

**PROVO CITY WELL DATA MAPPING WORKFLOW  
PROJECT ID: CEEN\_CPST\_008**

**by**

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**A Capstone Project Final Report**

**Submitted to**

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## Executive Summary

**PROJECT TITLE:** PROVO CITY WELL DATA MAPPING WORKFLOW  
**PROJECT ID:** CEEEn\_CPST\_008  
**PROJECT SPONSOR:** Barr Engineering  
**TEAM NAME:** Water Connect

Barr Engineering is an environmental and engineering consulting firm. They are currently working with the City of Provo to develop an aquifer sustainability plan. As part of the process, they have been collecting well data weekly for the past two years. They came to us looking for a more efficient way to organize and view their data.

We held a meeting with our capstone sponsor, Jeff Davis, and our mentor, Dr. Norm Jones, early last semester to determine the scope of our project. We decided that we would look into two software applications, the Groundwater Data Mapper Application on the Tethys platform and ArcGIS Online, to help Barr Engineering determine if either one would be a good option for organizing and analyzing their data.

The main steps in the process were researching to determine the pros and cons of each software application, building prototypes, using Python code to automate processes, and creating a workflow so that an employee at Barr Engineering can continue the process with future data.

After the researching process, we decided that ArcGIS Online would not be an adequate solution for reasons that will be explained as part of this report. We felt that the Groundwater Data Mapper Application would be adequate in most ways, but that there would be an associated “cost” to that approach. The pros and cons of each of these two software applications will be presented in this report, along with the prototypes and workflow that we created.

In summary, we concluded that the Groundwater Data Mapper Application would be a good option for Barr Engineering as long as they are willing to invest the resources necessary to create and monitor their own server or hire someone else to do so for them.

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## Introduction

### **Overview of the Project:**

The goal of this project was to provide Barr Engineering with an overview of two software applications that they could use to organize and visualize well data. These two options were ArcGIS Online and the Groundwater Data Mapper Application on the Tethys platform. The body of this project report contains 3 main sections:

- An overview of the pros and cons of each software application
- A prototype we made with each software application
- A workflow that we designed to demonstrate the steps that need to be taken to upload data to the Groundwater Data Mapper Application

After reading this report, and with the aid of the Groundwater Data Mapper website (<https://hydroinf.groups.et.byu.net/servir-wa/gwdm/>), an employee at Barr Engineering should understand the basic capabilities of both software applications and be able to upload well or water quality data to the Groundwater Data Mapper Application (GWDM).

### **Planned Schedule:**

- Research and build the prototypes (ArcGIS online, GWDM) (3 weeks)
- Upload the data (2 weeks)
- Create a workflow model for future use (2 weeks)
- Automate certain aspects of the data uploading process (3 weeks)
- Write Report (3 weeks)

### **Tasks:**

- ArcGIS Online Research – Matheus
- GWDM Research – Kyle
- ArcGIS Online Prototype – Matheus
- GWDM Prototype – Kyle and Matheus
- Python Code Automation – Dallin
- GWDM Workflow – Kyle and Dallin
- Final Report – Kyle, Matheus, and Dallin
- Final Poster – Matheus
- Final Presentation – Kyle, Matheus, and Dallin

**Assumptions:**

- We assumed that the well data will continue to come in the same format as the well data that we were given. The code that we created was made for the format of the data that we were given. If the format changes, the code will have to be modified to continue to perform its functions.
- We assumed that Barr Engineering will spend time to review the Groundwater Data Mapper website (<https://hydroinf.groups.et.byu.net/servir-wa/gwdm/>). We did not explain everything that needs to be done to use the GWDM. That is the purpose of the website. Implementing the GWDM will best be accomplished by using a combination of this report, the GWDM website, and the code that we wrote to automate the data formatting process.

**Expectations:**

- Barr Engineering expected us to provide a thorough analysis of ArcGIS Online and the Tethys Portal Groundwater Data Mapper as possible options for well data management.
- Barr Engineering expected us to create a workflow so that anyone at Barr Engineering can replicate the tasks necessary to utilize the GWDM application.

**Requirements:**

- The well data needed to be kept private.
- The software needed to include data visualization options.

## Assumptions & Limitations

To find the Ground Surface Elevation (GSE) of most of the wells, we used the Google Earth Engine. Thus, the accuracy of our GSE values is as accurate as those of the Google Earth Engine. We don't feel that this assumption adds any limitations to the project because the Google Earth Engine elevations are widely considered accurate.

We were most likely not exposed to every format of data file that Barr Engineering creates from their wells. The instructions and code that we wrote were written based off the data sheets that we were given. If someone tries to apply these steps or this code to data that is in a different format the code will not work properly.

The program (or code) itself has a few limitations. To find the well names the program looks for a few different things. The first thing it does is check to ensure that the given files are in .xlsx or .csv format. Then it opens the file accordingly. Any other file type is not supported. Second, the program checks to find "WL", "Bar", or "WQ" in the title of the excel file. Note that capitalization does matter. This will tell the program what type of data is stored in the file. Lastly the program sections out the ".xlsx", ".csv", "\_WL", "\_Bar", and "\_WQ" from the file name to retrieve the well name associated with the file. In short, the files should all follow this naming convention: MW-wellName\_welldatatype.

Table 1 illustrates the naming convention.

*Table 1: Naming Conventions*

Data Type	Naming Convention	Example Well
Water Elevation	MW-WellName_WL	MW-RC7_WL
Water Quality	MW-WellName_WQ	MW-5600N1-WQ
Barometric pressure	MW-WellName_Bar	MW-5600N1_Bar

The program also assumes that the files are formatted in a particular way. To find the data in each file the process is very similar. For water elevation, the program iterates down through column A in the excel file until it finds the keywords "Level Depth To Water (ft)". For Barometric and Water Quality the keywords are different but the process is the same. Once the keyword(s) are found the program notes the location. This spot marks the point where the important data needs to be collected. The program then assumes that dates are in the first column and adjusts the starting point to start at the chosen date. Then the program assumes the columns for the other variables and begins collecting the

data. For water elevation and Barometric pressure data, the columns were consistent across all excel sheets. The water quality data was not consistent. As a result, the program organizes the columns by variable name to collect the correct variables. Once data has been collected the program saves it to a .csv file that downloads to your computer. At this point, the data is ready to be uploaded onto the GWDM.

**Design, Analysis & Results**

This project report contains 3 main sections:

- A. An overview of the pros and cons of each of the two software applications we reviewed
- B. A prototype we designed with each software application
- C. A workflow that we designed to demonstrate the steps that need to be taken to upload data to the Groundwater Data Mapper Application

The design, analysis and results of our project are presented throughout these three sections.

**A) Pros and Cons of the Software Applications:**

**A Summary of the Pros and Cons of ArcGIS Online:**

ArcGIS Online is a collaborative cloud based geographic information system (GIS) software that has a vast number of features allowing one to create maps, and explore, analyze, and manage data efficiently. Table 1 summarizes the pros and cons of ArcGIS Online.

*Table 2: Pros and Cons of ArcGIS Online*

<b>Pros</b>	<b>Cons</b>
<ul style="list-style-type: none"> <li>- Cloud based software, making it easy to work collaboratively</li> <li>- Access to ArcGIS Pro, a very powerful asset for data analysis</li> <li>- Many tools available to perform various analyses and interpolations</li> <li>- Familiar software for many engineering students because there are several courses that use it</li> </ul>	<ul style="list-style-type: none"> <li>- \$1000 - \$3800 per user/per year</li> <li>- Visualization of data is not feasible within the software application</li> <li>- Difficult to analyze transitory data</li> </ul>

Creating graphs within ArcGIS online is difficult. The process would require much more manual work and expertise than would be worthwhile. Each time new data is collected the graphs would have to be reconfigured and relinked to the ArcGIS document.

In addition, a time dependent layer on ArcGIS cannot be easily created. The structure of ArcGIS does not lend itself to simple transitory data visualization. The training required to learn the necessary tools would be extensive and time consuming.

The lack of data/graph display operability of ArcGIS is an issue. Barr Engineering conducts pilot tests during specific periods of time and being able to visualize the period in question quickly and easily is essential. ArcGIS Online would not enable them to do this.

**A Summary of the Pros and Cons of the Groundwater Data Mapper:**

The Groundwater Data Mapper Application (GWDM) was created by students and faculty at Brigham Young University with funding from the NASA-SERVIR project. This project was started to help regions in Africa better understand aquifer sustainability to help them make more sustainable decisions moving forward. The GWDM allows a user to upload well data and visualize it with time. Table 2 summarizes the pros and cons of the Groundwater Data Mapper.

*Table 3: Pros and Cons of Groundwater Data Mapper*

Pros	Cons
<ul style="list-style-type: none"> <li>- The program itself is free.</li> <li>- Uploading data is a very simple process if the data is in the correct format.</li> <li>- Uploaded data can be kept private.</li> <li>- Any quantifiable variable can be uploaded (not just water table depth).</li> <li>- A graph of time vs. any variable is automatically generated when the user clicks on a well. That graph can be downloaded as a PDF.</li> <li>- Any time range can be selected when viewing a well data graph.</li> </ul>	<ul style="list-style-type: none"> <li>- Must have a server or pay someone who has a server to run the platform that the application is on.</li> <li>- Wells that share an exact location (upper and lower screens of the same well) cannot be viewed separately unless they are uploaded to different aquifers.</li> </ul>

The Groundwater Data Mapper seems to fit the needs of Barr Engineering. The only downside to the application is that it would require them to have a server or pay someone to run a server for the Tethys platform. This will be discussed further in the workflow section of the report.

**B) Software Application Prototypes:**

**ArcGIS Online Prototype:**

The prototype for ArcGIS Online was built using our own knowledge and research of the software.

*General Steps for uploading well locations and data:*

1. Create a shapefile from the well locations .csv file. ArcGIS offers a tool to transform an excel spreadsheet containing the name, latitude and longitude, as well as other well information, into a shapefile displaying all the wells on a map. The following website can be used as a guide:

<https://www.esri.com/arcgis-blog/products/arcgis-online/data-management/add-spreadsheet-data-to-arcgis-online/>

2. After using the Table to Shapefile tool, the file will contain each well in its respective location, and each well will have its own attribute table where other information like aquifer ID and name are stored. The next step of the uploading process would be adding the time dependent data to each of the corresponding wells, however, that is where ArcGIS Online lacked the features desired for our project.

Although ArcGIS Online does sustain chart creation using the information contained in the attribute tables of the wells, this does not help us achieve the final goals of the project since time dependent data can't be added to the attribute tables. This is due to the tables being extremely limited and only capable of storing a single row of information. A workaround to the issue would be to keep the well locations and basic data in the ArcGIS Online file and link the time dependent data in PDF format from an outside source. As a result of these issues, we chose to use the more autonomous application, the Groundwater Data Mapper.

Figure 1 shows a screenshot of the ArcGIS Online Map Viewer. The wells show up nicely, but there is no simple way to visualize the transitory data.

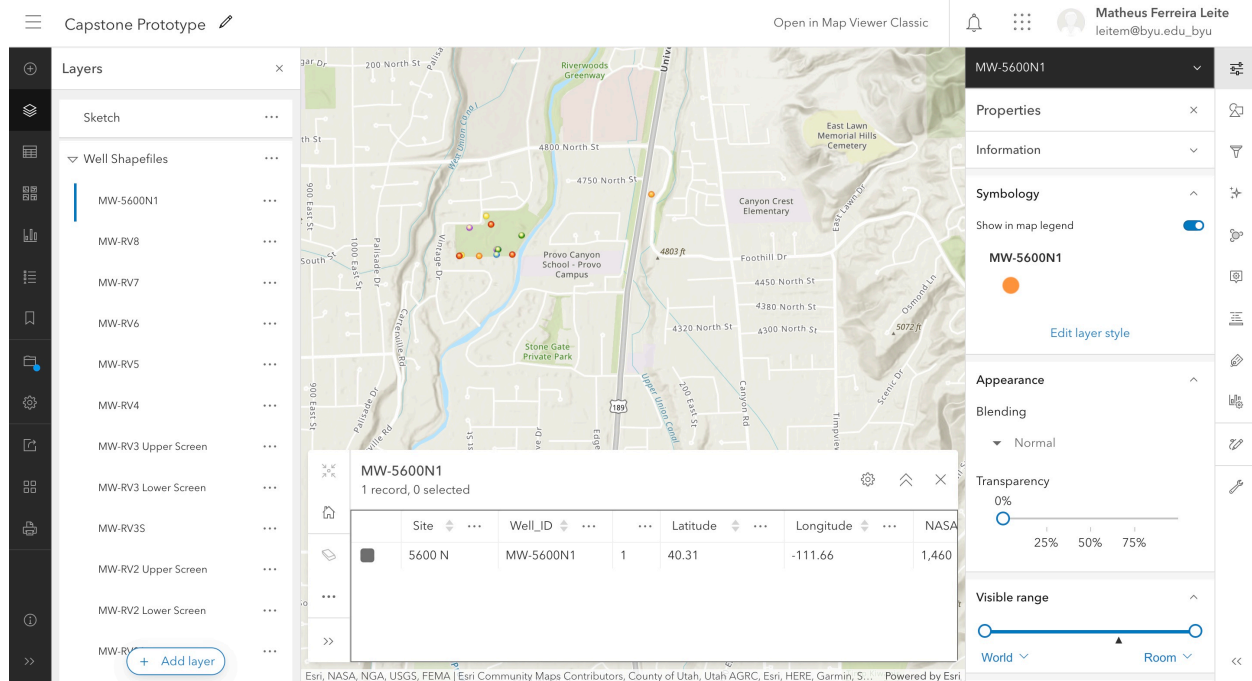


Figure 1: ArcGIS Online Map Viewer

**Groundwater Data Mapper Prototype:**

We used the instructions provided on the following website (referred to hereafter as “BYU GWDM website”) to build a prototype with the Barr Engineering well data:

<https://hydroinf.groups.et.byu.net/servir-wa/gwdm/>

The above website is a great tool to learn how to use the GWDM and is generally updated whenever the GWDM is updated. Even since we began this project, the website has changed in significant ways. As such, it is beyond the scope of this report to recreate the instructions provided on the website. We will, however, summarize the steps required to input data on the Groundwater Data Mapper to enable the reader to understand the structure of our prototype. Figure 2 shows the basic structure of the Groundwater Data Mapper. The figure is explained in more detail on the BYU GWDM website. We include it here to help the reader understand the relationship between regions, aquifers, wells and measurements.

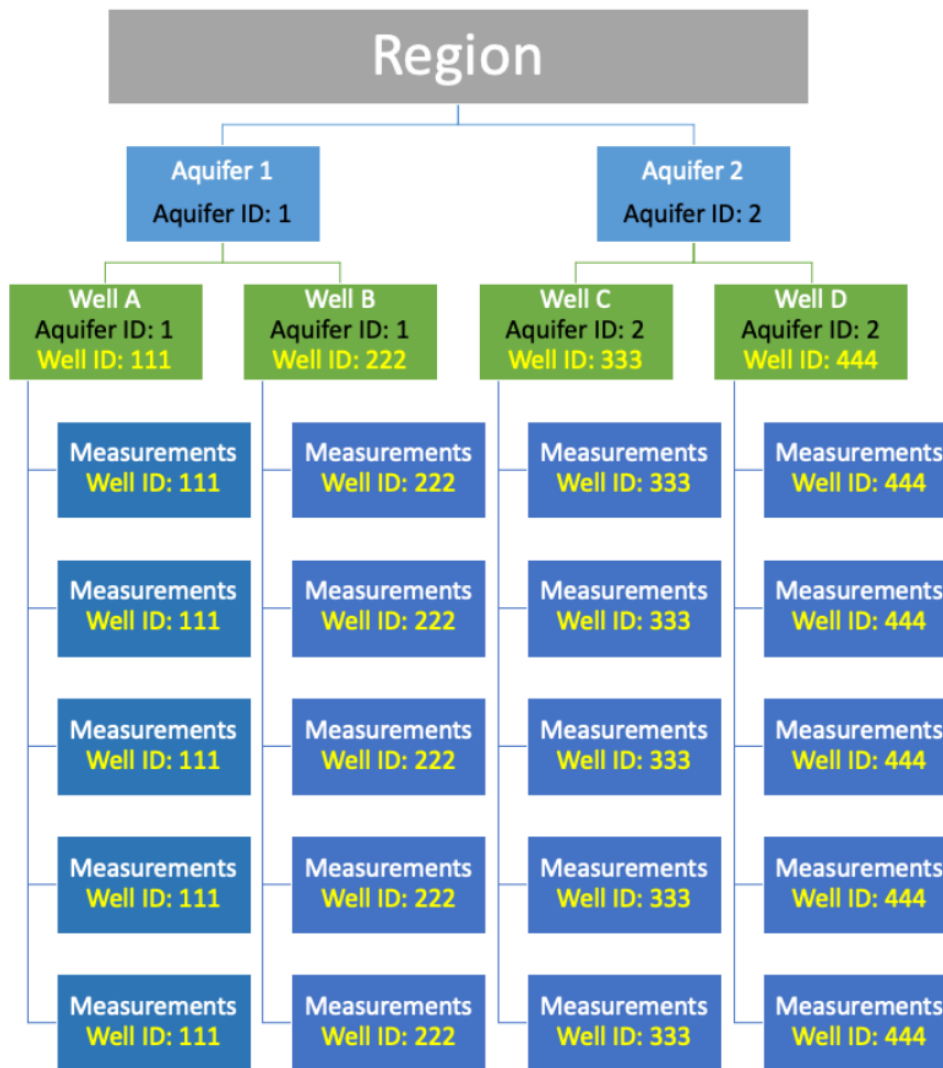


Figure 2: Basic Structure of the Groundwater Data Mapper

*General Steps for Uploading Data on the Groundwater Data Mapper:*

1. Identify Region – A region is the most general physical boundary for the locations of a particular set of data points. All the data points for a project should be located within the region boundary. The region is identified by uploading a boundary shapefile.
2. Identify Aquifers – A region may contain any number of aquifers, which are used to separate data points within a region for any reason (an aquifer boundary does not have to correspond to an actual aquifer, it can simply be a way to separate data points into different categories (i.e. “upper” and “lower” if a well has two screens)). The aquifers are identified by uploading boundary shapefiles.

3. Identify Wells – Wells must be assigned to a region and an aquifer and are associated with measurements (well data). The wells are identified by uploading a csv file with well names and latitude and longitude coordinates.
4. Add Measurements – Measurements of any kind can be uploaded and associated with a well. The measurements and the well are linked by the name of the well. Measurements are uploaded as csv files.

We created a prototype using the Groundwater Data Mapper with the data that Barr Engineering sent us. They sent us 3 types of data: Water Elevation Data, Barometric Pressure Data, and Water Quality Data. We created a region and an aquifer, added the wells to the aquifer, and then uploaded the data that they sent us. In this section of the report, we will present the prototype that we created.

1. *Region: Utah – Barr Engineering*

As can be seen in Figure 3, we used a shapefile of the state of Utah for our region boundary titled, “Utah – Barr Engineering”. Any shapefile can be used to create a region on the GWDM. We decided to use the Utah state boundary to give Barr Engineering plenty of space to work with in the future.

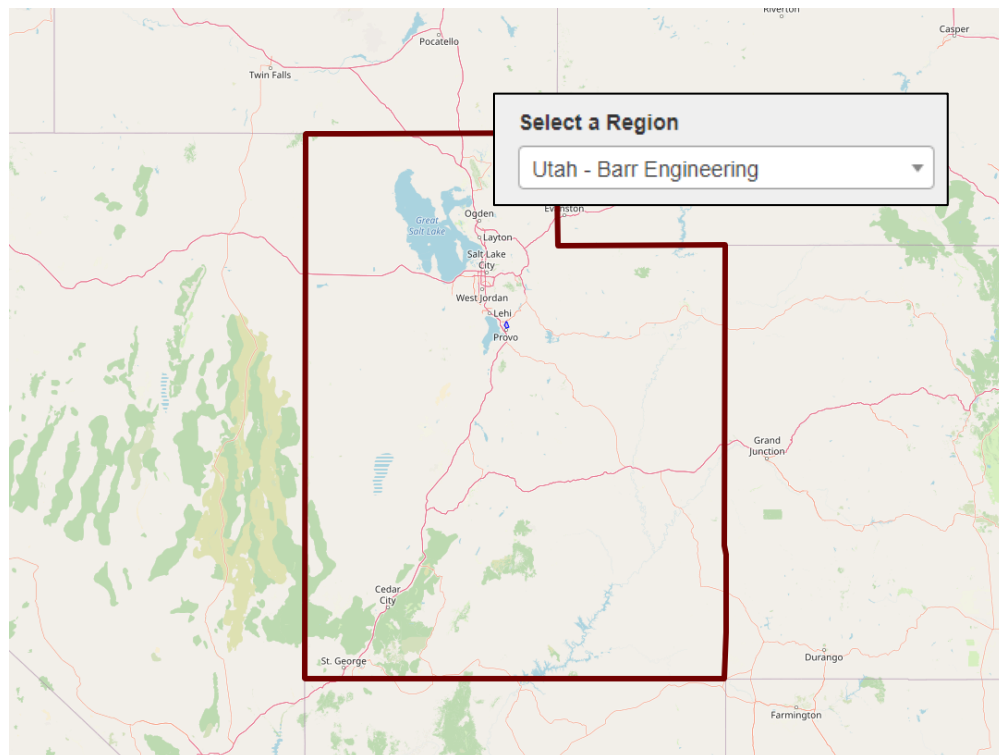


Figure 3: Region - Utah - Barr Engineering

2. *Aquifer: Provo Aquifer*

Throughout the project, we created 2 aquifers. Figure 4 shows the second aquifer, “Provo Aquifer”, which is the one that we ended up using. Our first aquifer was made with boundaries provided by the USGS. Figure 5 shows the USGS aquifer boundary (Northern Utah Valley-east aquifer). We decided to create the second aquifer because the USGS aquifer covered a much larger area than was necessary. We manually created a boundary shapefile in ArcGIS that would better fit the wells. This shapefile became our final aquifer (back to Figure 4).

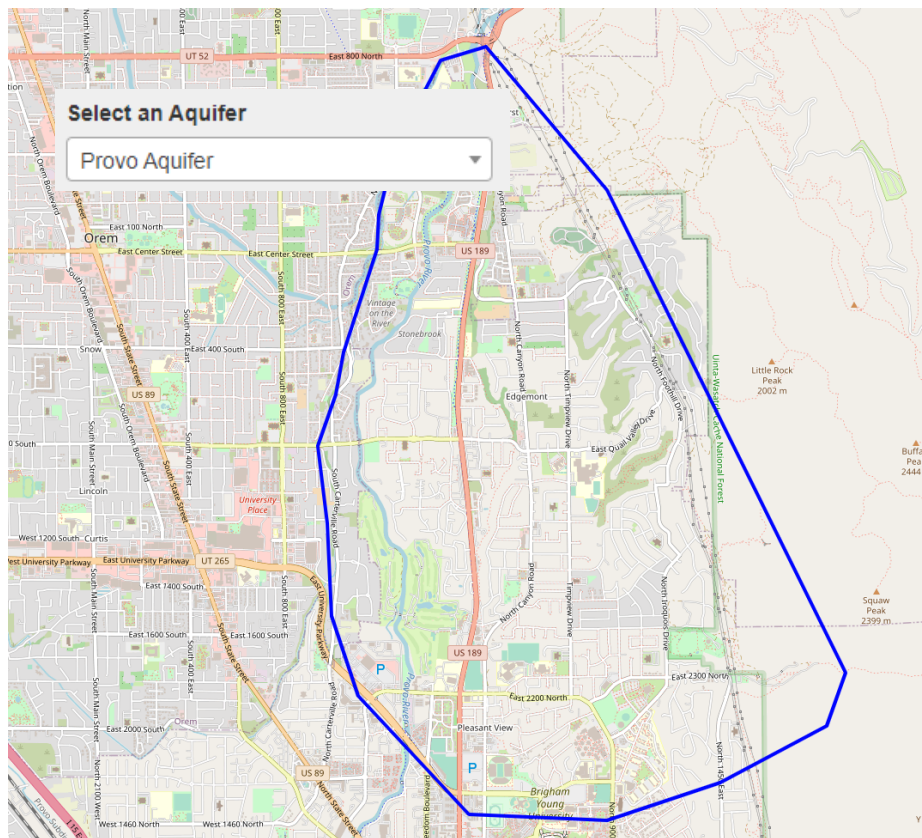


Figure 4: Aquifer - Provo Aquifer

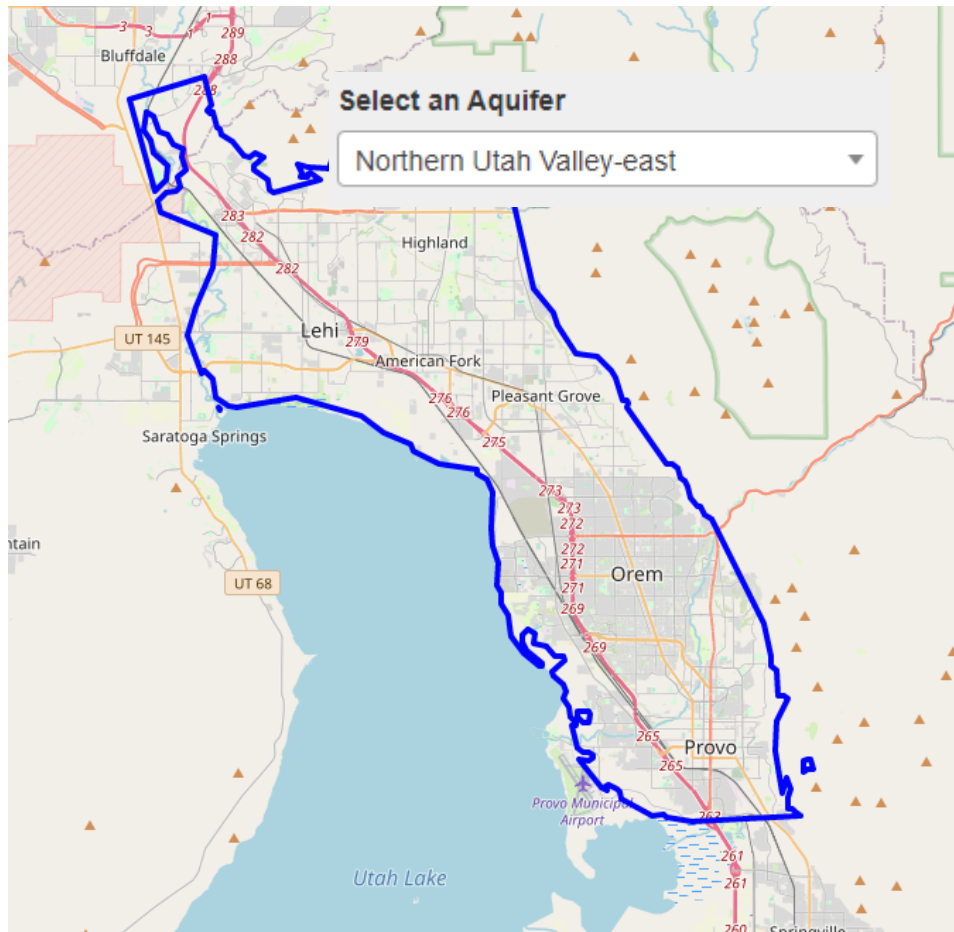


Figure 5: Original Aquifer Boundary

### 3. Wells

After creating the aquifer, we were able to add wells to the GWDM. We formatted the list of wells that we were given by Barr Engineering as directed on the BYU GWDM website. Figure 6 shows the Provo aquifer that we created with Barr Engineering's 32 wells.

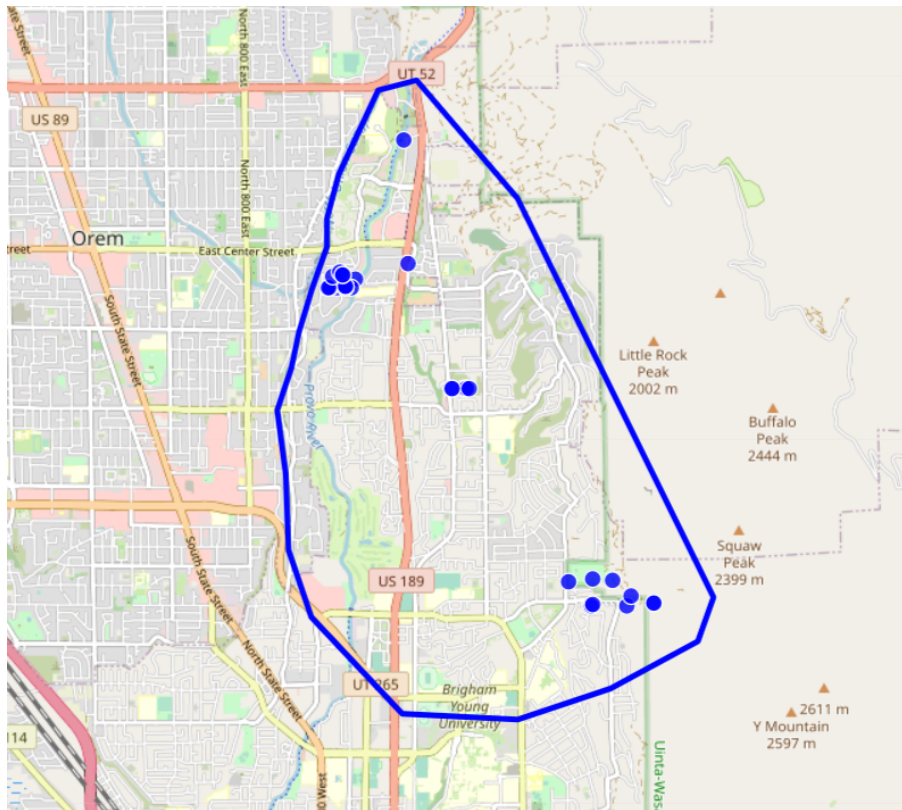


Figure 6: Provo Aquifer with Wells

4. *Adding Measurements:*

With the wells uploaded, we began the process of uploading the data that we had been sent. We used the directions and scripts on the BYU GWDM website to learn how the data needed to be formatted to be uploaded onto the GWDM properly. This process took a bit of trial and error, but we were able to successfully upload all the data. The formatting process took about 10 man-hours and the uploading process took about 3 man-hours. We spent a significant amount of time writing Python code to automate the data formatting process. The Python code shortened the entire process (formatting and uploading) to less than 1 man-hour. Barr Engineering will be able to save a significant amount of time as they use this code to format their data.

5. *Results (Data Visualization Options)*

After the uploading process was complete, the data could be viewed in graphical form. To view data on the GWDM, one selects the region, aquifer, and measurement type that he is interested in and uses the interactive map to pick the well(s) that he would like to view. Figure 7 shows what the Viewing Option Box looks like. Figure 8 shows the graphical representation of the water table elevation for one of the wells along with the well location on the interactive map and the well metadata.

Region Name: Utah - Barr Engineering

Select a Region  
Utah - Barr Engineering

Select an Aquifer  
Provo Aquifer

Select Variable  
Select a Variable

- Specific Conductivity, (µS/cm)
- Barometric Pressure, mbar
- Water Table Elevation, ft**
- Oxidation Reduction Potential, mV
- Partial Pressure Oxygen, Torricelli
- pH (mV), pH (mV)

Figure 7: Viewing Option Box

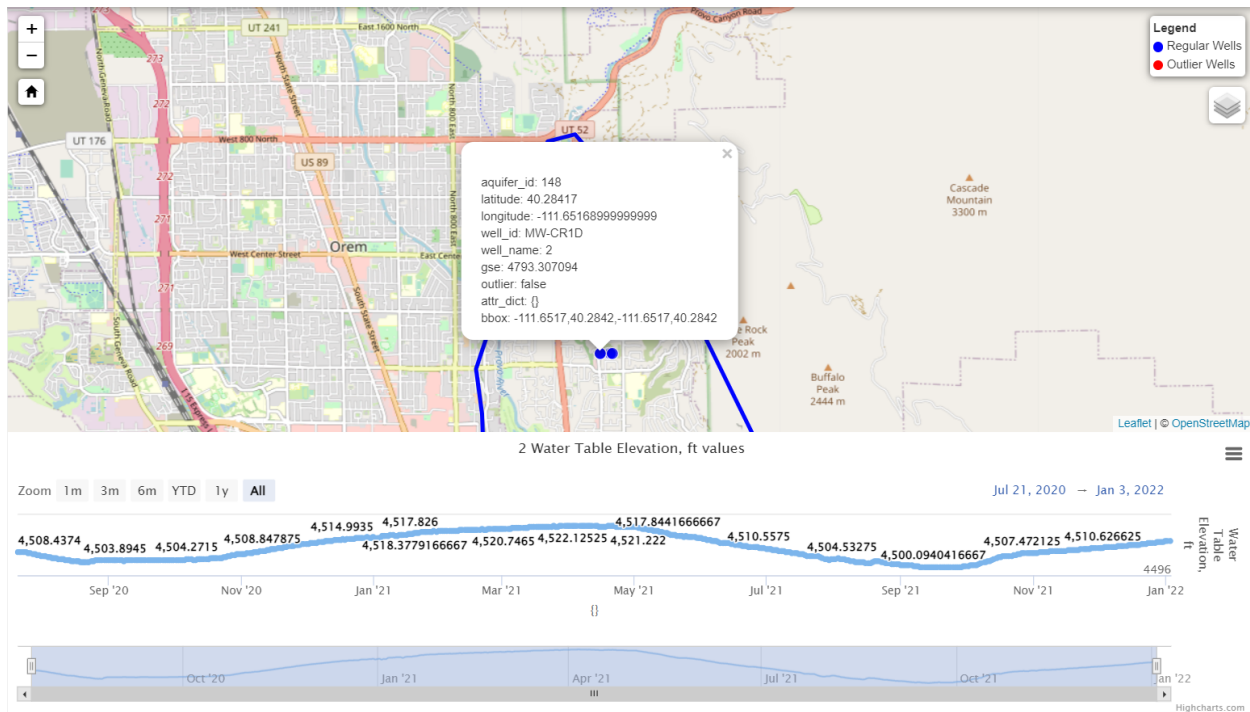


Figure 8: Water Table Elevation Data for a Well

Dr. Jones informed us in the last couple of weeks that one can now view multiple wells at the same time. The user can select the wells he would like to view by

either selecting them one by one or by selecting them with a polygon. This update has not been made public yet, so we do not have pictures of it in this report.

Some of the measurement types only apply to a couple of wells (all of the water quality measurements). However, when these measurements are selected, all the wells still show up on the interactive map. To get the wells without measurements to disappear, the user simply enters a small integer in the lower limit of the filter input box as seen in Figure 9.

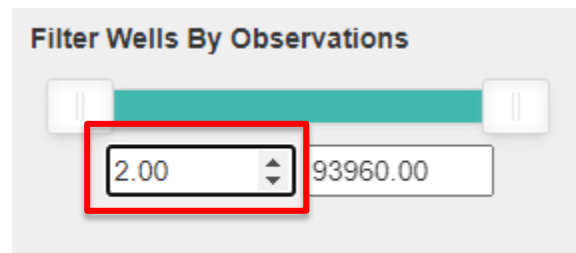


Figure 9: Well Observations Filter

Once the user has selected a well, he can change the range of time that he would like represented on the graph by dragging the bars shown in Figure 10, or by manually changing the dates as shown in Figure 11.



Figure 10: Bars to Adjust Time Range

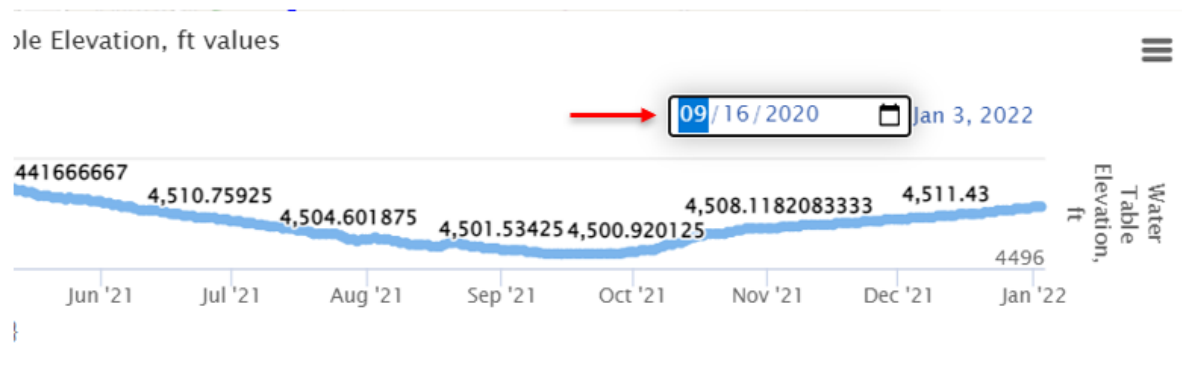


Figure 11: Adjusting Time Range Manually

The Groundwater Data Mapper was created to enable users to easily view trends in well data over time, not necessarily to perform calculations with the data. To perform calculations with the well data, the user would need to use a software application such as Excel. For this reason, the GWDM gives one the option to download the data for the well that he is viewing. As seen in Figure 12, the user can download the data as a csv file or an xls file. In addition, the option box

allows him to view the chart in full screen and allows him to print the chart. The user is also able to download a PNG or JPEG image or a PDF of the chart.

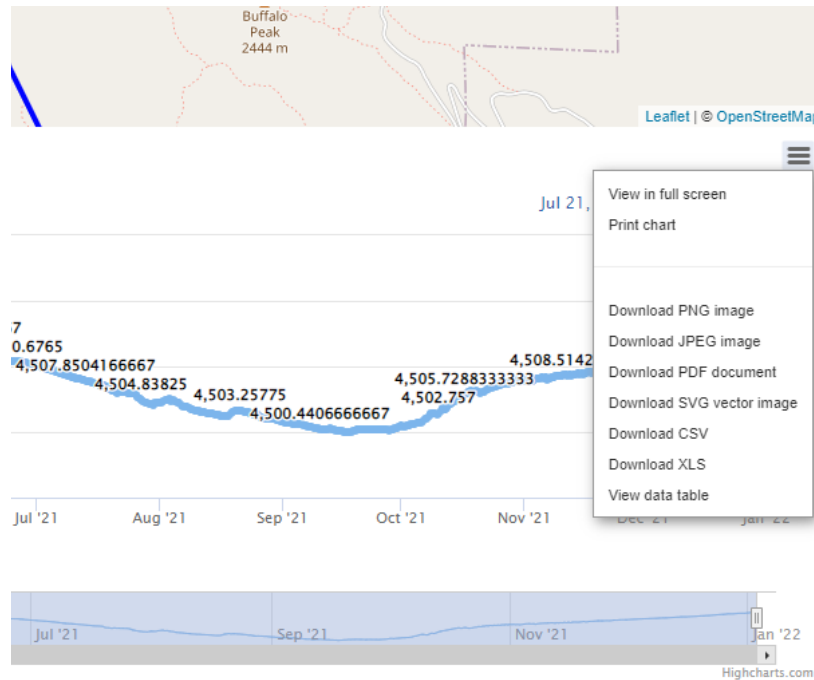


Figure 12: Well Data Options

When the data is downloaded in .csv or .xls form, the time column is in a strange format. This is to account for all the different time zones throughout the world. Uploaded time data is automatically converted to a standard time format that is the same throughout the world. The following excel equation can be used to convert back to a recognizable time format:

$$T_{normal} = \frac{T_{weird}}{1000 * 86400} + DATE(1970,1,1)$$

Where "DATE(1970,1,1)" is an excel function.

### C) Groundwater Data Mapper Workflow:

Using the Groundwater Data Mapper consists of the following 6 steps:

1. Setting up a Server and the Tethys Platform
2. Setting up the GWDM
3. Collecting Data
4. Formatting the Data and Keeping the Reference Files Updated
5. Uploading the Data
6. Altering the GWDM Setup (when needed)

We will summarize each of the steps and explain how they are done.

1. *Setting up a Server and the Tethys Platform*

The Groundwater Data Mapper is hosted on a free platform called Tethys. The Tethys platform requires a server. A server can be set up physically by Barr Engineering or it can be set up physically by another company for a fee. Aquaveo, one of the companies that sell hosting services, provided us with a list of options for Barr Engineering, along with documentation to help them through the process.

There are 4 main options:

- a. Manual Installation
- b. Docker Production Installation
- c. Microsoft Azure Virtual Machine Image
- d. Aquaveo

The first 3 options would not involve Aquaveo. The link below provides documentation for each of the first 3 options:

<https://docs.tethysplatform.org/en/stable/installation/production.html>

To learn more about the fourth option, reach out to Nathan Swain at Aquaveo. Below is his email address:

[nswain@aquaveo.com](mailto:nswain@aquaveo.com)

2. *Setting up the GWDM*

The GWDM application can be installed with the following instructions:

<http://hydroinf.groups.et.byu.net/servir-wa/gwdm/install.php>

Setting up the GWDM consists of 4 parts: a) creating/identifying a region; b) creating/identifying aquifers; c) uploading well locations; d) creating measurement types. These steps are described in detail on the BYU GWDM website (under the Data Preparation section).

We will not describe these steps in this report, but we have sent the region shapefile, aquifer shapefile, and well location csv file that we used to Barr Engineering. Barr Engineering will only need to upload these once, but if they ever add wells, they will need to upload the well location csv file again with the additional wells. When they upload the well location csv file again, any wells that

have already been added will not be reset or duplicated – only the new one(s) will be added.

If the user would like to add a new well, he will need to have/create the following information:

- Latitude of well
- Longitude of well
- Well ID - how the GWDM connects measurements and wells, so we used the ID's that Barr Engineering was currently using (ex. The Riverview 7 well is "MW-RV7").
- Well Name - a number that we assigned based on the order of the wells on the spreadsheet. As far as we know this number has no importance other than to order the wells.
- Aquifer ID - only required if the region has multiple aquifers. Even in the case that the region has multiple aquifers, the user doesn't need the Aquifer ID if he is uploading data for one aquifer at a time. The only time he would need the Aquifer ID is if he is uploading a sheet of wells that are located in multiple aquifers. In this case, he would need to make sure that the Aquifer ID matches the Aquifer ID of the corresponding aquifer in the GWDM.
- Ground Surface Elevation (GSE) - we used a script provided on the BYU GWDM website under the tab "Support Scripts" to find the GSE's for all of the wells.

For more information on setting up the GWDM, go to the BYU GWDM website that we have provided.

### 3. *Collecting Data*

This step involves going out to the sites and gathering data from the well sensors. We were not involved in this step, so we will not go into any more detail.

### 4. *Formatting the Data and Keeping Reference Files Updated*

To simplify the formatting process, we created Python code. We used Google Colab to house the code. The steps for following the code are described in the Google Colab Sheet. The Colab Sheet was sent to Adam Damman of Barr Engineering.

The data must follow the naming and sheet formatting as described in the "Assumptions and Limitations" section found earlier in the report. All files given to us followed this convention. As long as future files follow this convention the

program will have no trouble collecting the data. For new wells, The TOC File and Well File must be updated so the program can process the data.

- To Properly add a new well, you must add the well name to the “TOC measurements.xlsx” File provided by us. The file name must be exactly as described before. To add a new well simply create a new row and fill out each column. The name must be exactly the same as the name in the file title. Then repeat the same process with the “Provo\_well\_locations.csv” file. Fill out the name and all columns on a new row. Once the new well has been added to each sheet it will be able to run in the program. If there is an error the program will not run the file and will output an error message describing why it could not run the new well.

*Example:*

Consider a new well Titled “MW-NewWell\_WL”. To add this well to the TOC and well files it would look like Figure 13 and Figure 14.

15	MW-RC5	3.09
16	MW-RC6	3.64
17	MW-RC7	3.23
18	MW-RC8	2.31
19	<b>Riverwoods</b>	
20	MW-RW1	2.77
21	<b>5600N</b>	
22	MW-5600N	2.55
23	<b>Riverview</b>	
24	MW-RV1L	2.46
25	MW-RV1U	2.46
26	MW-RV2S	2.40
27	MW-RV2U	2.38
28	MW-RV2L	2.38
29	MW-RV3S	-0.38
30	MW-RV3U	2.42
31	MW-RV3L	2.42
32	MW-RV4	2.38
33	MW-RV5	-0.46
34	MW-RV6	-0.38
35	MW-RV7	-0.50
36	MW-RV8	-0.44
37	MW-RV9	-0.52
38	MW-NewWell	( new well toc Value)

*Figure 13: New Well Example - TOC Measurements File*

1	Site	ID	Latitude	Longitude	NASA_GSE	AW3D_GSE	Avg_GSE	Avg_GSE (ft)	Surveyed CA	AquiferID	Aquifer_Name
2	5600 N	MW-5600N1	40.30723	-111.658	1460	1462	1461	4793.307094		5	Northern Utah Valley-east
3	3950 North	MW-CR1D	40.28417	-111.652	1460	1462	1461	4793.307094	4793.62	5	Northern Utah Valley-east
4	3950 North	MW-CR1S	40.28417	-111.652	1460	1462	1461	4793.307094	4793.531	5	Northern Utah Valley-east
5	3950 North	MW-CR2	40.28426	-111.65	1463	1462	1462.5	4798.228354		5	Northern Utah Valley-east
6	3950 North	MW-CR3	40.2842	-111.65	1460	1461	1460.5	4791.666674		5	Northern Utah Valley-east
7	3950 North	MW-CR4	40.28427	-111.65	1462	1462	1462	4796.587934		5	Northern Utah Valley-east
8	3950 North	MW-CR5	40.28418	-111.65	1462	1463	1462.5	4798.228354		5	Northern Utah Valley-east
9	Rock Canyc	MW-RC1S	40.26452	-111.627	1585	1584	1584.5	5198.490822		5	Northern Utah Valley-east
10	Rock Canyc	MW-RC1D	40.2645	-111.627	1585	1584	1584.5	5198.490822	d	5	Northern Utah Valley-east
11	Rock Canyc	MW-RC2	40.26666	-111.635	1514	1509	1511.5	4958.989509		5	Northern Utah Valley-east
12	Rock Canyc	MW-RC3	40.2651	-111.63	1563	1560	1561.5	5123.031504		5	Northern Utah Valley-east
13	Rock Canyc	MW-RC4	40.26416	-111.631	1561	1560	1560.5	5119.750664		5	Northern Utah Valley-east
14	Rock Canyc	MW-RC5	40.26425	-111.635	1537	1544	1540.5	5054.133866		5	Northern Utah Valley-east
15	Rock Canyc	MW-RC6	40.26657	-111.632	1537	1535	1536	5039.370086		5	Northern Utah Valley-east
16	Rock Canyc	MW-RC7	40.26423	-111.635	1536	1542	1539	5049.212606		5	Northern Utah Valley-east
17	Rock Canyc	MW-RC8	40.26639	-111.638	1503	1509	1506	4940.944889		5	Northern Utah Valley-east
18	Riverview	MW-RV1U	40.29469	-111.665	1443	1445	1444	4737.532816		5	Northern Utah Valley-east
19	Riverview	MW-RV1L	40.29469	-111.665	1443	1445	1444	4737.532816		5	Northern Utah Valley-east
20	Riverview	MW-RV2U	40.29373	-111.665	1441	1445	1443	4734.251976		5	Northern Utah Valley-east
21	Riverview	MW-RV2L	40.29373	-111.665	1441	1445	1443	4734.251976		5	Northern Utah Valley-east
22	Riverview	MW-RV2S	40.29374	-111.665	1441	1445	1443	4734.251976		5	Northern Utah Valley-east
23	Riverview	MW-RV3U	40.2935	-111.666	1443	1444	1443.5	4735.892396		5	Northern Utah Valley-east
24	Riverview	MW-RV3L	40.2935	-111.666	1443	1444	1443.5	4735.892396		5	Northern Utah Valley-east
25	Riverview	MW-RV3S	40.29352	-111.666	1443	1444	1443.5	4735.892396		5	Northern Utah Valley-east
26	Riverview	MW-RV4	40.29456	-111.666	1440	1445	1442.5	4732.611556		5	Northern Utah Valley-east
27	Riverview	MW-RV5	40.29353	-111.665	1441	1448	1444.5	4739.173236		5	Northern Utah Valley-east
28	Riverview	MW-RV6	40.29427	-111.663	1444	1452	1448	4750.656175		5	Northern Utah Valley-east
29	Riverview	MW-RV7	40.29499	-111.665	1445	1448	1446.5	4745.734915		5	Northern Utah Valley-east
30	Riverview	MW-RV8	40.2935	-111.666	1441	1444	1442.5	4732.611556		5	Northern Utah Valley-east
31	Riverview	MW-RV9	40.29355	-111.664	1445	1447	1446	4744.094495		5	Northern Utah Valley-east
32	Riverwood	MW-RW1	40.29582	-111.657	1450	1446	1448	4750.656175		5	Northern Utah Valley-east
33	NewSite	MW-NewWell (LAT)	(LONG)	(NASA_GSE(AW#D_GS	(AVG GSE)	(AVG_GSE ft)				5	Northern Utah Valley-east

Figure 14: New Well Example - Well Locations File

Once the reference files have been updated, and as long as the new well files are named correctly, you can run them through the Google Colab script to prepare them to be added to the GWDM.

### 5. Uploading the Data

Once the data has been formatted, it is ready to be uploaded onto the GWDM. The uploading process is described in detail under the "Importing Data" tab of the BYU GWDM website. We would like to provide a few pointers to make the importing process as easy as possible:

- The code that we wrote does not associate the wells with a particular aquifer. Because all of the wells were part of the same aquifer (Provo Aquifer), we were able to specify that during the uploading process. If the wells are ever split into multiple aquifers, the data for each aquifer would need to be uploaded separately, or the code would need to be altered to associate the well data with a particular aquifer.

- When assigning an aquifer to the data, one does so in only one place. An error results if you try to “double-assign” the aquifer. Below are the places where you are given the chance to identify the aquifer (Figure 15 and Figure 16):

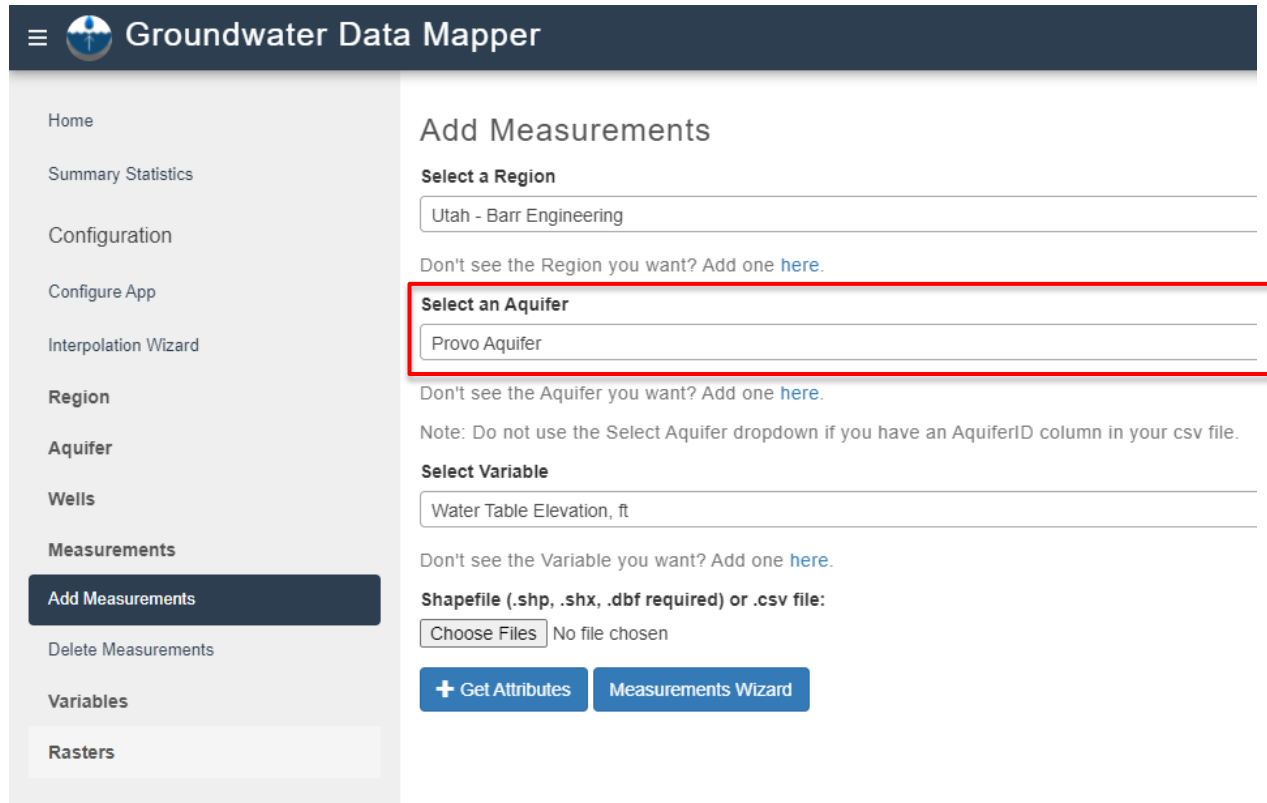


Figure 15: Add Measurements Window

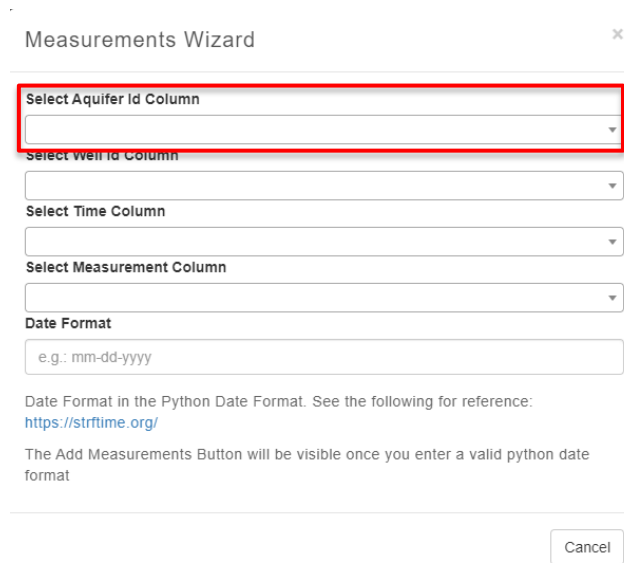


Figure 16: Add Measurements Wizard, (the window that pops up after clicking "Get Attributes")

- The uploading window requires the user to input the date format of the data that he is uploading. Any data that is uploaded using the Python code that we wrote will use the following date format:

%Y-%m-%d %H:%M:%S

If the user uploads data that he has formatted manually, then the date format will likely be different. The BYU GWDM website explains this in more detail under the “Add Measurements” section of the “Import Data” tab. The website below provides additional information.

<https://strftime.org/>

6. *Altering the GWDM Setup (when needed)*

Some GWDM changes require the user to re-upload data. Other changes are simple and cause little disruption. We will summarize common adjustments and the issues that they cause:

- Altering the Region Boundary – If one would like to alter the region boundary, the only way to do so is to create a new region. This means that the user will have to upload everything all over again. Thankfully, the code that we created and the instructions on the website that we provided make this an easier process. Once someone has become familiar with the process, we estimate that everything can be reset in less than an hour (though it depends heavily on the amount of data that is involved).
- Altering the Aquifer Boundaries – If you are changing the shape of your existing aquifer, then you would need to re-upload all the wells and data. However, if you are just adding an additional aquifer, you would not necessarily need to re-upload all the data. Any wells that the user would like to be associated with the new aquifer should be changed on the well location reference sheet and re-uploaded to the GWDM. In this case, you would also need to make sure that each well is assigned an aquifer in the “Provo\_Well\_Locations.csv” file. We have not faced this issue, so we do not know if the measurements will transfer over or if they will need to be uploaded again.
- Altering/Adding Wells – Simple process. The user just alters the well location reference file and re-uploads it.

## **Related Issues**

Barr Engineering's project aims to create an aquifer sustainability plan for the City of Provo through the development of aquifer storage and recovery (ASR) systems. ASR is a method where excess water from spring runoff is injected into subsurface aquifers and then pumped out later according to necessity. In order to achieve this goal, the company runs pilot tests on water wells during specific periods of time, and then studies the data obtained to determine the results of the test. Data management and visualization is essential to this analysis.

Engineering solutions have always had a major impact on society. The first fundamental canon of the Code of Ethics for engineers created in 1946 by the National Society of Professional Engineers (NSPE) is to "Hold paramount the safety, health and welfare of the public." Back then the main concerns were solely related to humans and their well-being, however, in 2006 the NSPE formally recognized the importance of sustainability by adding a new professional obligation to the Society's Code of Ethics. The new provision stated, "Engineers are encouraged to adhere to the principles of sustainable development in order to protect the environment for future generations."

Therefore, engineers have to account for the impacts that their projects may have in a variety of areas, such as public health, public welfare, and global and environmental factors.

*Some of the impacts of Barr Engineering's project are:*

- Public Health: water quality and availability effects public health. Creating a sustainable aquifer and a clear data management and display tool will allow the Provo Water Department to have a higher control over water quality, especially having up to date data for many wells in the area.
- Welfare: water quality improves the quality of life. Through the use of better monitoring practices, the population in Utah County will have access to better water quality, improving the overall quality of life in the valley.
- Global, Social, and Economic Factors: setting a standard for a sustainable and good quality aquifer. The efforts of Barr Engineering along with the tool designed by us will

allow for a new standard in creating sustainable, well monitored aquifers throughout the United States and the world.

- Environmental Factors: better environmental practices regarding groundwater projects. The creation of a sustainable aquifer through the use of ASR method offers better environmental practices regarding groundwater projects, decreasing the size of the impact usually caused to the environment.

## Lessons Learned

The challenges that we faced as a team represent challenges that we anticipate to encounter frequently in our careers. We would like to summarize the 4 main challenges that we faced and what we did to overcome them. The first challenge that we faced was learning how to become familiar with our project. The second challenge was learning how to become familiar with the potential solutions. The third challenge was dealing with the time it took us to upload data. And the fourth challenge was learning how to effectively lead people through the steps that we needed to take to make use of the software.

The first challenge that we faced was becoming familiar with the project. 2 of us are emphasizing in geotechnical engineering, and the other is emphasizing in structural engineering. We have each had a class or two relating to water and environmental engineering, but the subject of aquifer sustainability was relatively new to all of us. We used our sponsors, Jeff Davis and Adam Damman, along with our mentor, Dr. Norm Jones, to help us understand the subject material better. We met frequently and asked lots of questions. We are by no means experts in aquifer sustainability, but we learned enough to successfully complete the project.

The second challenge that we faced was becoming familiar with the software/applications. We have all used ArcGIS, so becoming familiar with that software was not an issue. None of us had used the GWDM. Dallin had some experience using Python, but Matheus and Kyle did not. Becoming familiar with the GWDM took a lot of trial and error. We made many errors in the process. We overcame the challenges that we faced by using the BYU GWDM website, Dr. Jones' advice, and online Python code resources.

The third challenge that we faced was dealing with the time it took to upload the data. Formatting and uploading the data took us 13 man-hours the first time that we did it. We determined that no one would want to use the GWDM if formatting and uploading data took that long. To overcome this challenge, we wrote Python code that automated the formatting process. With the code, the formatting and uploading process takes less than 1 man-hour.

The fourth challenge that we faced was writing a report to enable anyone to replicate what we did. It is one thing to become acquainted with a particular software. It is a totally different thing to explain how to use the software to someone with little or no experience with the application. This process took time. We also had someone unfamiliar with the application read through the workflow and give us feedback on how we could make the process clearer.

Throughout this project we learned the importance of frequent communication. We learned the importance surrounding oneself with people that know what they are doing. We learned that success takes time, but that coding can decrease the amount of time it takes to be successful in the future.

## **Conclusions**

We learned that most companies need to deal with large amounts of data. Each company must find its own method of organizing and analyzing their data. For companies that gather a large amount of well data, the GWDM is an effective method of organization and visualization. This application is constantly being improved and will continue to become an effective tool for environmental and engineering consulting firms in the future.

Why do we hold this opinion? Within the course of 9 months, we have seen significant developments in the GWDM in response to the desires of our sponsor. We were involved with developing a workflow and code to enable Barr Engineering to efficiently use the GWDM, but other developments such as being able to map multiple wells at the same time and being able to toggle on and off data measurements have shown that the developers of the application are capable and willing to meet the needs of the industry.

## **Recommendations**

We recommend that Barr Engineering follow the steps outlined in the GWDM workflow that we have presented in this report. The GWDM application seems to meet the needs of Barr Engineering. In addition, Brigham Young University has recently received grant money that will be used in part to further develop the GWDM. As a primary user of the GWDM, Barr Engineering would be able to give suggestions for application development. The only cost associated with the application would be setting up and maintaining the server. Barr Engineering could handle this easily by hiring a company like Aquaveo to set up and upkeep the server for them.

## Appendix A

### Schedule

#### **Week 1:**

(3/Jan/2022-9/Jan/2022)

##### *Accomplishments:*

- Created VBA code to format the well data effectively

##### *Challenges:*

- Encountered some issues with uploading data on the GWDM
- Discovered we are only allowed to upload one variable at a time to the GWDM
- Determined we were lacking well data due to security or communication issues

#### **Week 2:**

(10/Jan/2022-16/Jan/2022)

##### *Important Milestones:*

- Held first meeting with new sponsor representative, Adam Damman

##### *Accomplishments:*

- Sufficiently researched ArcGIS Online to determine that it is not a viable option for Barr Engineering's purposes
- Communicated our need for more data and were granted access to all of the data that we needed

##### *Challenges:*

- Discovered that some of the data sheets had null values – GWDM cannot upload sheets with null values

#### **Week 3:**

(17/Jan/2022-23/Jan/2022)

##### *Accomplishments:*

- Made significant progress in the data uploading process

##### *Challenges:*

- Unsure of what data needed to be uploaded to the GWDM
- Uncertain of how to distinguish between different excel sheets in our code

**Week 4:**

(24/Jan/2022-930/Jan/2022)

*Important Milestones:*

- Uploaded all of the well data that had been sent to us
- Started writing the project report

*Accomplishments:*

- Significant progress in writing the python code to format the well data sheets
- Talked to Dr. Jones about our opinion that ArcGIS would not be a viable solution for Barr Engineering - he agreed with our reasoning

*Challenges:*

- Decided that we needed to make a new shape file for the aquifer, which would require us to upload all of the data again

**Weeks 5 + 6:**

(31/Jan/2022-13/Feb/2022)

*Accomplishments:*

- Completed well data python code and most of it worked

*Challenges:*

- Unable to meet with Adam for our last team meeting
- Encountered a problem in the code relating to differentiating between different file types

**Week 7:**

(14/Feb/2022-20/Feb/2022)

*Accomplishments:*

- Created the new aquifer shape file and uploaded it to the Groundwater Data Mapper

*Challenges:*

- Hadn't been able to meet with Adam in over a month

**Week 8:**

(21/Feb/2022-27/Feb/2022)

*Important Milestones:*

- Met with Dr. Jones and Adam
- Showed Adam our prototype and got his feedback concerning some of the challenges that we had been having

*Accomplishments:*

- Code worked other than some issues with the file names

*Challenges:*

- Had issues with some of the file names - we needed Adam to tweak the way that he names the files for our code to work
- Difficulty in determining the social impacts of our project

**Week 9:**

(28/Feb/2022-6/Mar/2022)

*Accomplishments:*

- Started brainstorming the impacts of our project

*Challenges:*

- Realized that Adam may not be able to change the names of the wells before we needed to finish our project

**Week 10:**

(7/Mar/2022-13/Mar/2022)

*Important Milestones:*

- Received news from Adam that he had renamed all of the wells!

*Accomplishments:*

- Uploaded all the data to the new aquifer shapefile
- Almost finished with the prototype write-up

*Challenges:*

- Had not figure out how to use code to append only certain ranges of data

**Week 11:**

(14/Mar/2022-20/Mar/2022)

*Important Milestones:*

- Started the process of transferring our code to Google Colab

*Accomplishments:*

- Completed a significant portion of the written report

*Challenges:*

- Awaited a significant update to the GWDM that would allow the user to view multiple wells at the same time – not sure if it would be finished by the time we needed to submit the project

**Week 12:**

(21/Mar/2022-27/Mar/2022)

*Accomplishments:*

- Completed the first draft of the prototype write-up

*Challenges:*

- Realized that our code for the water quality was faulty because the example file we had been given was not a raw datasheet

**Week 13:**

(28/Mar/2022-3/Apr/2022)

*Important Milestones:*

- Transferred the code to Google Collab
- Finished and turned in the poster

*Accomplishments:*

- Divided the remainder of the project into manageable chunks for each of us

*Challenges:*

- Encountered issues when trying to delete large amounts of data from the GWDM

**Week 14:**

(4/Apr/2022-10/Apr/2022)

*Important Milestones:*

- Held our final meeting with Adam for any last-minute requests
- Finished writing the report
- Presented our project in Seminar
- Set up a time to present our project to Barr Engineering and their colleagues

*Accomplishments:*

- Tested code and everything seemed to be working correctly

**Matheus Ferreira Leite**

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**EDUCATION**

**Brigham Young University - Provo** Apr 2022  
**Bachelor of Science: Civil Engineering** Provo, UT

- GPA: 3.48
- Full Athletic Scholarship - Men's Tennis Team
- Relevant Course Work: Statics, Geomatics, Linear Algebra, Computational Methods, Calculus (I, II & III)
- Software: AutoCAD, Civil 3D, Revit, Navisworks, ARCGIS Pro, R Studio
- Coding Languages: VBA in Excel and Python

**Texas Tech University** Aug 2017-May 2019  
**Bachelor of Science: Civil Engineering** Lubbock, TX

- GPA: 3.63
- Half Athletic Scholarship - Men's Tennis Team
- Top 25 Presidential Academic Scholarship

**EXPERIENCE**

**Brigham Young University** Aug 2019-Current  
*Men's Tennis Team - Captain* Provo, UT

- Lead the team as captain for 2 years, managing coach-team relations, organizing activities, and improving morale
- Persistently train for 20 hours a week, traveling twice a month to compete while maintaining a rigorous course load

**BYU Capstone Project: Water Wells Data Analysis for Barr Engineering** Sep 2021-Apr 2022  
*Civil Engineering Student* Provo, Utah

- Analyzed and identified different options to solve a major business problem outlined by the company sponsor
- Wrote python script to parse through Excel spreadsheet, extract the necessary data, and produce the desired output
- Prepared a thorough workflow to assist Barr Engineering and City of Provo, UT, to continue using the tool designed
- Presented the project results to company executives, and provided them with a detailed guide of the process

**Coe & Van Loo Consultants Inc.** May 2021-Aug 2021  
*Engineer In Training* Phoenix, Arizona

- Produced essential documents for building proposals, permit applications, and discussions
- Generated statements of quantities and prepared budget assessments
- Designed drawings, reports, and exhibits used to relay information to other engineers and clients
- Effectively communicated with other designers and project managers
- Utilized specialized engineering software, tools, and equipment to complete tasks

**Texas Tech University Men's Tennis Team** Aug 2017-May 2019  
*Men's Tennis Team - Player* Lubbock, TX

- Trained for 20 hours a week while traveling to compete at universities across the United States
- Guided team to a top 35 ranking at the end of freshmen season and top 30 at the end of sophomore season
- Recorded the most wins in the team in singles (23-16) and doubles (18-10) during freshman season
- Facilitated tennis lessons and practices for kids and teenagers of different ages every day for 4 weeks
- Advised over 60 campers along with 5 other tennis coaches, during practice and extracurricular activities

**AWARDS, ACHIEVEMENTS, INTERESTS**

- Fluent in Spanish, English, and Portuguese
- Ranked #248 the world by the International Tennis Federation Juniors Circuit (2017)
- Ranked #1 in Brazil Under-18 (2016-2017)
- Visited more than 18 countries and 25 US states throughout tennis career
- 2020 and 2021 Intercollegiate Tennis Association Scholar Athlete Award
- 2020 and 2021 West Coast Conference 1<sup>st</sup> Team All-Academic
- Cryptocurrency, Traditional and Decentralized Finance, Cars, Music, Travel, and Sports

**Kyle Cannon**

Provo, UT 84606 | (385) 535-1682 | kylecannon827@gmail.com

**Education**

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***Bachelor of Science Candidate in Civil Engineering, Brigham Young University, Provo, UT (Expected Graduation: April 2022)***

- Current Cumulative GPA: 4.0
- GRE Score: 167 Quantitative, 160 Verbal, 4.5 Writing
- Phi Kappa Phi Candidate (top 10% of class)
- Edwin S. Hinckley Scholarship (full tuition x 1.3) (*current*)

**Work Experience**

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***Teaching Assistant – Civil Engineering Department, Brigham Young University, Provo, UT (Aug 2021 – Present)***

- Lead 25 students through 11 labs throughout the semester
- Grade lab reports and provide feedback and advice to help the students develop technical writing skills

***Summer Apprentice – Engineer Research and Development Center, Vicksburg, MS (Jun 2021 – Aug 2021)***

- Processed soils and ran tests on hundreds of samples to help determine soil characteristics
- Personally assisted team engineer, scientist, and lab supervisor in a variety of tasks

***Teaching Assistant – Excel Basics Course, Brigham Young University, Provo, UT (August 2020 – May 2021)***

- Tutored approximately 60 students in an Excel/VBA class on an individual level
- Evaluated and corrected weekly assignments and midterm exams
- Communicated and coordinated with the professor to provide solutions to student’s concerns

***Assistant Administrator, Trestlewood, Lindon, UT (Summer of 2020)***

- Tested and resolved issues with company website ([www.trestlewood.com](http://www.trestlewood.com))
- Worked on and collected data from a company-wide database (Progress)
- Performed other administrative and customer service-related tasks as requested such as conducting interviews with our salespeople to align company and individual goals, creating training videos with CAMTASIA software, and developing a prospecting initiative for the company

**Volunteer Experience**

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***Volunteer Representative, The Church of Jesus Christ of Latter-day Saints, LA and MS (June 2017- Jun 2019)***

- Trained and motivated 20+ full-time volunteers in areas of administration, organization, and planning
- Created weekly progress reports and utilized results to help representatives measure and improve performance
- Set, reviewed, and achieved daily, weekly, and six-week goals and key performance indicators
- Taught basic English-speaking skills to native Spanish speakers.
- Worked with leadership and peer leaders to plan trainings to improve key performance indicators for 150+ volunteers.

**Skills and Proficiencies**

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- Proficient in Microsoft Word, Excel, and PowerPoint.
- Basic understanding of and ability to use VBA
- Basic skills in and understanding of ArcGIS, WMS (Watershed Modeling), and GMS (Groundwater Modeling)
- Video-making skills using Camtasia
- Conversant in Spanish

**Dallin N. Smith**

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**EDUCATION**

---

**BS, Civil and Environmental Engineering** Graduation April 2022

*Brigham Young University, Provo, Utah*

- GPA: 3.1
- Member, American Society of Civil Engineers, BYU 2018 – Present
- BYU Presidents Leadership Council Scholarship

**PROFESSIONAL EXPERIENCE**

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**Liquefaction Research Assistant** April 2021 – Present

*Brigham Young University, Provo*

- Developed a liquefaction analysis-oriented app with a team of 3 that is capable of running a full probabilistic liquefaction model based on SPT values from any soil profile for any number of points in the US.
- Generated over 150,000 points across the US from peak ground acceleration using Arc GIS
- Generated 918 liquefaction hazard contour maps for every state in the US.

**BYU Soil Mechanics Teacher Assistant** August 2021 – December 2021

*Brigham Young University, Provo*

- Led 8 students in completing various soil tests (sand cone, consolidation, shear, etc.) accurately and safely.
- Guided students 6 hours a week in course concepts and homework.
- Graded homework and labs submitted by the students.

**APPLICABLE CLASSES & SKILLS**

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Foundation Engineering	Geomatics	Excel VBA Coding
Soil Mechanics	In-Field Soil Classification	C++ Coding
Steel Design	AutoCAD	Python Coding
Concrete Design	ArcGIS	Data Structures
Advanced GIS	Revit	Visual Studio
Hydraulics	Surveying	EPA 608 type I, II, III certified
Environmental Eng.	Microsoft Office	

**OTHER EXPERIENCE**

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**Energy Efficiency Technician** May 2018 – August 2020

*Synergy Companies, Perris, CA*

- Serviced 3-4 customers per day replacing and optimizing A/C refrigerant, Fans, Furnace, lighting, electric circuits, and plumbing.
- Entrusted to work independently and drive a company vehicle.
- Attended to “fix it” appointments where I was expected to correct other technician’s mistakes and repair HVAC systems.

**Building Care Student Lead** August 2018 – March 2020

*Brigham Young University, Provo, UT*

- Led a group of 15 Students in their daily tasks.
- Maintained equipment
- Led safety training meetings biweekly.