2010

Springs of Texas Project

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Texas Hydrological Innovations

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Abstract

Springs are characteristic of Texas' unique landscape and diversity. The springs are currently documented and monitored by various organizations and agencies throughout the state. The data that are collected and available will vary according to different sources. Currently, spring data exists in formats that limit access of this data to exclude large portions of the community. It is our goal to combine these data to create a comprehensive database that is accessible for all in the community. The best way to preserve these extraordinary features is through a shared community effort. It is our goal to generate a public interest in Texas' springs. Using ArcGIS software, Texas Hydrological Innovations (THI), successfully combined the data from four databases (listed in Table 1) to create one comprehensive database. The comprehensive database is available in two formats: shapefile and a Keyhole Markup Language Zipped (KMZ). Our comprehensive database will offer a platform for further research while allowing members of the community to have access to spring data throughout the state. Allowing the community to have access to these data will promote the preservation of one of Texas' most precious resources.

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1 Introduction

1.1 Background

Springs are naturally occurring features creating a valuable freshwater resource for Texas. Texas Springs have tremendous economic, cultural, ecological, aesthetic, and recreational value. Springs can be formed in any kind of rock; however, most of the aquifers in Texas are sedimentary (USGS, 2010). Springs form from when a weak carbonic acid (solution formed when precipitation mixes with the carbon dioxide in the air and soil) dissolves the rock creating caverns and aquifers. Aquifers and caverns are characteristic of Texas topography. The aquifers store and transmit the groundwater and Texas contains nine major aquifers and 21 minor aquifers (TWDB). The amount of water that issues from a spring depends on many variables including aquifer water pressure, the rock sizes in the cavern, spring basin characteristics, precipitation trends, and anthropogenic uses. Anthropogenic uses include consumption and extraction for irrigation, agriculture, sanitation, industry, and energy. Since springs are recharged through precipitation, a spring's health is a delicate balance between its physical composition, its use, and precipitation availability. Spring flow can vary greatly, with some springs having a relatively constant flow while other springs will have flow that fluctuates greatly according to season and precipitation trends. Discharge from springs ranges from thousands of gallons per minute (gpm) to almost nothing (Besse, 2010). Texas' springs have a remarkable importance to the state and are a symbol of Texas' diversity.

1.2 Problem

Springs in Texas are documented by various agencies and organizations throughout Texas. The current problem is that a particular spring's exact spatial location and attribute data may vary according different sources. The various sources for spring data has resulted in duplicate data entries for the same spring. For without access to GIS software, Texas' spring data is not easily accessible due to the format it is in. Currently, the spring data exists in a shapefile format or the data can found through complicated queries from the source website. Most people do not have access to GISsoftware and do not have the GIS training required to operate the software; therefore, the data is currently unavailable for many Texans.

ArcGIS is software that provides a standards-based platform for spatial analysis, data management, and mapping. ArcGIS was utilized by THI for efficient data management. Using ArcMap, THI was able to proficiently integrate the data from multiple tables into one central table (ESRI, 2010).

1.3 Objective

The goal of THI was to combine the data from four primary databases into one comprehensive map based database. The springs in the resulting comprehensive databaseare compiled in shapefile format for those that have access to GIS software. In addition, spring data was created in a user friendly format, compatible with Google Earth, for those without GIS software access. It is the goal of this project to create a resource for all those interested in learning more about Texas' springs. Through education and awareness, we hope to generate a public interest to preserve one of Texas' most remarkable features. This comprehensive database will potentially serve as a platform for additional data collection, documentation, and analysis for the springs in Texas. Ideally, this database will be used to add new or additional springs in order to build a more resourceful database. The expanding population requires a collaborated effort to ensure that there is enough fresh water to sustain current and future populations.

1.4 Scope

The spatial extent for this project included the state of Texas (shown in Figure 1). The state of Texas includes 254 counties, which were divided into zones. The zones were used to determine processing order of the springs.

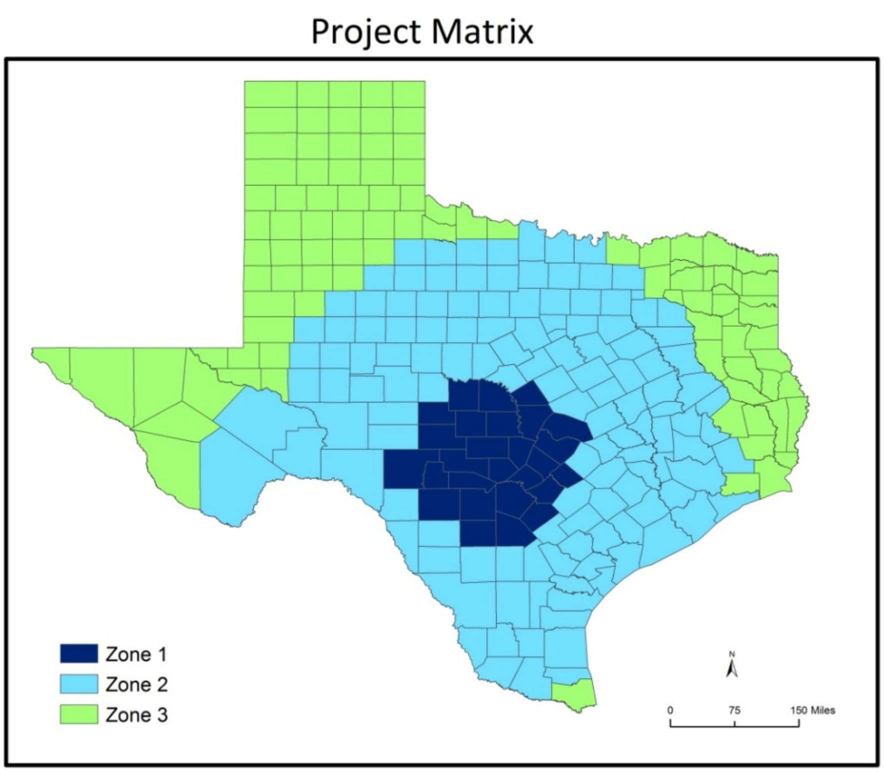


Figure 1. Zones indicate analysis organization and order.

1.5 Literature Review

In his thesis David Flores stated that "The importance of Texas groundwater has grown substantially in recent years due to population increase and drought" (Flores 2006 pg1). There is a need for extensive research on Texas' springs. Before the 1960s, little to no data was available on groundwater concerning the declining water table or Texas' springs. Detailed studies have only been made in the last 50 years or so (Brune 1981). Gunnar Brune made it his life's work to research the past and current state of springs in Texas. Brune stated that "we desire the opportunity to work exclusively with Texas' natural springs. Data for manmade springs and wells will not be considered" (Brune 1981). His desire to work exclusively with natural springs in Texas has provided THI with a dependable source that functions within the same scope as this project.

Natural springs have distinct characteristics that necessitate their existence. Springs must have:

1) An aquifer commonly composed of sand, gravel or limestone, capable of
2) carrying water to the spring
3) A sufficiently large recharge zone
4) Rock beds level or sloping toward the spring
5) Enough difference between the elevation of the recharge area
6) individual spring's elevation to cause issuing of groundwater
    i. A water table high enough to form a substantial hydraulic gradient
7) in the direction of the spring (Brune 1981 pg 4)

All of Texas' fresh water is replenished from precipitation collected on the Earth's surface and only 6% recharges the water table. The remaining precipitation is lost to runoff and evapotranspiration (Brune 1981). This suggests that ground water is far less reoccurring than perhaps commonly believed. If we can agree that spring water is the lifeblood of Texas, then we should agree that its preservation is obligatory. However, there is much evidence pointing to the decline of Texas' springs and their issuing aquifers.

Mr. Brune reported that "The story of Texas' springs is largely a story of the past. Many are gone" (Brune 1981 pg xvii). For example, travertine, formed by precipitated calcium bicarbonate in spring water, has been found many meters above existing springs. This suggests that the water table and springs were once located at higher elevations and have since receded (Brune 1981). Another indication of spring decline is the loss of water- loving trees. Many Cottonwoods to the west, Cypresses in the east, and Willows throughout the state of Texas are diminishing seemingly due to the decline of springs, caused primarily by human actions. Brune reported that "Heavy well pumping of underground waters for irrigation, municipal, and industrial purposes has continued the decline and disappearance of Texas springs" (Brune 1975 pg 1). Irrigation accounts for most of the groundwater usage. The USGS estimated that irrigation efforts generated around 6.4 billion gallons of groundwater withdrawal per day in 2000 (Flores 2006).

The majority of Brune's work provides collections of flow records, water quality analyses, contamination reports, historical documents and maps, archeological reports, and biological studies related to the springs which he collected before performing field work. Once in the field, Brune performed chemical tests on spring water and studied geologic structure and lithology. He also took photographs of the springs in order to provide additional information on the environments found in and around Texas' springs (Brune 1981). Brune's research for 183 Texas counties was compiled and published in Springs of Texas Volume One in 1981. It was intended that the data for the remaining 71 counties would be released by Brune in a follow-up edition to the original publication. Brune never finished the follow up edition pertaining to the remaining 71 counties. Helen Besse, in coalition with the Ecological Recovery Foundation resumed the work of identifying the location of Texas' springs and their characteristics. She managed to compile much of the remaining unpublished data and notes collected by Gunnar Brune. She published the data for the TWDB in Interim Report for Contract No. 2006-001-069, which discussed the springs in the 71 counties that were excluded from Springs of Texas Volume One.

Throughout the state of Texas, other studies on springs have been conducted pertaining to specific regions. Extensive research has been done on the Edwards Aquifer while the Trans-Pecos region of Texas has received little attention. David Flores conducted research on the Trans-Pecos region of Texas in which he utilized the piper diagram in order to analyze water quality. The Piper diagram displays the major cations and anions contained in spring water and it depicts groundwater's previous interaction with geologic structures in the aquifer and recharge zones (Flores 2006). Such information will lead to a greater understanding of aquifers and their spring's, allowing for more advanced analysis and problem solving.

2 Data

The data used for the completion of this project consists of Heitmuller and Reece (2003), Texas Water Development Board (TWDB), USGS Compilation of Historical Water-Quality Data in Texas, and USGS National Water Information System (NWIS). The Ecological Recovery Foundation (ERF) data was researched but was not included in the project due to privacy issues with the spring owners. Raymond Slade, Jr. PH directed THI to the four databases that were used for the completion of the project.

The Heitmuller and Reece database was obtained from a disk given to THI. This database was in shapefile format and was input into ESRI ArcMap. The TWDB database was obtained through a query search. The data was processed in Microsoft Excel and then converted into Microsoft Access. Microsoft Access was then used to convert the file into a database file, which allowed for the database to be implemented into ESRI ArcMap. NWIS and USGS Compilation of Historical Water-Quality Data were obtained from their websites in shapefile format. These shapefiles were applied into ESRI ArcMap.

Heitmuller and Reece collected and processed data but also used USGS data to complete their database. USGS collected and processed the data for NWIS and USGS Compilation of Historical Water-Quality Data in Texas databases. TWDB collected and processed data and also used USGS data for the completion of their database. THI processed the data from the four mentioned databases but did not collect any primary data themselves.

The data was based on the need to aggregate data from several sources into a single comprehensive database. The data was used to perform a comparative and statistical analysis for the creation of a single database of the springs in Texas. The field names in the attribute table were created by THI so that the novice user would have the ability to understand the data.

County and river basin names were added instead of relying on the numeric codes. This was created to provide relevance of the numeric codes for the novice user.

3 Procedure

THI integrated data from the above mentioned databases to create a comprehensive map-based database of the springs in Texas. THI created a systematic standard for the categorization of the spring data. The standard was created by locating commonalities in attributes between the primary databases and determining which other attributes were pertinent to the study. A unique standard for this project was created using Microsoft Excel. The attribute table created from the standard was then converted into Microsoft Access. Using Microsoft Access the file was converted into a database file and then implemented into ESRI ArcMap.

THI operated by organizing the springs by county and applied the counties to a series of three prioritized zones. Zone 1 included 992 springs issuing from 27 counties and this represents 44.4% of the total known springs in Texas. Zone 2 included 587 springs issuing from 131 counties and this represents 26.2% of the total known springs in Texas. Zone 3 included 658 springs issuing from the remaining 96 counties and this represents 29.4% in Texas. THI performed a comparative analysis one county at a time. Each team member was assigned specific counties for the analysis.

Using the standard that THI created, a comparative analysis was completed and pertinent data was added when available. All springs that were common to more than one database were compiled into one Excel table. Springs that existed in only one database were added to a separate Excel table. When duplicate data was found, THI combined the data. When the USGS spatial location for a spring was available, it was determined to be the most accurate. If the USGS spatial location for a spring was not available, Heitmuller and Reece and then TWDB were utilized. When the coordinates were only found in TWDB they were converted into decimal degree format from degrees, minutes, and seconds format. Elevation was only found in the Heitmuller and Reece, TWDB, and USGS Compilation of Historical Water-Quality Data in Texas databases. When the Heitmuller and Reece elevation for a spring was found it was determined to be the most accurate. If the elevation was incomplete, USGS Compilation of Historical Water-Quality Data in Texas and then TWDB were used. Owner information was only located in the TWDB database. For all other attributes, when available, Heitmuller and Reece was used first followed by NWIS, USGS Compilation of Historical Water-Quality Data in Texas and then TWDB. The attribute table was then simplified and instead of using numerical codes to identify county name, river basin, and coordinate accuracy THI added a column for each of these by using the common name.

THI used Heitmuller and Reece to complete a statistical analysis for flow discharge data for springs when the data was available. A unique standard for this project was created using Microsoft Excel. For each spring that had available data, the number of records and earliest and latest date were recorded in the Excel book. When there was more than one record found, the 90^{th} percentile, 10^{th} percentile, and mean flow were calculated using the statistical tools in Excel. The attribute table created from the standard was then converted into Microsoft Access. Using Microsoft Access the file was converted into a database file and then implemented into ESRI ArcMap.

The two GIS layers were joined together. The joined GIS layer was then converted using a Keyhole Markup Language (KML). The KML produces a .kmz file that allows for the spatial display of the springs in Texas in an interactive format using Google Earth. Applicable field names in the interactive map were given an appropriate alias to better explain the attributes to a novice consumer

Figure 2. Procedure

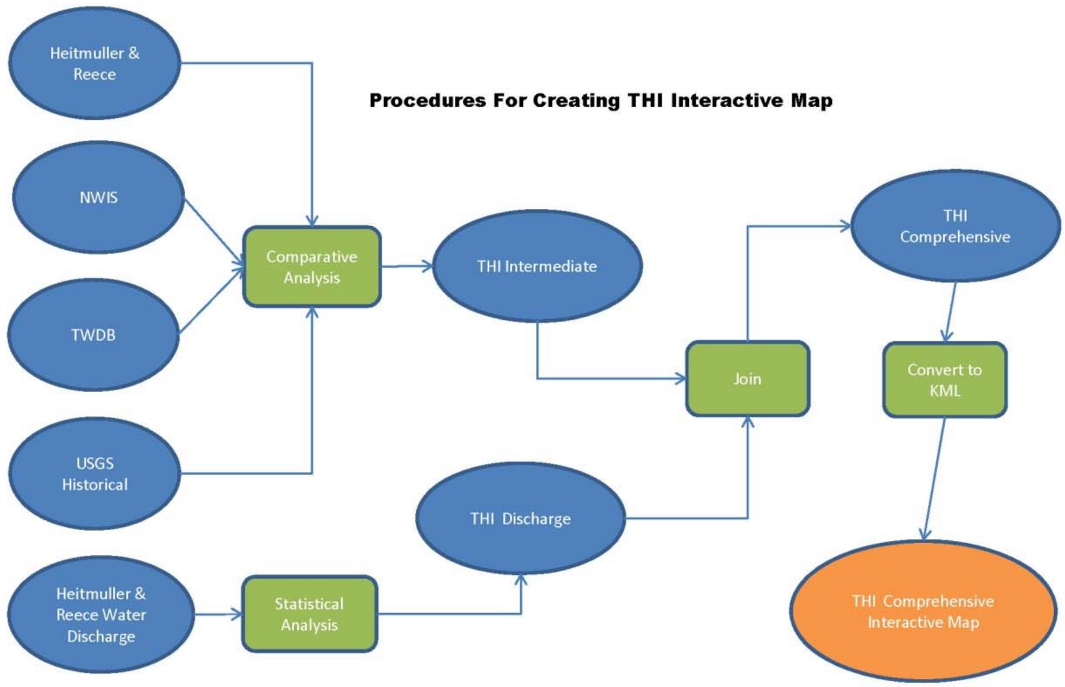
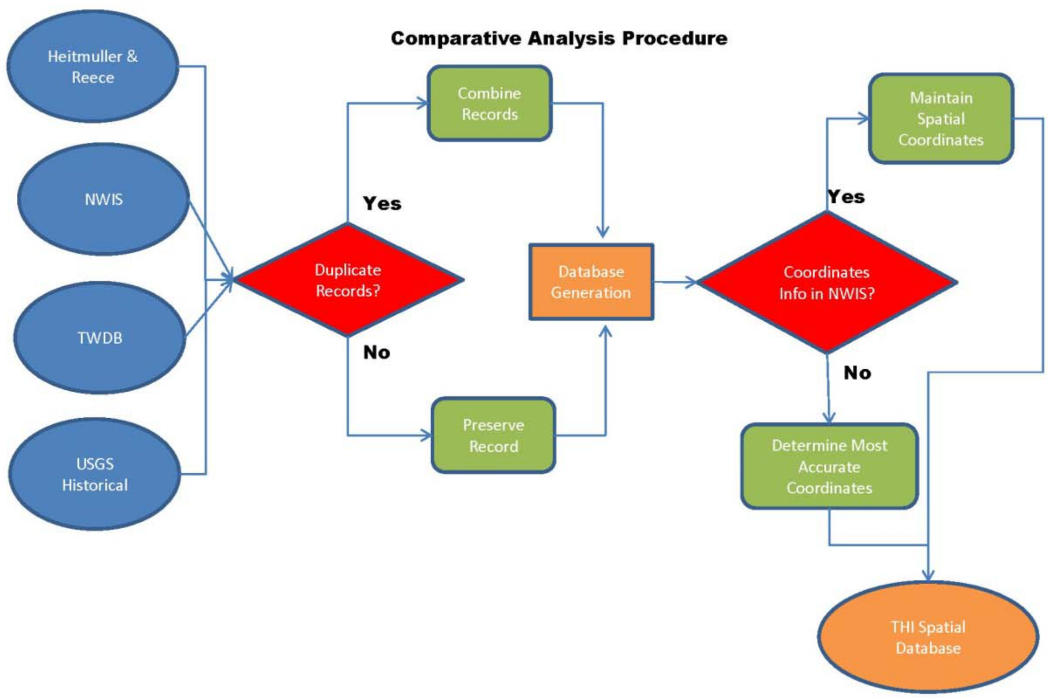


Figure 3. In depth Analysis



4 Results

Over the past ten weeks, THI has worked to produce a comprehensive map based database that serves the purpose of improving freshwater management in Texas. As previously discussed, data for springs in Texas is scattered and not conducive to promoting efficient freshwater management. As a result of combining the databases, the THI Comprehensive database shares springs common to multiple databases in addition to springs found in only one database. The comprehensive database eliminates data inconsistency and duplicate data. The following table shows the number of springs from each database as well as the total number of springs in the THI Comprehensive database.

Table 1. Datasets sources included in comprehensive database.

Database	Number of Springs
Heitmuller and Reece	2000
TWDB	2143
NWIS	2075
Historical Springs	232
THI Comprehensive	**2238**

THI analyzed each database carefully and based on expert decision, created a standard. The Excel spreadsheet with the updated standard was the first result produced by THI. The image shown in Figure 2 reflects the results of the standard created for spatial attributes of the springs.

NWIS_site_no	state_well_no	spring_nm	dec_latitude	dec_longitude	coord_acy	coord_acy_	elevation_ft	state_cd	county_nm	county_c	fips_cd	aquifer_cd	basin_nm	basin_cd	primary_use	secondary_use	owner
7307700	2210104	Roaring Springs	33.853333	-100.865278	+/- 1.0 sec	S	2480	48	Motley	345	48345	231DCKM	Red River	2	domestic	recreation	Matador
8103500	4163510	Hannah Springs	31.06889	-98.176944	+/- 1.0 sec	S	1000	48	Lampasas	281	48281	218TVPK	Brazos River	12	unused	unknown	Unknown
8127200	4353708	Anson Springs	31.13000	-100.48	+/-1.0 sec	S	2060	48	Tom Green	451	48451	218EDRDA	Colorado River	14	unused	unknown	H. Leslie
8129000	4350201	Spring Creek Springs near	31.221389	-100.814444	+/- 0.1 sec	H	2210	48	Irion	235	48235	218EDRDA	Colorado River	14	unknown	unknown	Reginald
8129500	4351403	Dove Creek Springs	31.185168	-100.731213	+/- 1.0 min	M	2175	48	Irion	235	48235	218EDRDA	Colorado River	14	unknown	unknown	Lillian Wi
8143900	5516106	Springs at Fort McKavett	30.83434	-100.093969	+/- 5.0 sec	F	2060	48	Menard	327	48327	218EDRDA	Colorado River	14	unknown	unknown	Unknown

Figure 4. Standard used for database attributes.

In addition to the Excel spatial data spreadsheet, THI also produced an Excel spreadsheet for discharge data. The following image (Figure 3) reflects the results of the standard created for discharge data of springs.

site_no	disc_src_cd	disc_dt	date_tm	disc_va	disc_meth	records	meanflow	10th_per	90th_ per	flow	date	remarks
7307700	A	1/1/1937	Y	480	R	153	618.27	480.21	726.60		1/1/1937-1/27/94	
8103500	S	1/17/1973	D	619.34	R	81	4556.58	476.17	1052.44		12/01/1909-04/04/1973	
8127200	Z	4/23/1905	D	2000	E	15	5232.30	2176.59	7243.63		4/23/1905-07/24/1964	Digital data acquired from Capitol Environmental Services.
8129000	Z	6/5/1936	D	2000	E	14	3600.22	2678.44	4399.59		6/5/1936-07/24/64	Digital data acquired from Capitol Environmental Services.
8129500	A	1/1/1967	Y	350	E	352	5461.81	2029.92	10771.20		04/26/1944- 09/17/2002	
8143900	S	1/25/1973	D	9559.44	R	136	8606.73	4151.40	14720.64		08/14/1942 -08/15/2002	

Figure 5. Template used for discharge attributes.

After the production of the database in Excel, production of the THI springs shapefile began. As a result of these efforts, THI produced an updated map based database that provides the GIS user with comprehensive spring data in shapefile format. The database used in a GIS allows for easy customer queries of the available data. With the shapefile, THI achieved the goal of providing a foundation for further scientific research however access to the database through this format is still limited to GIS users only. The following image(Figure 4) is a GIS map of springs in Texas.

Map Produced with ArcGIS

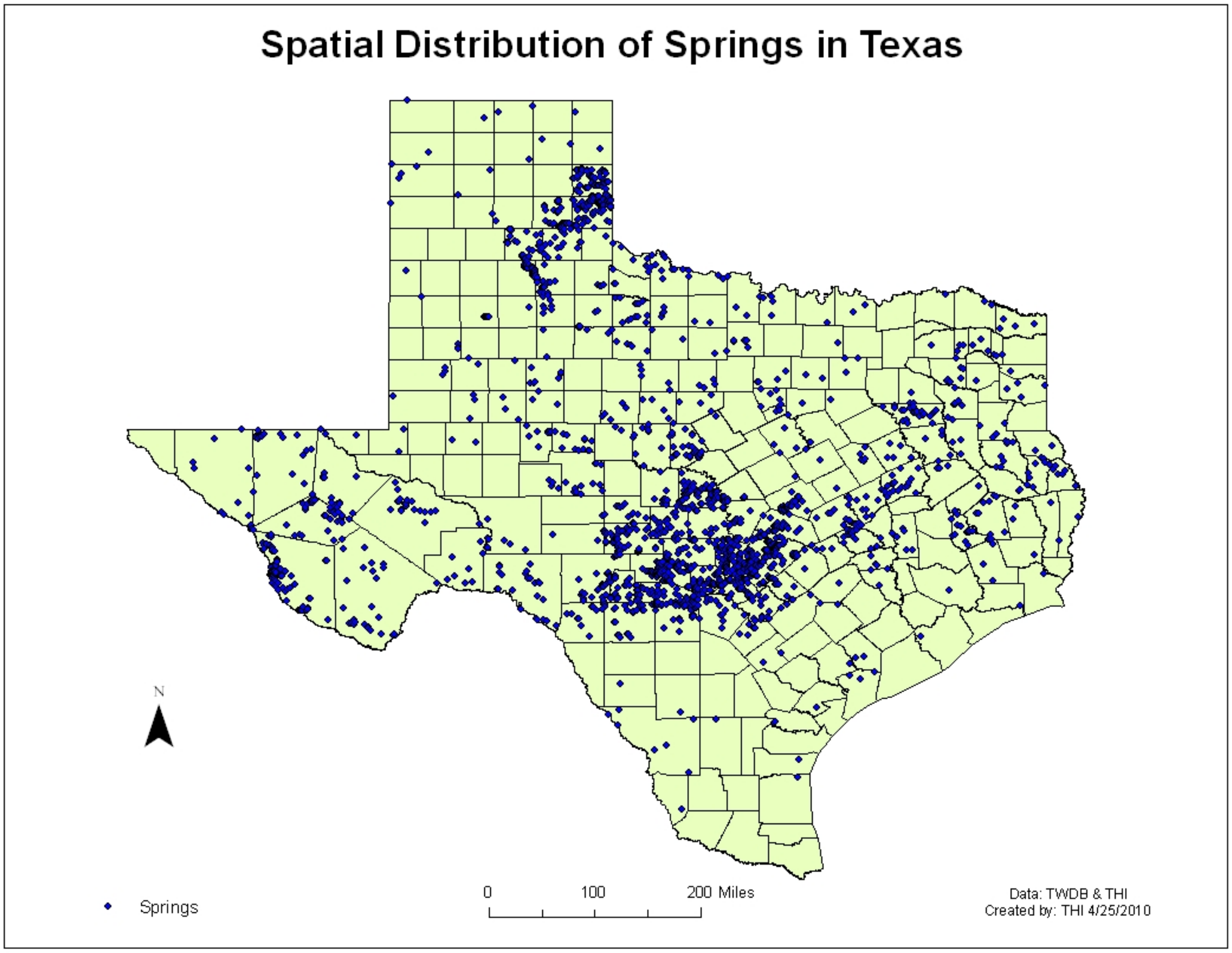


Figure 6. THI comprehensive database includes 2238 springs.

In order to have a significant impact on the community, THI reproduced the comprehensive map based database resulting in a final product that can be accessed and understood by those outside the scientific community. THI provided the user with an attribute table that has technical and nontechnical field names to satisfy the requirements of the professional hydrologist and the novice user. Hosted by the THI web site, an interactive Google Map (shown in Figure 5) has been produced that allows anyone with internet access to search for springs in Texas and view pertinent data in an easy to read pop up widget.

Interactive Google Earth Map

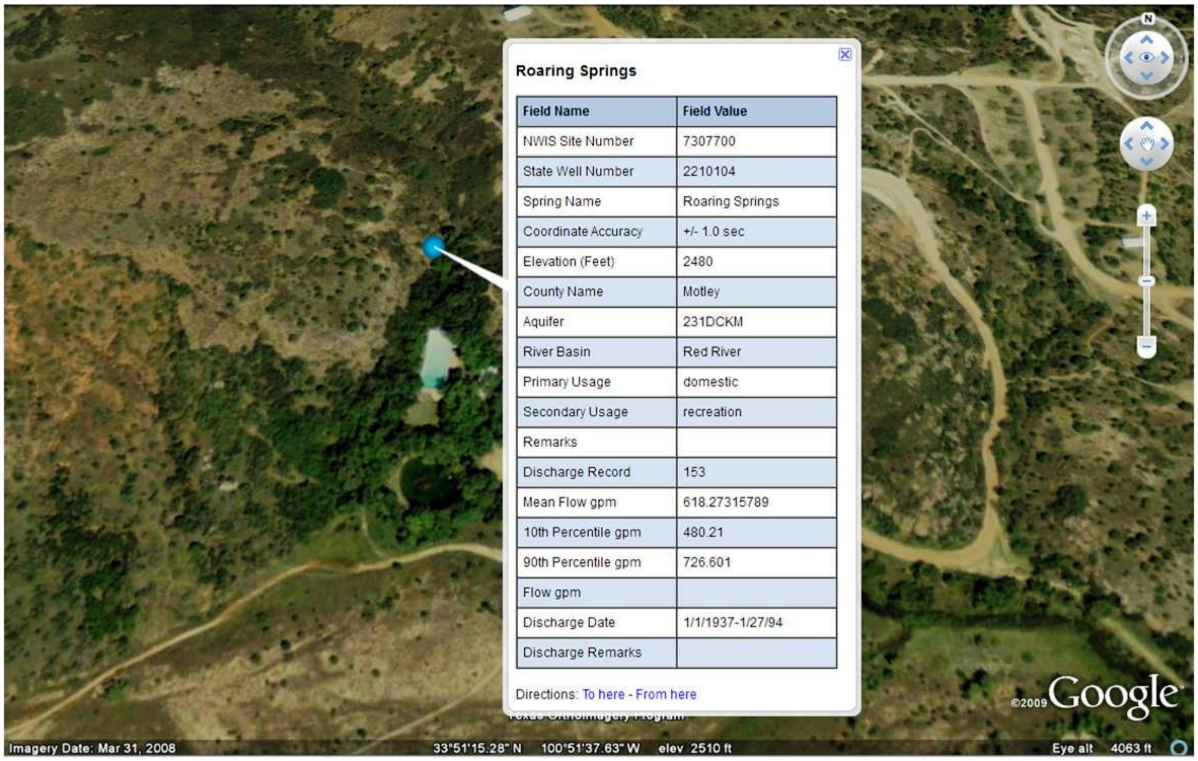


Figure 7. User friendly, interactive map.

The widget containing the spring data appears when a specific spring is selected in Google Earth. The fields have been simplified from their original format providing the user with clear data display that pertains to each individual spring. The website allows for any user to view the results of the project and to copy and/or print static maps and all other documents located on the web page.

The final result of the work performed by THI is an overview of the entire project presented in poster form. The poster allows for visual comprehension of the processes involved in this project.

5 Discussion

A highly prioritized objective of Texas Hydrological Innovations (THI) has been to generate better spring awareness and groundwater management. THI has provided a comprehensive database for the springs of Texas. Prior to the completion of this project, data for springs in Texas were scattered and difficult to manipulate. The THI Comprehensive Database offers the user an easily navigable database that can be used as a reference for spring information or as a foundation for further research. THI created the standard for the database which involved eliminating fields less pertinent to the study. Links are provided on the website to all of the databases we referenced. Also Included on our website is an interactive Google map which allows for spring owners to easily identify springs on their property and view pertinent attribute data. Due to privacy issues, some spring locations are not precise. The best way for THI to overcome this issue was to include a margin of accuracy for each location indicating how precise the location is. This is especially helpful when utilizing the interactive map.

We began the project expecting for the database standard and water quality analysis to be the main objective. Later we discovered that the highest priority is the production of an interactive map. There was time spent by our team members analyzing water quality data. The focus on water quality detracted from the project because we could have been working to develop other aspects of the project such as the development of Adobe Flash maps. The positive aspect about the water quality incident is that it provided us with the opportunity to adapt to the adversity of losing time. THI redirected the project focus and reestablished the tasks to be completed. THI then successfully proceeded with the project and achieved our goals.

The method that THI implemented for the database creation is superior to previous methods taken by other organizations. This is because the other databases contain scattered data that cannot easily be easily manipulated by the user. Some pertinent data can be found in one database, while other very important data must be found from another source. For example, the Heitmueller and Reece database contains river basin information however for ownership information the database created by the Texas Water Development Board must be referenced. The ability to have all the most pertinent attributes in one database elevates the THI Comprehensive Database to a level above that of the other databases. We also added the full names of attributes in addition to the codes in order for anyone to understand the data easily. Another aspect that makes our database superior is that all of the data sources referenced can be accessed via the THI webpage. This can allow for more rigorous research that may possibly require fields left out from the THI standard. This will not be common because the average user of this map based database will not require the excluded fields that exist for GIS purposes. This leads to another example of why our database is superior and that is because GIS is not needed to view the data.

With further research, aquifer analysis can be performed by those who desire to update our database. There are almost 800 springs that are missing aquifer source information. Interpolation of the source aquifer by analyzing the surrounding springs is a sufficient method for determining source aquifer. A method that would produce more conclusive results is the implementation of the Piper Diagram.

As mentioned in the Literature Review, the Piper Diagram analyzes major cations and anions from water quality samples. The first step to the Piper Diagram is to fill in the missing water quality fields that are needed. The fields of cations and anions must all be completed in order to run the model. It was common for Potassium records to be missing in the sources we referenced however this can be resolved by adding all the anions together, and then adding all of the cations together. The difference between the cations and anions will provide the missing potassium records because number of cations and the number of anions must equal each other.

Once the water quality fields are completed, run the Piper Diagram for springs with known aquifers. Enter water quality data for as many different known aquifers as possible to create a skeleton for the diagram. Then add the water quality data for springs with unknown aquifers. The known springs plotted on the diagram will indicate what aquifer unknown springs are feeding from based on commonalities in cations and anions.

Discharge collection of rivers and springs is a necessity in the continuation of this project. Many springs have no records, or only a few records ever recorded. In order to manage our ground water resource more efficiently, the statewide collection of discharge data is mandatory. The compilation of precipitation data, spring discharge data, well withdrawal data, and soil type data can be utilized for the creation of an aquifer recharge model using a GIS. If Texas is to conserve this limited resource during a time when the population is expanding and demand for water is increasing, aquifer use and recharge models can be implemented to generate high efficiency groundwater management.

6 Conclusion

Scientists have the ability to perform research that can change the world although the power of change commonly occurs where there are great numbers to enforce such change. In the state of Texas, continued research is greatly encouraged, but it is through community outreach and increased awareness of springs that the state will preserve our precious groundwater resource. The work performed by THI promotes freshwater management throughout the state of

Texas by providing a map based database for the scientific community as well as the non-scientific community. It is the intention of THI to provide our results in a manner that will effectively provide a data resource to the people of Texas, in order to generate interest in protecting the health of the springs. The interactive Google Earth map will change the way spring data is interpreted and provide for greater spring awareness. Without the vital resource of freshwater to the state, Texas' ecological diversity will be adversely affected. Everyone must do their part to protect this common property that sustains life in Texas. THI has provided this work to make everyone else's part a little bit easier.

7 References Cited

References

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8 Appendix I. Maps and Figures

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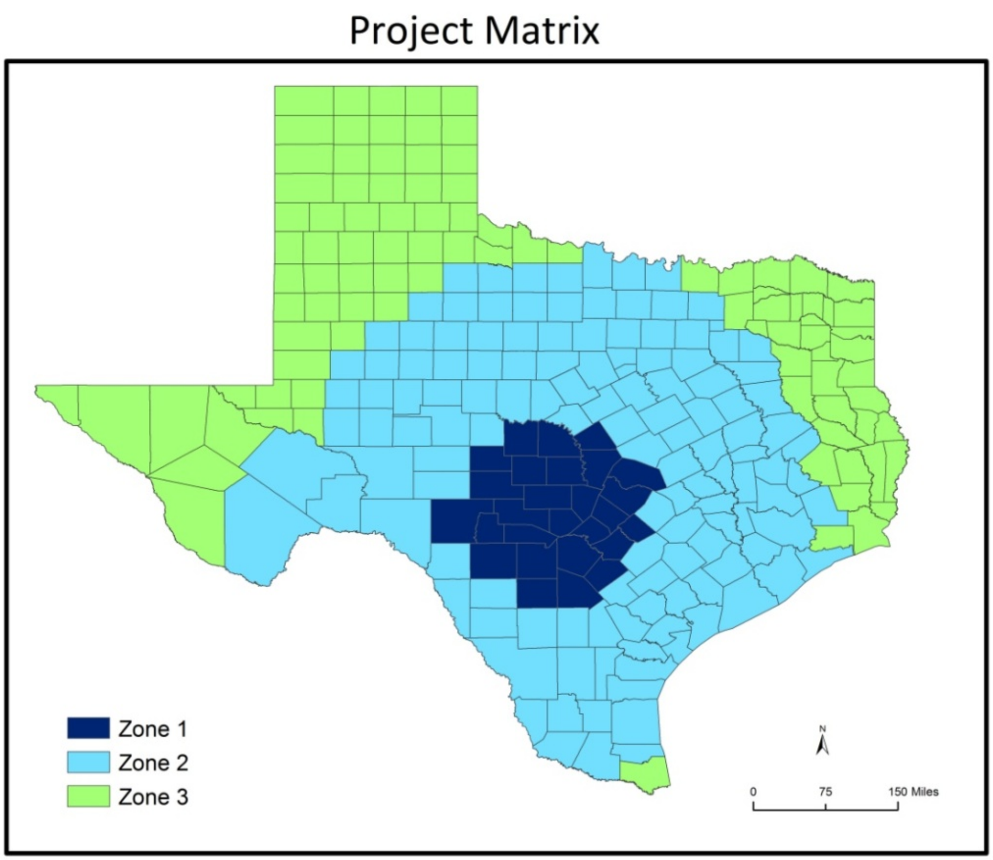
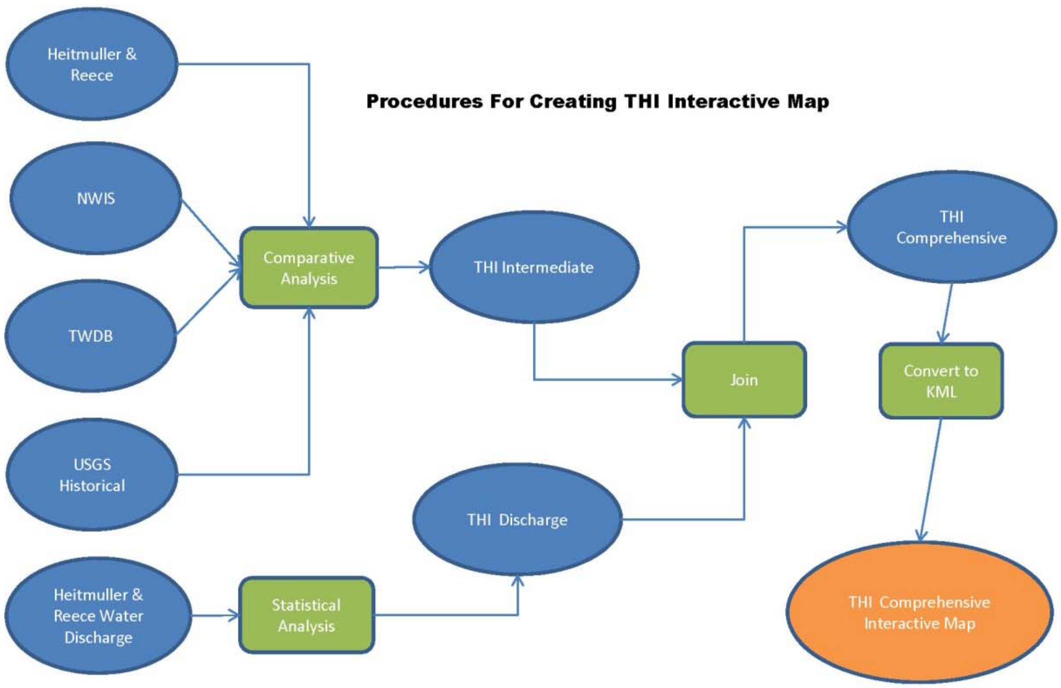


Figure 1. Zones indicate analysis organization and order.

Figure 2. Procedure



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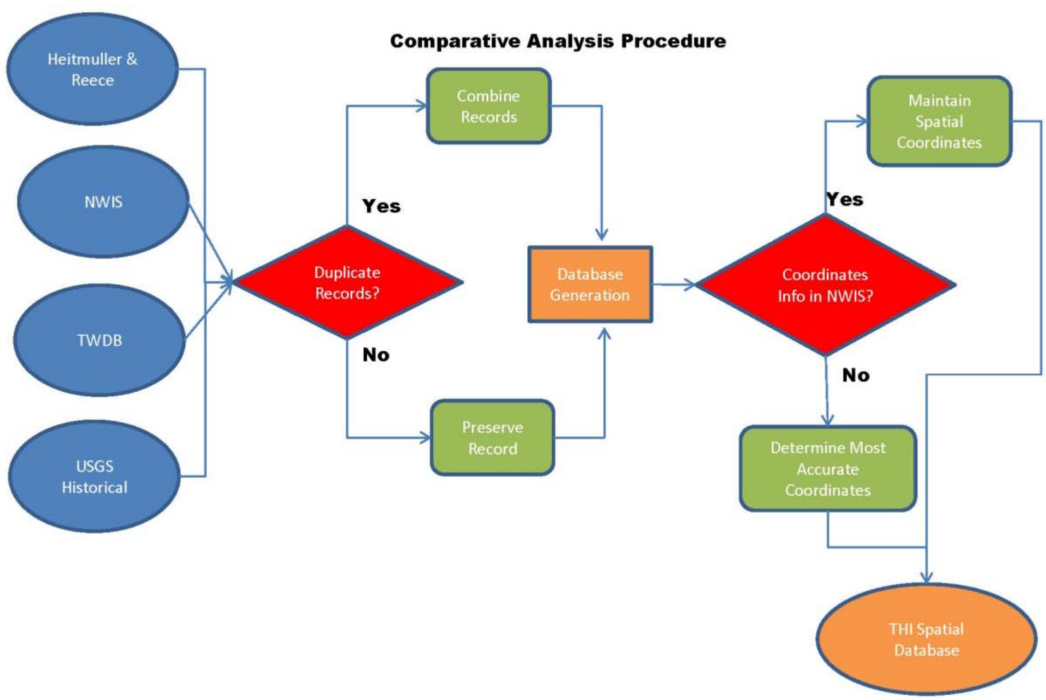

NWIS_site_no	state_well_no	spring_nm	dec_latitude	dec_longitude	coord_acy	coord_acy_	elevation_ft	state_cd	county_nm	county_c	fips_cd	aquifer_cd	basin_nm	basin_cd	primary_use	secondary_use	owner
7307700	2210104	Roaring Springs	33.853333	-100.865278	+/- 1.0 sec	S	2480	48	Motley	345	48345	231DCKM	Red River	2	domestic	recreation	Matador
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Figure 4. Standard used for database attributes.

site_no	disc_src_cd	disc_dt	date_tm	disc_va	disc_meth	records	meanflow	10th_per	90th_per	flow	date	remarks
7307700	A	1/1/1937	Y	480	R	153	618.27	480.21	726.60		1/1/1937-1/27/94	
8103500	S	1/17/1973	D	619.34	R	81	4556.58	476.17	1052.44		12/01/1909-04/04/1973	
8127200	Z	4/23/1905	D	2000	E	15	5232.30	2176.59	7243.63		4/23/1905-07/24/1964	Digital data acquired from Capitol Environmental Services.
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8129500	A	1/1/1967	Y	350	E	352	5461.81	2029.92	10771.20		04/26/1944- 09/17/2002	
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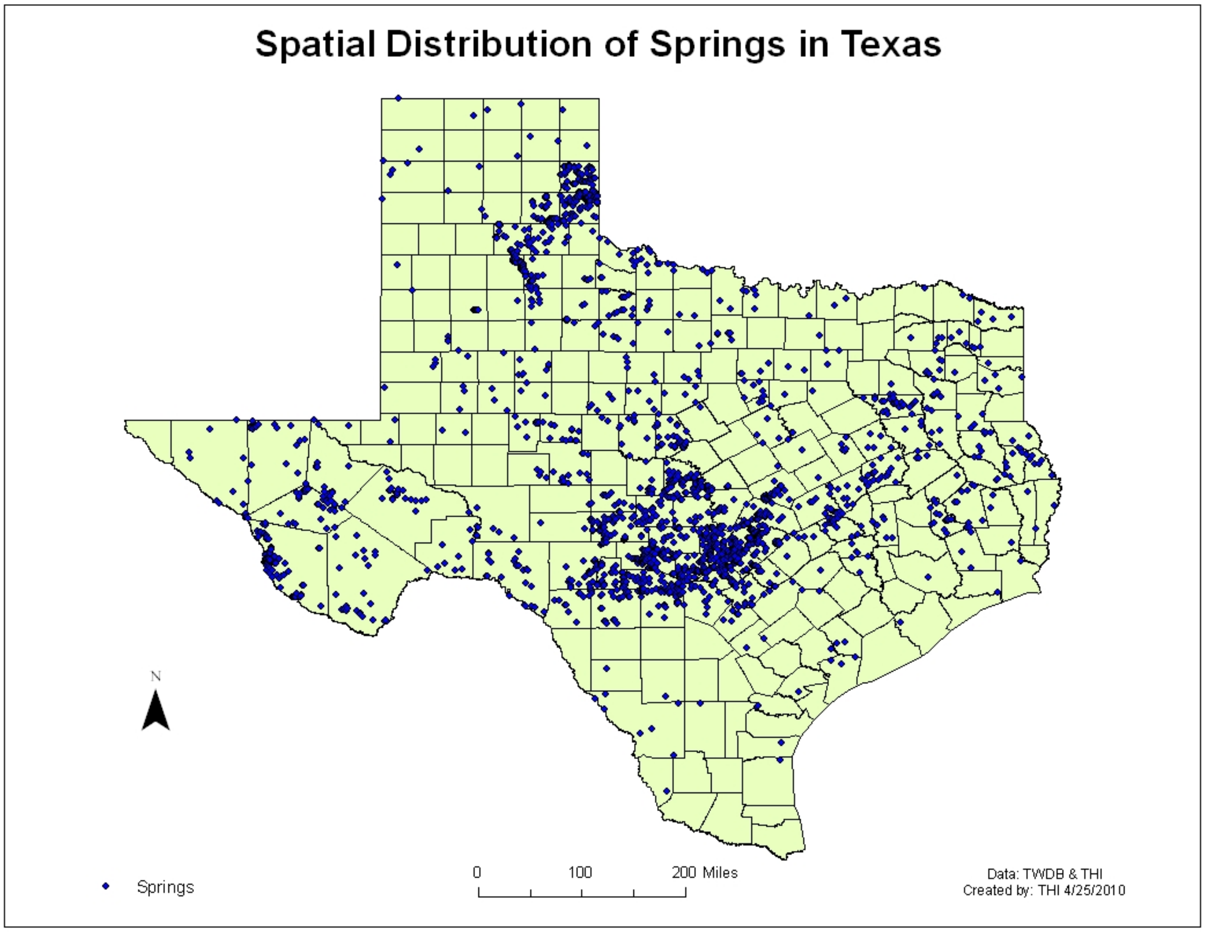

Figure 6. THI comprehensive database includes 2238 springs

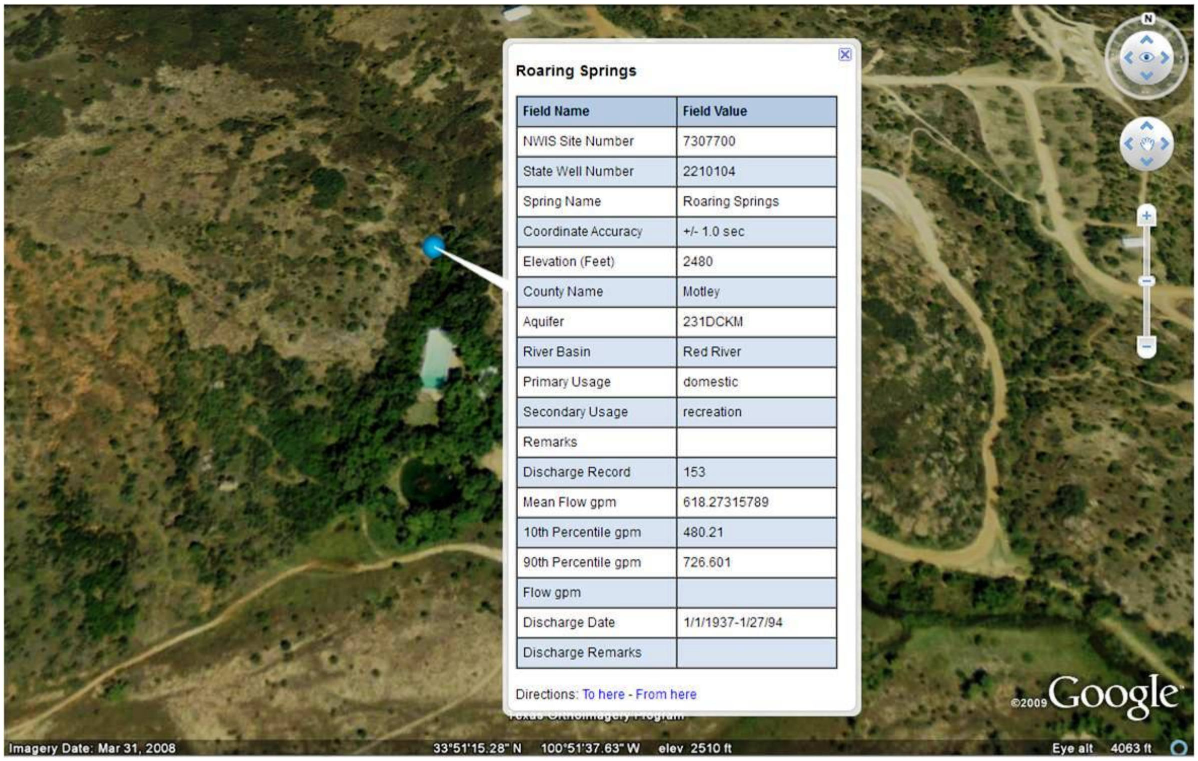

Figure 7. User friendly, interactive map.

9 Appendix II. Metadata

Identification_Information:
Citation:
Citation_Information:
Originator: Texas Hydrological Innovations
Publication_Date: May 04, 2010
Publication_Time: 0800
Title: Texas Springs Project
Edition: 1.0
Geospatial_Data_Presentation_Form: vector digital data
Publication_Information:
Publication_Place: Texas State University - San Marcos
Other_Citation_Details: Department of Geography
Online_Linkage: http://geosites.evans.txstate.edu/g4427/2010/s10/
Larger_Work_Citation:
Description:
Abstract:

Spring in Texas are currently documented and monitored through various organizations and agencies throughout the state. The format of spring data currently available limits access to large portions of the community. This dataset is an aggregate of four datasets compiled into one comprehensive database. This dataset is also available in .KMZ format, compatible with Google Earth, to allow members of the community to have access.

This dataset provides information about springs in Texas including spring names, identification numbers, location, and, if available, aquifer, owner, discharge, water source and use. This dataset includes springs documented by Heitmuller and Reece (2003), Texas Water Development Board (TWDB), USGS Compilation of Historical Water-Quality Data in Texas, and USGS National Water Information System (NWIS). Texas Hydrological Innovations made every effort, to remove duplicate data and any data inconsistencies that might exist for a spring among the documenting agencies or organizations.

Purpose: The purpose of this project is to aggregate information about springs in Texas and their associated spring flow into a comprehensive digital database that is also accessable to members of the community.

Supplemental_Information: Collection of data included in this project was limited to digital data from Heitmuller and Reece (2003), Texas Water Development Board (TWDB), USGS Compilation of Historical Water-Quality Data in Texas, and USGS National Water Information System (NWIS).

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -105.725556 dd
East_Bounding_Coordinate: -93.608611 dd
North_Bounding_Coordinate: 36.491670 dd
South_Bounding_Coordinate: 26.800000 dd
Keywords:
Theme:
Theme_Keyword: springs
Theme_Keyword: spring
Theme_Keyword: discharge
Place:
Place_Keyword: Texas

Place_Keyword: Texas Hill Country
Place_Keyword: United States
Place_Keyword: North America
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: Attribute accuracy is dependent on the source information. Team members checked the attribute data for completeness and accuracy according to its source.
Logical_Consistency_Report: All records are attributed
Completeness_Report: Complete
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report: Positional accuracy is determined from the original data source.
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: Elevational accuracy dependent on source data.
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: Texas Water Development Board (TWDB)
Publication_Date: Unpublished material
Type_of_Source_Media: digital database file
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 1900
Ending_Date: 1997
Source_Citation_Abbreviation: not applicable
Source_Contribution: spring location, owner, state well number, and elevation
Source_Information:
Source_Citation:
Citation_Information:
Originator: U.S. Geological Survey National Water Information System (NWIS)
Online_Linkage: http://waterdata.usgs.gov/tx/nwis/inventory
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 1932
Ending_Date: 2009
Source_Contribution: location and site number
Source_Information:
Source_Citation:
Citation_Information:
Originator: Heitmueller and Reece
Publication_Date: 200309
Title: Springs of Texas
Publication_Information:
Publication_Place: Austin, Texas

Publisher: U.S. Geological Survey
Type_of_Source_Media: digital database
Source_Contribution: Name of spring, spring location, when available elevation, aquifer, river basin, discharge (gpm), and discharge date.
Source_Information:
Source_Citation:
Citation_Information:
Originator: U.S. Geological Survey
Publication_Date: 2006
Title: Selected Texas springs
Geospatial_Data_Presentation_Form: vector digital data
Series_Information:
Series_Name: Data Series (DS)
Issue_Identification: 230
Publication_Information:
Publication_Place: Austin, Texas
Publisher: U.S. Geological Survey
Source_Contribution: NWIS site number, state well number, spring name, river basin, aquifer, water use.
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution: 0.000000
Longitude_Resolution: 0.000000
Geographic_Coordinate_Units: Decimal degrees
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: mean sea level
Altitude_Distance_Units: feet
Altitude_Encoding_Method: attribute values
Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: spring
Entity_Type_Definition: spring locations
Entity_Type_Definition_Source: U.S. Geological Survey
Attribute:
Attribute_Label: OBJECTID
Attribute_Definition: Internal feature number
Attribute_Definition_Source: ESRI
Attribute:
Attribute_Label: NWIS_site_
Attribute_Definition: unique site identifier

Attribute_Definition_Source: U.S. Geological Survey
Attribute:
Attribute_Label: state_well
Attribute_Definition: Texas state well identification number
Attribute_Definition_Source: Texas Water Development Board
Attribute:
Attribute_Label: dec_latitu
Attribute_Definition: Latitude in decimal degrees
Attribute_Definition_Source: U.S. Geological Survey
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 26.66018
Range_Domain_Maximum: 36.520145
Attribute_Units_of_Measure: decimal degrees
Attribute:
Attribute_Label: dec_longit
Attribute_Definition: Longitude in decimal degrees
Attribute_Definition_Source: U.S. Geological Survey
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 106.037604
Range_Domain_Maximum: -93.212723
Attribute_Units_of_Measure: decimal degrees
Attribute:
Attribute_Label: coord_acy
Attribute_Definition: Coordinate accuracy
Attribute_Definition_Source: U.S. Geological Survey
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: s
Enumerated_Domain_Value_Definition: accurate to +/- 1.0 sec
Enumerated_Domain_Value_Definition_Source: USGS National Water Information System (NWIS)
Enumerated_Domain:
Enumerated_Domain_Value: M
Enumerated_Domain_Value_Definition: accurate to +/- 1 minute
Enumerated_Domain_Value_Definition_Source: USGS National Water Information System (NWIS)
Enumerated_Domain:
Enumerated_Domain_Value: U
Enumerated_Domain_Value_Definition: Uknown
Enumerated_Domain_Value_Definition_Source: USGS National Water Information System (NWIS)
Enumerated_Domain:
Enumerated_Domain_Value: 1
Enumerated_Domain_Value_Definition: Accurate to +/- 0.1 second (differentially corrected GPS)
Enumerated_Domain_Value_Definition_Source: USGS National Water Information System (NWIS)
Enumerated_Domain:
Enumerated_Domain_Value: H
Enumerated_Domain_Value_Definition: +/- 0.01 second (differentially corrected GPS)
Enumerated_Domain_Value_Definition_Source: USGS National Water Information System (NWIS)

Attribute:
Attribute_Label: elevation
Attribute_Definition: elevation of the ground surface in feet above mean sea level
Attribute_Definition_Source: U.S. Geological Survey
Attribute:
Attribute_Label: state_cd
Attribute_Definition: FIPS state cd
Attribute_Definition_Source: National Institute of Standards and Technology
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 48
Enumerated_Domain_Value_Definition: Texas
Attribute:
Attribute_Label: county_cd
Attribute_Definition: FIPS county cd
Attribute_Definition_Source: National Institute of Standards and Technology
Attribute_Domain_Values:
Codeset_Domain:
Codeset_Name: FIPS county codes
Codeset_Source: <http://www.itl.nist.gov/fipspubs/co-codes/states.htm>
Attribute:
Attribute_Label: aquifer_cd
Attribute_Definition: aquifer code
Attribute_Definition_Source: Texas Water Development Board (TWDB) ground-water data system dictionary
Attribute_Domain_Values:
Codeset_Domain:
Codeset_Name: Texas Water Development Board ground-water data system dictionary
Codeset_Source: <http://www.twdb.state.tx.us/publications/manuals/UM50%20Data%20Dictionary/um50.pdf>
Attribute:
Attribute_Label: basin_cd
Attribute_Definition: River basin cd
Attribute_Definition_Source: Texas Water Development Board (TWDB) ground-water data system dictionary
Attribute_Domain_Values:
Codeset_Domain:
Codeset_Name: Texas Water Development Board (TWDB) ground-water data system dictionary
Codeset_Source: <http://www.twdb.state.tx.us/publications/manuals/UM50%20Data%20Dictionary/um50.pdf>
Attribute:
Attribute_Label: primary_use
Attribute_Definition: primary water use
Attribute_Definition_Source: Texas Water Development Board (TWDB) ground-water data system dictionary
Attribute_Domain_Values:
Codeset_Domain:
Codeset_Name: Texas Water Development Board (TWDB) ground-water data system dictionary

Codeset_Source:
<http://www.twdb.state.tx.us/publications/manuals/UM50%20Data%20Dictionary/um50.pdf>
Attribute:
Attribute_Label: secondary_use
Attribute_Definition: secondary water use
Attribute_Definition_Source: Texas Water Development Board (TWDB) ground-water data system dictionary
Attribute_Domain_Values:
Codeset_Domain:
Codeset_Name: Texas Water Development Board (TWDB) ground-water data system dictionary
Codeset_Source:
<http://www.twdb.state.tx.us/publications/manuals/UM50%20Data%20Dictionary/um50.pdf>
Attribute:
Attribute_Label: Records
Attribute_Definition: total times discharge was recorded
Attribute:
Attribute_Label: MeanFlow
Attribute_Definition: Mean flow for discharge recorded more than twice
Attribute_Definition_Source: THI
Attribute:
Attribute_Label: 10th_Per
Attribute_Definition: descriptive statistic used to describe 10th percentile of all recorded discharge.
Attribute_Definition_Source: THI
Attribute:
Attribute_Label: 90th_Per
Attribute_Definition: descriptive statistic used to describe 90th percentile of all recorded discharge.
Attribute_Definition_Source: THI
Attribute:
Attribute_Label: FLOW
Attribute_Definition: When only one discharge record exist, this value is that reocrded flow from the source.
Attribute_Definition_Source: THI
Attribute:
Attribute_Label: Date
Attribute_Definition: When only one discharge record exist, this value is the date of the documented reocrded flow from the source.

Attribute_Definition_Source: THI
Attribute:
Attribute_Label: REMARKS_1
Attribute_Definition: discharge notes documented by source agency
Metadata_Reference_Information:
Metadata_Date: 20100504
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization:
Texas State University-San Marcos

Depatment of Geography
Contact_Electronic_Mail_Address: http://geosites.evans.txstate.edu/g4427/2010/s10/
Contact_Instructions: Contact via email from website. Geo4427/ Semester 2010
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata

Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: none
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Language: english

10 Appendix III. Team Member Contributions

Appendix

Analysts	# of Counties	% of Counties	# of Springs	% of Springs
Ben Bates	64	25%	566	25.3%
Jason Pickett	89	35%	673	30.1%
Mark Pillon	39	15%	324	14.5%
Yasmin Sierra	62	25%	675	30.1%

Jason Pickett

Meeting

- Researched RFP for questions pertinent to the project study.

Data

- Researched the databases for standard template design with Yasmin and Mark.

Analysis

- Completed all spring integration for all springs in my designated section for all 3 zones
- Completed all spring integration for all springs in Marks designated zone 3.
- Organized and converted Ben Bates zones 2 and 3 into proper template format.
- Compiled the spring data comprehensive (excluding discharge data) for all 4 team tables for all 3 zones with Yasmin.
- Converted the comprehensive and discharge Excel tables into Access tables.

- Converted the comprehensive and discharge Access tables into .dbf files.
- Implemented the .dbf file in ArcMap and joined the two layers to create the comprehensive layer.
    - Created appendix table for team member contribution.

Proposal Report/Presentation

- Comprised the introduction, purpose, and scope sections for the written report.
- Edited written report with all team members.
- Designed and organized the PowerPoint presentation with Yasmin.
- Edited PowerPoint presentation with all team members.

Progress Report/Presentation

- Comprised the description and conclusion sections for the written report.
- Rewrote Ben Bates completed, present, and future work status sections with Yasmin.
- Edited written report with all team members.
- Designed and organized the PowerPoint presentation with Yasmin.
- Edited PowerPoint presentation with all team members.

Final Report/Presentation

- Comprised the data and procedure sections for the written report.
- Created the procedures for creating THI interactive map flowchart.
- Created the comparative analysis procedure flowchart.
- Edited written report with all team members.
- Designed and organized the PowerPoint presentation with Yasmin.
- Edited PowerPoint presentation with all team members.
- Contributed on results and conclusion sections for final written report

Poster

- Comprised the procedure and result sections.
- Created the flowchart.
- Static map was created and designed with Yasmin.
- Edited poster with Yasmin.

Logo

- Came up with initial design of logo.

Website

- Designed website with Mark.
- Performed Quality control with Mark on the website.

Interactive Map

- Converted the comprehensive database layer using KML with Mark.
- Created the .kmz file for use in Google Earth.
- Assigned aliases for the field names to simplify the widget popup feature for the novice user.
- Edited the null values in KML that display in the widget popup.
    - Used grepWin to accomplish the edit
- Created a new .kmz file without the null values

Quality Control

- Quality control was performed by all team members on all databases created by THI.
- A random sample of 120 springs was divided equally amongst the team members for the quality assurance.

Readme

- Created readme file

Yasmin Sierra

Data

- Gathered, extracted and organized all data
- Printed all metadata, readme files, and reports assosiciated with data
- For NWIS and TWDB performed queries and data conversions in order to retrieve data
- Gathered, imported, and interpreted water quality data
- Did background research including Gunnar Brune's *Springs of Texas* and Flores's Using Major anions and cations to describe trans-pecos springs.
- Downloaded software for ModFlow (for piper diagram) and metadata

Analysis

- Completed all spring integration for all springs in my designated section for all 3 zones
- Compiled the spring data comprehensive(excluding discharge data) for all 4 team tables for all 3 zones.
- Helped clean discharge data
- Attempted piper diagram
- Metadata for comprehensive database

Meetings

- Raymond Slade twice
- Helen Besse twice
- Picked up spring booklets from Helen Besse

Metadata

- Completed metadata for the entire project

Proposal Report/Presentation

- Comprised the methodology and implications for the written report.
- Edited written report with all team members.
- Designed and organized the PowerPoint presentation with Jason.
- Edited PowerPoint presentation with all team members.
- Created presentation template
- Created proposal template
- Created memo template

Progress Report/Presentation

- Comprised the introduction, summary, and purpose sections for the written report.
- Rewrote Ben Bates completed, present, and future work status sections with Jason.
- Edited written report with all team members.
- Designed and organized the PowerPoint presentation with Jason.
- Edited PowerPoint presentation with all team members.

Final Report/Presentation

- Comprised the abstract, background, problem, and objective sections for the written report.
- Edited written report with all team members.
- Designed and organized the PowerPoint presentation with Jason.
- Edited PowerPoint presentation with all team members.

Poster

- Created template and design for poster

- *Co*mprised the background and purpose sections.
- Static map was created and designed with Jason.
- Edited poster with Jason.

Quality Control

- Quality control was performed by all team members on all databases created by THI.
- A random sample of 120 springs was divided equally amongst the team members for the quality assurance.

Mark Pillion

Meetings

- RFP- analysis of the request for a proposal and notes regarding clarification of RFP
- -First meeting with Ray Slade. Discussed the project and attempted to clarify desired deliverables. Clarification of situation and need for the project.

Literature review

- Gunnar Brunes Springs of Texas, Helen Besse *Interim Report for Contract No. 2006-001-069*

Data

- Familiarization with data and metadata in order to understand each data source.
- Search for literature sources and more data sources

Analysis

- Completed all spring integration for all springs in my designated section for 2 zones
- Determination of most accurate spatial data such as lat and long and elevation
- Design the template for the Discharge

Proposal Report/Presentation

- Generation of timetable to provide structure to our list of goals
- Comprised the literature review and references used sections
- Lots of editing (I consider myself the primary editor on the proposal document)
- Edited PowerPoint presentation with all team members.
- Assured that all slides projected clearly and effectively relayed information with Jason

Progress Report/Presentation

- Comprised the Problems section for the written report
    - I discussed the problems we had faced, the effects the problems had on our progress and the solutions we took to move forward.
- Edited written report with all team members.
- Edited PowerPoint presentation with all team members.
- Assured that all slides projected clearly and effectively relayed information with Jason

Final Report/Presentation

- Comprised the discussion and literature review sections for the written report.
    - Content includes our results with implications of results, explanation of why THI db is superior, future work and research
- Contributed on results and conclusion sections for final written report
- Edited written report with all team members.
- Edited PowerPoint presentation with all team members

Logo

- Development of logo using adobe Photoshop

Website

- Created and format and design template
- Dreamweaver tutorials- in person/online
- Formatting and Design
- Embedding the interactive map
- Providing all pertinent documents and data regarding our project
- Development of maps for the site
- All edits, all links
- photography that is in our progress report and website

Ben Bates

Meeting

- Researched RFP for questions pertinent to the project study.

Analysis

- Cleaned and cleared duplicate data from my section of the three zones
- Added all lat/long entries and characteristics for my three zones
- Organized discharge data
  - Counted number of springs in each section with average, 10^{th} and 90^{th} percentile.
  - Helped to add begin and end dates with Yasmin

Proposal Report/Presentation

- Comprised the conclusion and budget sections of proposal
- Had proposal edited at writing lab twice
- Edited written report with all team members

Progress Report/Presentation

- Contributed to work completed and work in progress sections of the written progress report
- Edited written report with all team members

Final Report/Presentation

- Contributed on results and conclusion sections for final written report
- Created table 1 for results section or final report

Website

- Edited budget for proposal report stored on website

Metadata

- Created metadata for NWIS

Quality Control

- Quality control was performed by all team members on all databases created by THI.
- A random sample of 120 springs was divided equally amongst the team members for the quality assurance.