# Using GIS To Estimate Changes in Runoff and Urban Surface Cover In Part of the Waller Creek Watershed Austin, Texas

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Introduction

The goal of this project is to understand runoff changes in Waller creek due to land changes and tree growth in the area. The project aims to understand how much tree growth has occurred in the area, how this has affected runoff in the water shed, as well as how much urbanization has occurred since the 1940's. To understand these changes, imagery from the 1940's and 2008 were used along with various current data to achieve the desired output. An area of interest was determined on Waller creek by the coverage and quality of the historical imagery, along with observable surface cover changes. After developing raster files for the changes in the surface cover, map algebra was used to understand spatial changes in runoff. The changes in the surface cover are also analyzed for estimates on quantifying changes in urbanization.

Data

Imagery was obtained from TNRIS. The historical imagery used was part of the USDS- ASCS 1940 Travis County, Texas collection. The images are .tiffs and are not geo-referenced. The TOP 2008 Travis County mosaic was downloaded from TNRIS.org. The mosaic is a .jp2 file and came with a NAD 1983 UTM zone 14N spatial reference. A 10m resolution DEM of the Austin East quad along with a .shp file of all roads in Travis County was obtained from TNRIS as well. The NHD for Travis County, Texas was downloaded from the TNRIS website. The NHD came with a Geographic coordinate system GCS North

American 1983.  The NHDFlowline.shp was used for representation of Waller Creek.   Five feature classes were also created, as described in the Data Storage section of this paper,  that represented surface cover of the area. Meta data was created feature classes and later raster files with short descriptions of what they cover and how they were created.  Pyramids were created for effective viewing of the imagery for working with it at varying scales.

Data Storage

A personal geodatabase was created for this project.  It contained one dataset with 5 feature classes.  The feature classes were for tree cover 2008, tree cover 1940, permeable cover 2008(i.e. fields, cleared land), permeable cover 1940, and a watershed boundary.   All feature classes were for polygons.shp files that contained an extra field Cover.  Cover was a short integer field with a default value of 1(this is for later rasterizing of the polygons).  The raster files were not stored in the personal geodatabase.  This project was created using the NAD 1983 UTM zone 14N coordinate system.

Watershed Boundary Creation

The NHD file was added to ArcMap.  It was symbolized by GNIS Name to display only Waller creek.  The watershed boundary was created from the 10 Meter DEM.  The .dem was brought into ArcMap and symbolized by categories with defined intervals of 3meters. Every fourth interval was colored dark to symbolize local divisions better.  A polygon was then drawn along the topographic highs surrounding Waller creek (see figure 1).

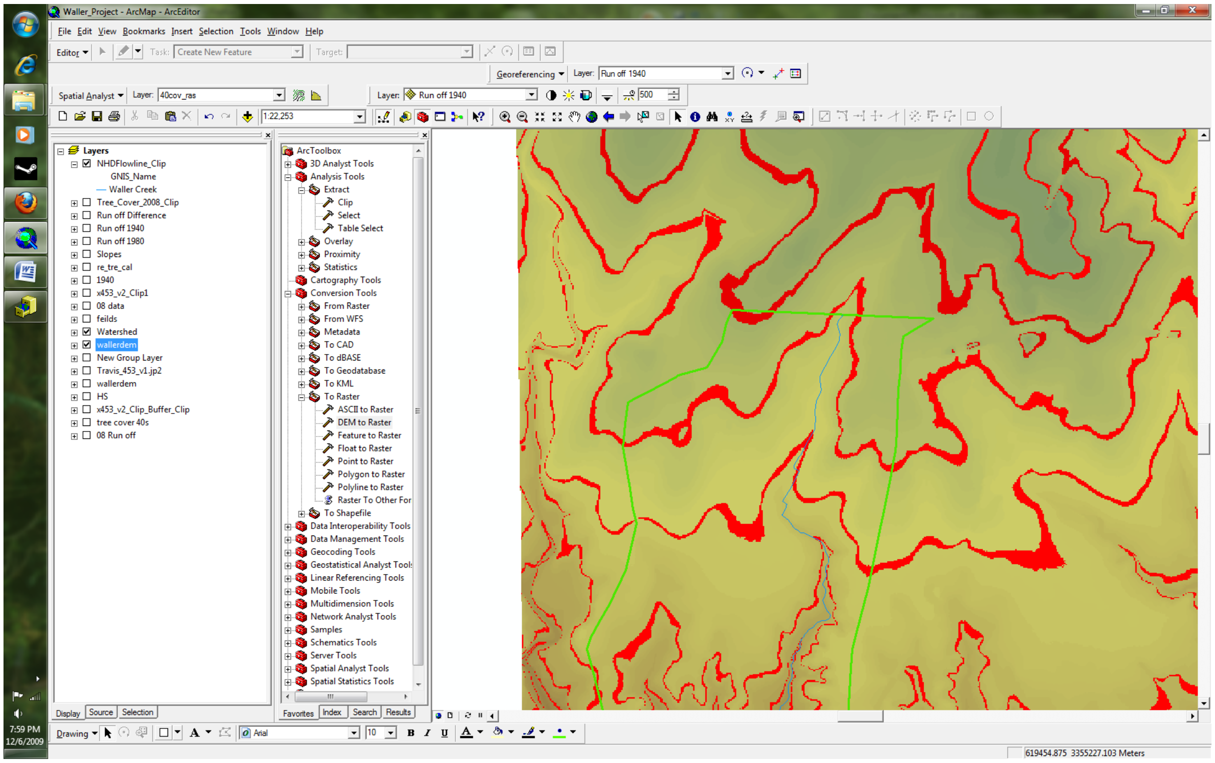



**Figure 1:Watershed polygon created with symbolized DEM**

This polygon will be used to understand a reasonable representation of the Waller creek watershed. The watershed is constrained to from Koeing lane to just South 24$^{th}$ Street. This polygon will be used for the clip boundary and as the mask for the Spatial Analyst tool when creating files for the area of interest.

## Imagery Preparation

The historical imagery was georeferenced with the Georeferencing tool with the 2008 multi-band imagery (see Figure 2). Images were referenced with 6 control points using the 1$^{st}$ Order Polynomial (Affine) transformation. The images were referenced with an RMS error at a maximum of 5. They were referenced to the coordinate system NAD 1983 UTM zone 14N.

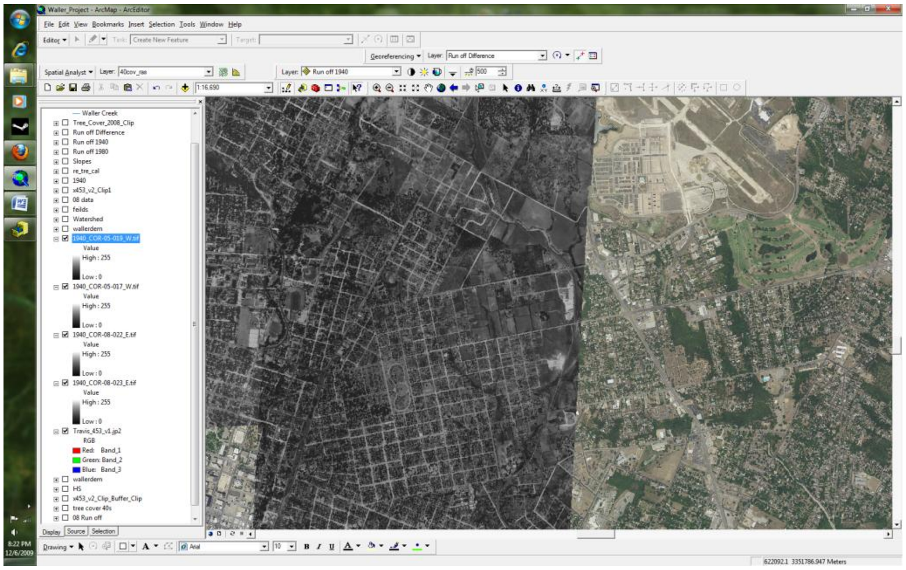
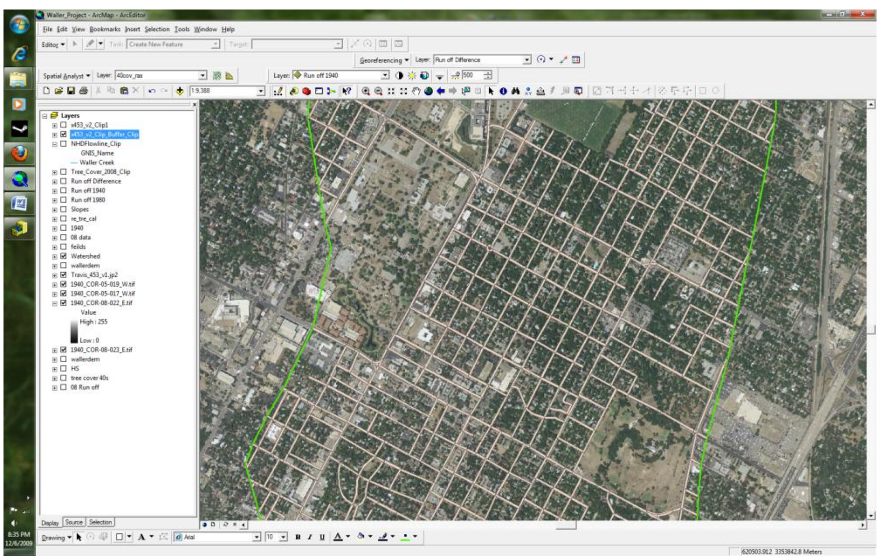


Figure 2: Georeferenced 1940's imagery with 2008 imagery

## Creating the Feature Classes

To begin with the road file was then clipped to the watershed boundary. It was then buffered by 5meters to represent the impervious of the streets. This was done using the buffer tool.



Next the Polygon representing tree cover was created. Using the Create New Feature on the editor, polygons were drawn around tree cover. The tree cover 2008 polygons were snapped to the water shed boundary and streets. The 1940's tree cover was created in the same manner.

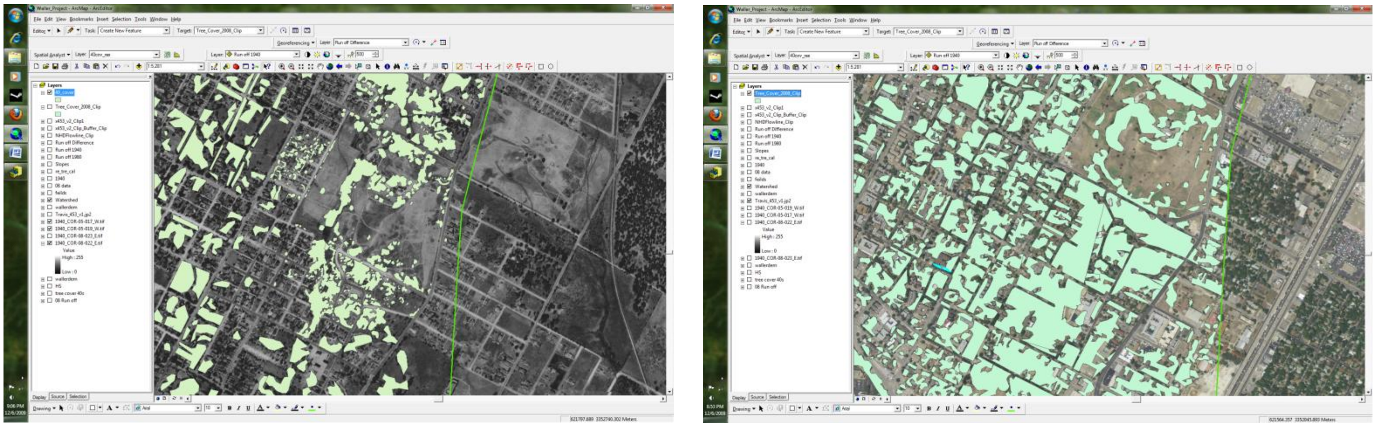


Figure 3.  2008 and 1940 Tree Cover Polygons

Next, the permeable cover polygons were created.  This polygon was drawn around fields and any areas where no building and just bare ground was for the 1940 and 2008 imagery.  These polygons were snapped to the watershed boundary and street polygons.

The 1940 dataset used a modified road shape file since some of the roads that were shown in the 2008 roads were not built yet. Most roads were present but some were deleted using the Editor tool.

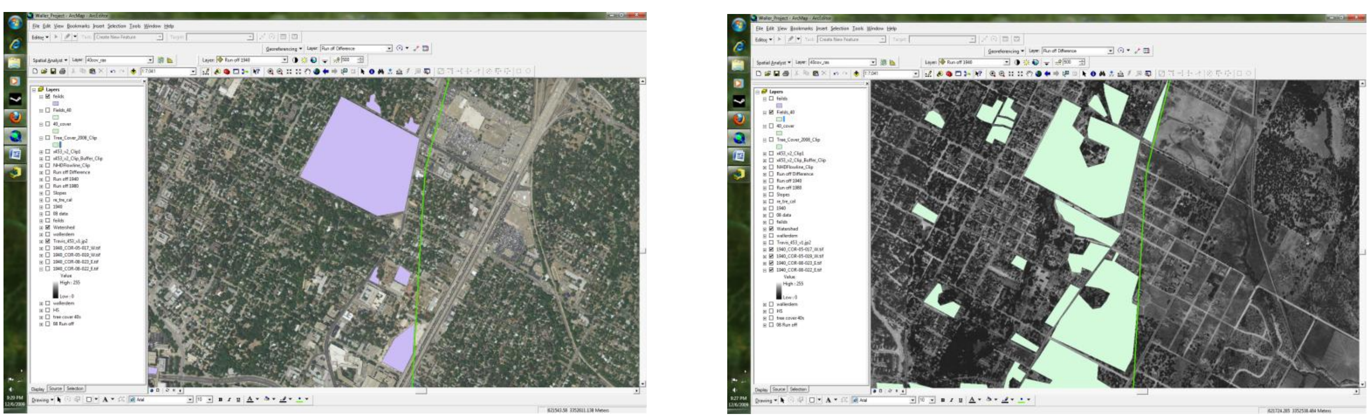


Figure 4. 2008 and 1940 Permeable Cover Plygons

Converting the Polygons to Raster Files And Creating an Impermeable Cover Raster

The above mentioned feature classes were then converted to raster files using the Feature to Raster Converter tool.  The street polygons were converted to raster using the Polygon to Raster converter. The field used in this conversion was the Cover field ( default value of 1). They were created with a resolution of 5 meters.

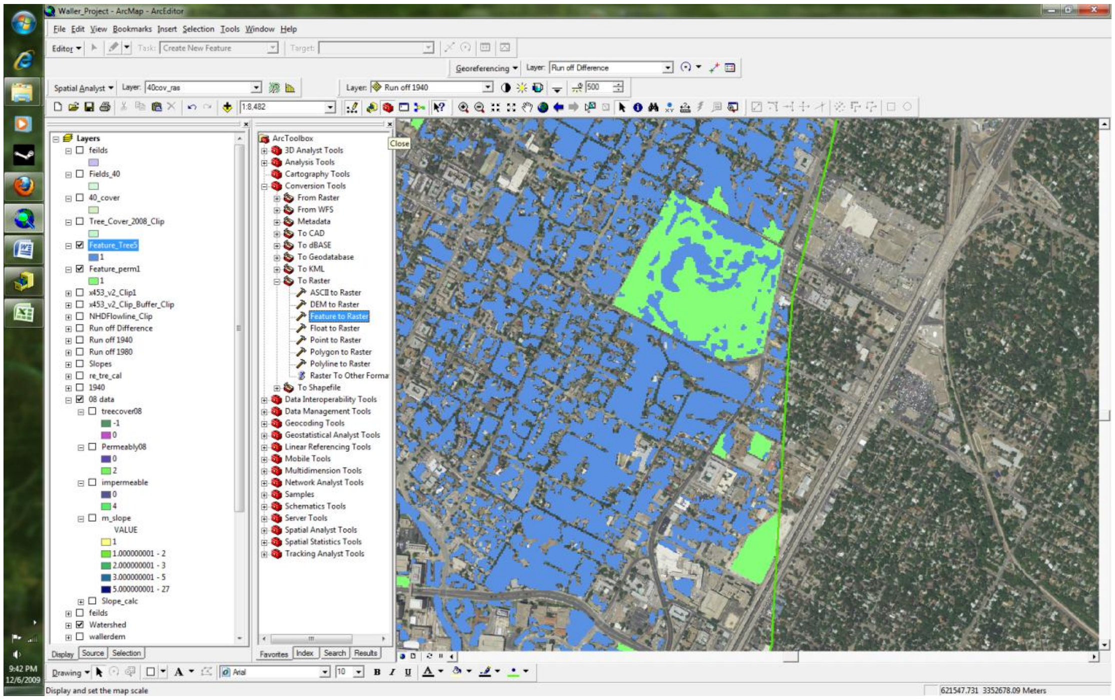


Figure 5. Raster files of the 08 Cover Polygons

After creating these raster files they were reclassified as follows.

Table 1. First Reclass

| Layer | Cover | NoData |
|---|---|---|
| Tree cove | 1 | 0 |
| Tree cove | 1 | 0 |
| Permeabl | 1 | 0 |

After this reclass, Spatial Analyst was used to create an impermeable cover raster file. The impermeable raster was obtained by using Raster Calculater adding the tree cover and impermeable cover, and then a reclass of the calculation making the zero value 4 and all other values 0(see Figure 6.) The street file is will not be included in the rest of the analysis. Since the other layer files were snapped to it, the streets are incorporated in the impermeable cover raster file.

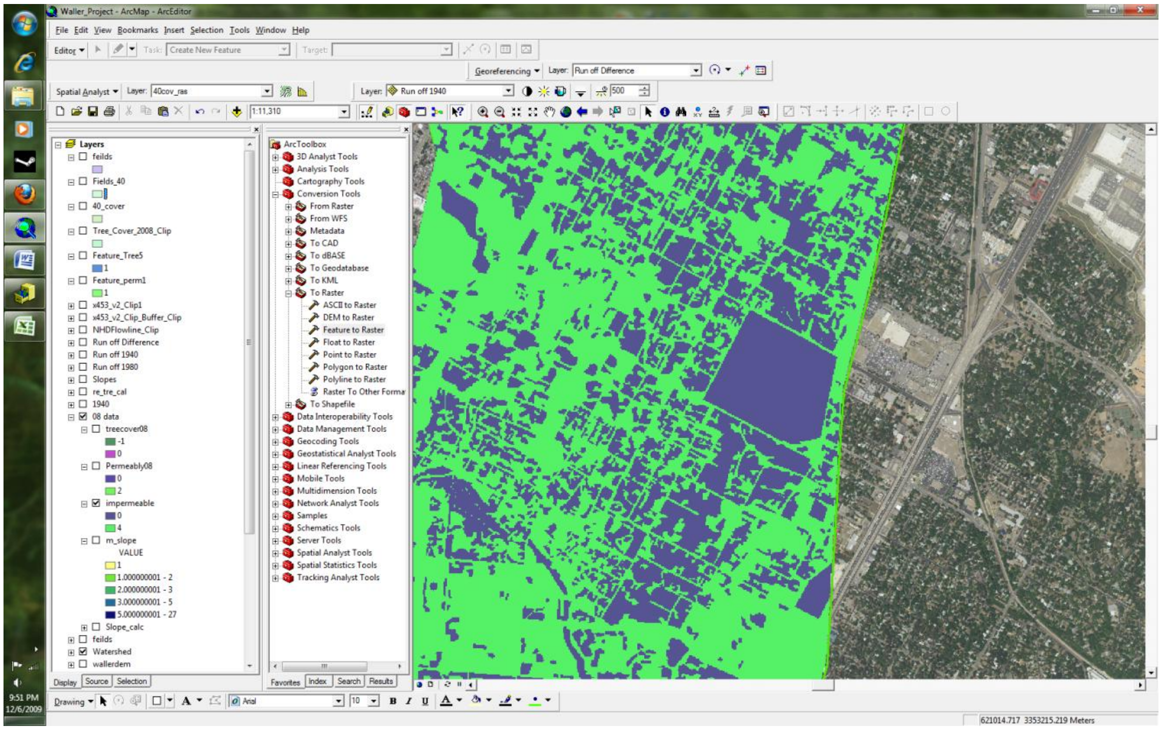


**Figure 6. Impermeable Cover Raster**

The same analysis was used on the 1940 data set for creating the raster files and reclassifying them.

<u>Slope Calculation</u>

The next raster needed for the runoff equation is the slope calculation. The slope was calculated using the 10m DEM. The Raster was created using spatial analysis and the surface analysis tool. The slope was then symbolized using geometrical intervals to express the areas of least slope to greatest slope. Five intervals were used for the geometric intervals for the slope. The slope calculation was then reclassed to express these values 1 being the least slope and 5 being the greatest slope (see Figure 7). This slope calculation was used for both the 2008 and 1940 data sets.

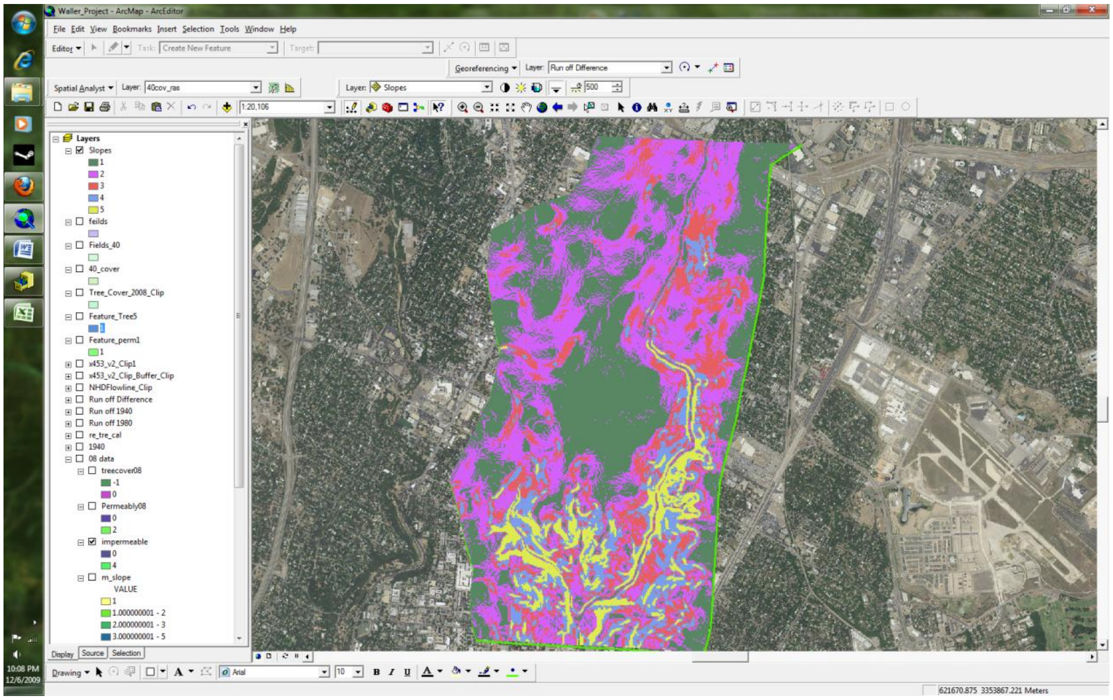


Figure 7. Slope Calculation Reclassified to 5 values

<u>Final Reclassifications and Raster Calculations</u>

The raster files were reclassified one more time before the final raster calculations (See Table 2)

Table 2. Second Reclass of Raster Files

| Layer | Value | | NoData |
|---|---|---|---|
| Initial | 1 | 0 | NoData |
| Tree cover 08 | -1 | 0 | NoData |
| Tree cover 40 | -1 | 0 | NoData |
| Permeable Cover 08 | 2 | 0 | NoData |
| Permeable Cover 40 | 2 | 0 | NoData |
| Impermeable Cover 08 | 4 | 0 | NoData |
| Impermeable Cover 40 | 4 | 0 | NoData |
| Slope | 1-5 | | NoData |

It should be noted that the Slope and Impermeable cover files already have their final values needed and do not require a final reclass. Now that the final reclass is finished, a raster calculation ranking areas with more or less run off is possible. Using Spatial Analyst and Raster Calculator the following map algebra is used. Slope+ Tree Cover + Permeable Cover+ Impermeable Cover= Run Off Ranking. Upon finishing this calculation a runoff ranking raster is achieved (see Figure 8) which contains 9 ranked values. The two data sets use the same equation for the run off calculation.

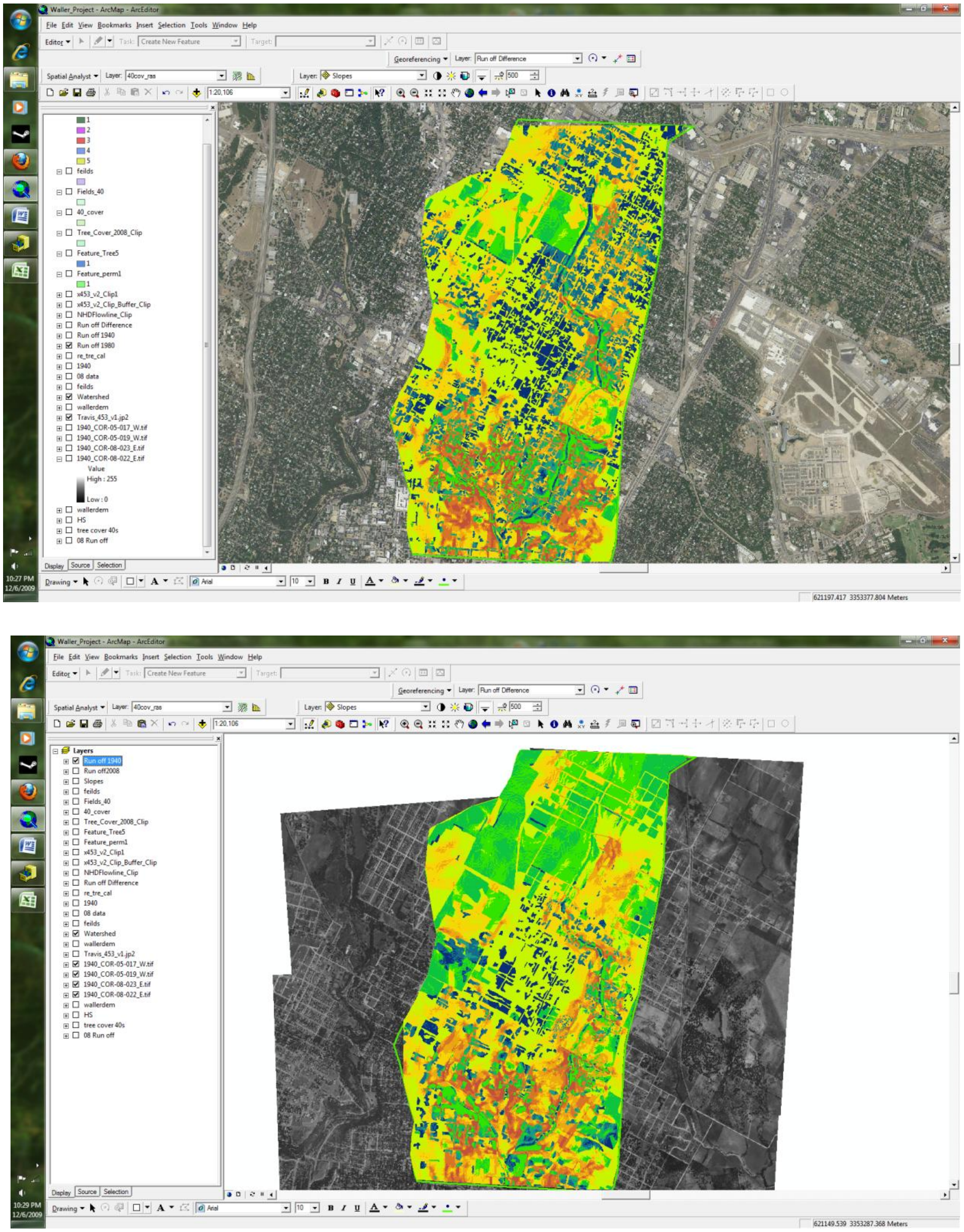



Figure 8. Run Off Rankings for 2008(above) and 1940(below) Symbolized by an Inverted Precipitation Scheme

Now that the run off ranking are finished, a comparison of how run off has changed since 1940 can be observed. By looking at the data and the imagery the forties are seen to have much less run off. This is due to the vast difference in impermeable cover. Because of this fact, to compare the rasters the 1940 runoff will be subtracted from the 2008 runoff. By applying this in Raster Calculator a difference in runoff between the two time periods is seen (see Figure 9)

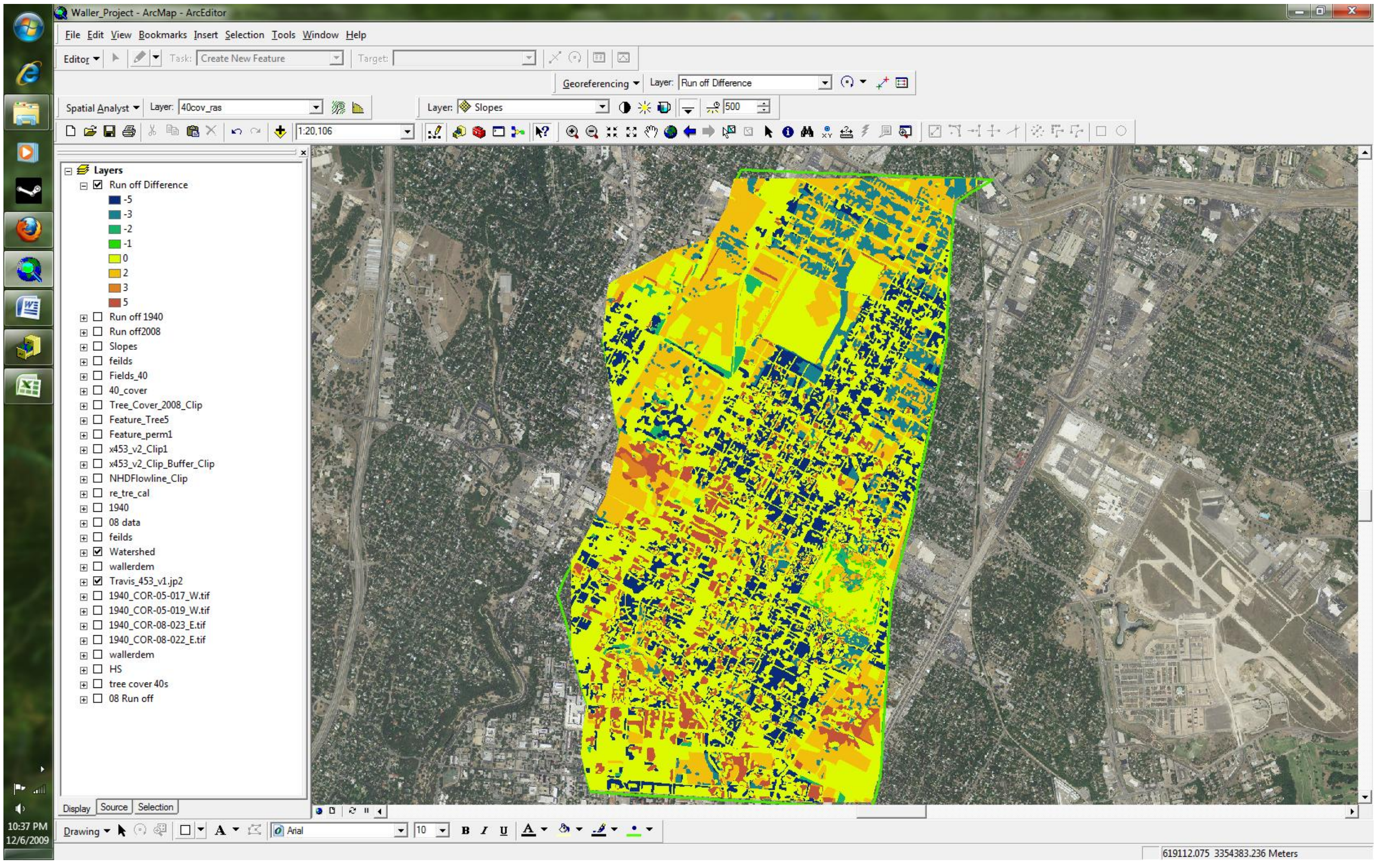



**Figure 9. Runoff Difference between 2008 and 1940 Symbolized by an Inverted Precipitation Scheme**

I was interested in looking at trends in the area of where runoff increased and decreased. To get an overall average of the regional changes I applied a Neighborhood Statistics to create a raster. The raster was constrained by obtaining the mean values in the surrounding 3 cells and having a resolution of 20(a change of resolution by 1:4). This trend is seen in figure 10 below.

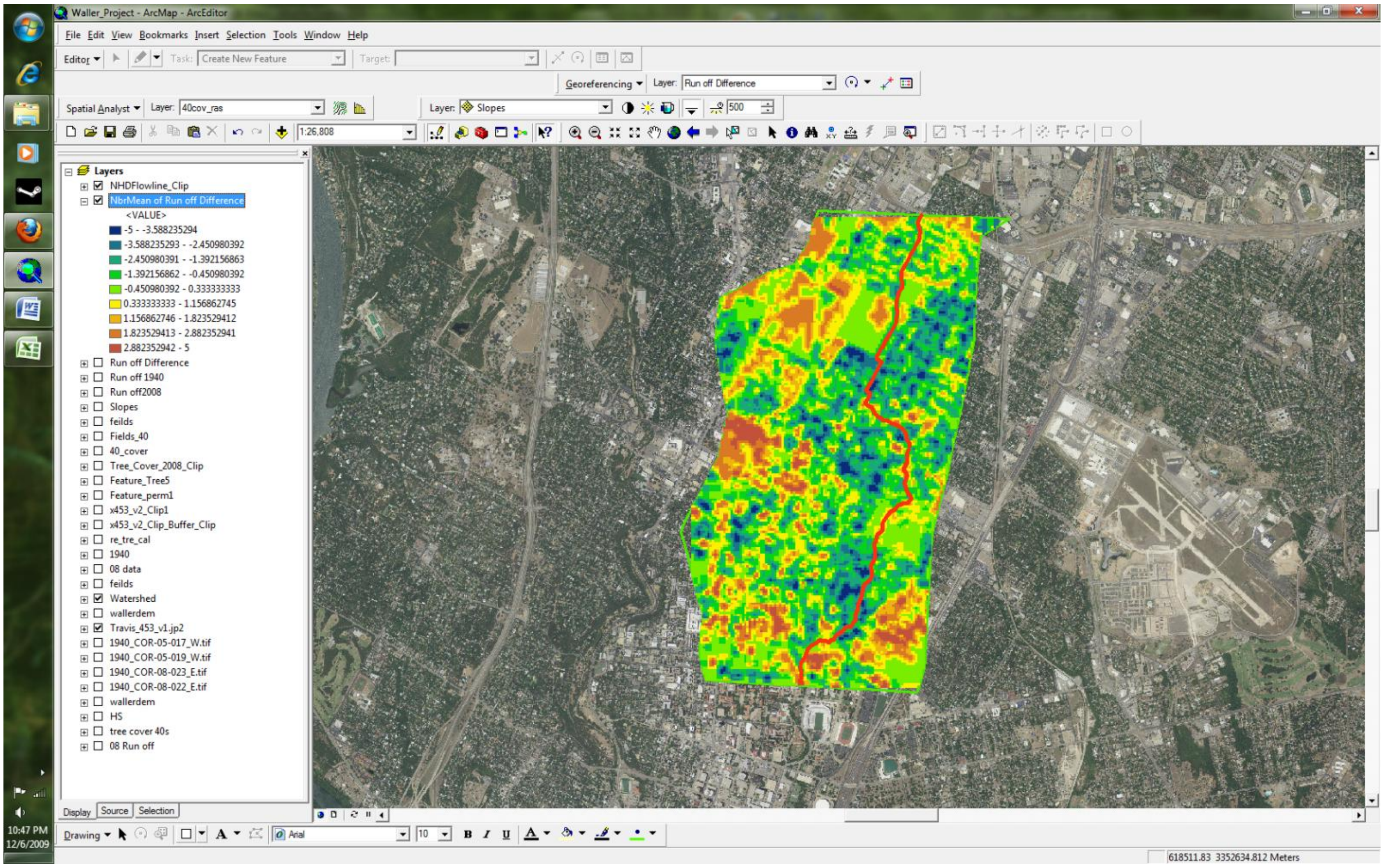



**Figure 10. Neighborhood Statistics of the Runoff Difference Symbolized by an Inverted Precipitation Scheme(blue is negative minimum and red is the positive maximum, Waller creek is symbolized by the Red Line Running North to South**

<u>Urban Change Analysis</u>

Because the polygons expressing Tree cover, permeable cover and impermeable cover, the change in urbanization and tree growth can be estimated. Area statistics were observed in the attributes table to analyze this change in urbanization. When area was not present, an area field was created and using the calculate geometry function area could be calculated. The Impermeable cover raster files were converted to shape files first to calculate geometry and to look at the statistics. The values of change can be seen in Table 3 below.

**Table 3. Changes in Urban Surface Cover**

| | | |
|---|---|---|
| Tree cover 08(km^2) | Tree cover 40(km^2) | % Change (increase) |
| 2.540312408 | 1.316184521 | 48.1880844 |
| Permeable Cover 08(km^2) | Permeable Cover 40(km^2) | %change(decrease) |
| 0.747057164 | 2.866652782 | 73.93974015 |
| Impermeable Cover 08(km^2 | Impermeable Cover 40(km^2) | %change(increase) |
| 5.656259 | 4.251173 | 24.84125992 |

Discussion

The change in the urban surface cover is apparent in the Waller creek control area. The tree cover is seen to increase by an estimated 48%. Permeable surface cover decreases by 73%. With impermeable cover is increasing by 24%. These changes can be observed in Figure 10 showing increased runoff ranking in land toward the outside of the watershed of Waller creek. However, the runoff ranking is seen to decrease in the local vicinity of the creek due to increased tree growth. The increased tree growth representing more base flow by macropores and decreased runoff by canopy catchment is a trend that can be looked into to understand the changes occurring in the watershed. This trend may be drowned out by the increased impermeable surfaces and also artificial channeling of water in the watershed by anthropogenic means, but it could be analyzed in the falling limbs of a Waller creek hydrograph. Balance of the increased run off against decreased run off appears to favor increased runoff. Since most of the permeable surface was paved or built on, the runoff from them (which is a much greater area compared to tree growth) is much more than the decrease caused by tree growth. Runoff is most certainly increasing with every parking lot and building that is constructed, but it appears that tree growth is also affecting the runoff around the creeks and rivers increasing base flow and recharge of water in this urban setting. A completed map of each runoff ranking can is seen as figure 11. A completed map showing the explanation and full view of the final runoff change calculation can be seen in Figure 12.

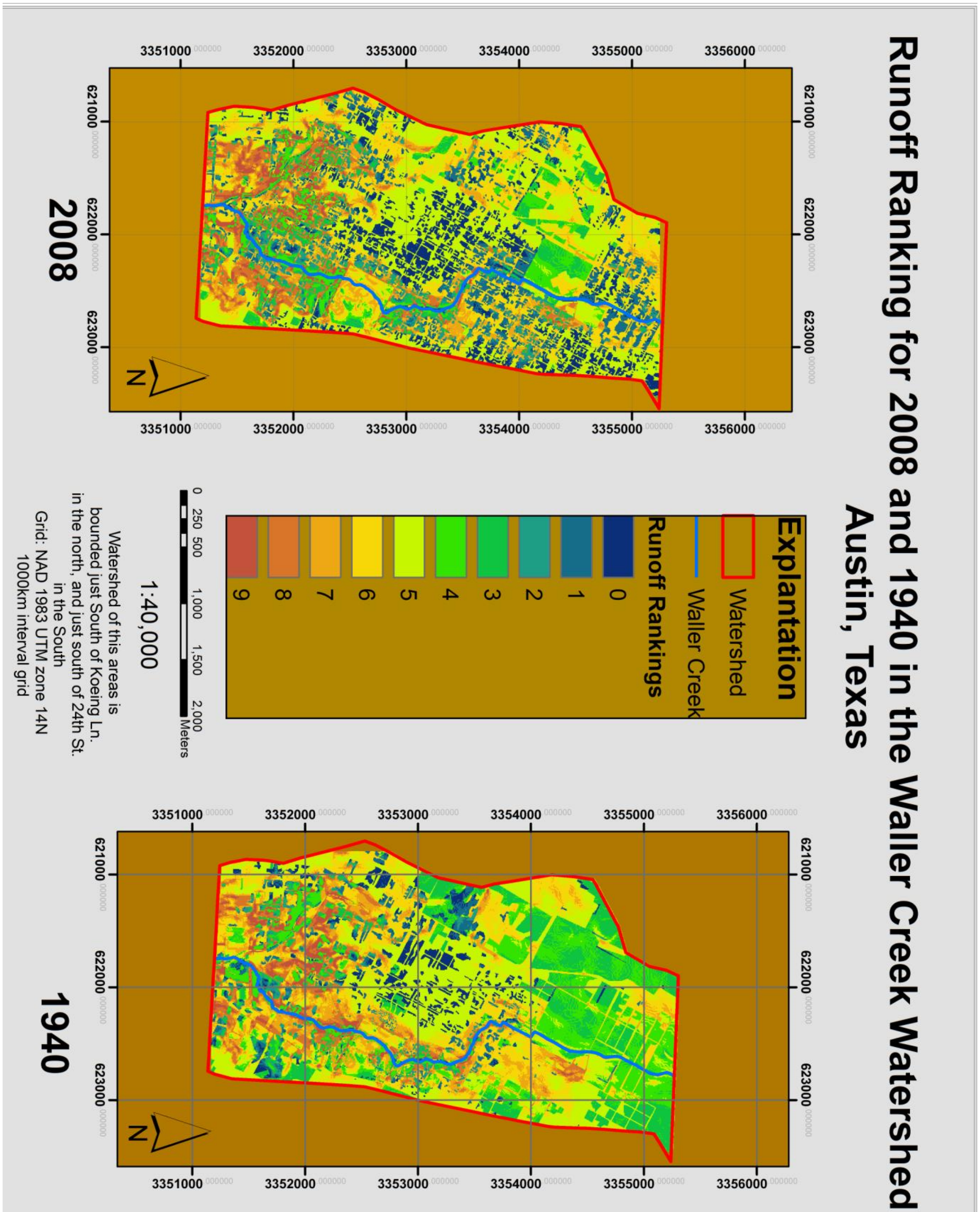



**Figure 11. Runoff Rankings for 1940 and 2008 map**

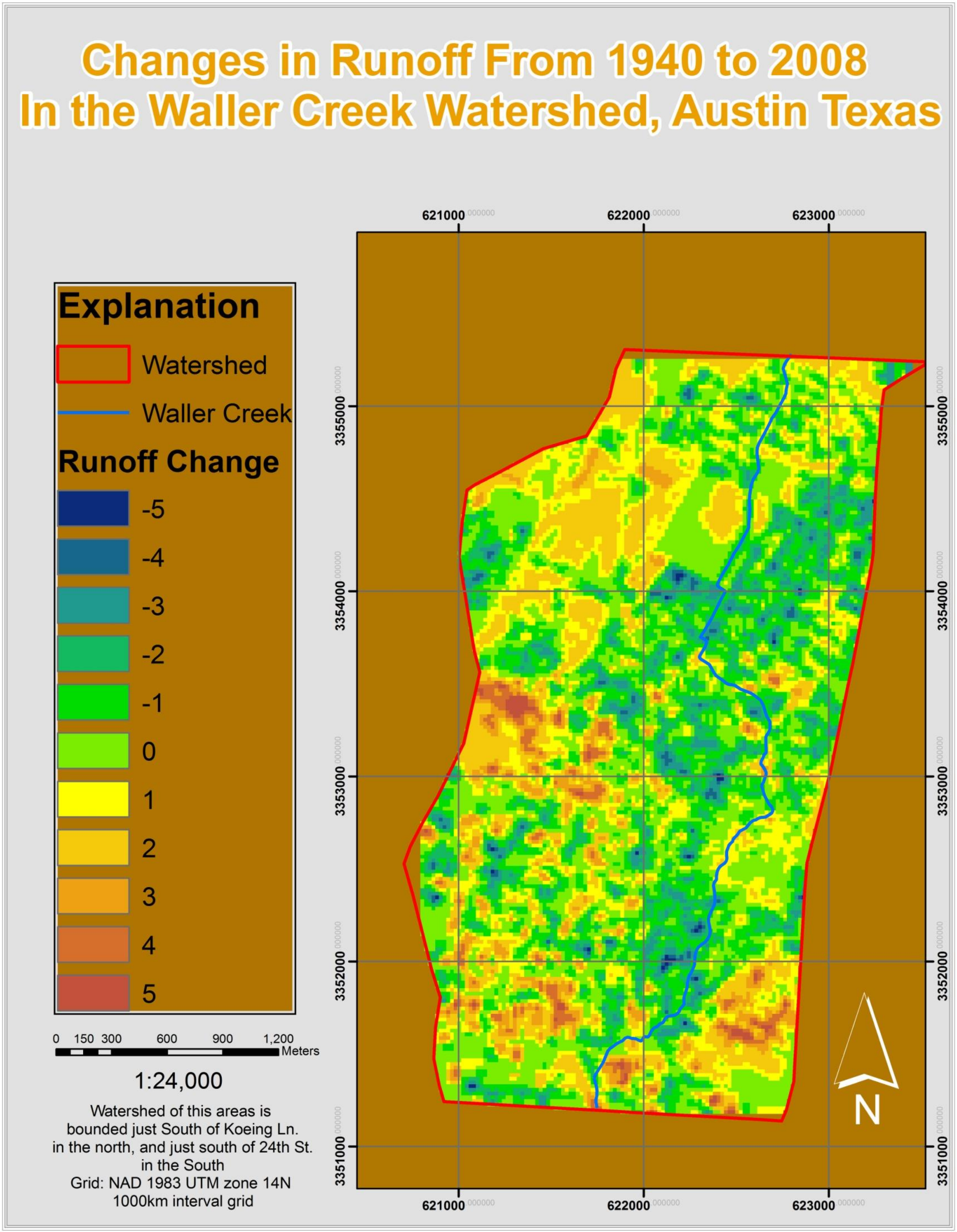



**Figure 12. Changes in Runoff 1940-Present**

**Errors**

Errors associated with this project are mainly tied to the creation of the surface cover polygons. Drawing of these is come with some error due to creation at a certain scale, usually around a scale of 1:1000-1:2000. The polygons were snapped to prevent overlap, however what they covered (ie. Tree cover) can be seen to contain small amounts of other areas. Because of these errors this analysis is best described as an estimate. Some tree cover was also incorporated into permeable cover area due to low tree density or small trees that could be considered shrubs or brush. People's lawn areas are also not considered since they are reasonably hard to pick up or differentiate, and thus they were incorporated into other groups. In the event of recognizing a lawn or area they were considered permeable cover. The Neighborhood statistics that were calculated for the runoff difference also has some error since it is an average of the neighboring raster cells. It was effective for viewing a geographical trend, and was used to show such a trend.

**Figure 13. Changes in Runoff from 1940 to the Present in Waller Creek**