



GIS Project:

**Groundwater analysis for the Rhodes property
(Socorro, NM).**

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Motivation and background

River restoration currently constitutes a broad and an active area of research in water resources (Wohl et al., 2015). A successful restoration project involves coupling of ecological, hydrological and environmental sciences with the aim to recreate, initiate or accelerate the recovery of an ecosystem that has been disturbed (Vaughn et al., 2010). Over the past decades different restoration projects and approaches have been implemented in New Mexico. Some of these initiatives have been fostered by the state (e.g. River Ecosystem Restoration Initiative) and others by non-profit organizations (e.g. Save our Bosque Task Force, SOBTF).

This semester, as part of our Stream Restoration Class (CE 598), we had the opportunity to contribute to one of the projects conducted by the SOBTF in a privately owned land in Socorro County referred from here on as the Rhodes property. The property is located 75 miles south of Albuquerque, on the east side of the Rio Grande (Figure 1).

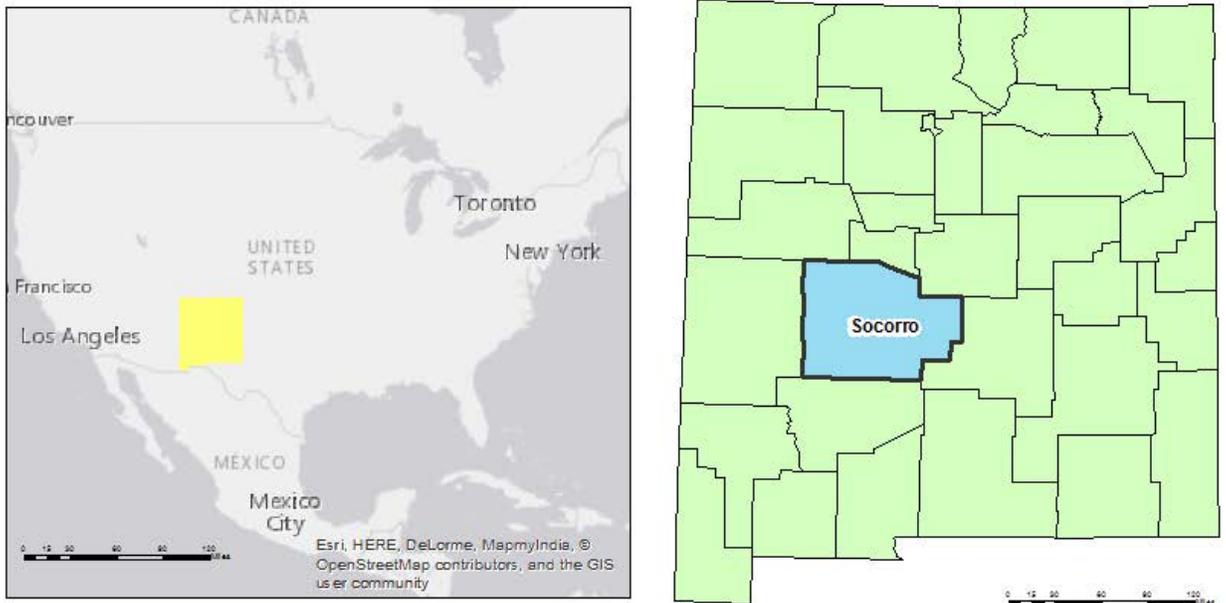
For the current phase of the project our class is proposing a restoration approach that involves restoration of native vegetation and assessment of the water resources (quality and availability) of the area to help the landowner pursue funding and partnership from different federal organizations.

Objectives

Part of the assessment of water resources consisted on studying the groundwater to ensure a sustainable restoration design. The main objectives for this project are:

- Evaluate past and present hydrogeologic conditions of the site
- Assess the groundwater quality of the area
- Study the feasibility of the proposed vegetation restoration goals based on the groundwater quality and availability

Rhodes Property. Groundwater Study



Site location. Area of study

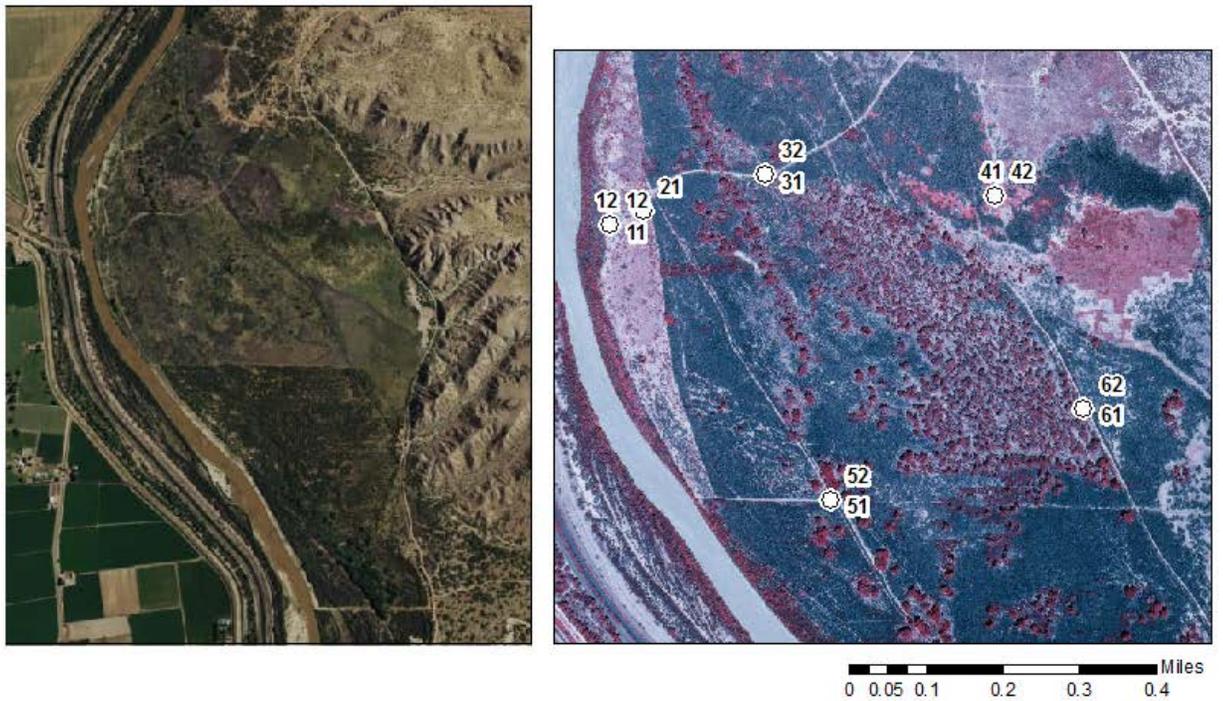


Figure 1. Rhodes property location map

Methods

Data sources

The data sets required for this analysis were:

- USA Counties Dataset: I downloaded the data from UNM learn, this was part of the database used for assignment 2. In order to select Socorro county, I used the select by attribute and export data tools.
- Shape files of the Rhodes property: I acquired these files thanks to GeoSystems Analysis (GSA), a company that collaborates in this project with SOBTF. They provided a group of people in the class with all the GIS data they had available.
- Location of wells, water elevation and quality data: I directly contacted the Interstate Stream Commission (ISC) and they provided me with all the data they had regarding groundwater in the property.

Projection used

I chose to project all the data in Universal Transverse Mercator (UTM) Zone 13N with NAD 83 Datum because most of the shape files provided were already represented using this projection.

Software

I used ArcGIS 10.3.1 and ArcGIS 10.1 (ArcMap and ArcCatalog). I specifically used the latest version for the Spatial Analyst toolbox and the Georeferencing toolbox.

For the groundwater elevation analysis, I was provided with an extensive amount of data from different data loggers as well as point measurements from the different wells in the property. In order to process all this data more efficiently I decided to use the Arc Hydro Tools for Groundwater analyst (AHGW), due to the availability of a user friendly interface and statistical

analysis within the toolbox. The groundwater analyst application was not compatible with ArcGIS 10.3.1, in that sense I had to use ArcGIS 10.1 for this portion of the project.

General Methodology

I started by introducing the shape file of the property to make sure all the following data introduced would be projected “On the fly”.

Groundwater elevation and water quality statistics

Using the data provided by the ISC, I created different tables in excel where I could classify the data (land elevation, water elevation, depth to water, field and laboratory measured water quality parameters) by well location and time period. Then I imported the well features into ArcMap using the AHGW Text Import command, I assigned the proper labels to each parameter and decided which ones I wanted to map.

Moreover, I imported the time series data using again AHGW Text Import command pairing a Feature ID column with the wells numbers in order to be able to match information from the previously imported data. Once the importing and fixing was completed, I performed a time series statistical analysis using AHGW Make Time Series Statistic tool for specific time intervals (summer and spring combined, as well as, fall and winter combined) for the wells with transient data, I established the mean values as the output statistical parameter. In order to make this process more efficient, I created a simple model using the Model Builder tool.

Finally, for the groundwater elevations I interpolated the point statistics to a raster using the Inverse Distance Weighted (IDW) interpolation tool within the Spatial Analyst toolbox making sure to set up the environment delimitations to fit the shapefile of the Rhodes property.

For the water quality I joined all the output statistical analysis for each of the available water quality parameter and created a feature class with all the information. Furthermore, I introduced this feature class to the map and changed the Symbology to Charts and then Pie.

Vegetation restoration goals

For this section I wanted to overlay the proposed vegetation plan with a raster that I created for the salinity in groundwater. The new vegetation approach was created by other group in our class which provided me a jpeg with the proposed plan. Because this picture did not have any spatial information I had to use the Georeferencing toolbox to make the figure match with the shape file of the property that had the salinity raster and the wells. I chose 4 identifiable common points in the image and the shape file, then I georeferenced it and adjusted the transparency of the salinity raster to obtain the desired final product.

Results

Overall the different figures obtained from the groundwater elevation analysis showed that this resource is readily available in the area, with no big temporal changes. Figure 2 shows the groundwater elevation contours for the spring and the summer of 2003, 2008 and 2011. Figure 3 displays the groundwater elevation contours for fall and winter of 2003-2005, 2007-2008 and 2010-2011. The groundwater quality data shows that the main anions are Sulphate and Bicarbonate while the main cations are Calcium and Sodium (Figure 4).

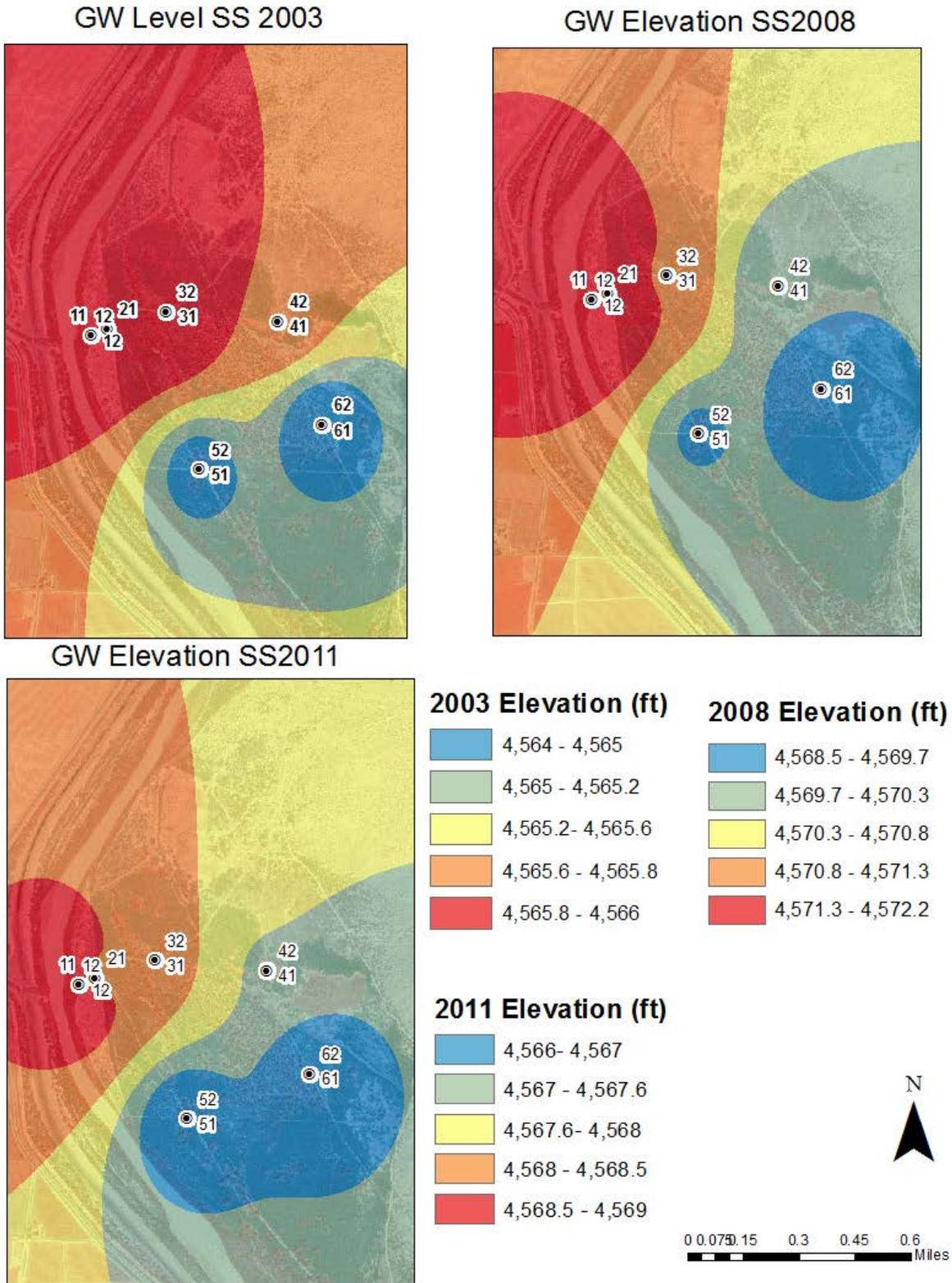
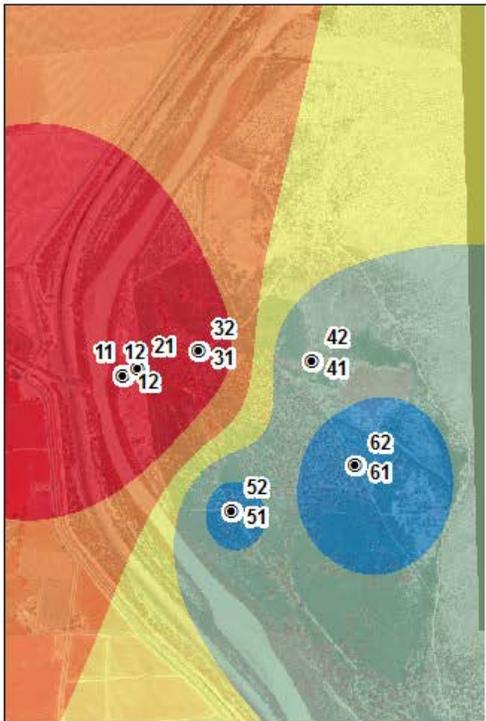
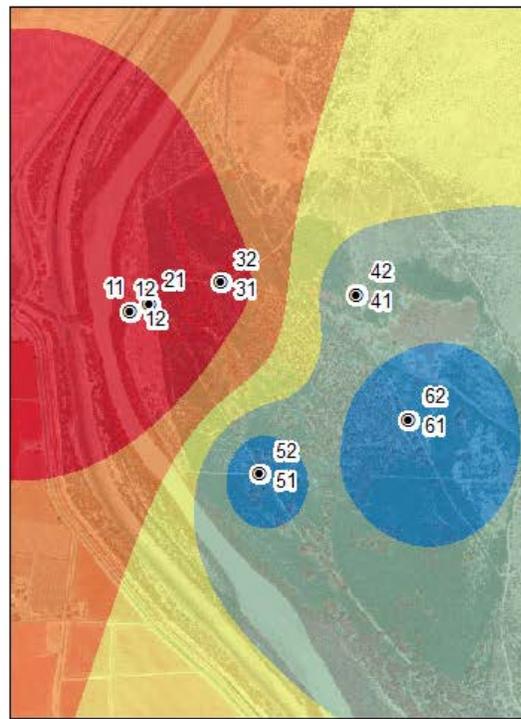


Figure 2. Temporal variations of groundwater elevations for spring and summer

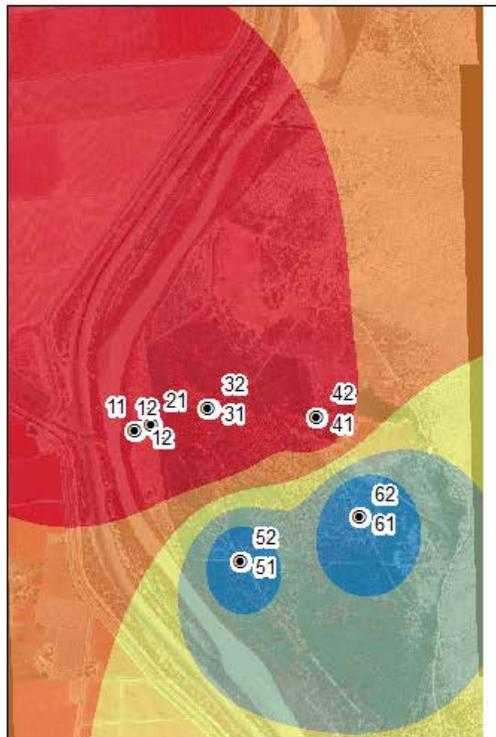
GW Elevation FW 2003-2004



GW Elevation FW 2007-2008



GW Elevation FW 2010-2011



**2003-2004
Elevation (ft)**



**2007-2008
Elevation (ft)**



2010-2011 Elevation (ft)

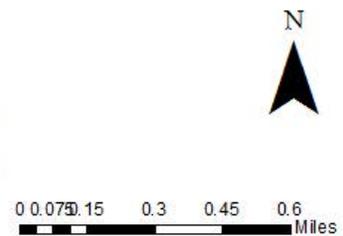


Figure 3. Temporal variations of groundwater elevations for fall and winter

Overview Groundwater Quality

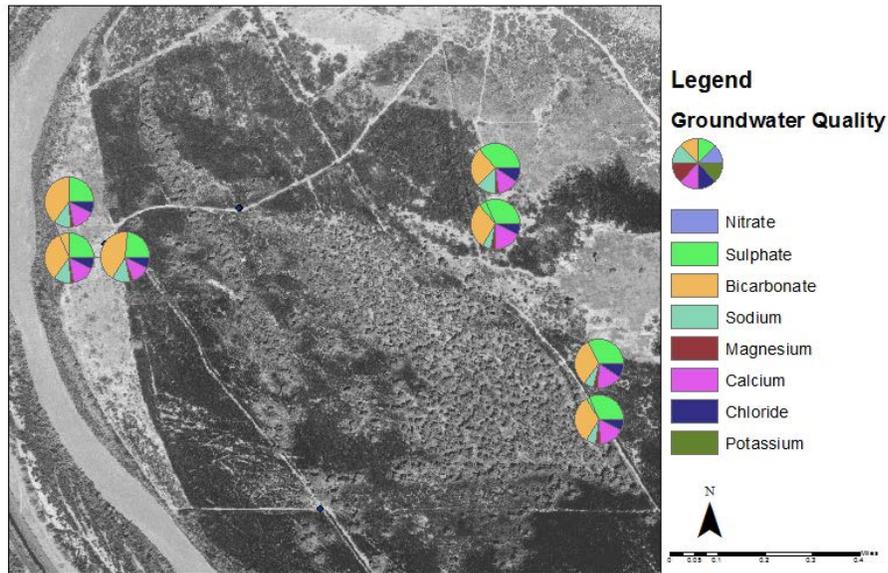


Figure 4. Overview of the groundwater quality on the Rhodes property

Finally, Figure 5 shows the proposed vegetation plan and based on the “Landscape Plant Lists for Salt Tolerance Assessment” published by Texas Agricultural Experiment Station (See Appendix) it can be concluded that the chloride concentration in the groundwater is not harmful for any of the proposed species of plants and shrubs, therefore these could potentially grow anywhere around the property (Figure 6).

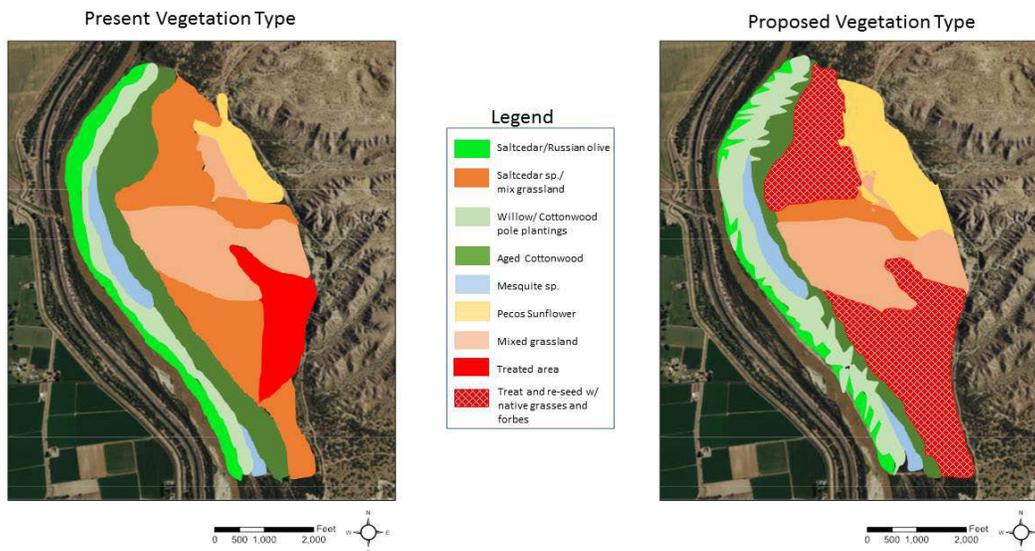


Figure 5. Current vegetation vs proposed restoration approach

Proposed vegetation and groundwater salinity

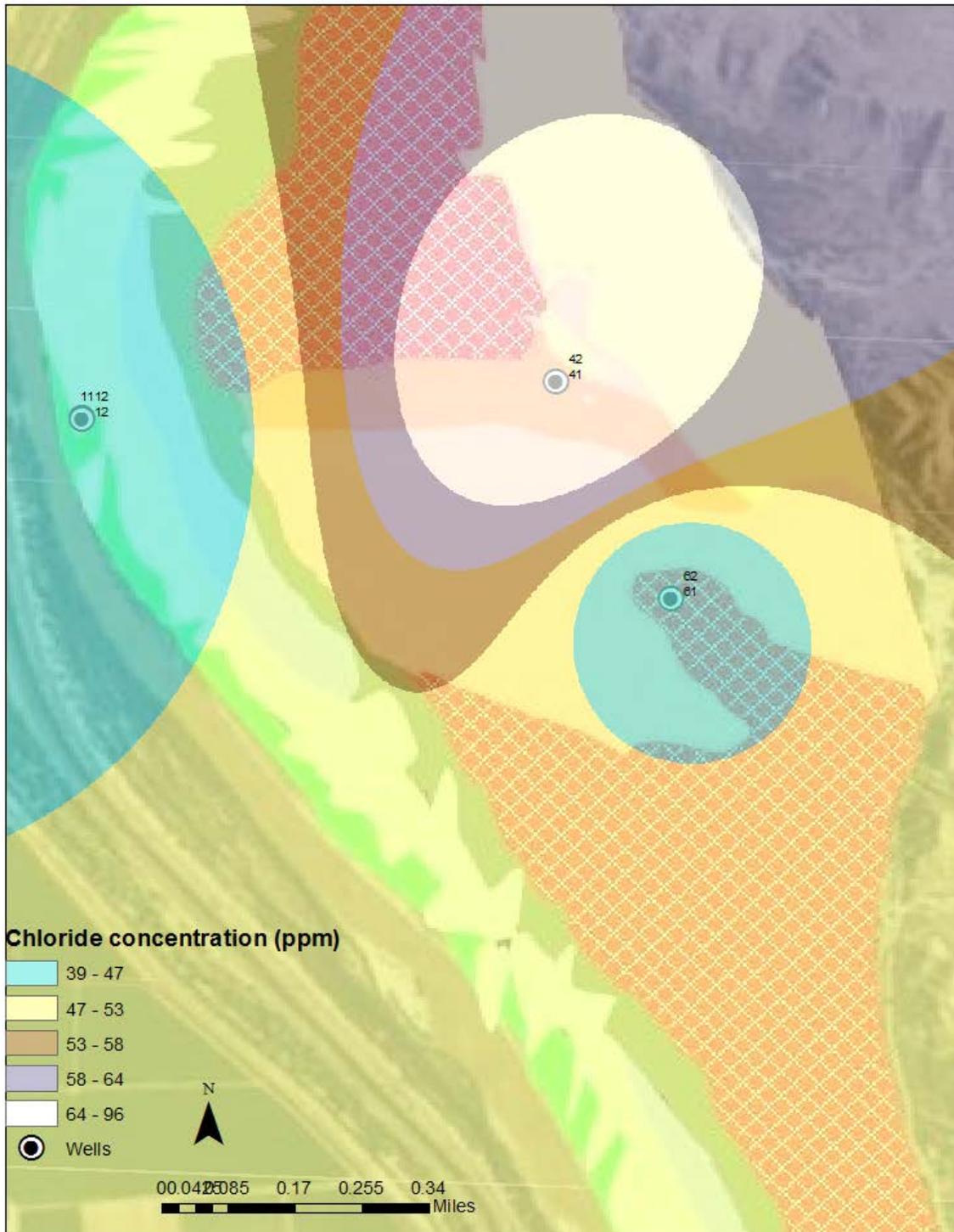


Figure 6. Overlay of groundwater salinity with proposed vegetation

Conclusion

The groundwater and the surface water are very well connected in this reach. The water quality meets all the public standards for drinking water supply with no treatment and is suitable for growing the proposed plants and shrubs for our restoration project. Finally GIS is a very useful tool for analyzing groundwater, in the future it would be interesting to directly model surface water influences in groundwater recharge and long term effects of evapotranspiration due to the change in vegetation.

References

Miyamoto, S., Martinez, I., Padilla, M., Portillo, A., & Ornelas, D. (2004). Landscape plant lists for salt tolerance assessment. *USDI Bureau of Reclamation*.

Vaughn, K. J., Porensky, L. M., Wilkerson, M. L., Balachowski, J., Peffer, E., Riginos, C. & Young, T. P. (2010) Restoration Ecology. *Nature Education Knowledge* 3(10):66

Wohl, E., Lane, S. N., & Wilcox, A. C. (2015). The science and practice of river restoration. *Water Resources Research*, 51(8), 5974-5997.

Websites

Aquaveo: <http://www.aquaveo.com/software/ahgw-groundwater-analyst>

SOBTF: <http://www.sobtf.org/#!completed/c1n52>

GSA: <http://www.gsanalysis.com/>

Appendices

Step by step procedure

Groundwater elevation analysis and groundwater quality statistics

1. Create a table in excel with the information required by the AHGW (general well information plus time series data). Open ArcCatalog and create a new geodatabase. Create a feature class to contain all the general information needed for the wells, in addition to that create as many tables as needed for the time series analysis, Figure A1 displays the basic fields needed for the feature class and the tables respectively.

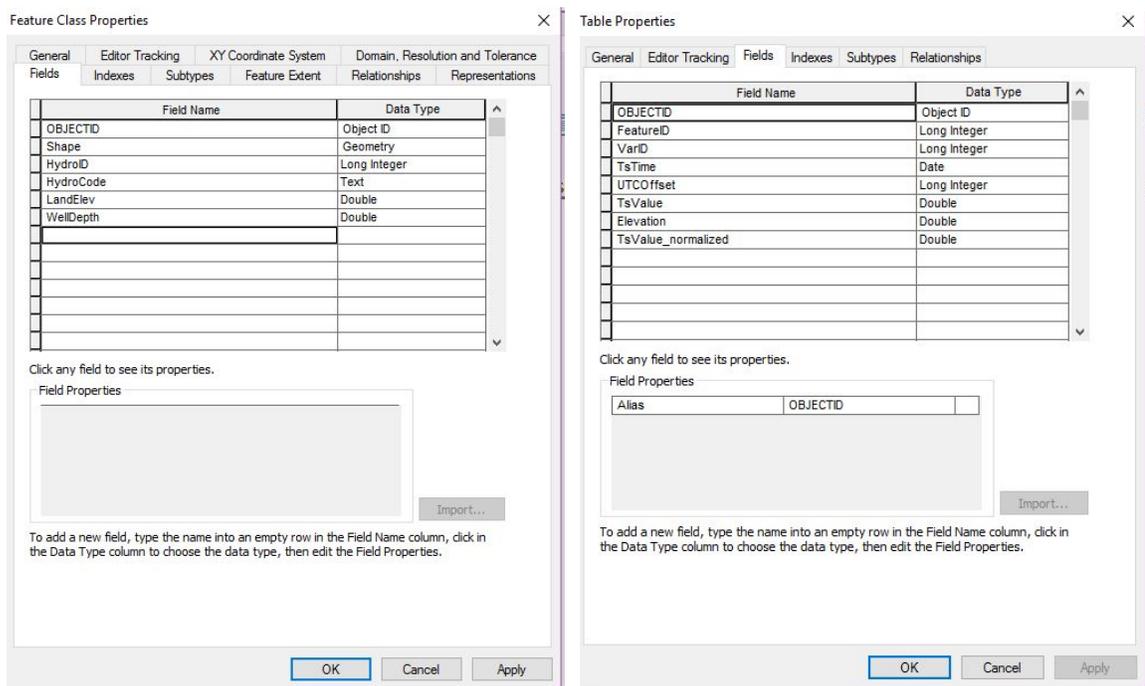


Figure A1: Example of the fields needed for spatial on the table

- Open ArcMap 10.1. Add the shape file of the Rhodes property. Add in the working map all the feature class and tables created in the previous step. Open the Text Import command on the AHGW toolbox. Import the table with the general information from the wells and select the proper header (Figure A2), associate all these data with the feature class. Once the importing process is completed successfully, open the attribute table of the feature class and use the Field Calculator to make the HydroID=HydroCode in order to have a field that would allow you to connect the feature class with the TimeSeries table.

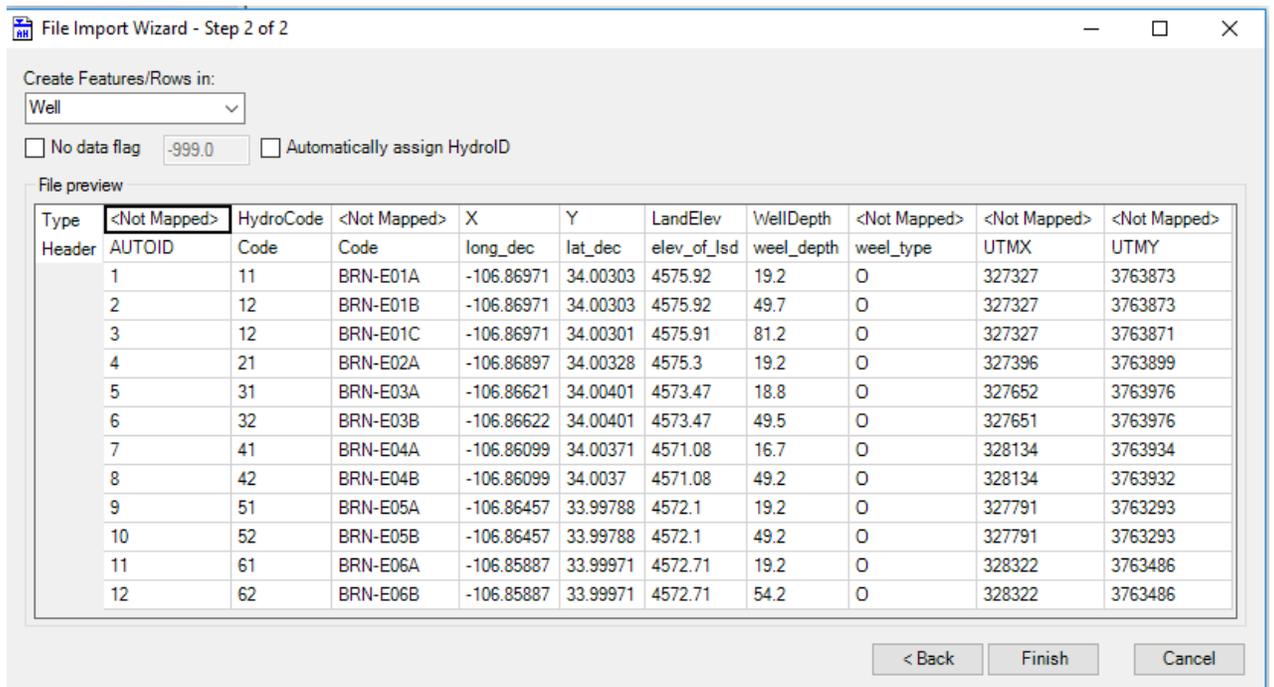


Figure A2: Importing data for the wells

- Use the Import Text command on the AHGW Toolbar to import the data for the water elevation (repeat this procedure several times for all the other water quality parameters) and select the headers as appropriate (Figure A3). Once completed the importing process, open the attribute table and use the field calculator to make VarID=1. In general this field is used to identify the type of time series and is an index to a separate VariableDefinition table. Since for the project only one type of variable is imported per each TimeSeries table, this number equals to 1.

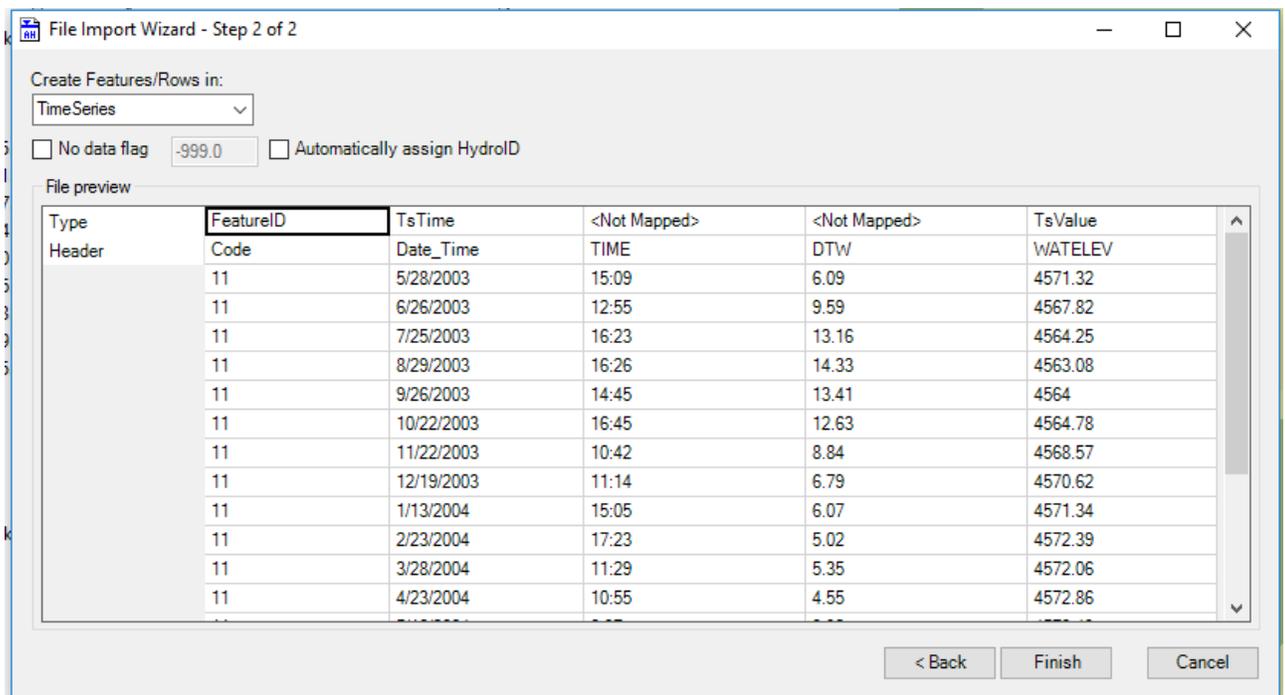


Figure A3: Importing data for time series

4. Calculate time series statistic for a specific time interval using the Make Time Series Statistics Toolbox on AHGW Toolbox. The database provided to me comprised the periods Fall 2003 through Summer 2014. To better understand the temporal aspects of the groundwater I divided my time series analysis in Spring-Summer and Fall-Winter for each year and I chose the mean value as a statistical parameter (Figure A4).

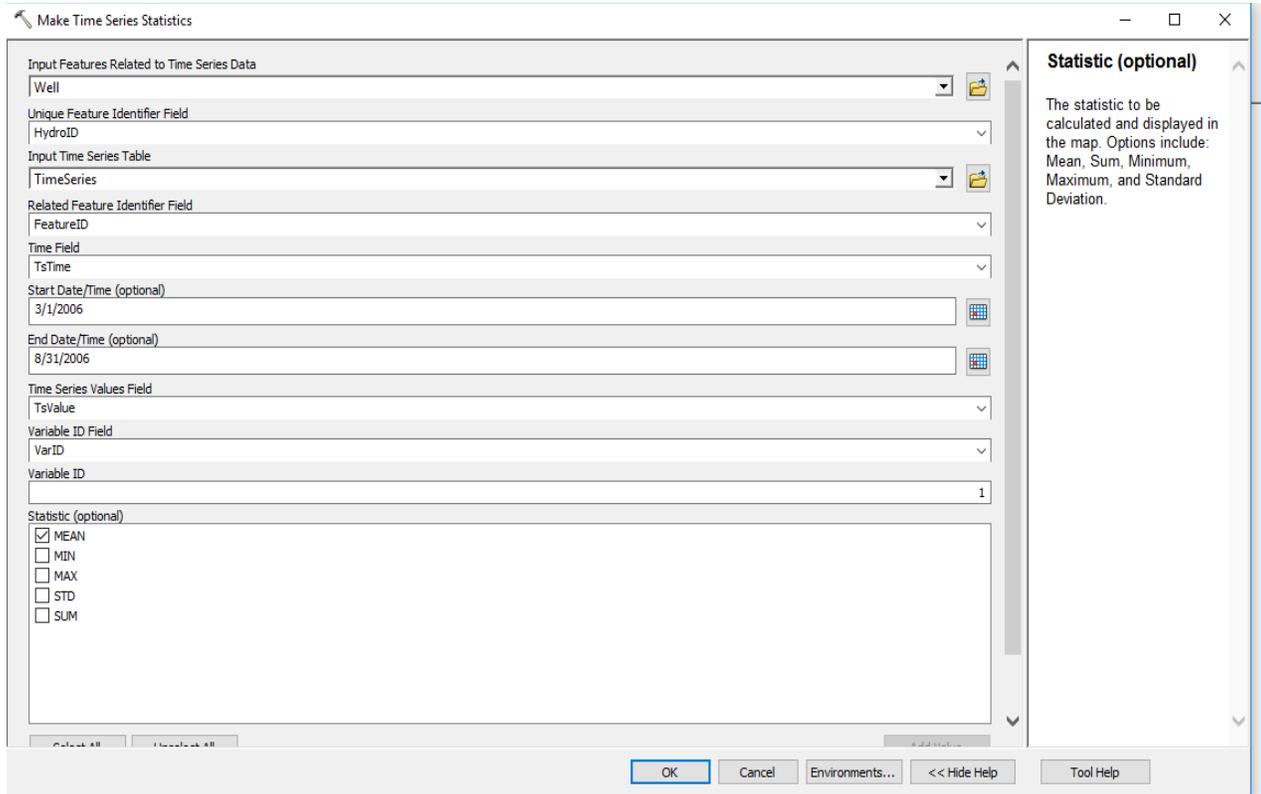


Figure A4. Time Series Statistics for Spring-Summer 2006

5. Build a small model using the Model Builder tool (Figure A5), in order to optimize the process of creating time statistics for each season and water quality parameter. Moreover right click on the model and create a Batch with all the different time periods to be introduced in the model. Then waited until all the processes is completed, you will see all that the new feature classes were added to the working map.

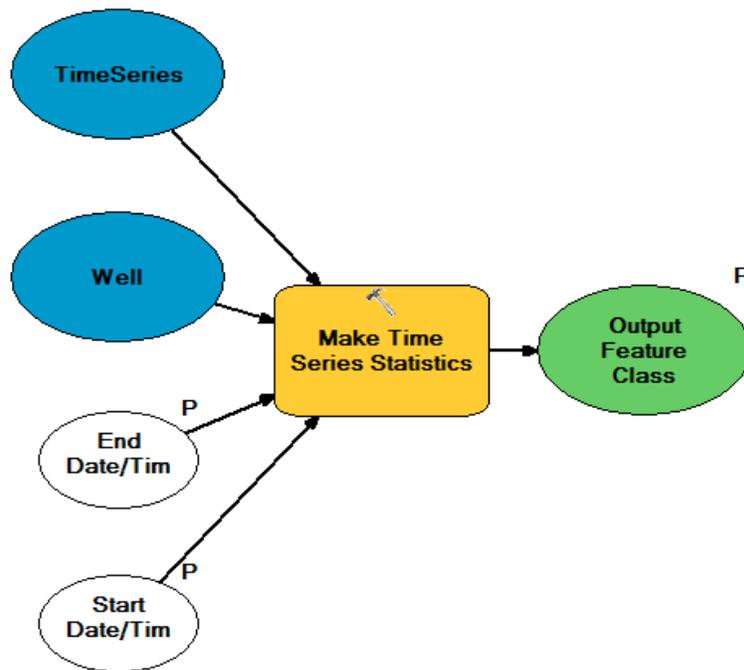


Figure A5. Simple Model to calculate Time Series Statistics

- Interpolate the point statistical data to a raster using the Inverse Distance Weighted (IDW) interpolation tool within the Spatial Analyst toolbox (Figure A6). Make sure to set up under Environment → Processing Extent → Same as layer shapefileRhodes and under Raster Analysis → Mask option to shapefileRhodes.

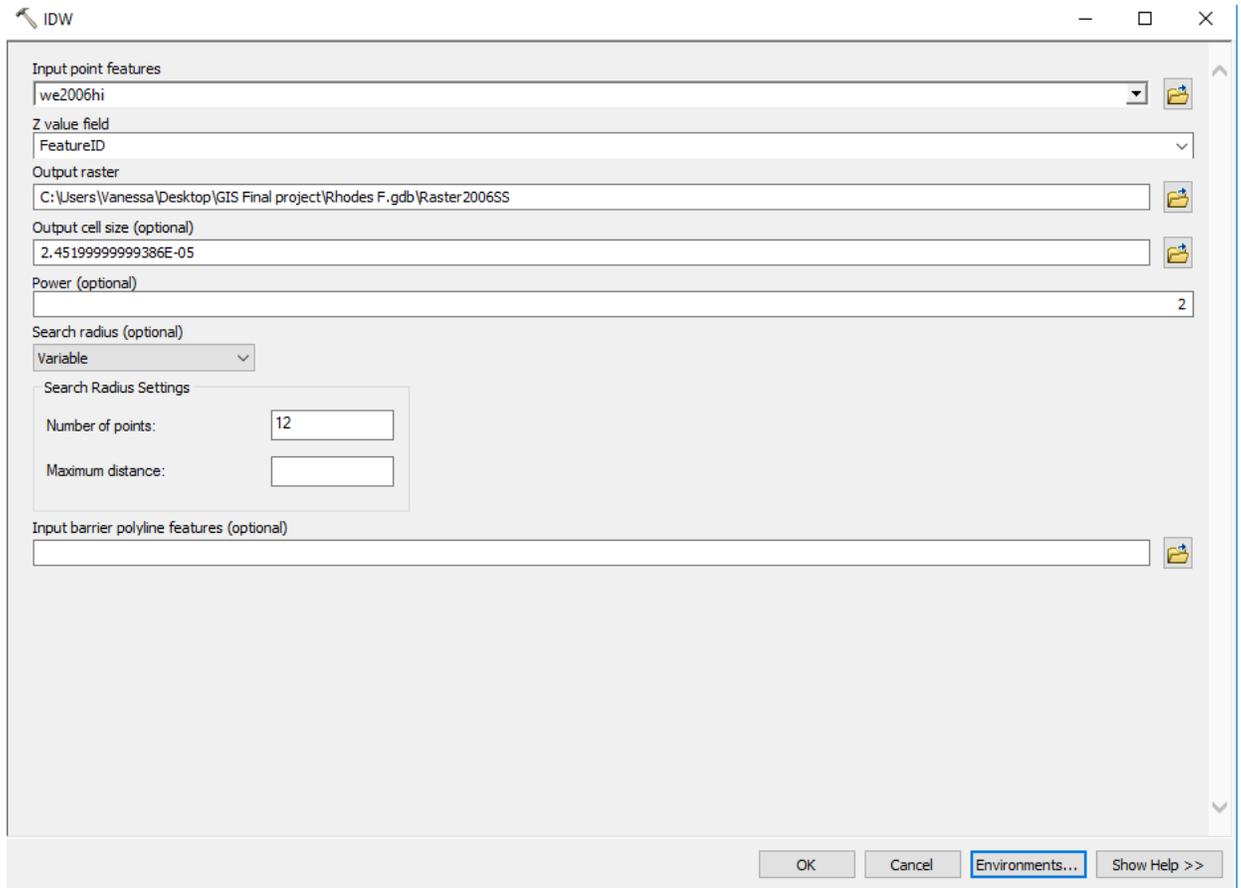


Figure A6. Interpolating raster from wells Summer-Spring 2006

- Repeat step 6 for all the other seasons and repeat steps 3-6 for all the water quality parameters

Groundwater quality figure

1. Once time statistics are created for each water quality parameter one individual feature class is also added to the ArcMap document. In order to create an informative map you need all the parameters within the same feature class. In that sense, join the feature classes using the FeatureID to a “main” feature class called Groundwater quality (Figure A7).

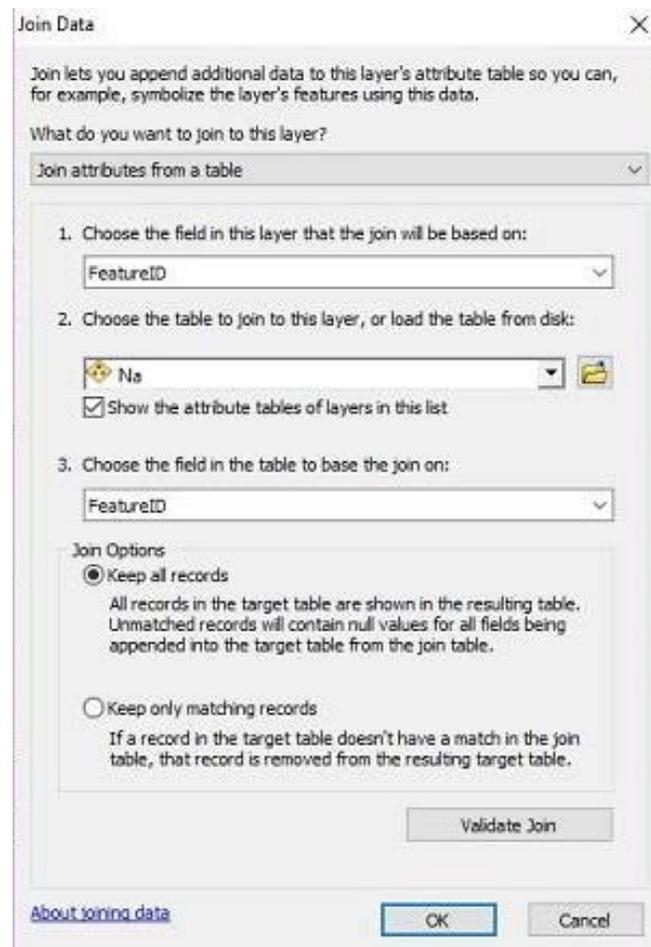


Figure A7. Joining tables and feature classes

2. Once you joined all the tables, create as many fields as parameters needed. Then use the field calculator to equal the statistical values to the new field creates. Remove the joins.

3. Finally change the Symbology of the Groundwater quality feature class. Charts → Pie (Figure A8).

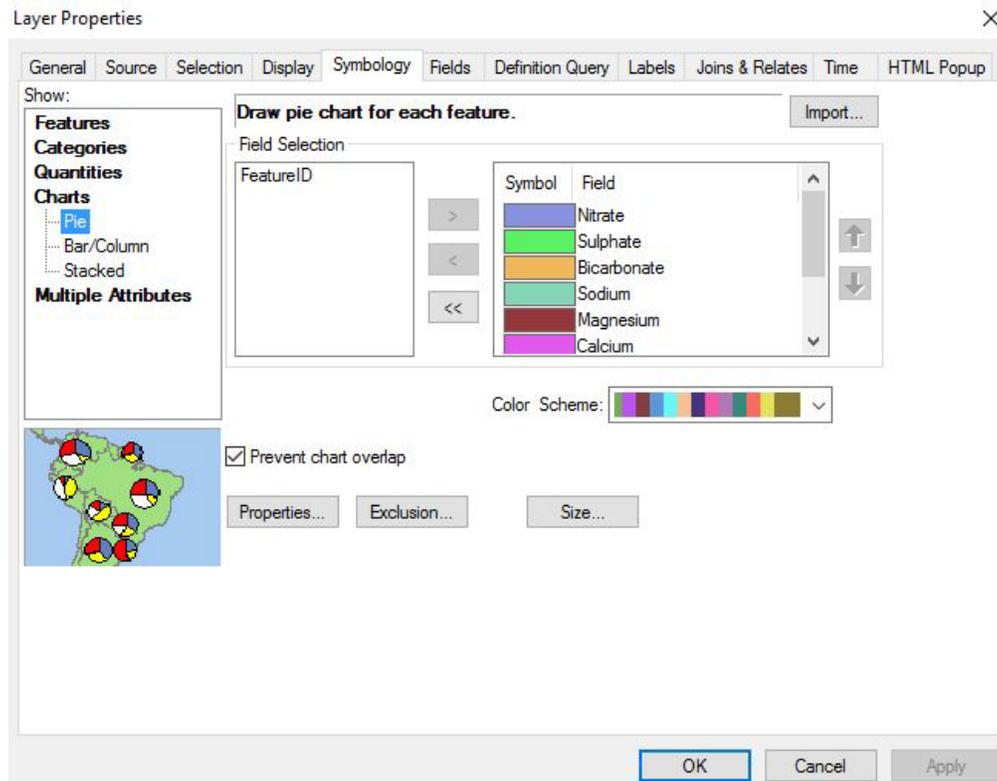


Figure A8. Symbology for pie charts

Overlaying salinity raster and vegetation picture

1. Open ArcMap 10.3.1. Load the Rhodes property shapefile. Activate the Georeferencing menu. Add the image that you want to georeference (proposed vegetation).
2. Zoom to the layer of the Rhodes shape file, then select the jpg that you want to reference and on the Georeferencing menu choose Fit to Display. You will notice that both images overlap but they don't exactly match with each other.

3. Select at least 4 point that can be common and identifiable from both images. Moreover click on the Add control Point tool. Click first on the jpg and then on the shapefile. Repeat this for all your point. Then click Rectify (Figure A9)

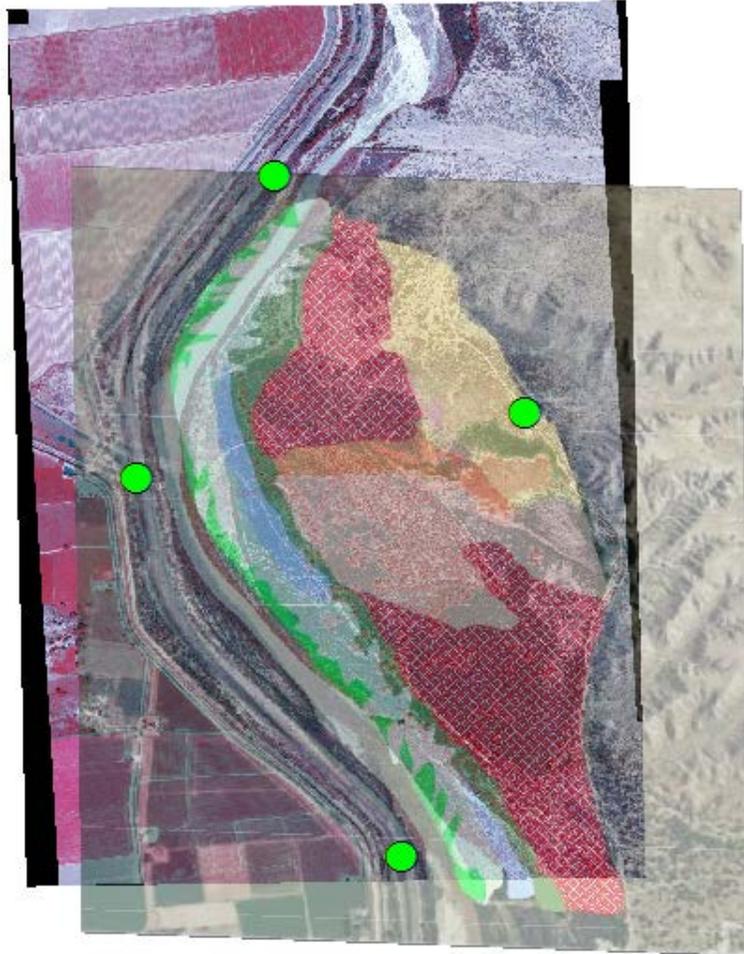


Figure A9. Final product after Georeferencing the jpg with the Rhodes shape file

4. Using the groundwater quality data, interpolate a raster using the steps described above. Add the interpolated raster to the working map and compare with the proposed vegetation (Figure A10).

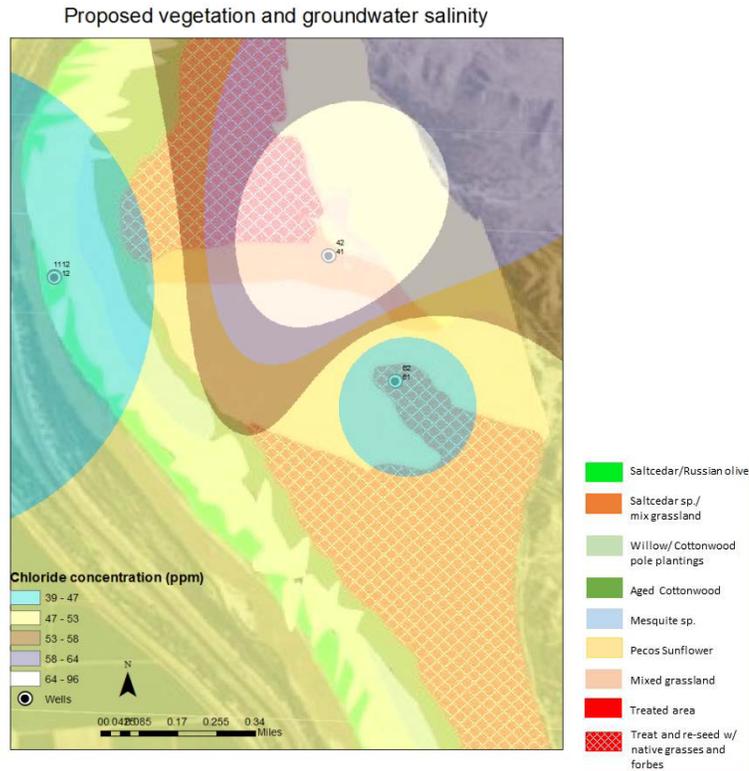


Figure A10. Overlay groundwater salinity with proposed vegetation

By analyzing the information provided on the “Landscape Plant Lists for Salt Tolerance Assessment” published by Texas Agricultural Experiment Station (see extract in Table 1.), it can be seen that both the current vegetation as well as the proposed vegetation (Figure A11) have a salt tolerance higher than the current salinity of the water, which determines that that chloride concentrations in the property are not harmful for the proposed restoration activities.

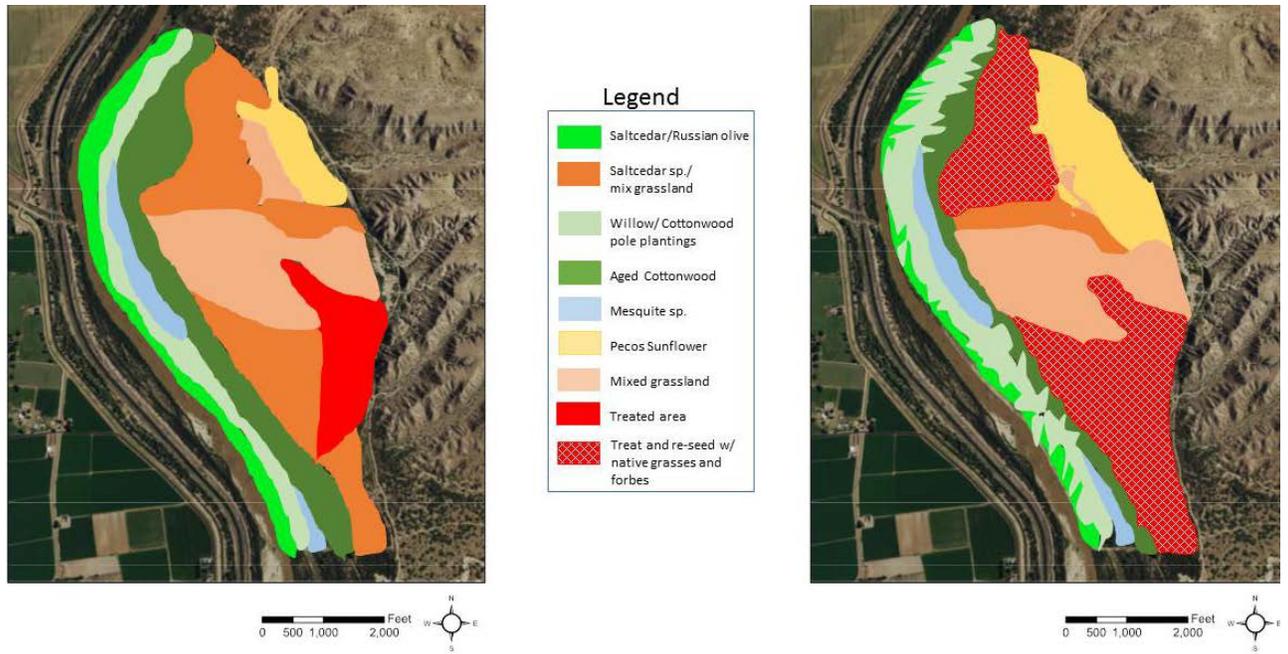


Figure A11. Current vegetation vs proposed vegetation

Table 1. Extract from “Landscape Plant Lists for Salt Tolerance Assessment” targeted to the species of interest for this study.

Common Name	Botanical Name	Threshold (mmhos/cm)	Chloride concentration in ppm (mg/L)
Cottonwood	<i>Populus fremontii</i>	2.1-4.0	145.8-291.4
Mesquite	<i>Prosopis glandulosa</i>	2.1-4.0	145.8-291.5
Willow	<i>Chilopsis linearis</i>	2.1-4.0	145.8-291.6
Salt Cedar	<i>Tamarix sp.</i>	8.0-10.0	598.0-751.2
Russian Olive	<i>Elaeagnus angustifolia</i>	6.0-8.0	445.0-598.0