

GIS & GPS Applications in Earth Sciences

# The Recharge and Discharge of the Edwards Aquifer

Located in South-Central Texas

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2011

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## INTRODUCTION

The Edwards Aquifer in south-central Texas is one of the most permeable and producing aquifers in the United States. The development of this aquifer was due to the Balcones Fault System and then by dissolution of carbonate sediments. Over 1.7 million people in fourteen counties (Edwards, Kinney, Real, Kerr, Bandera, Uvalde, Medina, Bexar, Kendall, Comal, Hays, Travis, Williamson, and Bell) as well as four large cities (San Antonio, Austin, Waco, and Dallas), depend on the water produced by this aquifer. Other uses include agriculture, industry, municipal, military and recreational purposes. While some discharge is used for domestic use, a significant amount is utilized to fill springs that serve as aquatic habitats for many threatened and endangered species in Texas. It hosts approximately 91 animal species including 44 endemic stygobites. Some species that can only survive in the Edwards Aquifer include the widemouth blindcat, Texas blind salamander, robber baron cave harvestman, helotes mold meetles, and the robber baron cave spider.

## PURPOSE

The purpose of this project is to examine the rate of recharge and where that recharge takes place as well as look at the rate of discharge and where that discharge takes place. From this point, you can calculate the change in storage of the aquifer, the percent of recharge that is lost due to discharge, and the annual total recharge of the aquifer.

## PROBLEM FORULATION

For these purposes of this project, I will gather shapefiles of the counties that contain the aquifer, the aquifer itself, the zones of recharge and discharge, the watershed and subwatershed boundaries, spring locations, and contour lines of the Edwards Aquifer and use these files in ArcMap to produce calculations concerning recharge and discharge.

## DATA COLLECTION

For this project I used two websites to gather ArcGIS data: The Edwards Aquifer Authority and Texas Natural Resources Information Systems (TNRIS). The Edwards Aquifer Authority was helpful in gathering shapefiles for the Edwards Aquifer and the Recharge Zones. The rest of the shapefiles were downloaded using TNRIS.

Link to Edwards Aquifer Authority:

[http://edwardsaquifer.org/display\\_technical\\_m.php?pg=gis](http://edwardsaquifer.org/display_technical_m.php?pg=gis)

Link to TNRIS: <http://tnris.net/datadownload/download.jsp>

However, for the areas of recharge (drainage basins) and spring locations as well and the rate of recharge and discharge, I used the Hydrogeologic Data Reports from the Edwards Aquifer Authority reported in 2010.

Link to Hydrologic Data Report:

[http://edwardsaquifer.org/files/EAA\\_2010HydrologicDataRD5.pdf](http://edwardsaquifer.org/files/EAA_2010HydrologicDataRD5.pdf)

## DATA PROCESSING

### LOCATION OF THE EDWARDS AQUIFER AND ZONES OF RECHARGE AND DISCHARGE

The first step is to locate the counties that contain the Edwards Aquifer as well as the recharge zones and springs. From the Data Report, we know that the counties that contain the Edwards Aquifer are the following: Atascosa, Bandera, Bell, Bexar, Blanco, Caldwell, Comal, Edwards, Frio, Gillespie, Guadalupe, Hays, Kendall, Kerr, Kinney, Medina, Real, Travis, Uvalde, Williamson, Wilson, and Zavala.

- 1) To display the location of the counties in relation to the State of Texas, I first loaded the shapefile of Texas that was separated into counties. I gathered this information from TNRIS
- 2) Next, I located the correct counties in the attributes table by sorting alphabetically and selecting the rows of the correct counties and holding down the shift key until all counties were selected

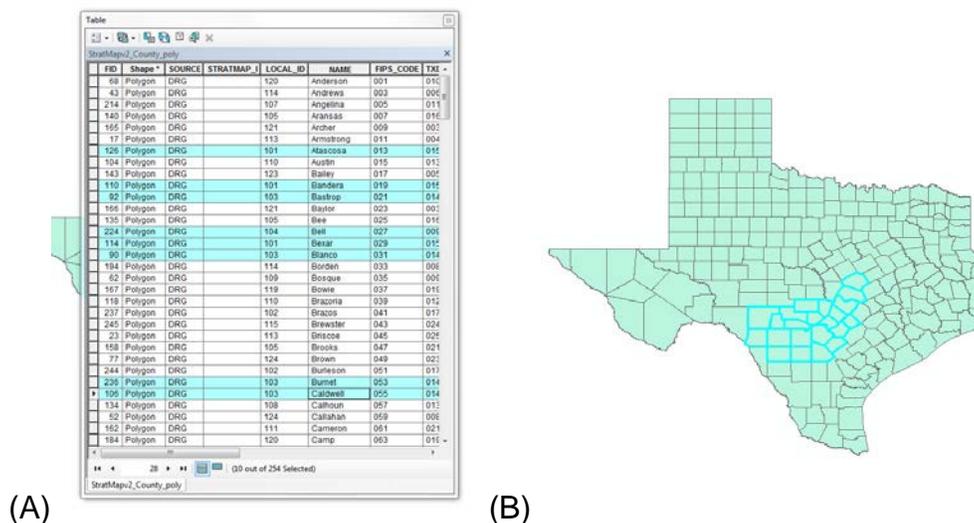


Figure 1

The selected and appropriate counties that are needed to contain the aquifer along with surrounding counties (B) Shows where these counties are located in relation to the State of Texas

- 3) Right click on the layer with the counties and scroll down to “Data” -> “Export Data”
  - a. Data box should look that same as below: Export – Selected Features, this layer’s source data, Output feature class – (choose a name)
    - i. \*Note: make sure you save the data as a shapefile

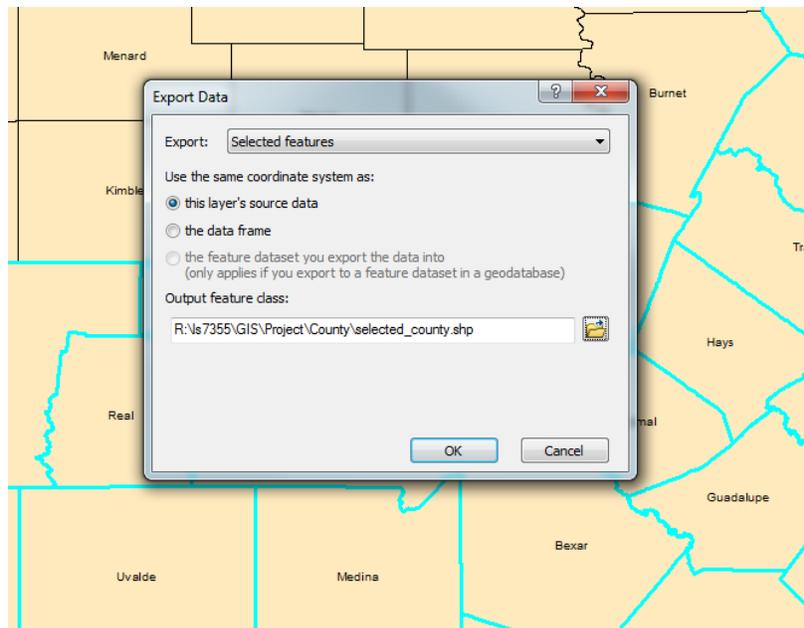


Figure 2

*The Export Data window with the correct selections*

- 4) The result will be a shapefile of only the counties you selected
- 5) To label the counties click the symbol for the label manager on the labeling toolbar
  - a. Make sure the selected counties box is checked and that it will be displaying the names of the counties
  - b. Select "OK"

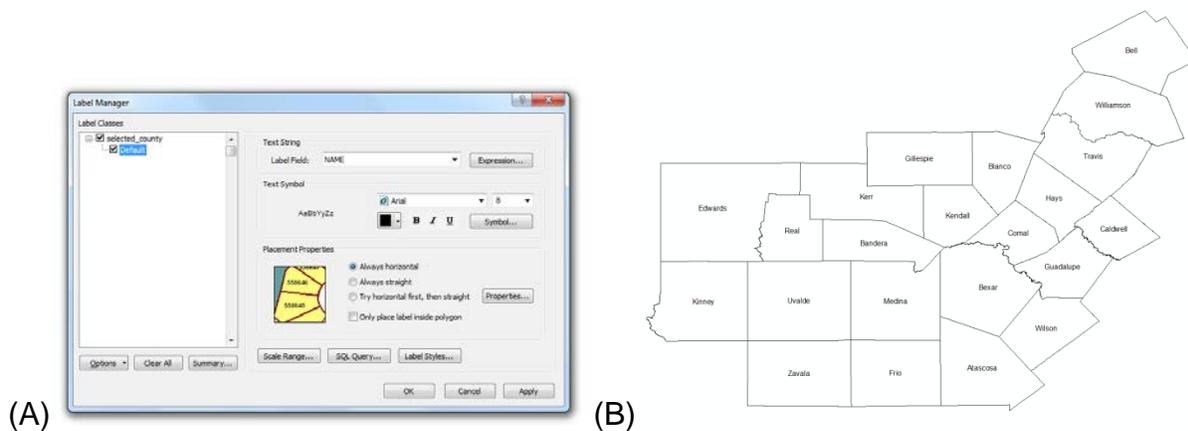


Figure 3

*(A) The Label Manager window with the correct selections (B) Results of completing the Label Manager, the counties that have the names of the counties contained in them*

- 6) Next step is to load the Edwards Aquifer shapefile onto the counties layer that it occupies; do the same for the Recharge Zones.

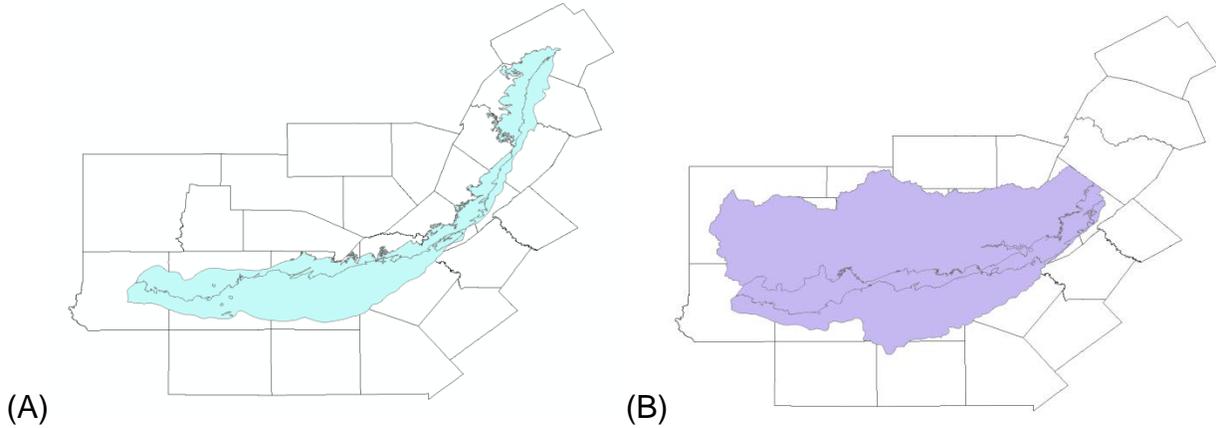


Figure 4

(A) Location of the Edwards Aquifer in relation to the counties that we selected earlier (B) Location of the recharge zones of the Edwards aquifer in relation of the counties that we selected earlier

- 7) I differentiate the different zones into the Recharge, Discharge, Artesian, and Transition Zones by double clicking the layer and selecting symbology tab. Categories, Value Field “ZONE”, and add all values with different colors or symbols

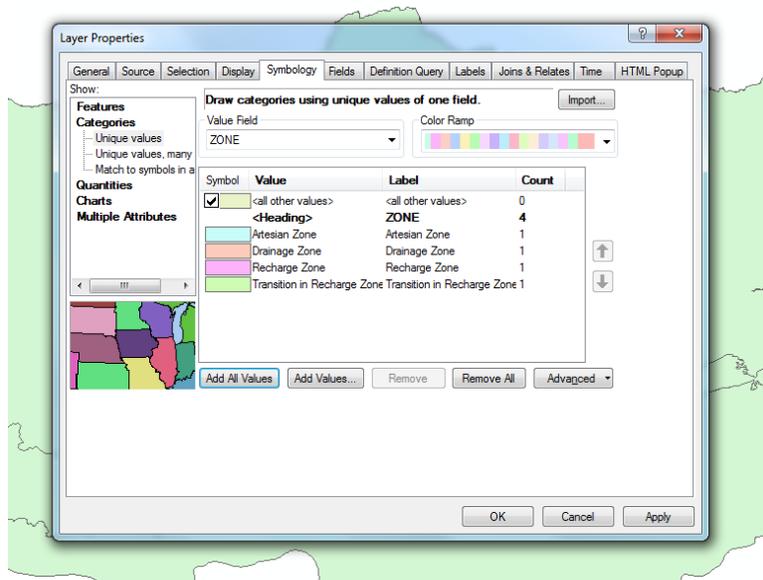
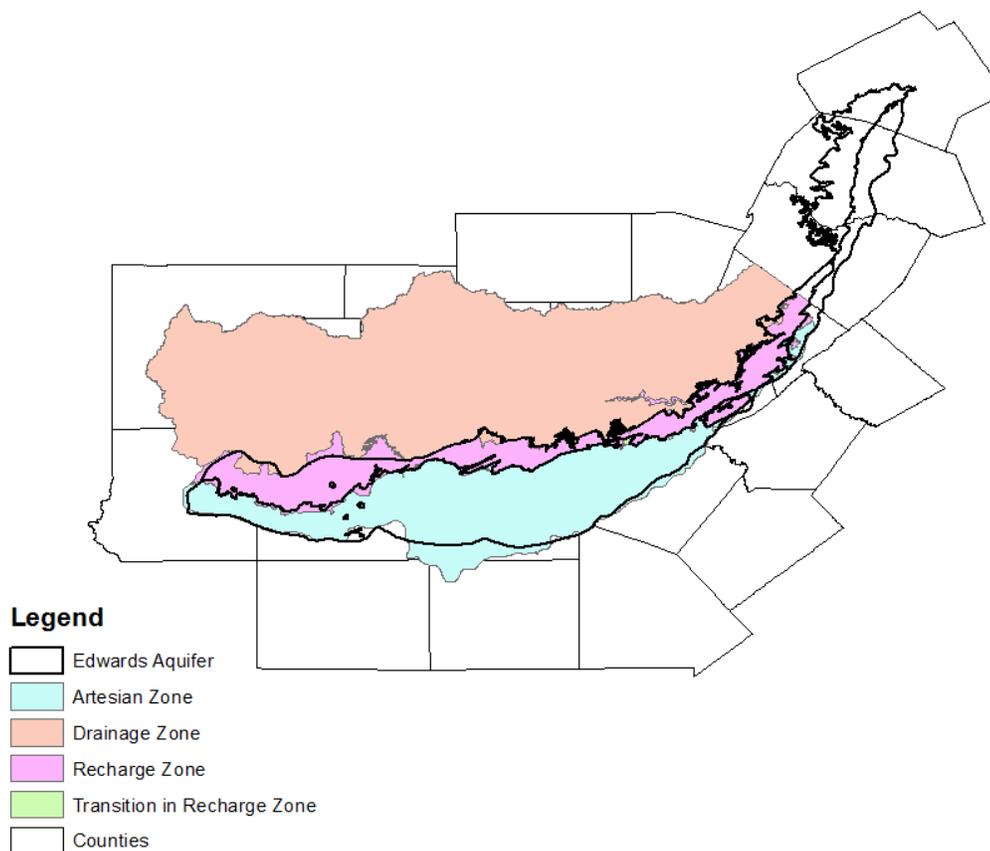


Figure 5

Symbology window located in the layer properties, with the correct selections to differentiate the Artesian, Drainage, Recharge, and Transition in Recharge Zones by color

- 8) From this, I add all the layers together to produce a map that would give the location of the aquifer and the zones of recharge in the appropriate counties



*Figure 6*  
Completed map of the Edwards Aquifer and its Recharge Zones

## CREATING THE DRAINAGE BASINS FOR RECHARGE

From the Aquifer Report Data, you can see the shapes and names of the drainage basins that contribute to recharge. In this section, I took the watershed boundaries and the subwatershed boundaries that I downloaded from TNRIS and selected the appropriate ones that make up these drainage basins.

- 1) I loaded the watershed and subwatershed boundaries. These boundaries help make up the drainage basins that allow recharge to enter the aquifer. However, choosing these watersheds was a little tricky in that, while the watersheds are named appropriately compared to the Data Report, not all of the watersheds of that basin are included. So to pick the appropriate ones that applied for recharge, I compared the shapes of the given basins in the data report to the shapes of the watershed and subwatershed boundaries. I also took into consideration the names in the attributes table to make sure that the selected items were truly apart of the appropriate basin.

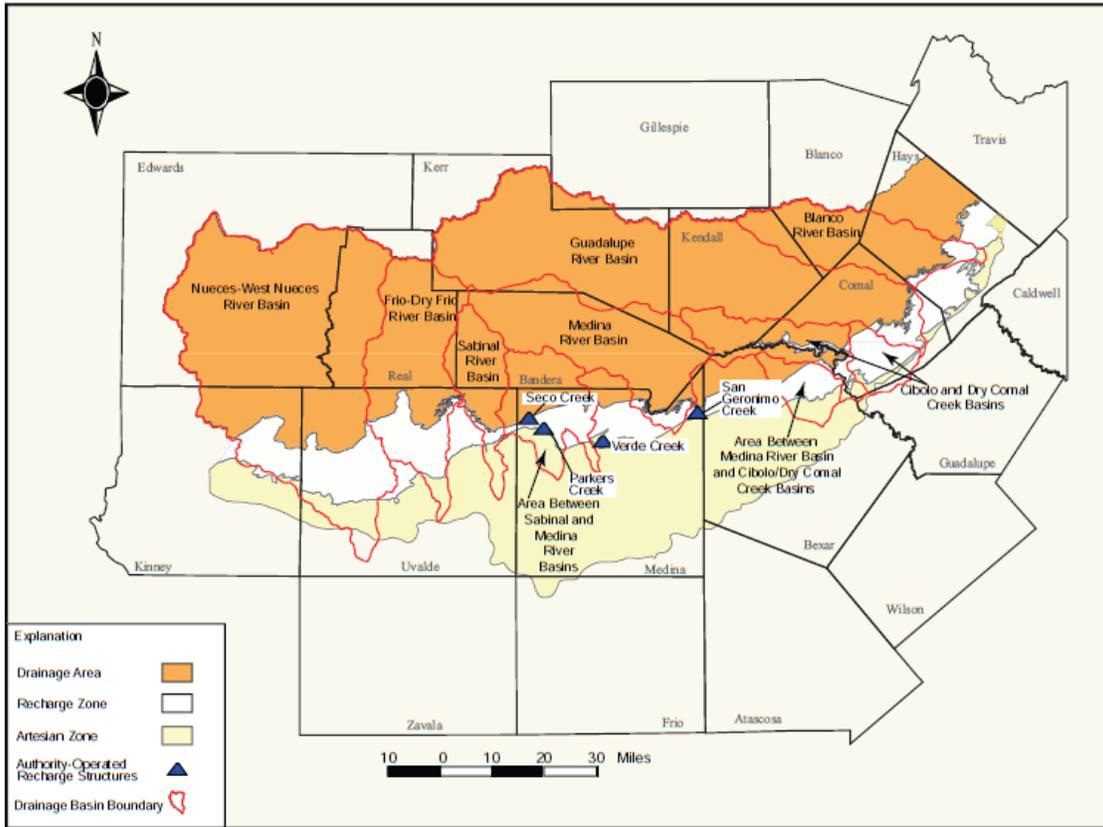


Figure 7

Shows the figure that is presented in the Aquifer Report that displays the location and shape of the recharge basins in the Edwards Aquifer

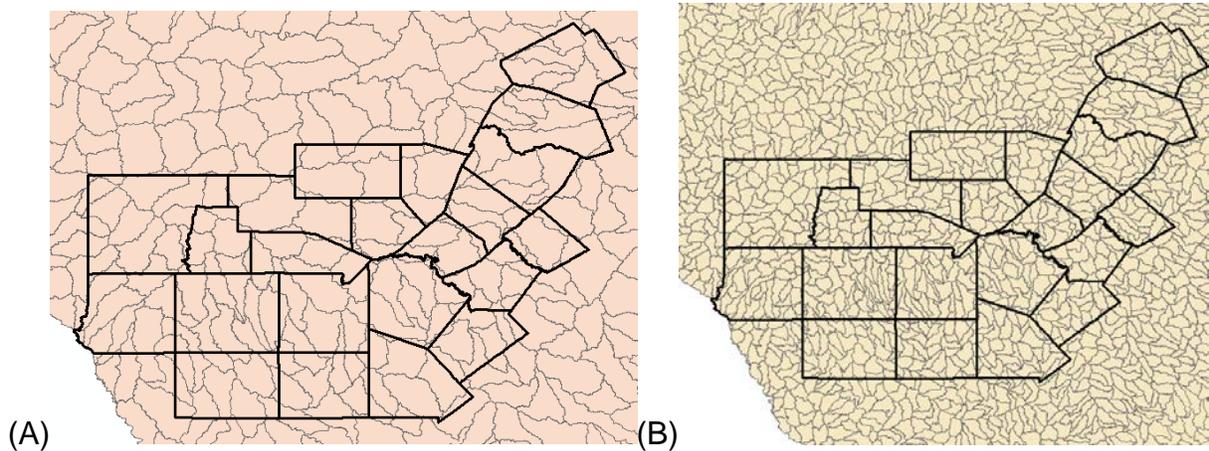


Figure 8

Shows the relationship of the counties to the (A) watershed boundaries and (B) subwatershed boundaries

- 2) Once I had the correct watersheds and subwatershed selected for each basin, I exported the data of the selected feature to create a new shapefile of the drainage basin and named it accordingly.

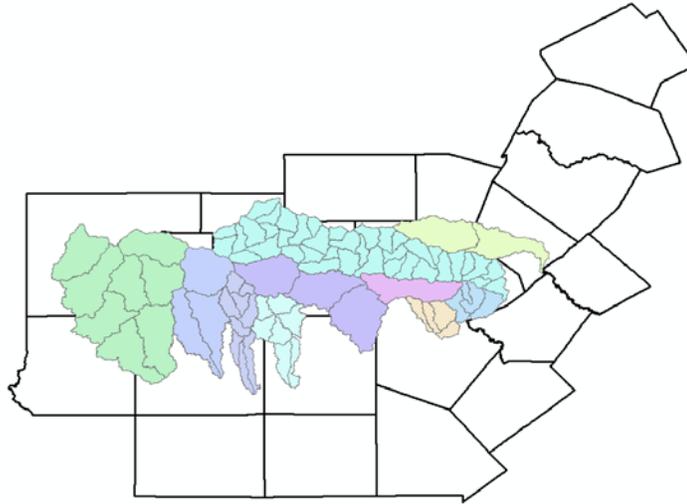


Figure 9

The drainage basins with the division of the watersheds and subwatersheds

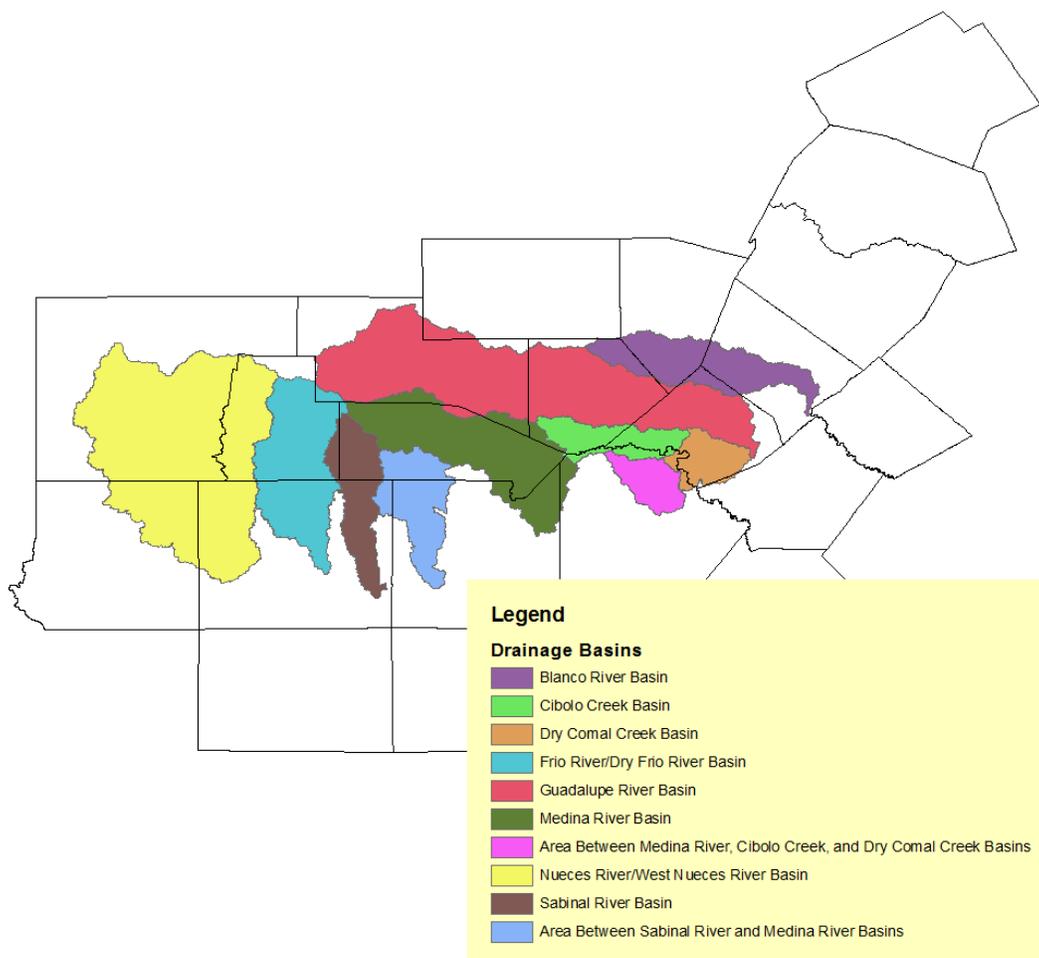
- 3) Once all basins were saved as new shapfiles, I wanted to eliminate the subdivisions of the watersheds and subwatersheds of each basin. I used to aggregate polygons tool to complete this task.
- 4) Then I wanted to combine the shapefiles together to give me one shapefile and an attribute table with all the basins and their information contained in this shapefile. I used the merge tool to combine these shapfiles into one.



Figure 10

The Aggregate Polygons and Merge Polygons windows with the appropriate selections

- 5) Once this was complete, I changed the symbology of the combined basins shapefile to show the different basins in different colors and related the location of these basins compared to the counties.



*Figure 11*

*Map showing the shape and location of the drainage basins that was created earlier*

## LOCATING AND CREATING THE POINT FILES FOR SPRING THAT DISCHARGE

The Aquifer Report Data lists the names and locations of the springs that discharge groundwater from the Edwards Aquifer. TNRIS provided a shapefile with all the springs in Texas and surrounding areas. This step will select the appropriate springs.

- 1) This shapefiles contains approximately 100,000 springs that would need to be sorted through to find the correct springs. To eliminate the majority of the springs, I cut the springs shapefile to eliminate all springs that are outside of the counties discussed above. This eliminated a majority of the springs that you have to sort through.

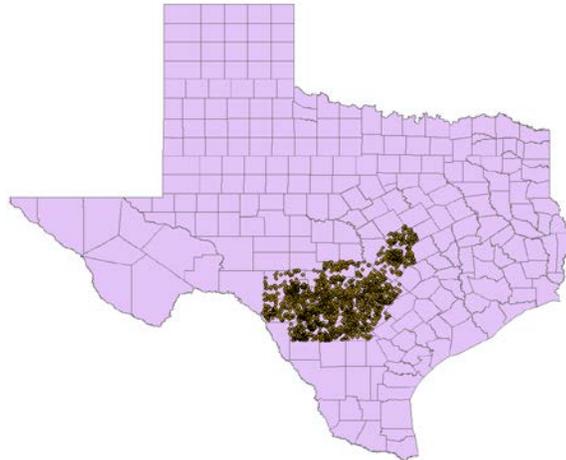


Figure 12

The location of only the springs located within the predefined counties in Texas. This was created by cutting the springs that were outside of the boundary

- 2) From the Aquifer Report Data, I selected the correct springs that are specified and extracted the data to create a new shapefile that contains only the springs that discharge groundwater from the aquifer, as well as the combined attributes table.
  - a. It was helpful adding in the main rivers to pick the correct springs because most of them are close to main rivers.

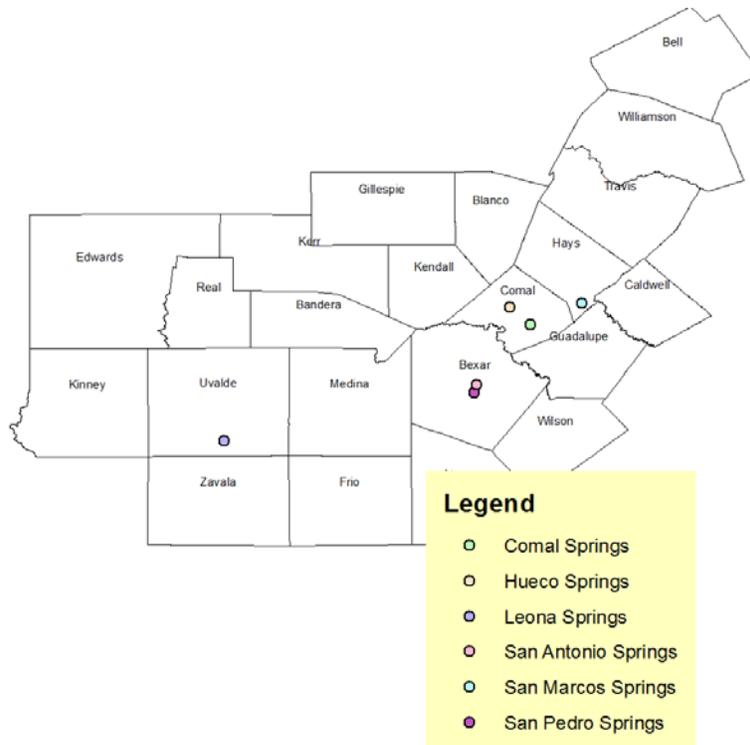


Figure 13

The springs that contribute to discharge in the Edwards Aquifer

## CREATING FIELDS FOR RECHARGE AND DISCHARGE AND JOINING TABLES

This section is the most important section because we are adding the fields of recharge and discharge to the appropriate drainage basin and spring, respectively. Excel is required to do this.

- 1) In excel, on two different sheets, I created two columns (one for the name so we can join tables in later steps and one for the recharge/discharge rates)

(A)

	A	B	C
1	Name	Recharge	
2	Seco	13500	
3	Sabinal	1800	
4	Nueces	58500	
5	Medina	45600	
6	Guadalupe	NULL	
7	Frio	30300	
8	Dry Comal	26400	
9	Cibolo	26400	
10	Blanco	27500	
11	Medina_Cibolo	7300	
12			

(B)

	A	B
1	Name	Discharge
2	San Marcos	156700
3	Hueco	51720
4	Comal	248300
5	San Pedro	5840
6	San Antonio	19180
7	Leona	8250

Figure 14

Excel sheets with the name of the drainage basins/springs and the rate of which they recharge/discharge

- 2) In ArcMap, with the combined basins shapefile and the combined springs shapefile in the Table of Contents, open the attribute table for the drainage basins and add a new field into the table. Name it "Name" and it is a text field with a maximum length of 20 characters. Not able to add the name of the basins in the Name field, I add to start editing to add the appropriate names and save the edits
- 3) To join the excel information into the attributes table, I did the "join data" function. I added the sheet to the table by using the names of the basins.
  - a. Note: The Guadalupe Basin does contribute to recharge because, according to the Aquifer Report, "the historical method of estimating recharge is based on the interpretation that the basin does not recharge the aquifer. However, the Authority is currently revising the methodology utilized for estimating recharge to the aquifer using the HSPF model." Thus, this value is -Null- but is still included because it does contribute to recharging the aquifer

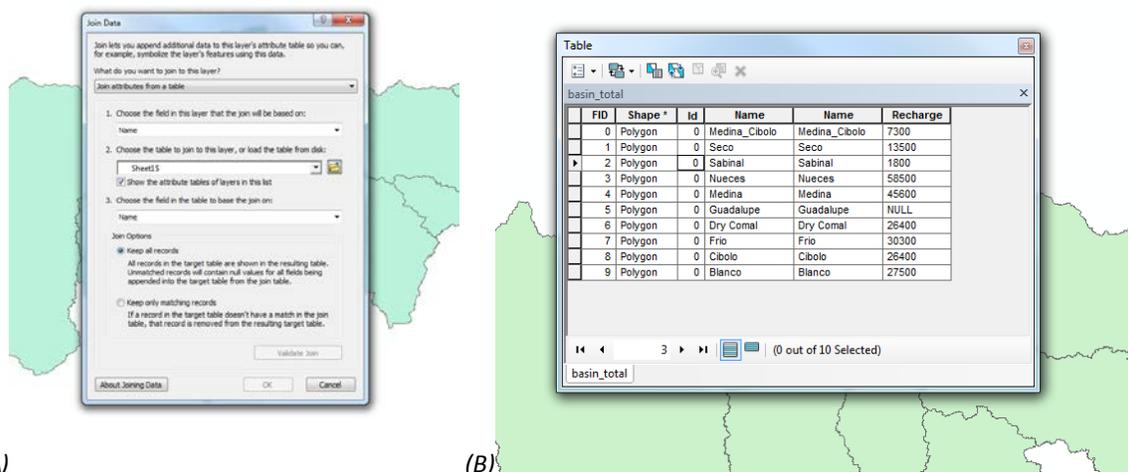


Figure 15

(A) the Join Data window with the correct selections (B) Attributes table after the join data with the recharge rates

- 4) I repeated the exact same process to join the discharge rates for the springs.
- 5) After doing this, I could produce a map that displays the counties surrounding the aquifer, the basins that contribute to recharge, and the springs that contribute to discharge.
  - a. Another map can show the same information but characterizes each basin and spring by the rate of recharge or discharge

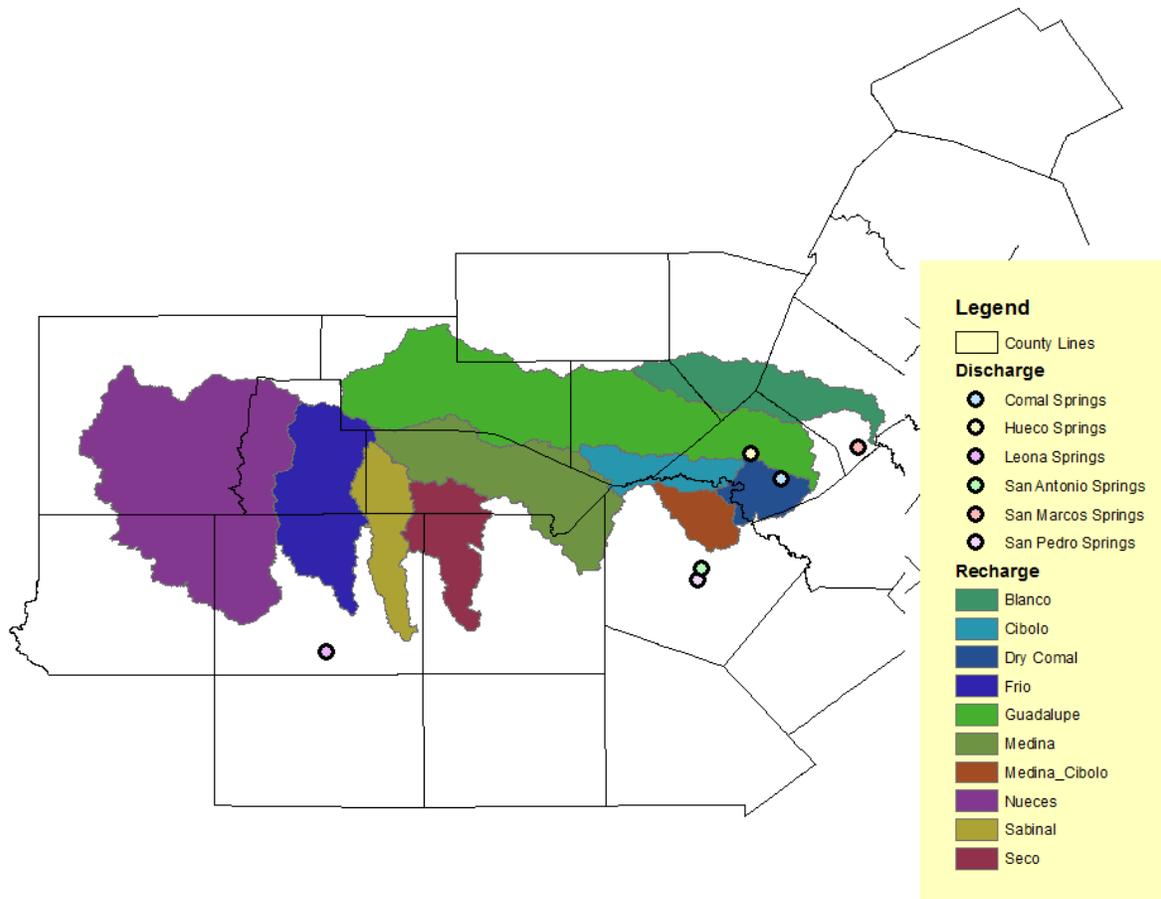


Figure 16  
Figure 17

Map of the drainage basins and there rates of recharge along with the springs with their names

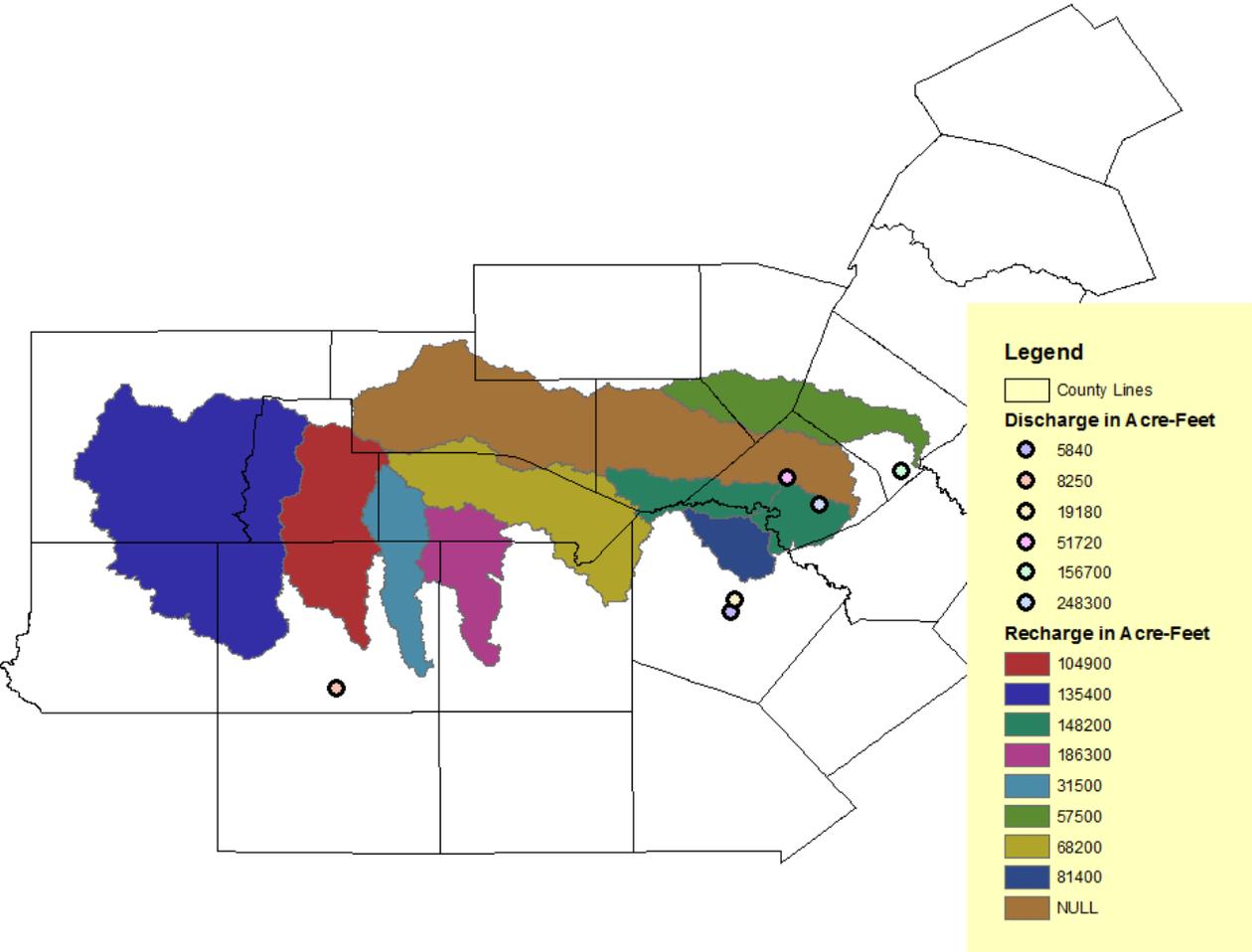


Figure 17  
Map of the drainage basins and there rates of recharge along with the springs with their rates of discharge

## RESULTS

These results answer the questions that were asked in the in the purpose section above.

- 1) For the total recharge and the total discharge, I auto summed the recharge data and the discharge data.
- 2) The hydrologic equation states that the recharge minus the discharge equals the change in storage of the aquifer; thus, I subtracted the total discharge from the total recharge.
- 3) The percentage of recharge that is lost due to discharge was calculated by dividing the total discharge by the total recharge. This is a percentage so it was appropriate to multiply the results by 100.
- 4) For the amount of recharge that remains in the aquifer and is not lost by discharge is calculated by taking the percentage of recharge that is lost due to discharge and subtracting that value from a hundred.

Name	Recharge in Acre-Feet	Name	Discharge In Acre-Feet
Nueces/West Nueces River Basin	135,400	San Marcos Springs	156,700
Frio/Dry Frio River Basin	104,900	Hueco Springs	51,720
Sabinal River Basin	31,500	Comal Springs	248,300
Medina River Basin	68,200	San Pedro Springs	5,840
Area Between Sabinal River and Medinal River	186,300	San Antonio Springs	19,180
Area Between Medina River and Cibolo/Dry Comal Creek Basins	81,400	Leona Springs	8,250
Cibolo Creek and Dry Comal Creek Basins	148,200		
Blanco River Basin	57,500		
<b>TOTAL</b>	<b>813,400</b>		<b>489,990</b>
<b>Hydrologic Equation: Recharge-Discharge=Change in Storage</b>	<b>323,410</b>		
<b>Percent of Recharge that is Lost due to Discharge</b>	<b>60.24%</b>		
<b>Annual Total Recharge</b>	<b>39.76%</b>		

Table 1  
Calculations and results

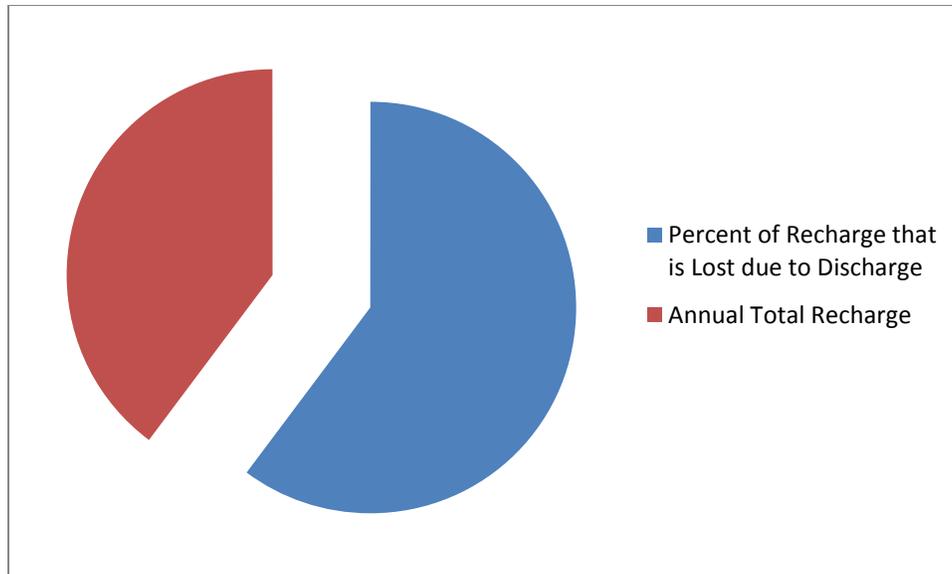


Figure 18

*Pie diagram showing the relationship of the percent of recharge that is lost due to discharge and the annual total recharge.*

### **CONCLUSION**

This report was conclusive in determining the location of the Edwards Aquifer, where recharge occurs and the rate at which it occurs, where discharge occurs and the rate at which it occurs. It also shows the change in storage of the Edwards Aquifer, percent of recharge that is lost due to discharge, and the annual total recharge.