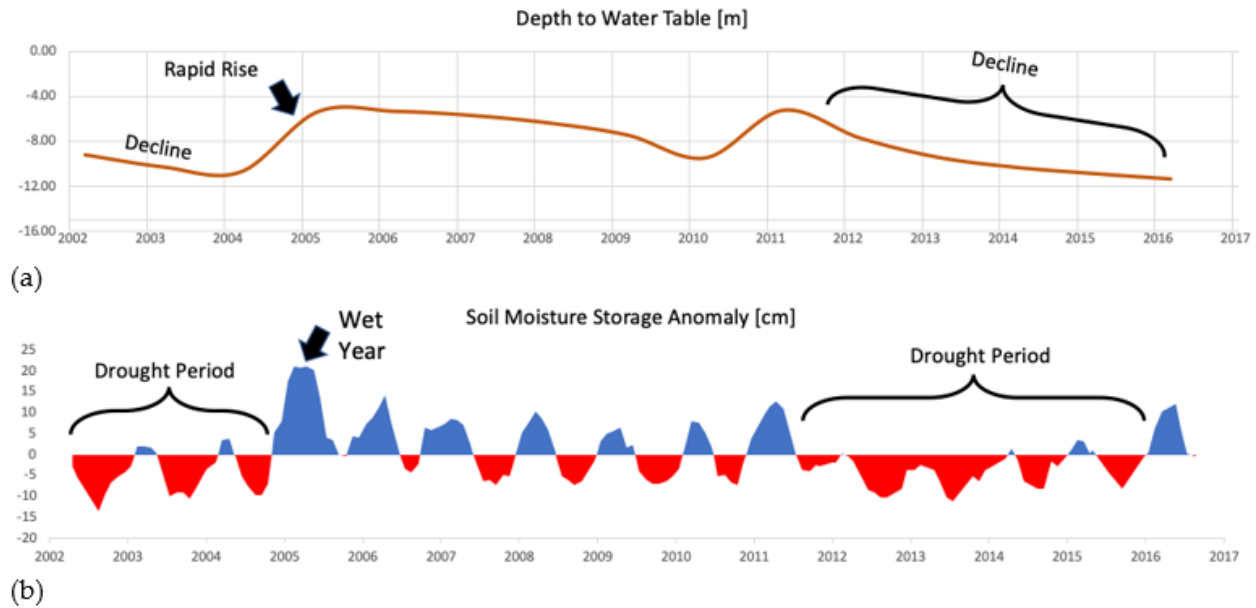
5.3.1 Simple PCHIP Interpolation

For reference, PCHIP stands for Piecewise Cubic Hermite Interpolating Polynomial. During this step we decide how close measurements must be to justify the use of PCHIP interpolation. We call this value the pad value. The image below shows some example results of PCHIP interpolation. In this example, the pad value was 365 days. Note that PCHIP only interpolates between measurements.

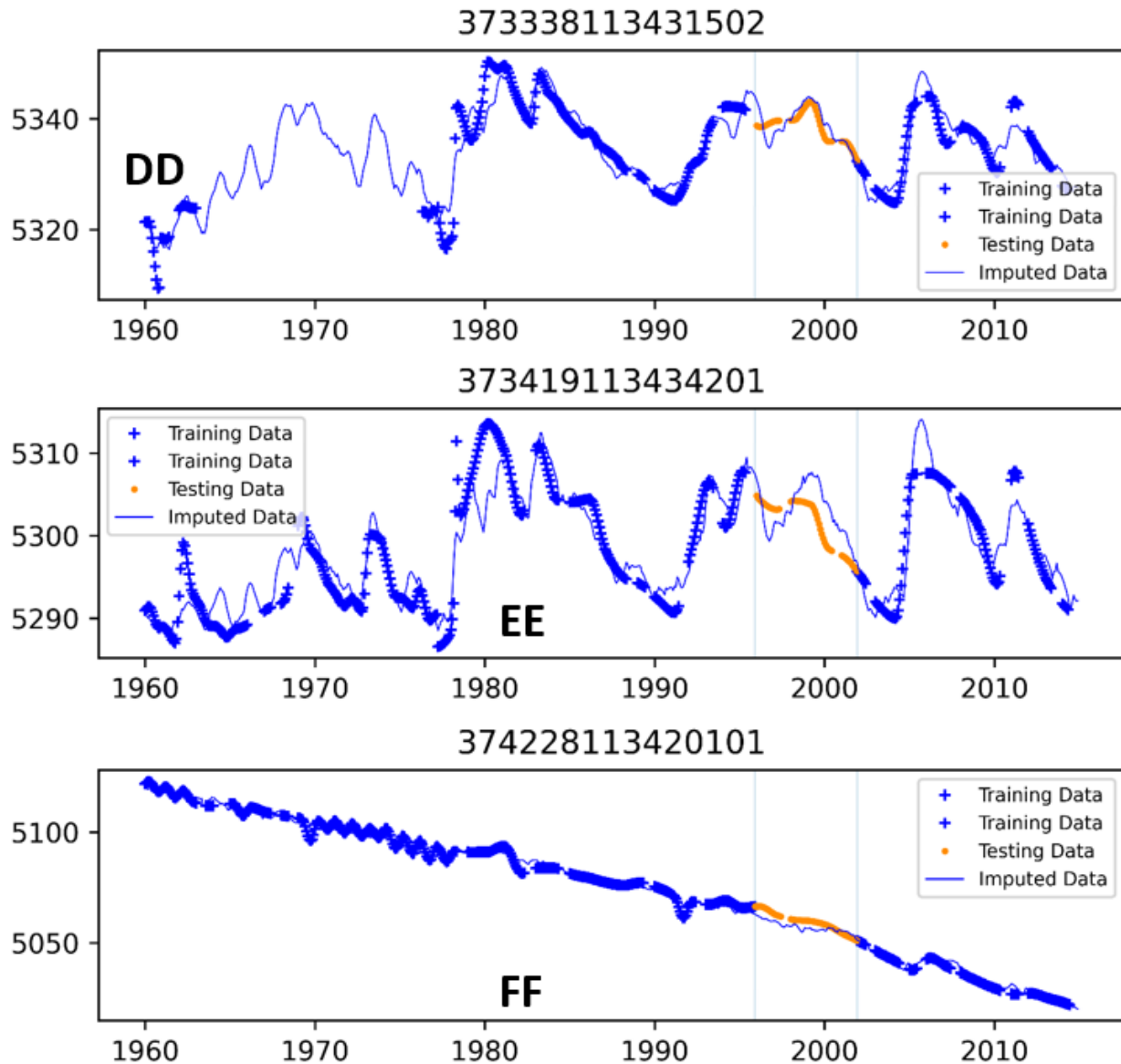


5.3.2 Machine Learning

For longer periods of interpolation that are harder to predict, we use machine learning to fill in the missing data. The machine learning finds correlations between Earth observations and water level measurements and then uses data imputation to fill in the gaps. For example, groundwater levels generally rise during wet periods due to increased recharge and decreased pumping. Alternately, water levels drop during dry periods due to reduced recharge and increased pumping. The following charts illustrate this relationship using soil moisture anomaly from the Global Land Data Assimilation System (GLDAS) model.



The machine learning algorithms use these correlations to predict missing water levels in gaps in the water level time series. The imputation is performed using a novel multi-linear regression (MLR) algorithm called Extreme Machine Learning (ELM) to impute missing data for infrequently sampled wells. The ELM is trained with water levels and the time-varying Palmer Drought Severity Index (PDSI) for the region in question. Sample imputation results are shown below.



5.3.3 Spatial Interpolation

Once the time series are complete, the time series curves for each well are sampled at the selected dates and spatial interpolation is performed to build the rasters. The algorithm applies GSLIB(Geostatistical Software Library) Kriging code to generate rasters with the user specified time steps. For the Kriging algorithm, we autofit a variogram to the data in the aquifer based on the size of the aquifer.

To learn more about these methods, see the papers published in [Remote Sensing](#) and [Environmental Modelling & Software journals](#).

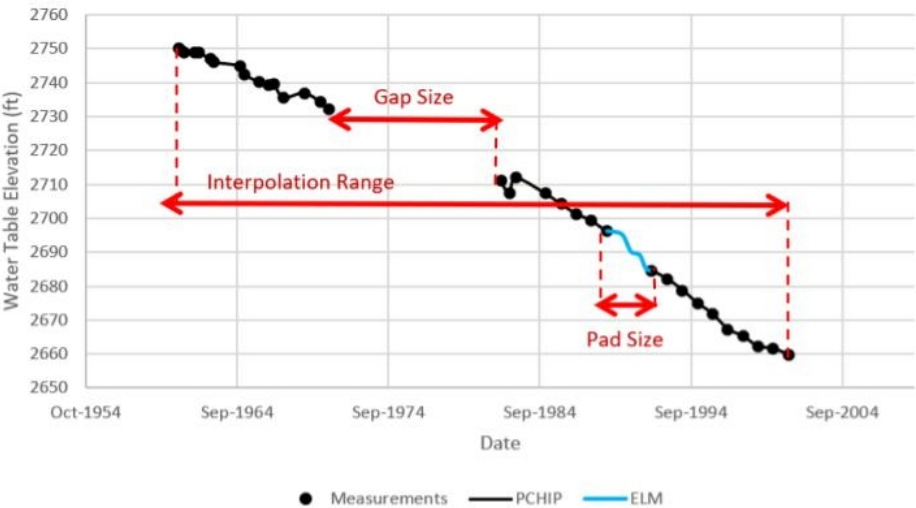
5.3.4 Water Level Mapping Google Colab Notebook

To run the water level mapping algorithm, you will first need to prepare your data. The algorithm requires three inputs as described in the following table. These are the same files (same content and format) that you would use to upload your original data to the GWDM mapper to visualize your wells and water level measurements. The only difference is that the aquifer file should only contain a single aquifer, while you could upload multiple aquifers at once to the GWDM app.

As you follow the instructions in the notebook and move from section to section, you will be prompted to select a series of options. The following table provides a guide on these options:

Parameter	Description
Select Draw-down Volume Units	These units are used to compute the groundwater storage change vs. time curve. The options are Acre-Ft, Cubic Metric (m ³), and Cubic-Ft. The units you select should match the units associated with the selected variable. If your variable is in meters, you should select the Cubic Meter (m ³) option. If your variable is in feet, you can select either of the other two options.
Output file name	A default name will be generated by the application. The default name will be appended to your input. The format will be yourinput_regionname_interp_somenumber.
Storage Coefficient	A typical value would be 0.15 to 0.20. For unconfined aquifers, this should be the specific yield. For more information on storage coefficients, visit this link. This parameter is used to compute the groundwater storage change vs time curve that is generated as part of the interpolation process.
Raster Extent	The extent of the interpolated raster is based on either the extent of the wells or the aquifer. If the wells option is selected, the resulting raster will be a rectangular box that just surrounds the wells and it is clipped by the aquifer boundary. If the aquifer option is selected, the spatial interpolation process extrapolates out to the limit of the aquifer and is clipped by the aquifer. In order to get a storage change vs time curve for the entire aquifer, you should generally select the aquifer option.
Time Interval	This indicates the frequency at which the spatial interpolation process generates a raster using kriging over the interpolation interval. For example, you select 1980 and 2020 as the starting and ending dates and a time interval of 5 years, you would get interpolated rasters at 1980, 1985, 1990, ... 2020.
Interpolation start and end dates	These two parameters set the date range for interpolation (i.e., the beginning and ending of the raster data set). For better results, select a range that is at least 10 years in length.
Gap Size	The maximum length of time over which the application will generate spatial interpolation layers using ELM (Extreme Machine Learning) for an individual well. If the time series for a well contains a gap longer than this size, the well is not included in the spatial and temporal interpolation process. We recommend a minimum of 10 years (3650 days) for best results.
Pad Value	The pad value determines when to use PCHIP interpolation as opposed to ELM. If the time between measurements is less than the pad value, it will interpolate using the PCHIP method. Otherwise, it will interpolate using ELM. We recommend a value between 90 to 180 days.
Spacing	Time between two points in the well data interpolation process, a month apart (1MS = 1 Month spacing, at the Start of the month). This is typically 1 month. The algorithm then creates a time series for each well with one- month intervals. The entries are filled with actual measurements and then PCHIP interpolation is used to fill gaps smaller than the pad size. Any remaining gaps are filled using the ELM machine learning process. Once the gaps are filled, values are extracted at each time interval and spatial interpolation is performed.
Min water level samples per well	The minimum number of measurements a well needs to be included in the temporal and spatial interpolation process. Wells with less than this number are ignored.

The graphic below illustrates the parameters of pad value, gap size, and interpolation start and end dates also referred to as the interpolation range. As you can see in the figure, the interpolation is only completed within the range given. If the time between measurements is smaller than the pad value PCHIP interpolation is used. If it is larger, then ELM is used. However, if the time between measurements is larger than the gap size, then that particular well is dropped during interpolation.



5.4 Sample Data and Parameters

To get started, here are two data sets of files; however, you are welcome to use your own files if you would prefer.

sunflower_test_files.zip

korama_test_files.zip

The Mapping Google Colab Notebook has parameters that can be set and changed by the user to obtain desired results. Here is a summary of each parameter with a suggestion. We will use the sample data provided (Sunflower test files)

Parameter	Sunflower Aquifer
Interpolation Start Date	2001
Interpolation End Date	2021
GAP Size	3650 days
Minimum Water Level Samples per Well	5 samples
Temporal Interpolation Method	P-chip & Extreme Learning Machine

5.5 Uploading and Viewing the Mapping Results

When the algorithm completes the calculations in the Colab notebook, it will generate a netCDF file containing the time varying rasters and the groundwater storage change time series. You can download that file from your Google Drive and then upload it to the GWDM app using the tools in the Rasters section of the admin control panel. This process is described in the Rasters section near the bottom of the Importing Data page.

The screenshot shows the 'Groundwater Data Mapper' web application. On the left is a sidebar menu with options: Home, Summary Statistics, Configuration, Configure App, Interpolation Wizard, Region, Aquifer, Wells, Measurements, Variables, Rasters, Upload Rasters (highlighted), and Delete Rasters. The main content area is titled 'Upload Rasters' and contains the following fields:

- Select a Region:** A dropdown menu with 'Kenya and Ethiopia' selected.
- Select an Aquifer:** A dropdown menu with 'Ethiopia' selected.
- Select Variable:** A dropdown menu with 'Borehole Runtime, Hours per Week' selected.
- NetCDF file:** A section with a 'Choose Files' button and the text 'No file chosen'.
- A green button labeled '+ Add Rasters'.

To view your uploaded rasters, return to the region's map by navigating to the home page. After selecting the aquifer within which you performed the interpolation, you can view the interpolation results by using the Interpolation Layer dropdown menu. Here are some sample results for an aquifer in Utah, USA and Niger.

Fig. 1: Cedar Valley, Utah Interpolation Results

Fig. 2: Goulbi Maradi, Niger Interpolation Results

To view the storage change vs time curve, click on the **View Drawdown Volume** button. The storage change curve will then appear in a new window.

INSTALLING THE GWDM APPLICATION

For this instruction, Mac OS was used.

6.1 Step 1: Install Tethys

Follow the Tethys installation steps ([link here](#)) and install the Tethys Platform on your computer. Before doing so, be sure to view the warning listed below.

Warning: As of April 1, 2021, the initial step creates an error when executing `conda create -n tethys -c tethysplatform -c conda-forge tethys-platform`. Understand to avoid negative consequences.

```
conda create -n tethys -c tethysplatform -c conda-forge tethys-  
→platform
```

Instead, install a development build of the Tethys Platform by executing

```
conda create -n tethys -c tethysplatform/label/dev -c  
→tethysplatform -c conda-forge tethys-platform
```

After the installation is complete, go to <http://127.0.0.1:8000/> and make sure the following page is displayed.



Log In

Welcome to Tethys Portal,
the hub for your apps.

Tethys Portal is designed to be customizable, so that you can host apps for organization. You can change everything on this page from the Home Page

6.2 Step 2: Clone/Copy the GWDM Application

Warning: If the Tethys server is running from the previous step, make sure to quit the server with CONTROL-C before proceeding to the next step.

1. Create a directory (folder) in the home directly and name it (e.g. “tethys_dev”). In this directory, the GWDM app will be cloned from the following link: <https://github.com/BYUHydroinformatics/gwdm>
2. On the right side of the repository, click on Code green box and then click on the button to copy the URL
3. Bring up a terminal window and go to the directory just created by executing the following command.

```
cd tethys_dev
```

tethys_dev should be modified if the directory is named differently.

4. The GDWM app will be cloned here. To clone the app, type the following:

```
git clone URL
```

Where URL is the URL that you copied to the clipboard. In other words, type `git clone` then paste the URL from the clipboard. When you are done, it should look like this:

```
git clone https://github.com/BYU-Hydroinformatics/gwdm.git
```

5. To complete the installation, we need to install the app we just cloned. First, we need to be in the Tethys virtual environment. In the Command Line, type:

```
conda activate tethys
```

Next, make sure you are at the top level of the new directory you just created (e.g. tethys_dev). There should be a new directory/folder called `gwdm` and the folder should contain `setup.py`. Go to the `gwdm` directly by executing:


```
cd tethys_dev/gwdm
```

Finally, this command is used to install the app on your portal:

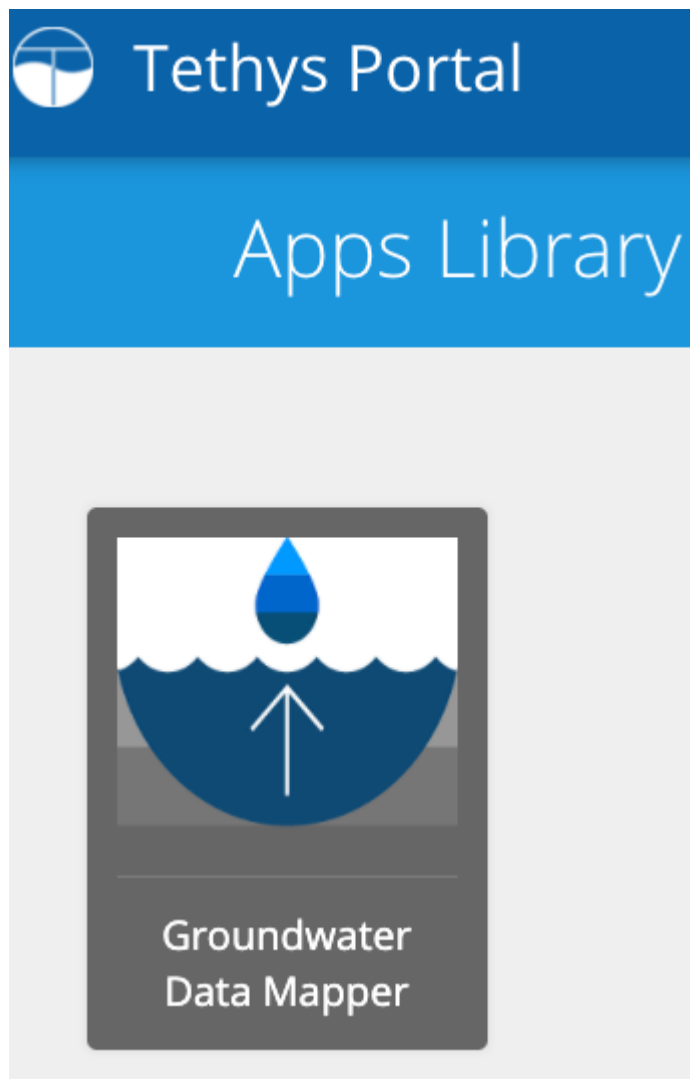
```
tethys install
```

To make sure that the app is installed on your local Tethys Platform, launch the Tethys portal by typing on the Command Line:

```
tethys manage start
```

Then, go to <http://127.0.0.1:8000/apps/> and the app should be displayed.

Note: The initial admin login ID and password is: Username: admin Password: pass



6.3 Step 3: Set Up Docker Containers

1. Create a new directory/folder in your home directory and name it Thredds. Make the Thredds directory public by typing in the Command Line:

```
sudo chmod -R 777 Thredds
```

2. Next, install Docker from <https://docs.docker.com/engine/install/> . Docker will be installed as an app on Mac. In the Command Line, type:

```
tethys docker init
```

This will initiate downloading necessary elements and may take anywhere from a few minutes to hours depending on the internet connection. After the Docker initializes, the Command Line will ask for several settings. For most of the cases, simply accept the defaults by hitting Enter.

Note:

1. For the password, put pass to keep it simple. If a different password is selected, that needs to be remembered as this password will be required in later steps.
 2. For the Thredds container, it will ask “Bind the THREDDDS data directory to the host?” To which you will respond “Y” for yes. The next option will ask you to specify the location. Respond with the file path to the Thredds directory that you created earlier.
-

Installing the GeoServer Docker container...

The GeoServer docker can be configured to run in a clustered mode (multiple instances of GeoServer running in the docker container) for better performance .

Number of GeoServer Instances Enabled (max 4) [1]:

Number of GeoServer Instances with REST API Enabled (max 1) [1]:

GeoServer can be configured with limits to certain types of requests to prevent it from becoming overwhelmed. This can be done automatically based on a number of processors or each limit can be set explicitly.

Would you like to specify number of Processors (c) OR set request limits explicitly (e) [C/e]:

Number of Processors (max 4) [1]:

Maximum request timeout in seconds [60]:

Maximum memory to allocate to each GeoServer instance in MB (max 4096) [1024]

:

Minimum memory to allocate to each GeoServer instance in MB (max 1024) [1024]

:

Bind the GeoServer data directory to the host? [Y/n]:

Specify location to bind data directory [/Users/rennishimura/.tethys/geoserver/data]:

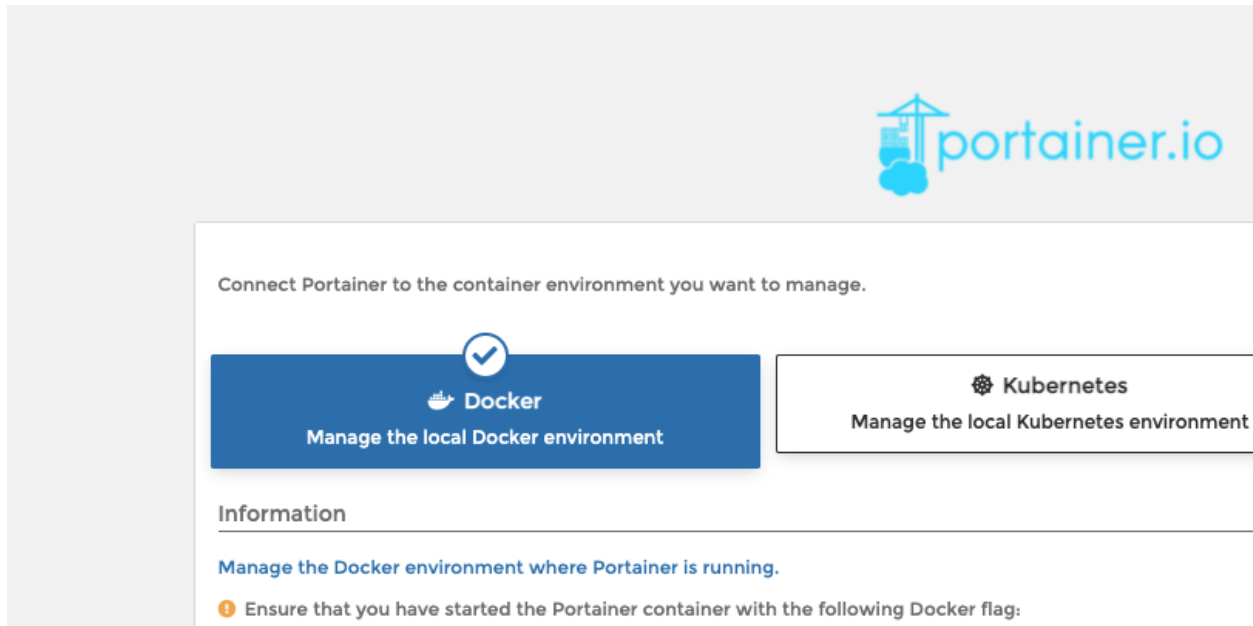
Respond by "Enter"



6.4 OPTIONAL: Set Up Portainer.io

Portainer gives a detailed status and health check of the Docker containers. In the Command Line, type:

Go to localhost:9000 to set up the userID and the password. On the next page, select “Docker” and complete the setting.



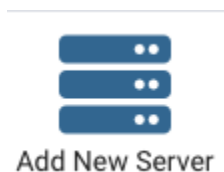
After the installation, Portainer should show up on Docker. Follow the steps below and make sure all the containers are healthy and running (you may have to start the new Tethys containers with the “Start” button).

```
Installing the THREDDS Docker container...
Provide configuration options for the THREDDS container or or pres
ept the defaults shown in square brackets:
[TDM Password [CHANGEME!]:  Input "pass"
Confirm Password: 
```

6.5 Step 4: Download PGAdmin 4 for Database Management

Download PGAdmin (<https://www.pgadmin.org/>). Download the macOS version (or whatever operating system you are using).

Open the application and add a new server



Name it as you desire (e.g. “postgis_thethys_docker”). Click the “Connection” tab and enter the following settings:

General **Connection** SSL SSH Tunnel

Host name/address ①
localhost

Port ②
5435

Maintenance database
postgres

Username
postgres

Password ③
....

Save password? ④
☒

- ▼ Servers (1)
 - ▼ postgis_thethys_docker
 - ▼ Databases (1)
 - ▼ postgres
 - > Casts
 - > Catalogs
 - > Event Triggers
 - > Extensions
 - > Foreign Data Wrappers
 - > Languages
 - > Publications
 - > Schemas
 - > Subscriptions
 - > Login/Group Roles
 - > Tablespaces

6.6 Step 5: Tethys Settings

Now in the Command Line, run:

```
tethys syncstores gwdm
```

and

```
tethys manage start
```

Go to the Tethys homepage (<http://127.0.0.1:8000/apps/>) and click the app icon. You should land on the page titled “Change Tethys App.”

1. Click the **plus mark** under **PERSISTENT STORE DATABASE SETTINGS**.

PERSISTENT STORE DATABASE SETTINGS				
NAME	DESCRIPTION	SPATIAL	INITIALIZED	PERSISTENT STORE SERVICE
gwdb	Ground Water Database	✓	✗	<div> <div>Click</div> <div>+</div> </div>

On the next page, set up the settings to:

Note:

- Name: Arbitrary Name (e.g. Postgresql)
- Engine: PostgreSQL
- Port: 5435
- Username: postgres

Change Persistent Store Service





Name:	<input type="text" value="Postgresql"/>
Engine:	<input type="text" value="PostgreSQL"/> ▼
Host:	<input type="text" value="localhost"/>
Port:	<input type="text" value="5435"/>
Username:	<input type="text" value="postgres"/>
Password:	<input type="password"/>

Now, save the settings.

2. Add a Spatial Dataset Service (for GeoServer) and select it in the app settings

Note:

- Name: Arbitrary Name (e.g. geoserver)
- Engine: GeoServer
- Endpoint: <http://127.0.0.1:8081/geoserver/>
- Username: admin
- password: geoserver

SPATIAL DATASET SERVICE SETTINGS			
NAME	DESCRIPTION	SPATIAL DATASET SERVICE	ENGINE
primary_geoserver	Geoserver for app to use	<input type="text" value="-----"/> ▼ 	
primary_thredds	Thredds for app to use	<input type="text" value="-----"/> ▼ 	

Click

Add Spatial Dataset Service

Name:	<input type="text" value="geoserver"/>
Engine:	<input type="text" value="GeoServer"/> ▼
Endpoint:	<input type="text" value="http://127.0.0.1:8081/geoserver/"/>
Public Endpoint:	<input type="text"/>
Apikey:	<input type="text"/>
Username:	<input type="text" value="admin"/>
Password:	<input type="password" value="....."/>

3. Add another Spatial Dataset Service (for thredds) and select it in the app settings

Note:

- Name: Arbitrary Name (e.g. Thredds)
 - Engine: THREDDS
 - Endpoint: <http://127.0.0.1:8383/thredds/>
 - Username: admin
 - password: pass
-

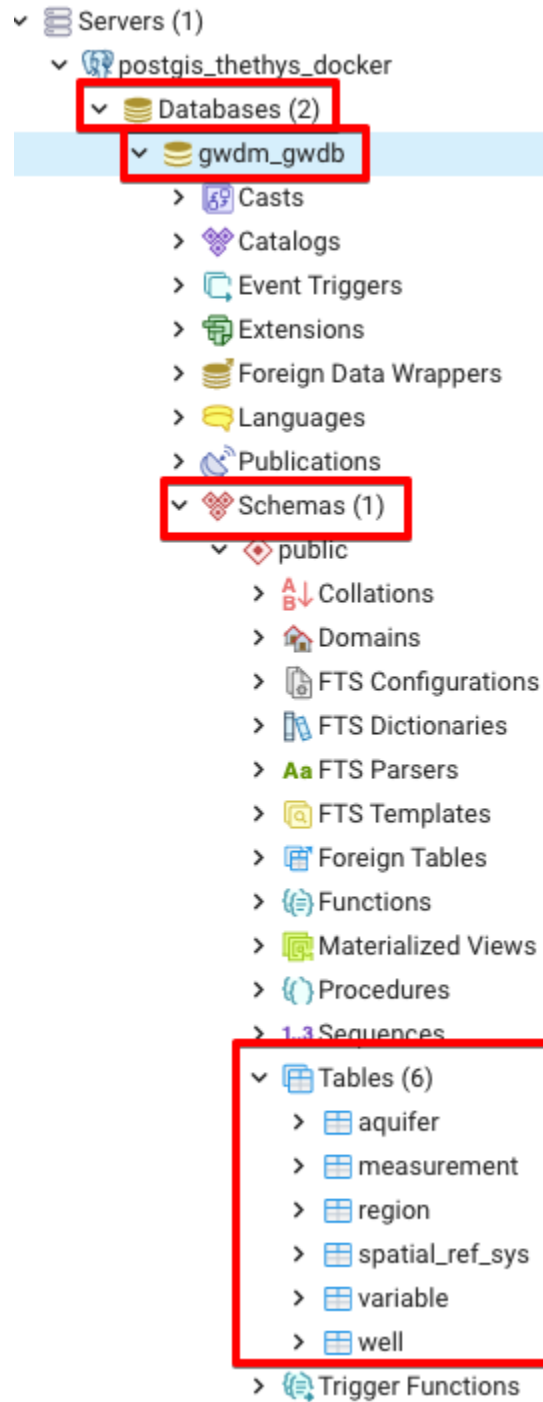
Change Spatial Dataset Service

Name:	<input type="text" value="Thredds"/>
Engine:	<input type="text" value="THREDDS"/> ▼
Endpoint:	<input type="text" value="http://127.0.0.1:8383/thredds/"/>
Public Endpoint:	<input type="text"/>
Apikey:	<input type="text"/>
Username:	<input type="text" value="admin"/>
Password:	<input type="password" value="...."/>

4. Make a directory in your Thredds directory in **thredds/public/testdata** and call it “**groundwater**”. Add the file path to this new groundwater directory to the thredds file path in the app settings

```
tethys syncstores gwdm
```

Open up PGAdmin4 again to check that the database is initialized. Under Databases, “**gwdm_gwdb**” should now show up. Within gwdm_gwdb, if you select Schemas>public>Tables the different parameters should be visible (aquifer, measurement, well, etc.)



6.7 Step 6: Edit Thredds Files

1. Go into the thredds directory and open the “Catalog.xml” file with an editor (Pycharm, Notepad++, etc.)

- Uncomment the wms, wcs, and ncss service tags within the service section
- In the “datasetScan” tag, change the name attribute from Test all files in a directory to All Datasets
- In the “Filter” section towards the bottom of the file:

Remove one of the “include” tags and change the other one to say `<include wildcard="*" />`

- Delete the “catalogref” tag at the very bottom

If you need help, the screenshot below shows what it should look like.

```

1 <?xml version="1.0" encoding="UTF-8"?>
2 <catalog name="THREDDS Server Default Catalog: You must change this to fit your server!"
3   xmlns="http://www.unidata.ucar.edu/namespaces/thredds/invCatalog/v1.0"
4   xmlns:xlink="http://www.w3.org/1999/xlink"
5   xmlns: xsi="http://www.w3.org/2001/XMLSchema-instance"
6   xsi:schemaLocation="http://www.unidata.ucar.edu/namespaces/thredds/invCatalog/v1.0
7     http://www.unidata.ucar.edu/schemas/thredds/invCatalog-1.0.6.xsd">
8
9   <service name="all" base="" serviceType="compound">
10     <service name="odap" serviceType="OpenDAP" base="/thredds/dodsC/" />
11     <service name="dap4" serviceType="DAP4" base="/thredds/dap4/" />
12     <service name="http" serviceType="HTTPServer" base="/thredds/fileServer/" />
13     <service name="wcs" serviceType="WCS" base="/thredds/wcs/" />
14     <service name="wms" serviceType="WMS" base="/thredds/wms/" />
15     <service name="ncss" serviceType="NetcdfSubset" base="/thredds/ncss/" />
16   </service>
17
18   <service name="dap" base="" serviceType="compound">
19     <service name="odap" serviceType="OpenDAP" base="/thredds/dodsC/" />
20     <service name="dap4" serviceType="DAP4" base="/thredds/dap4/" />
21   </service>
22
23   <datasetRoot path="test" location="content/testdata/" />
24
25   <dataset name="Test Single Dataset" ID="testDataset"
26     serviceName="dap" urlPath="test/testData.nc" dataType="Grid"/>
27
28   <dataset name="Test Single Dataset 2" ID="testDataset2"
29     serviceName="odap" urlPath="test/testData2.grb2" dataType="Grid"/>
30
31   <datasetScan name="All Datasets" ID="testDatasetScan"
32     path="testall" location="content/testdata/" />
33   <metadata inherited="true">
34     <serviceName>all</serviceName>
35     <dataType>Grid</dataType>
36   </metadata>
37
38   <filter>
39     <include wildcard="*" />
40   </filter>
41
42   <catalogref xlink:href="test/threddsConfig.xml" name="threddsConfig" />
43
44 </catalog>

```

2. Open the “threddsConfig.xml” file

- Uncomment the CORS tag and enable it to “true”

```
<paletteLocationDir>/WEB-INF/palettes</paletteLocationDir>
```

```

204 <WMS>
205   <allow>true</allow>
206   <allowRemote>true</allowRemote>
207   <maxImageWidth>2048</maxImageWidth>
208   <maxImageHeight>2048</maxImageHeight>
209   <paletteLocationDir>/WEB-INF/palettes</paletteLocationDir>
210 </WMS>
211

```

6.8 Step 7: Set Up GeoServer

1. Open GeoServer browser and log in (localhost:8081/geoserver)

Add a new workspace:

Go to “Workspaces” tab > “Add New Workspace” link. Name it “gwdm” (Namespace can be anything)

Add a new store:

Stores tab > “Add New Store” link > “Postgis” link. Select gwdm workspace from dropdown and set:

Note:

- Name: postgis
- Host: 172.17.0.1
- Port: 5435
- Database: gwdm_gwdb
- Schema: public
- User: postgres
- Password: pass
- Save it

>Publish the Layers

Go to “Layers” tab > “Add a new resource” link > “gwdm:postgis” from dropdown

- Click “Publish” for the region layer
- Under the “Bounding Boxes” section, click “Compute from data” and “Compute from native bounds”
- Save it
- Repeat the process for the aquifer and well layers

Success

Now you can add data and begin using the app.
