Hill Country Project

Characterization of the Jacob's Well Spring, Hays County

Term Project of the GIS in Water Resources CE 394K

Prepared by Sili Liu

The University of Texas at Austin

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1 INTRODUCTION

1.1 Background information

The Hill Country is a region located in central Texas, which is comprised of 25 counties including the study area, Hays County. What gives the Hill Country its very special character are its extraordinary water resources: its magical hidden springs, crystal-clear swimming holes, peacefully wandering creeks and clear, swiftly flowing rivers. These precious Hill Country resources supply our drinking water and allow for irrigation of pastures, farms, and vineyards. They also contribute to the region's amazing quality of life and, from a practical perspective, help us maintain some of the highest property values in the state and healthy, diverse local economies. However, the water supplies are limited, and require sound management to sustain in the face of exploding demand.

The Hill Country contains several environmentally significant rivers and hundreds of miles of contributory streams. The source of these rivers and streams is the limited reserve of water which lies beneath most area of the Hill Country. Assorted aquifers including the relatively extensive Trinity Aquifer and the shallower, somewhat discontinuous Edwards Aquifer are generally replenished by rainfall seeping through the ground and streamflow leaking through streambeds. Water from these aquifers discharges onto the surface in some areas, forming gushing springs, such as the Jacob's well spring, that replenish stream and river flow.

1.2 Purpose

The term project is focused on the Jacob's Well Spring located in the southwest of the Hays County, Central Texas. There are three main purpose of the project.

1. Upstream watershed delineation for the Jacob's well spring;
2. Time series hydrological data analysis of the Jacob's well spring;
3. The population of the upstream watershed of the spring and its influence on the water usage.

2 Study area

The Jacob's well spring is located in the City of Wimberley in southwestern Hays County, Texas. The spring is a karst spring that discharges from the Trinity aquifer and serves as one of the sources for Cypress Creek that joins Blanco River downstream, which flows southeast through Wimberley and over the Edwards aquifer.

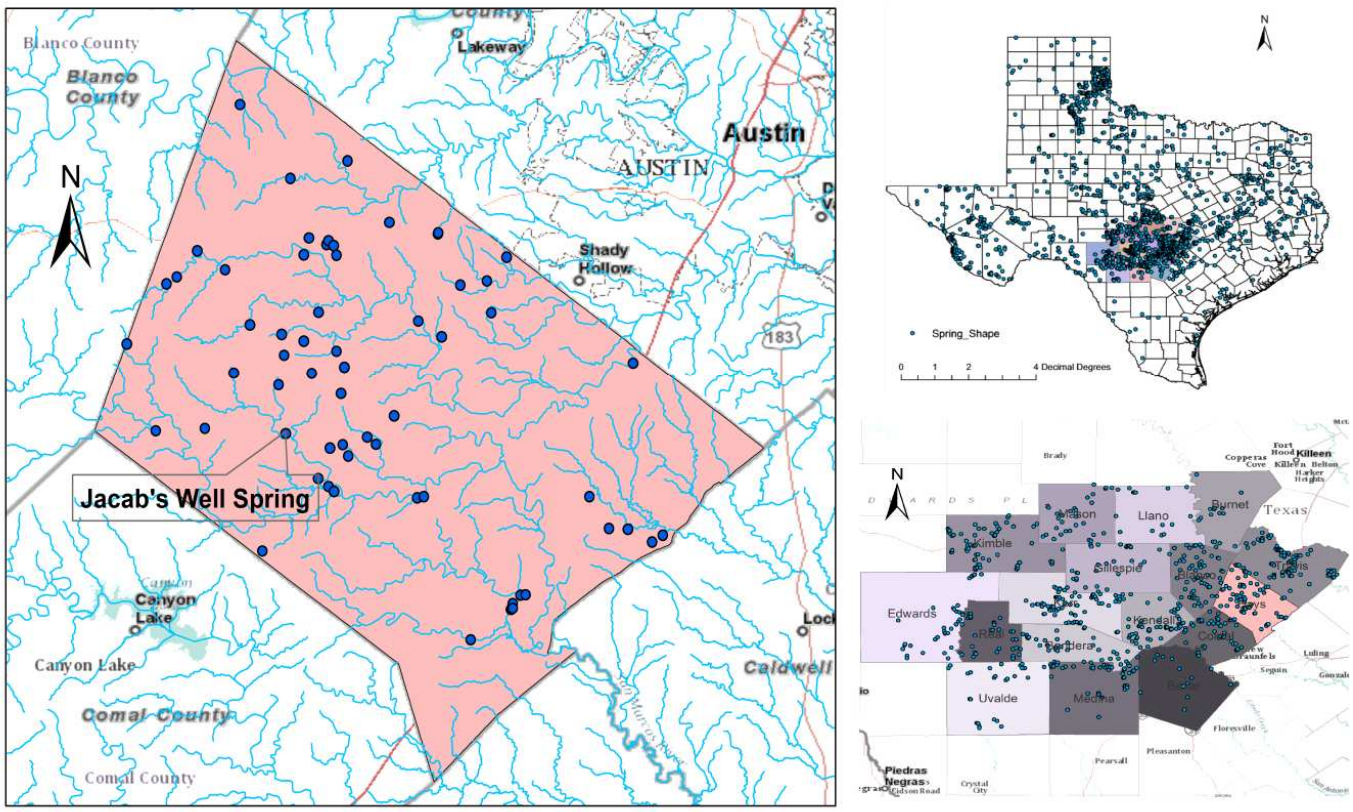

Fig. 1 Jacob's Well Spring in the Hays County

3 Data Resources

Most of the data used in this project can be found in the GeoSpatialDataGateway of Natural Resources Conservation Service of the United States Department of Agriculture (USDA), including NRCS Counties by State data, 12 Digit Watershed Boundary Dataset 1:24,000, and National Elevation Dataset 10meter.

http://datagateway.nrcs.usda.gov/GDGOrder.aspx

The spring location data was offered by the Hill Country Alliance (HCA). Data was downloaded from the Texas Hydrological Innovations Website.

http://geosites.evans.txstate.edu/g4427/2010/s10/THI/maps.html

The flow line data was from the exercise 4 of the GIS class.

Water temperature data and time series discharge data was achieved using the ArcHydro Desktop.

Population Data was from the U.S. Census Bureau at http://www.census.gov/ .

4 Analysis

4.1 Delineate the upstream watershed of the Jacob's Well Spring

In order to delineate the upstream watershed of the Jacob's Well Spring, a 10m Digital Elevation Data map which include 25 maps was download from the GeoSpatialDataGateway. The "Mosaic to New Raster" tool was used to yield a continuous whole map of the 10m Digital Elevation Data for the Hays County for the convenience of analysis. The DEM was then projected into Texas Centric Albers Equal Area projection.

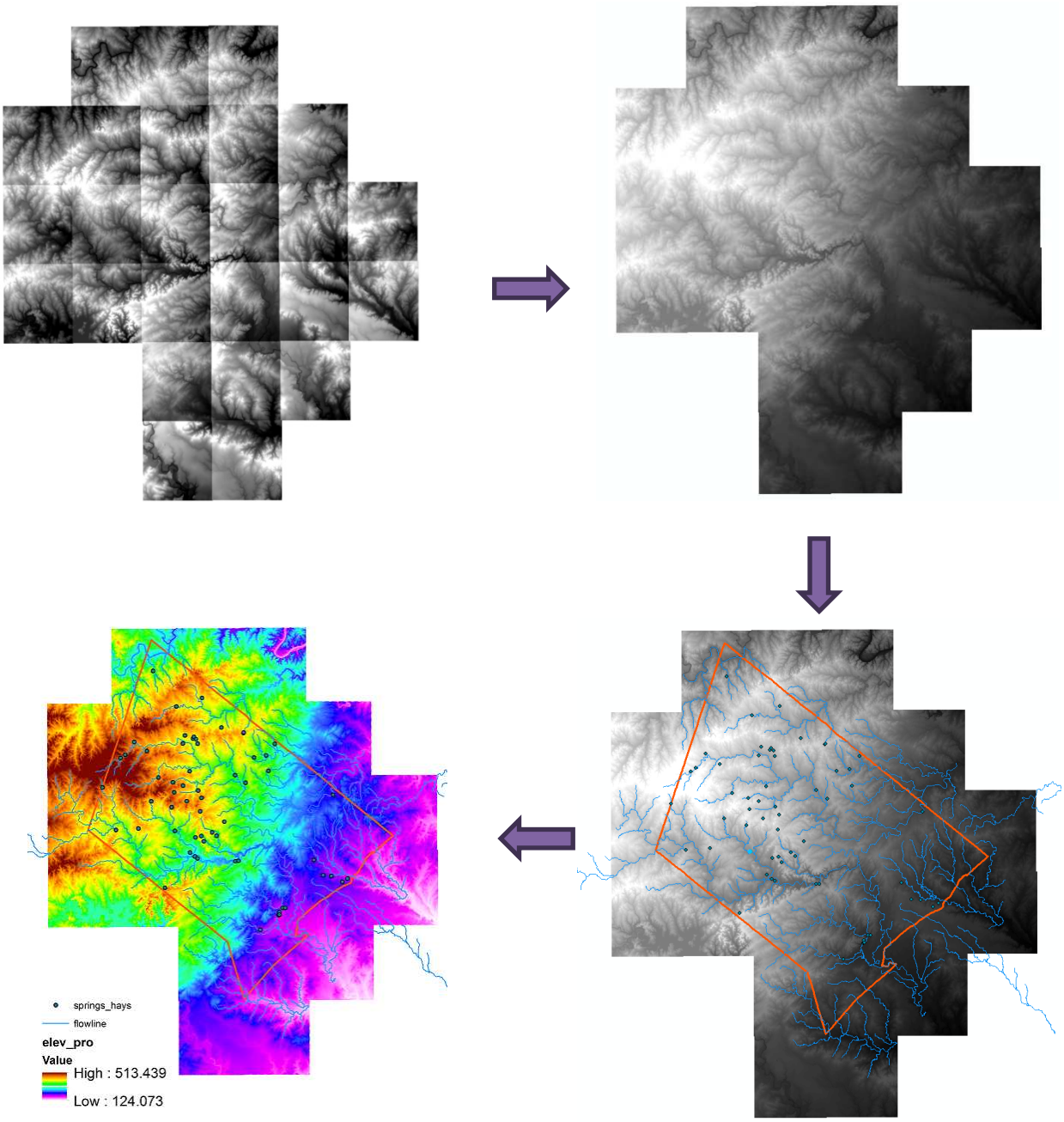

Fig. 2 Mosaic and projection of the DEM map of the Hays County

Flow direction based on the DEM was calculated after the DEM reconditioning and sink filling. The result of the flow direction is shown in Fig. 3.

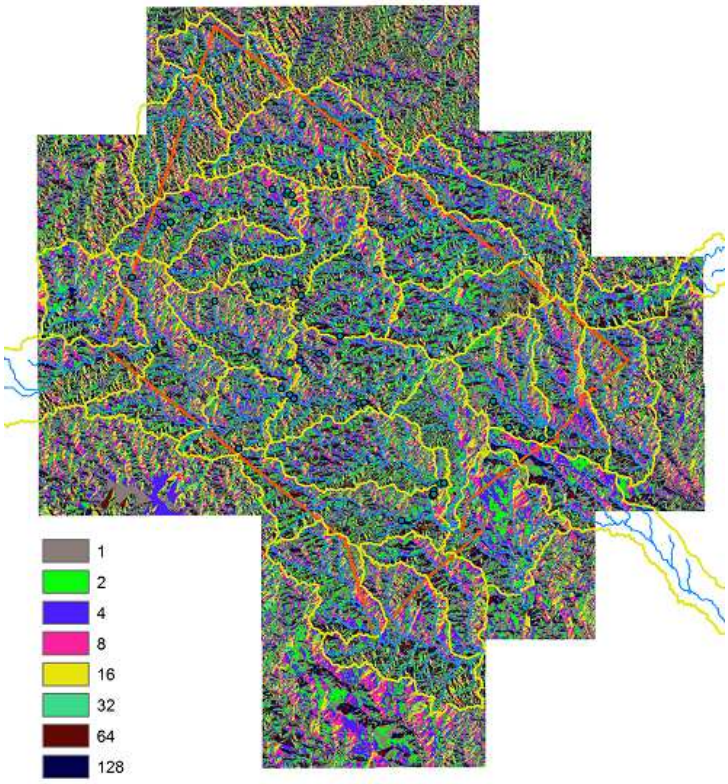

Fig. 3 Flow direction of the study area

Flow accumulation tool computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell for all the input grids. Fig. 4 shows the result of the flow accumulation near Jacob's Well Spring.

Fig. 4 Flow accumulation

The Jacob's Well Spring is not exactly located on the stream lines. In order to delineate its upstream watershed, the spring point should be put on the nearest stream using the Snap Pour Point tool. Then the snap pour point was chosen as the input feature to delineate the upstream watershed for the Jacob's Well Spring using the Watershed tool. The delineated watershed is shown in Fig. 5, and the drainage area can then be calculated by multiplying the grid cells numbers and the cell size.

Drainage area = Grid cells × Grid size = 625232 × 100m^2 =62523200 m^2

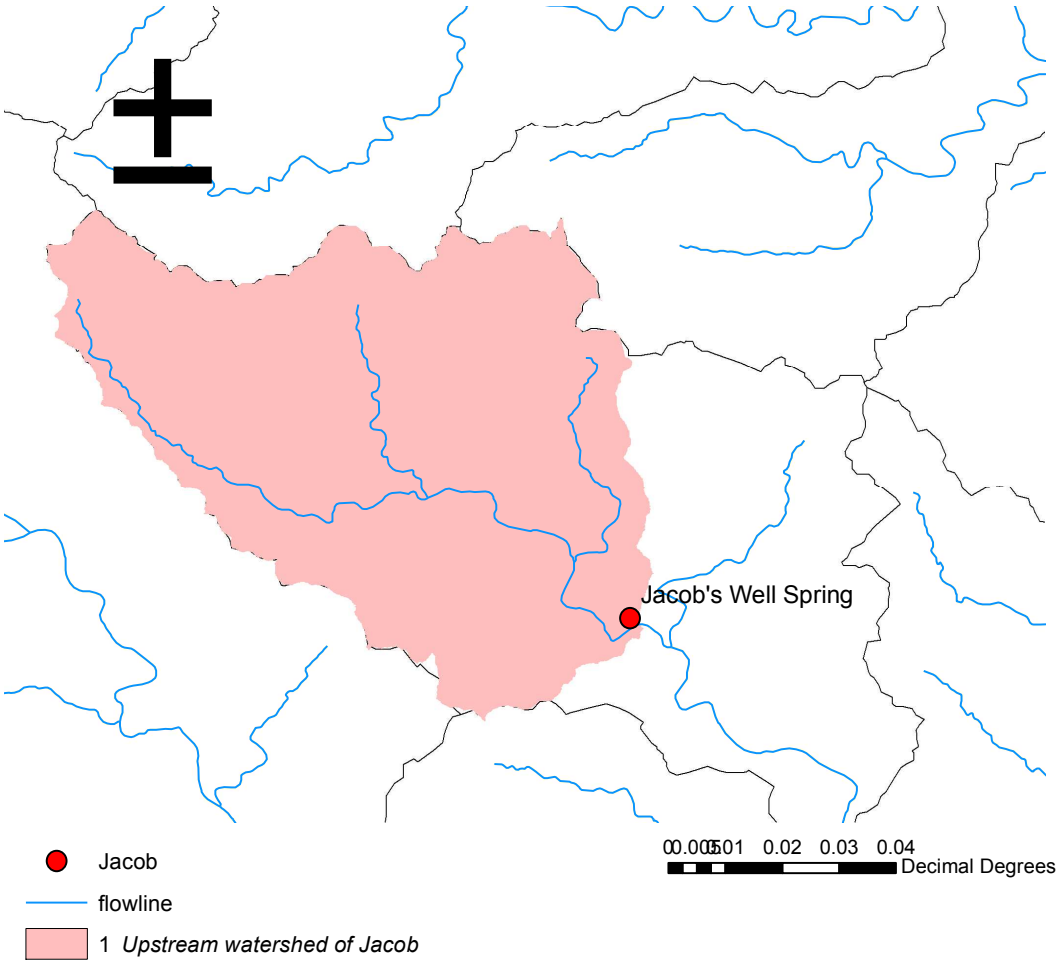

Fig. 5 Upstream Watershed of the Jacob's Well Spring

4.2 Hydrological characteristics

Mean Annual Flow of the Cypress Creek is labeled in Fig. 6. (Note: The unit of mean annul flow is cfs.)

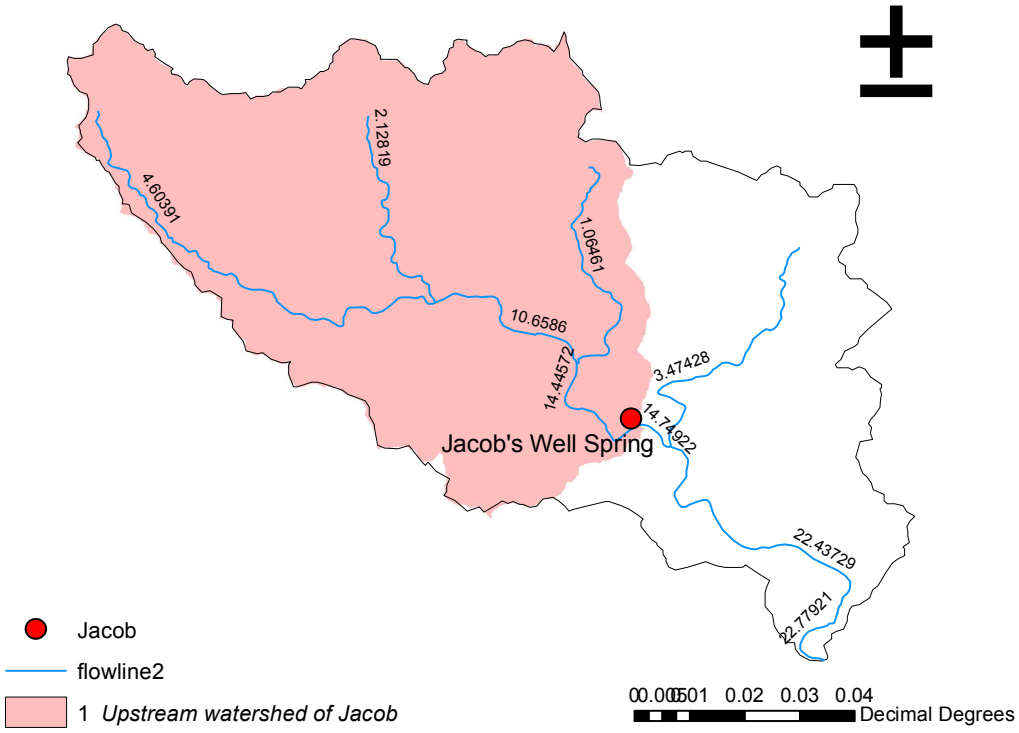

Fig. 6 Mean Annual flow of the subwatershed

Let's firstly get into some basic knowledge about the water dicharge. Fig. 7 demonstrates a basic model of the water that flows into the spring. Ground water flows underground until it reaches a discharge zone, an area where the water is above the land surface. Springs are clearly visible discharge zones. Evaporation by plants can also contribute to the discharge of the groundwater. However, in order to simplify the analysis here, the evaporation was igonored in this project.

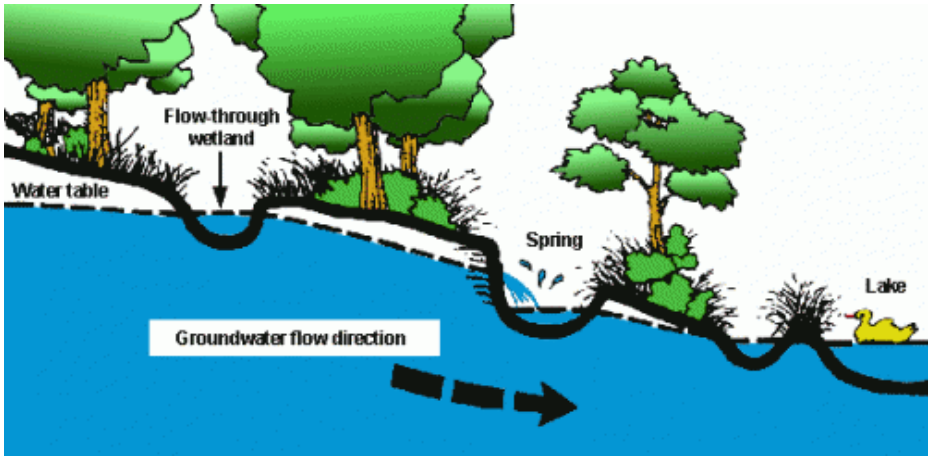

Fig. 7 Water discharge

http://groundwater.oregonstate.edu/groundwater/html/GroundwaterMovement.htm

If add the major aquifer data into GIS, it can be realized that Jacob's well spring is right located at the discharge area of the Trinity Aquifer. It is obvious that the major water source of the spring is from the Trinity Aquifer.

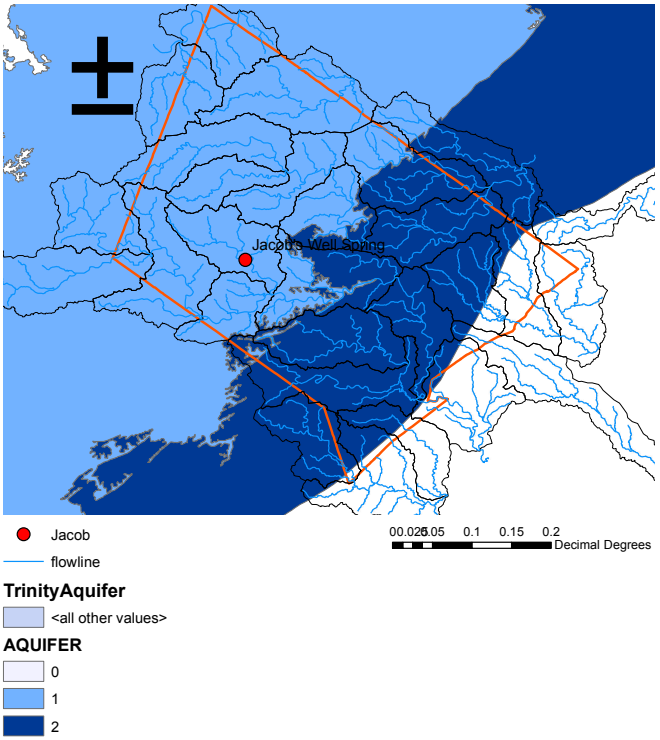

Fig. 8 Trinity Aquifer at the Hays County

In order to get a best understanding of water sources of the Jacob's Well Spring, the temperature data of the surface water and spring water is needed in order to decide the percentage of the water that comes into the spring. Equipment monitoring the velocity and temperature of the Jacob's Well Spring was set up at 54 feet below the water surface on May 10, 2005.

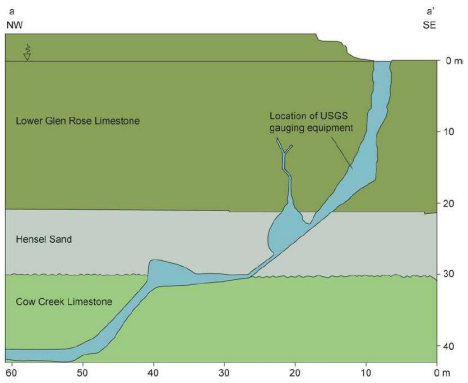

Fig. 9 Monitoring point

http://water.usgs.gov/osw/images/2007_photos/Hydroacoustics.html

The time series temperature data of the Jacob's Well Spring from Jan. 2009 to Jan. 2011 was plotted using GIS graph tool. It should be noticed that the temperature of the groundwater is almost fixed. However, the temperature of the monitoring point decreased dramatically during the spring season as shown in Fig. 10, and increase slightly in the summer.

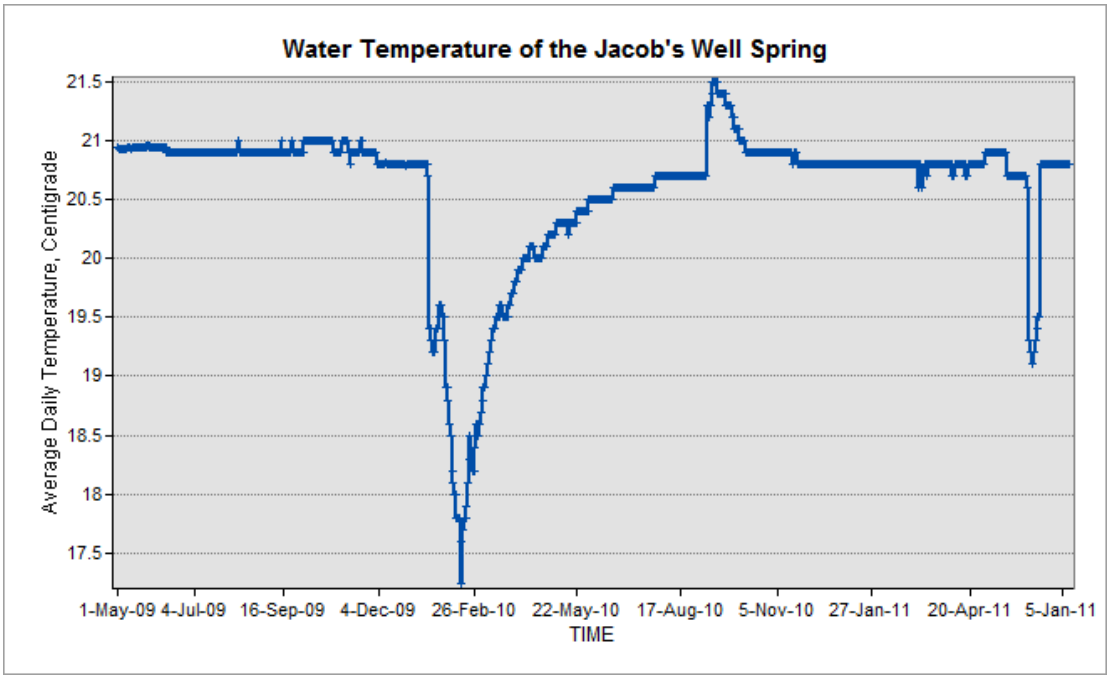

Fig. 10 Water temperature of the Jacob's Well Spring

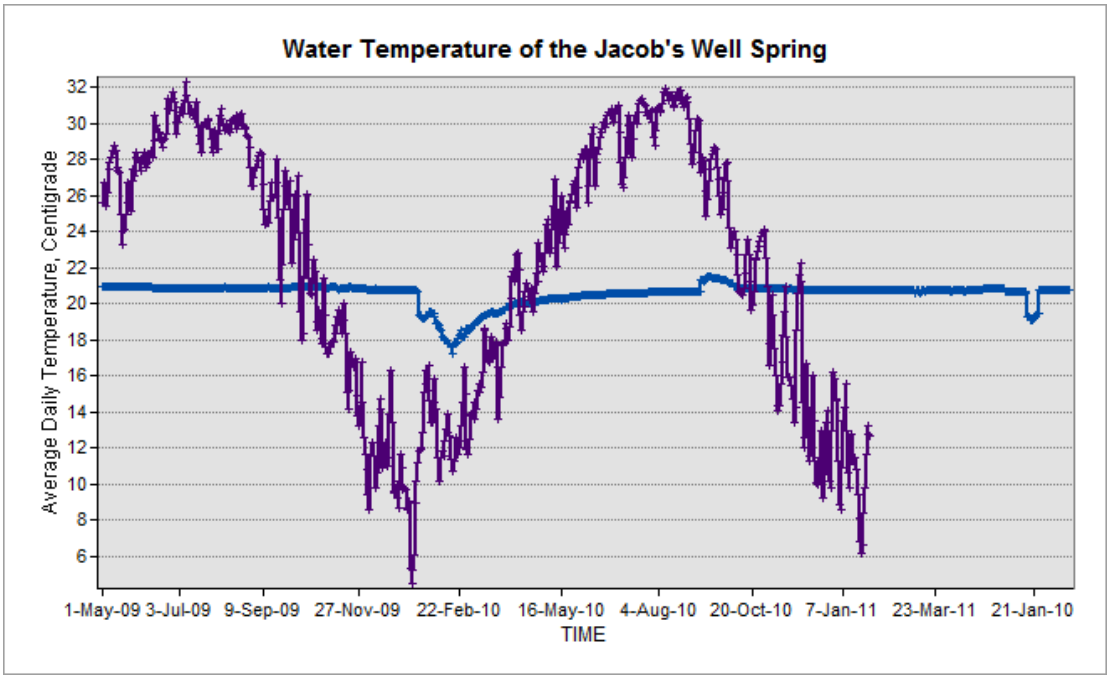

Fig. 11 Comparison of surface water temperature and groundwater temperature

According to Fig. 11, the surface water temperature varies periodically, reaching the highest point in the summer and lowest point in the winter. In conclusion, the groundwater temperature decreases in the winter which indicates an inflow with lower temperature from the surface water. Similarly, the temperature of the groundwater gets a little higher in the summer due to another inflow from the surface water with higher temperature. The discharge of the Jacob's well spring is shown in Fig. 12. It is obvious that the contribution of the surface water to the spring is significant during the summer and winter period.

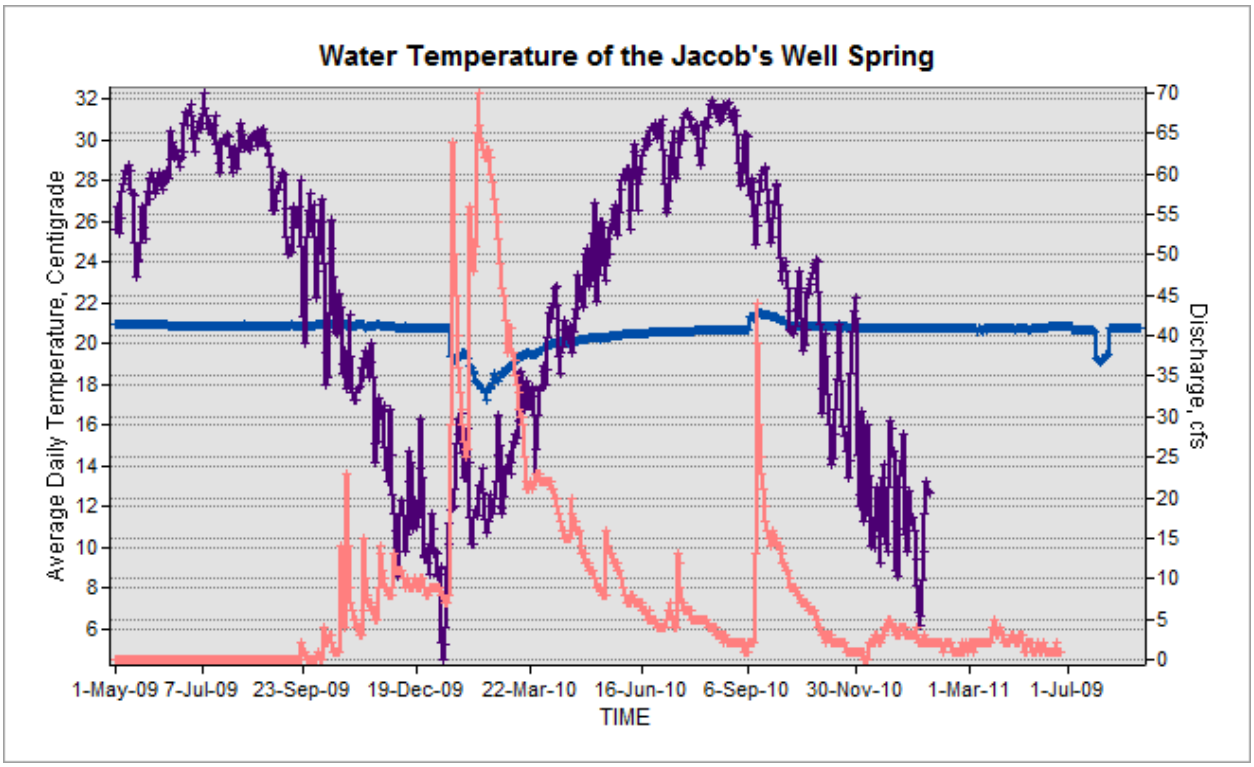

Fig. 12 Discharge of the Jacob's Well Spring

4.3 Population of the Hays County

Population increase plays an important role in the water quantity and quality conservation. Because the water resource is limited, a sound management of water use should be achieved considering the population growth, and the water pollution due to human activity should also be realized, and considered. According to a statistic of population in Texas which is shown in table 13, Hays County has the highest increase percentage of population from 2010 to 2050. The population is going to increase 177.76%.

County	County Size (Ac)	Population 2000	Population 2010	2000-10 Percentage Increase	Projected Population 2050	2010-50 Projected Population Increase
Bandera	510,107	17,645	20,485	16.10%	56,642	176.50%
Bexar	804,045	1,392,931	1,714,773	23.11%	2,369,950	38.21%
Blanco	456,498	8,418	10,497	24.70%	16,641	58.53%
Burnet	652,665	34,147	42,750	25.19%	78,981	84.75%
Comal	367,818	78,021	108,472	39.03%	278,626	156.86%
Edwards	1,356,643	2,162	2,002	-7.40%	2,264	13.09%
Gillespie	678,784	20,814	24,837	19.33%	30,861	24.25%
Hays	434,065	97,589	157,107	60.99%	436,388	177.76%
Kendall	423,970	23,743	33,410	40.72%	89,312	167.32%
Kerr	708,100	43,653	49,625	13.68%	61,204	23.33%
Kimble	799,456	4,468	4,607	3.11%	4,702	2.06%
Llano	618,056	17,044	19,301	13.24%	24,393	26.38%
Mason	597,060	3,738	4,012	7.33%	3,891	-3.02%
Medina	855,074	39,304	46,006	17.05%	75,370	63.83%
Real	447,657	3,047	3,309	8.60%	3,070	-7.22%
Travis	655,606	812,280	1,024,266	26.10%	1,770,347	72.84%
Uvalde	999,896	25,926	26,405	1.85%	36,876	39.66%
Total	**11,365,501**	**2,624,930**	**3,291,864**	**25.41%**	**5,339,518**	**62.20%**

Table 13 Population and population increase of Texas

Hillcountryalliance.org

In order to get the idea of the population increase of the subwatershed where the Jacob's Well Spring is located, the population data was put into the GIS and was confined to the subwatershed using the clip tool. The result can be seen in Fig.14. Each dot represents one person on the map.

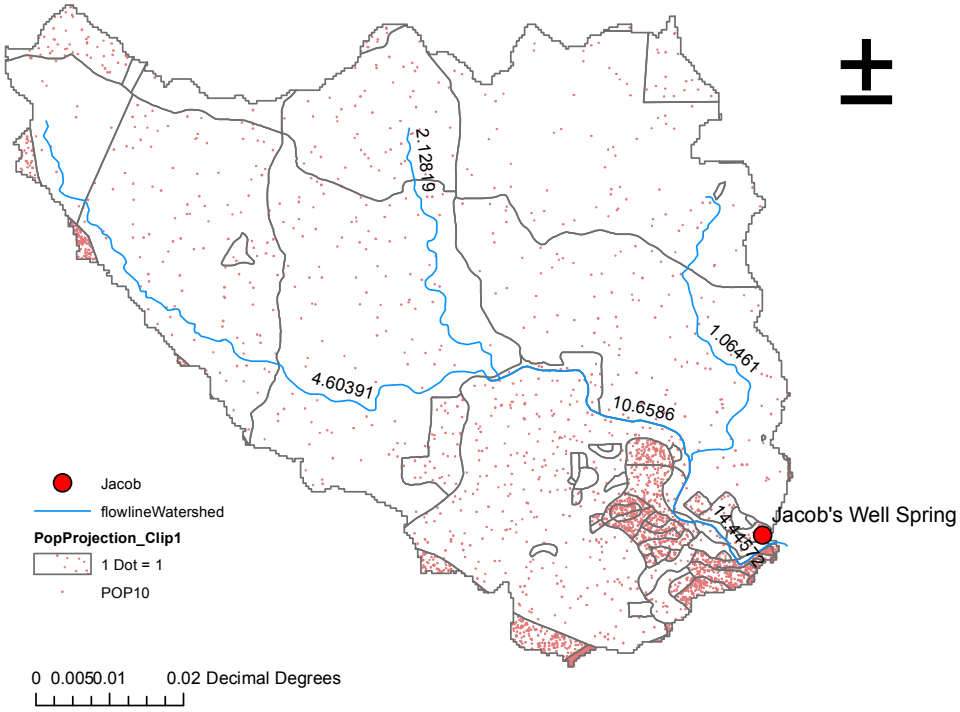

Fig. 15 Current population density

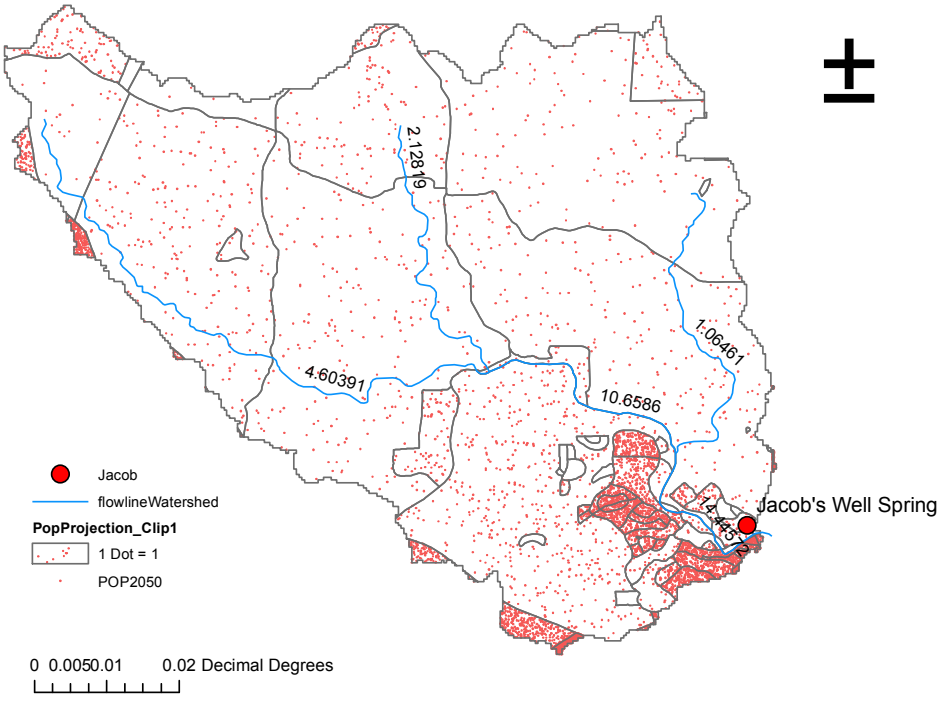

Fig. 16 Population density in 2050

Fig. 15 and Fig. 16 indicate the distribution of population in the upstream watershed of the Jacob's well spring. It is clear that the population is close to the Jacob's Well Spring and is distributed mostly along the upstream cypress creek of the spring.

Population is highly correlated with public water supply, about 56 percent of which is allocated for domestic (household) purposes. According to the U.S. Geological Survey, the average per capita public water use in the United States in 1995 was about 179 gallons per capita per day (gpcd) and that for domestic water use was about 101 gpcd. An average per capita figure for all water uses in the United States in 1995 (municipal, industrial, agricultural, etc.) was estimated to be about 1,280 gpcd.

The impact of population on the ability of water sources to meet the demands placed on them by society is paralleled by the effects of population on the quality of water resources. People alter the properties of water as they use it, often degrading the quality with each successive use. Water used in households for drinking, bathing, and cooking becomes contaminated by various chemicals and other constituents introduced during its use. Drainage from water applied in agricultural irrigation carries away chemicals that have been applied to crops to enhance their growth and control weeds and pests. Industries introduce chemicals needed for the manufacture of their products.

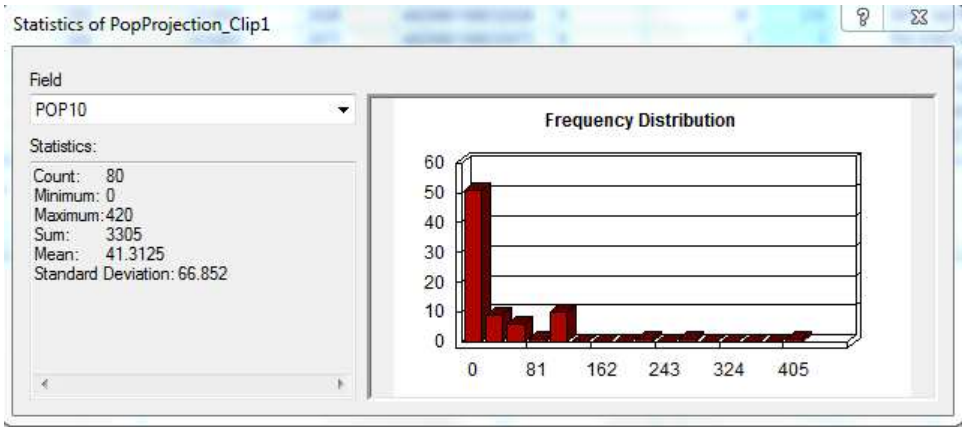

Fig. 17 Population statistics of 2010

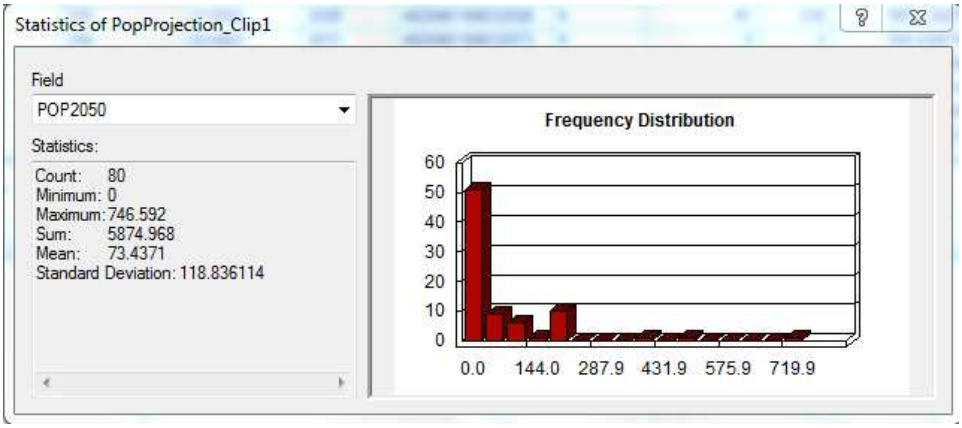

Fig. 18 Population statistics of 2050

The total population of this area in 2010 and 2050 can be calculated by statistics tool. The result is shown in figure 17 and figure 18.

Use	Gallons per Capita	Percentage of Total Daily Use
Showers	11.6	16.8%
Clothes Washers	15.0	21.7%
Dishwashers	1.0	1.4%
Toilets	18.5	26.7%
Baths	1.2	1.7%
Leaks	9.5	13.7%
Faucets	10.9	15.7%
Other Domestic Uses	1.6	2.2%

Fig. 19 Statistics of daily water usage per capital

http://www.drinktap.org/consumerdnn/Home/WaterInformation/Conservation/WaterUseStatistics/tabid/85/Default.aspx

With the population increase in this upstream watershed, the water demand and water burden of the watershed will be intensified as well. According to the statistics in figure 19 done by the American Water Works Association, the daily indoor water usage of the upstream watershed can be calculated as 229036.5 gallons per day in 2010 and 407137.5 gallons per day in 2050.

5 Conclusion

The Jacob's Well Spring reflects the ground water level of the trinity aquifer, and it joins the Cypress Creek serving as the source for the downstream water. However, the spring water will also suffer periodically from a return of the surface water during the summer and winter period. The delineation of the upstream watershed of the Jacob's Well Spring plays an important role in the analysis of population influence on the area. The fast growth of population in this area should be paid enough attention to, because human activity will greatly impact the water amount and water quality of the springs especially during the summer and winter period when the surface water will possibly return to the spring.

Reference

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