Correlation Between Stream Flows and Land Use in Cache County, UT

GIS in Water Resources Term Project

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The purpose of this paper was to determine if there is any correlation between stream flows and land use in Cache County, UT. GIS was used to analyze mean annual stream flow and land use changes.

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Introduction:

I have taken an interest to the way water moves and changes over time. At the beginning of this term project I thought it would be interesting to examine the effect of land use and urbanization on stream flows. I selected Cache County as my area of study as this is the area in which I live. I began by gathering data concerning land use, population, and stream flows but I soon learned that there are many factors of uncertainty it a project of this nature. In order to decrease some of this uncertainty I also examined temperature and precipitation data to make sure that potential trends were not simply functions of climate. I selected a range of study between 1970-2011 however, some data was not available for this full range of dates. An analysis of stream flow and land use using ArcGIS10 showed that stream flow is decreasing as land use changes from rural to urban.

Data Sources:

To increase accuracy of my findings many data sources were selected in order to compare the results.

Beginning with the US Census, population data was collected for Cache County between 1900-2010. In 1970 the US Census began collecting data on the number of housing units as well. This data serves as land use change and increased water use information.

Temperature and precipitation data were collected from the Utah Climate Center (Utah State University, 2011). This service is run by Utah State University and is available by internet. Data was collected from the USU monitoring station between 1970-2011.

Information regarding stream flow and land cover was obtained from the USGS. Stream flow data was selected as yearly averages for the time period of study. Land cover data was retrieved from the seamless application on the USGS site for the years 1992, 2001, and 2006.

Hydrography and Hydrologic Units data was gathered from the NHDPlus 16 data set (NHDPlus, 2010). This information provided the average annual stream flow, monitoring points, as well as other hydrologic data.

Data Collection:

To begin data collection I looked to the U.S. Census for population data. While looking for population data I also found that the Census began collecting the number of housing units in 1970. I also gathered this information to show how land use was changing. Looking at Figure 1 we can see that for a while the population of Cache County was increasing slowly, about 1970 there was a sharp increase in the population growth rate. From the chart it is also clear that there has been a steady increase in housing units as well. In a Water Master Plan created by JUB Engineering they claim that the growth rate over the last 50 years was 2.1% and 2.7% in the last ten years for the City of Smithfield (JUB, 2005). As this statistic is for the Smithfield it does not represent the entire Cache County but it gives an indication the Cache County in continuing to grow and at a more rapid rate.

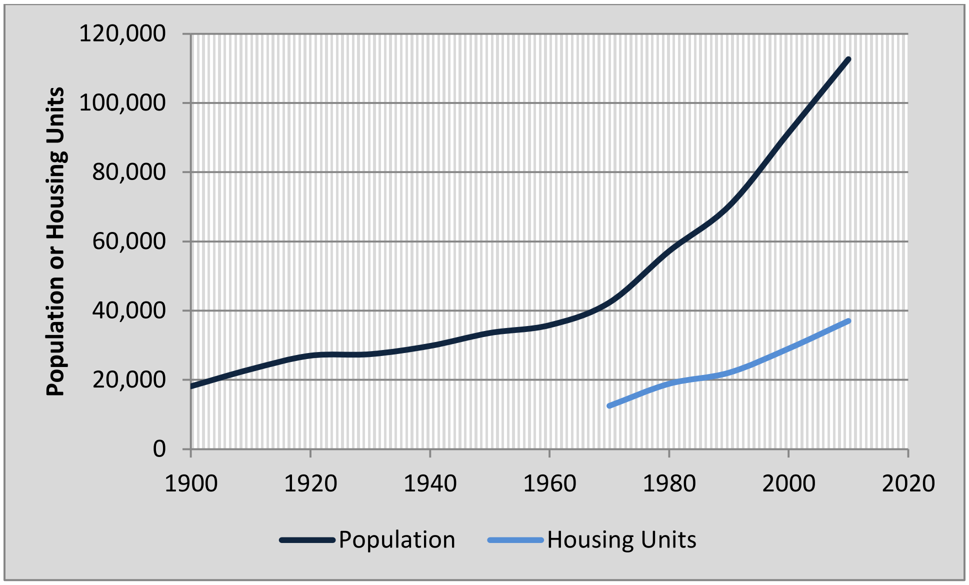

Figure 1 - Population and Housing Data

A suggestion I had during the course of this project was to look at the number of water connections throughout the Valley. Linda Holland of Logan City was able to help me with a table of connections in Logan for the past 20 years. Figure 2 shows these connections (Personal Communication October 26, 2011).

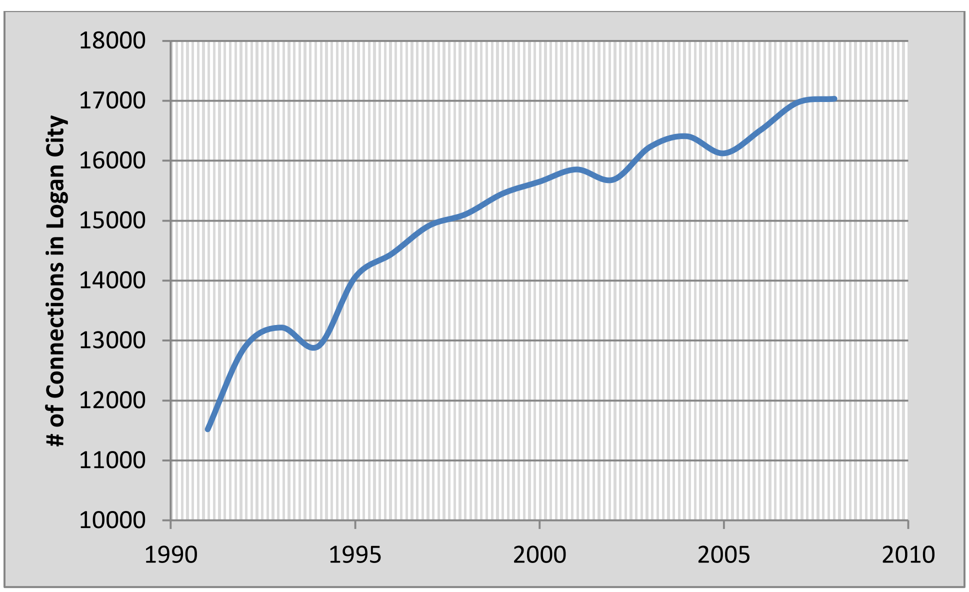

Figure 2 - # of Water Connections in Logan

This graph indicates that more water is always being used and since the majority of water in Logan is groundwater we know that more water is being pumped from the wells around Logan to meet the growing water demands. I also contacted the City of Smithfield, however they only had their current number of water connections and not a times series so I decided that that information was not useful.

If we take these two graphs as an indication as to what is happening in Cache County, we see that the population is constantly growing and that more water is being used.

After this basic data was collected GIS was used to show mean annual stream flows as well as land cover changes.

Using ArcGIS10:

Mean Annual Stream Flows:

In ArcMap a geodatabase was created for the area of study. NHDPlus 16 data was added to the map as well as a map of the counties in Utah. As can be seen in Figure 3, NHDPlus provided much more information than was needed for this project (NHDPlus, 2010). To use just the data for Cache County, the data was clipped using the Clip Tool in GIS. Data was clipped to the boundary of Cache County seen in Figure 4 (Utah GIS Portal, 2011).

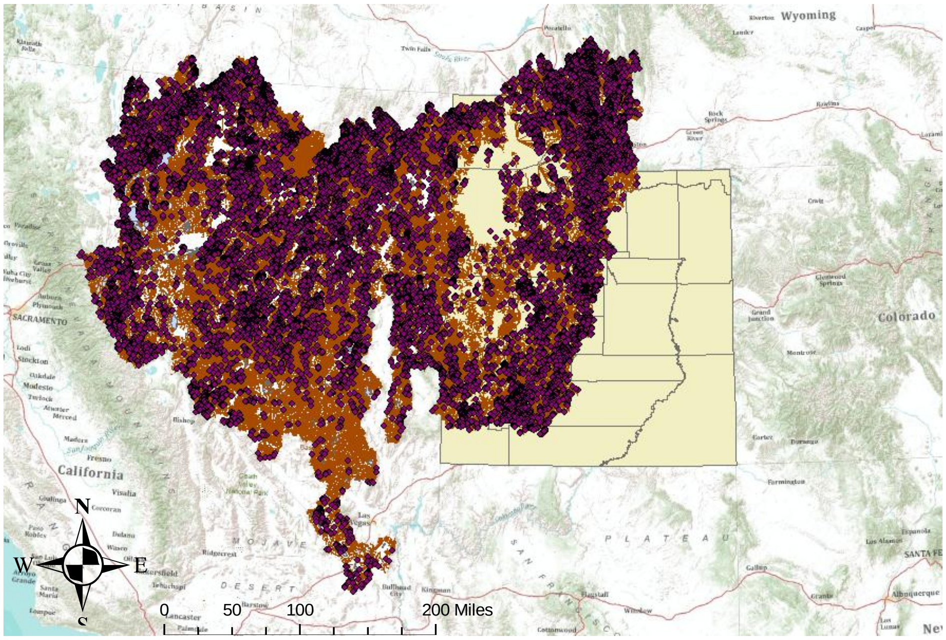

Figure 3 - NHDPlus 16 Sites and Stream Flow

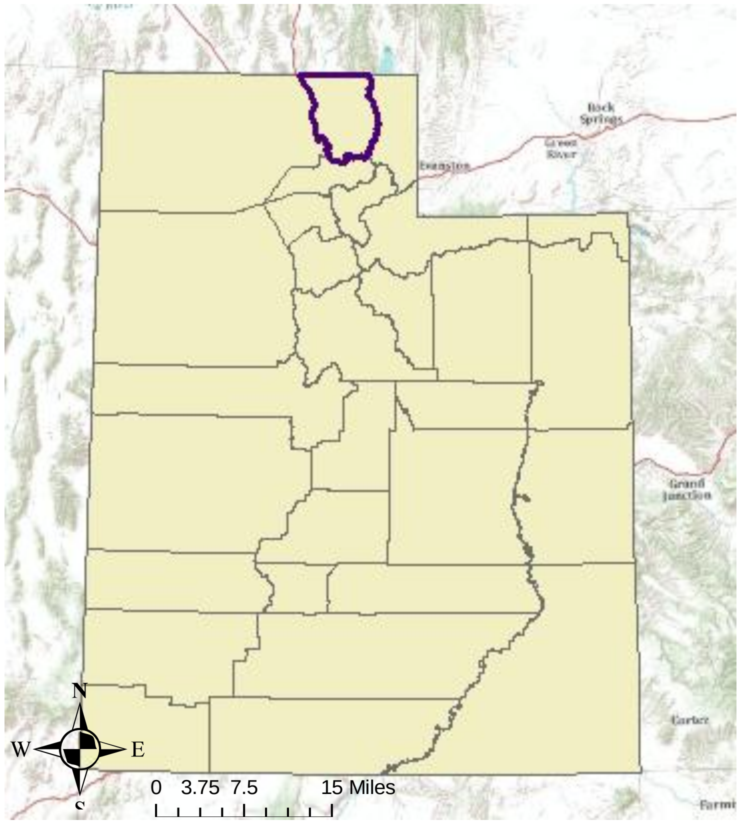

Figure 4 - Study Area: Cache County, UT

After data was clipped, it could then be used for analysis. To more clearly see stream flow and direction of the flow the streams were delineated. To begin, a Mean_Annual_Flow column was added to the flow lines attribute table. I was then able to join attribute tables using COMID to show the mean annual flow for my study area. The null values were filled in using the field calculator and my delineated area was created.

After delineation one can see that the major rivers are the Logan River, Blacksmith Fork River, and the Bear River, with all streams draining into the Bear River, Figure 5. Streams that have a thinner line width drain into those with larger line widths with the Bear River being the largest river in the study area. By clicking on and river on the map with the identify tool a table will be displayed where information such as the length of the reach and mean annual stream flow will be displayed. This is helpful in understanding the basic set up of the study area and where water is flowing from and towards.

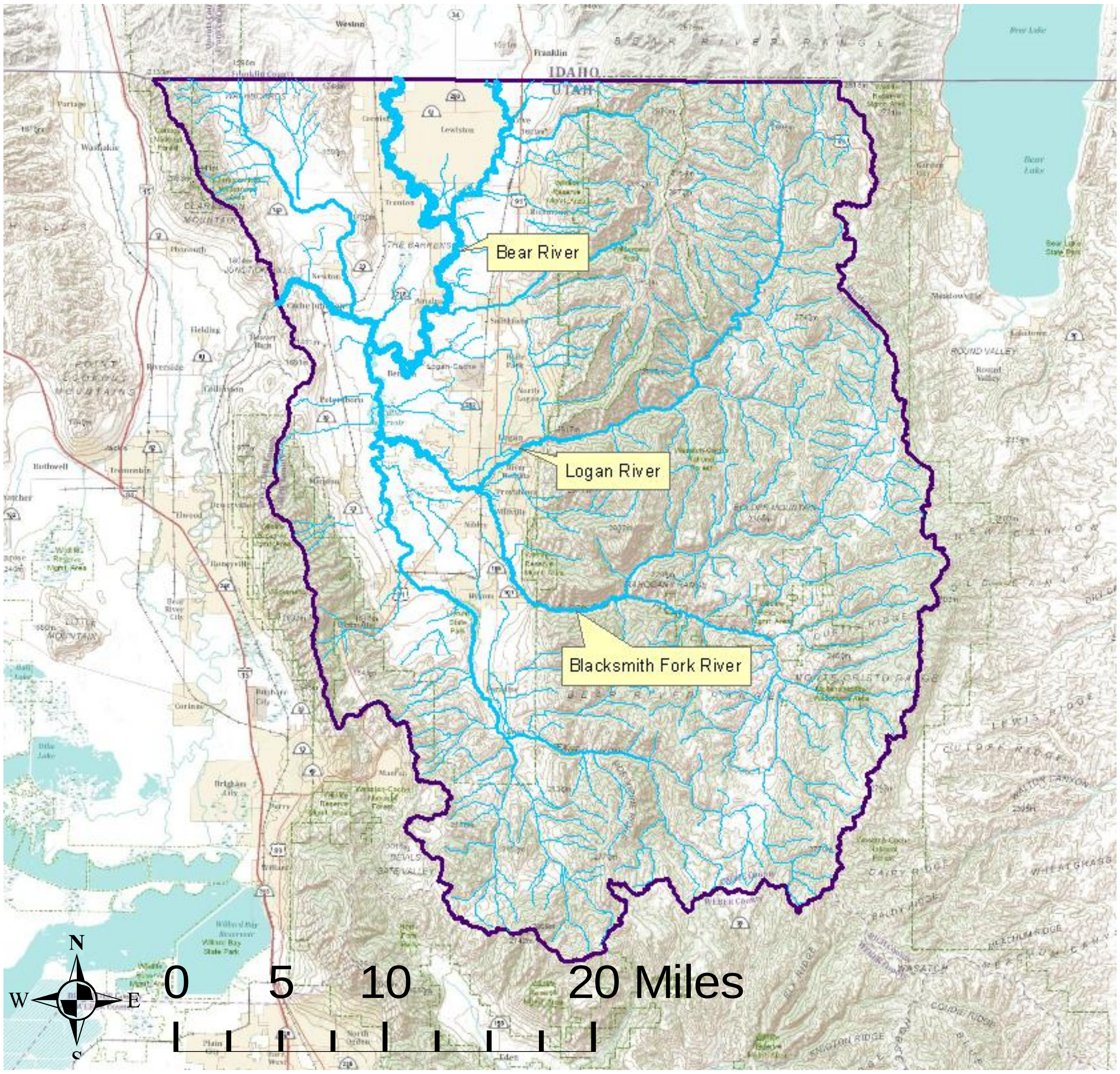

Figure 5 - Delineated Cache County

Land Use/ Land Cover Data:

To have a more visual image of the land use changes in Cache Valley I downloaded and clipped USGS Seamless data to fit the study area (USGS, 2010). Figure 6, 7, and 8 show the land use for 1992, 2001, and 2006 respectively. Data that was collect for the year 2001 did not contain the same information as for the year 1992 and 2006. Since the data is not comparable it was not used in the analysis as it would create non-useful results.

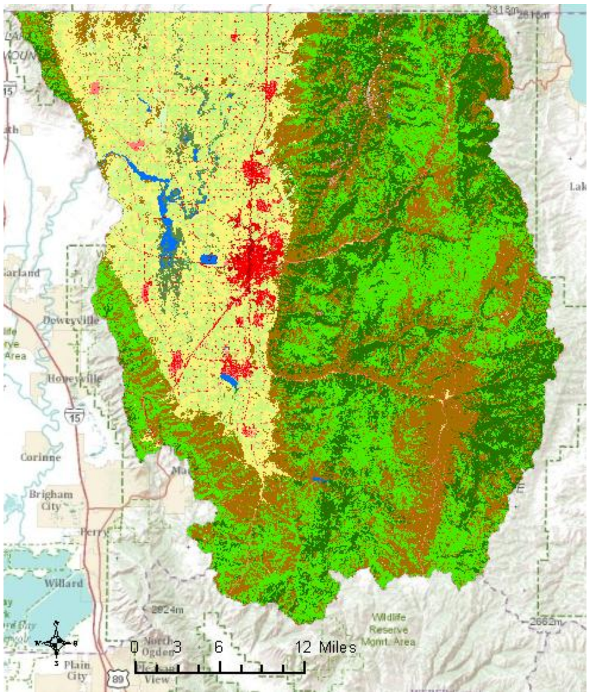

Figure 6 - 1992 Land Cover

Table 1 - 1992 Attribute Table

cc1992.vat:VALUE	cc1992.vat:COUNT	'1992Export_Output$'.Area_km^2	'1992Export_Output$'.Land_Use
11	20600	18.54	Open Water
21	72254	65.0286	Developed, Open Space
22	53508	48.1572	Developed, Low Intensity
23	13917	12.5253	Developed, Medium Intensity
24	5626	5.0634	Developed, High Intensity
31	7841	7.0569	Rock, Sand, Clay
41	865923	779.3307	Deciduous Forest
42	581720	523.548	Evergreen Forest
43	39021	35.1189	Mixed Forest
52	850586	765.5274	Shrub/Scrub
71	36061	32.4549	Grassland
81	407286	366.5574	Pasture/Hay
82	358227	322.4043	Cultivated Crops
90	20620	18.558	Woody Wetlands
95	42362	38.1258	Emergent Wetlands

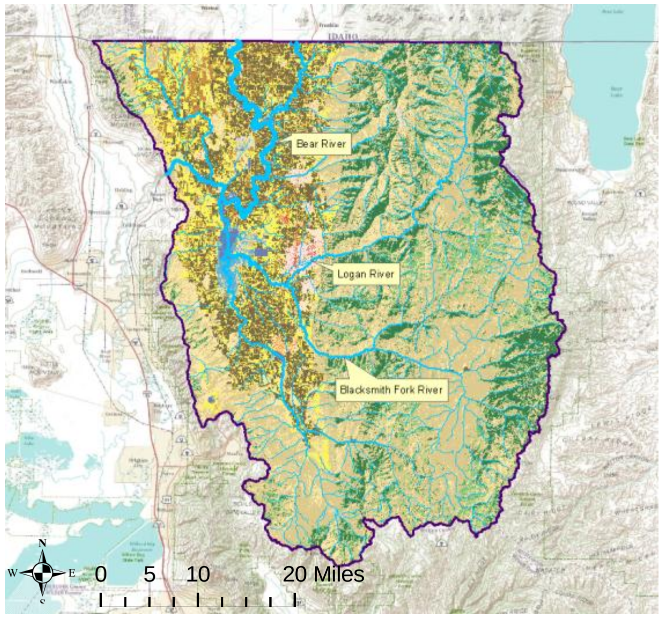

Figure 7 - 2001 Land Cover

As the same data was not available for 2001 as for 1992 and 2006, these results were eliminated as they would create inaccurate results.

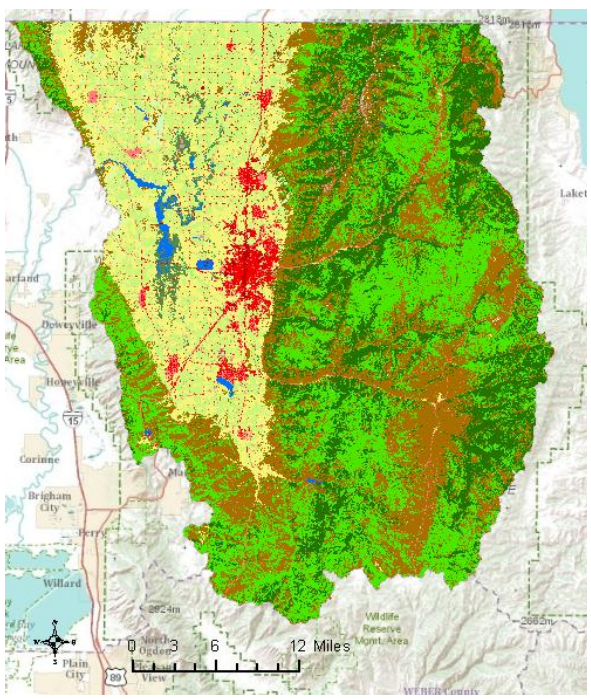

Figure 8 - 2006 Land Cover

Table 2 - 2006 Attribute Table

cc2006.vat:VALUE	cc2006.vat:COUNT	'2006Export_Output$'.Area_km^2	'2006Export_Output$'.Land_Use
11	21641	19.4769	Open Water
21	74545	67.0905	Developed, Open Space
22	56240	50.616	Developed, Low Intensity
23	16027	14.4243	Developed, Medium Intensity
24	6266	5.6394	Developed, High Intensity
31	8517	7.6653	Rock, Sand, Clay
41	867878	781.0902	Deciduous Forest
42	580605	522.5445	Evergreen Forest
43	38777	34.8993	Mixed Forest
52	848640	763.776	Shrub/Scrub
71	35982	32.3838	Grassland
81	402853	362.5677	Pasture/Hay
82	355583	320.0247	Cultivated Crops
90	20306	18.2754	Woody Wetlands
95	41692	37.5228	Emergent Wetlands

Figure 9 - Legend for 1992 and 2006 Land Cover Maps

The changes in land cover between 1992 and 2006 were much more difficult to see on the maps than had been expected. The attribute tables that were created were much more helpful in determining land used changes. The maps are broken into 30m*30m cells. On the table we can see how many cells there are per each land use category as well as the area used by each of the designated land uses. Area was calculated by multiplying the number of cells by the area of each cell. Table 3 highlights some of the most extreme changes in land use. Medium and high developed area, meaning 50 to 100% impervious area of the developed region, increased by quite a bit, while the wetlands and pasture areas did not decrease by much. One reason I see for this there is a large area of rural land and when a small portion is converted to urban the percent change of urban skyrockets while it does not make much of a change for the rural areas.

Table 3 - Land Use Changes Between 1992-2006

Land Use	1992 Area km^2	2006 Area km^2	% Change
Developed, Low Intensity	48.16	50.62	5.11
Developed, Medium Intensity	12.53	14.42	15.16
Developed, High Intensity	5.06	5.64	11.38
Pasture	366.56	362.57	-1.01
Woody Wetlands	18.56	18.28	-1.52
Emergent Wetlands	38.13	37.52	-1.58

Stream Flows:

After the investigation of land cover was complete I then needed to look at stream flows throughout Cache County. Throughout the County there are three major rivers that the majority of smaller rivers and streams flow into. Stream flow data for the Logan River, Blacksmith Fork River, and the Bear River were gathered from the USGS. The USGS collects data every day of the year (USGS, 2011). I took this data and created a yearly average during the period of study. Figures 10, 11 and 12 show yearly stream flow averages for the Logan River, Blacksmith Fork River, and Bear River respectively. After the data were plotted a trend line was drawn through each graph to see if stream flows were increasing, decreasing, or remaining the same. As can be seen all stream flows are decreasing for the data collected.

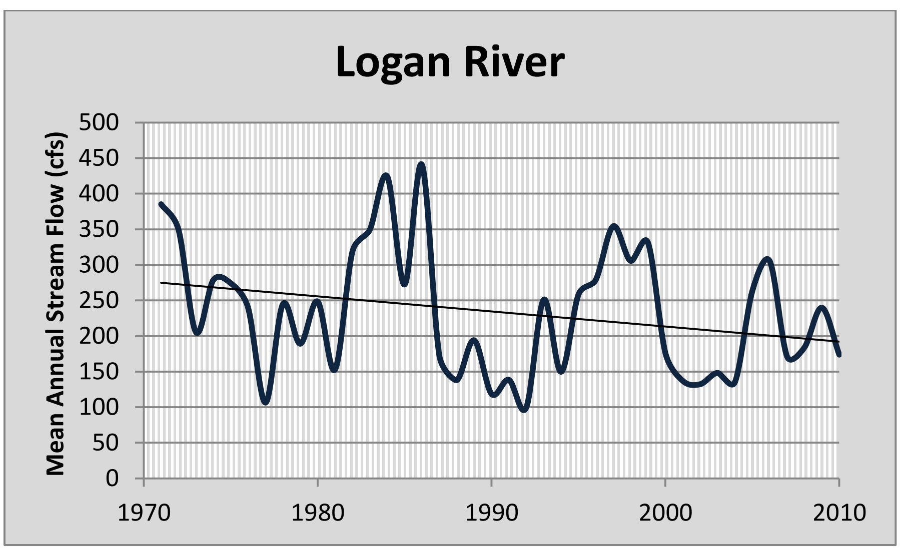

Figure 10 - Annual Average Stream Flow: Logan River

The slope of the trend line for the Logan River is 2.1%. This does not show a great decrease in stream flow over the last 40 years, but it does show that it is slowly decreasing. The Logan River provides water for recreation and irrigation throughout the Logan and Smithfield areas of Cache County.

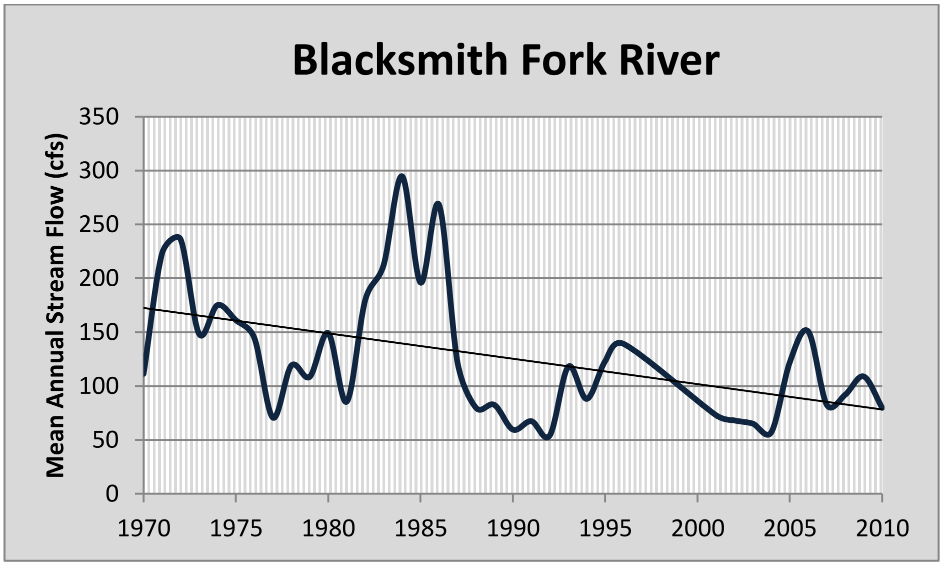

Figure 11 - Annual Average Stream Flow: Blacksmith Fork River

The Blacksmith Fork River has decreased in flow by 2.3% over the last 40 years. This is very similar to the Logan River in that stream flows have not changed a lot but have decreased. Both the Logan River and the Blacksmith Fork River flow into the Bear River, as just many of the Bear River's tributaries. The Bear River is one of the longest rivers in the United States and flows through many states before passing through Cache County.

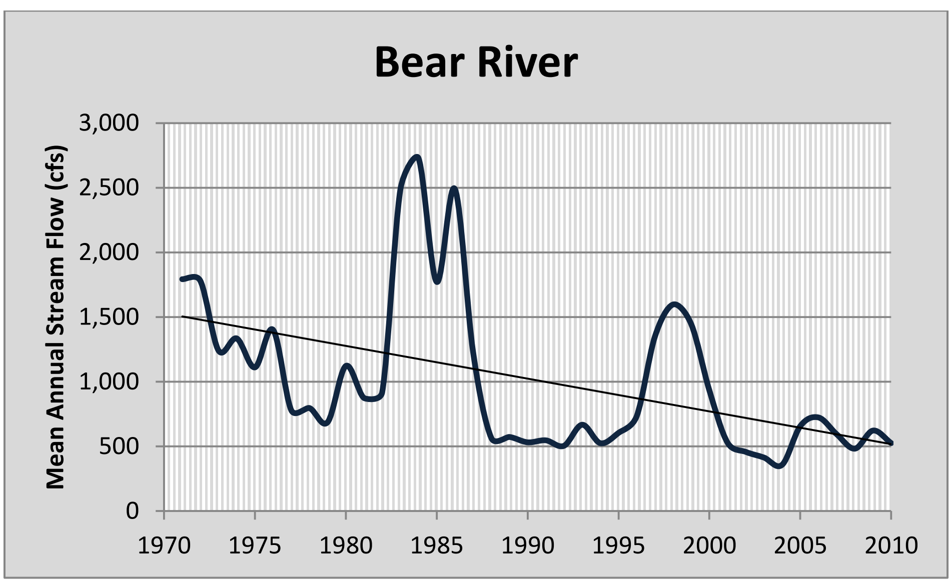

Figure 12 - Annual Average Stream Flow: Bear River

The Bear River has decreased in average annual stream flows by nearly 25% since 1970. There could be many reasons for all of flow decreases in these rivers and land cover could be one of those reasons. Because of the length and complexity of the Bear River system it is highly unlikely that the land use changes in Cache County are the sole reason for this decrease. It is more probable that the land use changes have affected the Logan and Blacksmith Fork rivers. Water from these rivers is typically used for irrigation, so if the irrigation land is decreasing it seems strange that the stream flows would be decreasing because of urbanization. One possibility lies with the amount of groundwater that is pumped to meet the water demands of Cache County. The majority of Cache County's water comes from groundwater springs and wells. As the population increases the amount of water pumped from the ground also increases. This leads to a decrease in height of the aquifers, creating a larger gradient between the aquifers and streams in Cache County. As the gradient increases more water will infiltration through the major rivers discusses and their tributaries. This is one possibility for how stream flows are decreasing with increased urbanization.

Temperature and Precipitation:

To verify that these decreases in stream flow are not because of climate changes I examined the temperature and precipitation for Cache County. The Utah Climate Center, operated by Utah State University, has many stations that collect temperature and precipitation data (Utah State University, 2011). These data were downloaded for Cache County and can be seen in Figures 13 and 14. To show if there was a change in the data over time a trend line was also created for these plots. As seen in both the temperature and precipitation data sets the slope is minimal, indicating that there has not been much of a change in climate over the last 40 years in Cache County. There are yearly variations but as a whole temperature and precipitation have remained constant.

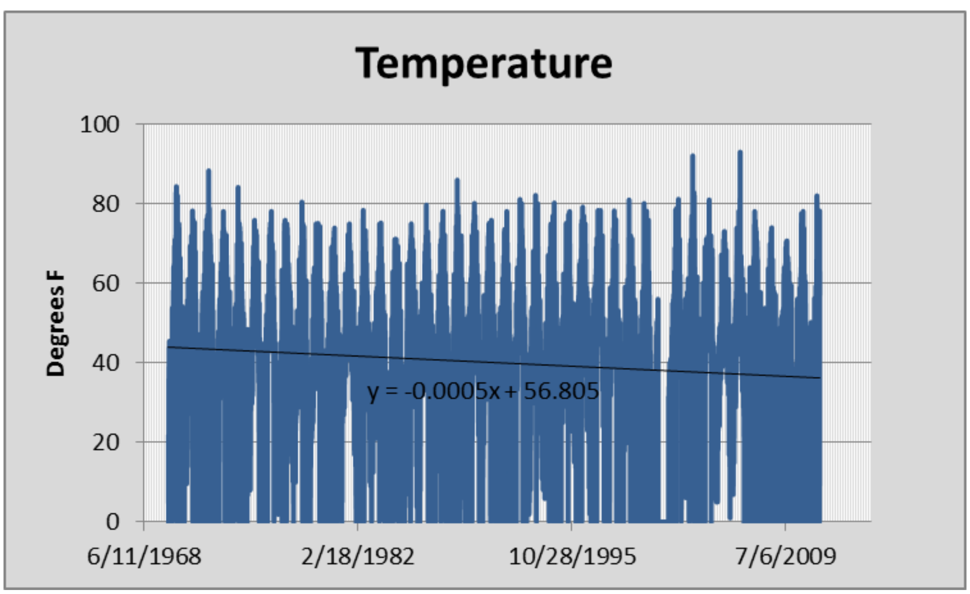

Figure 13 - Cache County Temperature Data

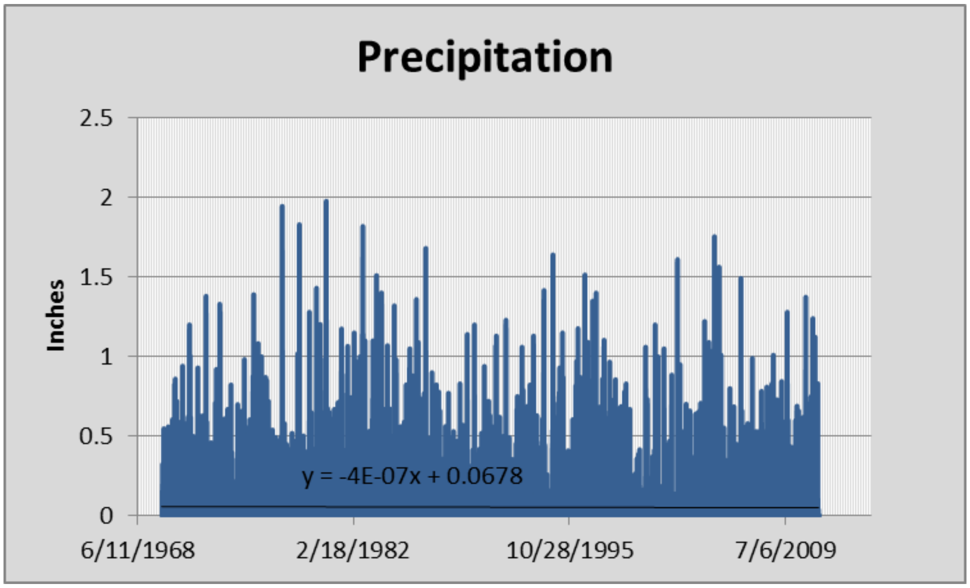

Figure 14 - Cache County Precipitation Data

From this information we can infer that temperature and precipitation have not played a role on the changing stream flows.

Conclusion:

Throughout the course of this project land use, population data, stream flow data, and temperature and precipitation data have been used to investigate if urbanization has an effect on stream flows. Understanding that there are many factors that contribute to stream flow variations additional research needs to be completed to verify these results. However through the use of GIS I have been able to more clearly visualize land use changes and make judgments as to how these changes are affecting stream flows. GIS was helpful in delineating the study area and finding flow directions. GIS was also helpful in looking at land use changes and mean annual stream flows. Maps were created to aid in visualization of what is happening over time. While I thought that these maps would be very useful, they were not a great as I had hoped. However, the attribute tables that were created were helpful in understanding how land use is changing.

Making a judgment call about land use and it's correlation to stream flow is tricky but I believe that there is some correlation. As previously stated the change in stream flows of the Bear River are to be attributed to many things, but it is more likely that the changes in stream flows of the Logan and Blacksmith Fork rivers are tied to urbanization. Urbanization is increasing while stream flows are decreasing. Secondary water from these rivers and their tributaries are being used as secondary water for lawns and gardens of new developments as well as infiltrating into aquifers the supply Cache County municipal water. I believe there is a direct tie between increased population and urbanization in Cache County and the decrease in stream flows in the area.

References:

JUB Engineers (2005). "Smithfield city water master plan." *2005-2020*, in press.

NHDPlus (2010). "Great basin." *Hydrology and hydrography data*, <http://www.horizon-systems.com/nhdplus/HSC-wth16.php> (Nov. 5, 2011).

USGS (2010). "Seamless data warehouse." *Land cover*, <http://seamless.usgs.gov/> (Nov. 18, 2011).

USGS (2011). "National water information system." *USGS surface water annual statistics for utah*,<http://waterdata.usgs.gov/ut/nwis/annual/?referred_module=sw&site_no=10105900&por_10105900_2=448885,00060,2,1992,2011&year_type=W&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list> (Nov. 10, 2011).

Utah GIS Portal (2011). "Utah SGID." *Vector gis data download*, <http://gis.utah.gov/sgid-vector-download/utah-sgid-vector-gis-data-layer-download-index?fc=CountiesGCDB> (Nov. 10, 2011).

Utah State University (2011). "Utah climate center." *Daily station normal of temperature and precipitation*, <http://climate.usurf.usu.edu/> (Nov. 19, 2011).