

# GROUNDWATER-SURFACE WATER INTERACTIONS ALONG THE BLANCO RIVER

GEO 327G FINAL PROJECT

YATES, KENDALL A

## OVERVIEW

The Blanco River and surrounding aquifers have become an area of interest for ground water hydrologists due to the extreme flooding of the summer of 2015. For almost a decade previous, the hill country region experienced severe drought conditions which caused low flow rates and a depletion of aquifers in the region's river systems. It is likely that the dramatic flooding and precipitation rates which interrupted the extended drought altered groundwater dynamics. This would imply different contributions from the surrounding spring systems and a theoretical increase in total input from the underlying aquifers of the region. Discharge measurements taken along the Blanco River were used in this research to track the inputs and outputs of various springs along a nine mile stretch of the Blanco River in Wimberley, Texas. The stretch in question includes four major springs, Little Park Spring, Main Park Spring, Miller Spring, and Pleasant Valley Spring. Discharge measurements above and below each spring resulted in a net difference equivalent to the springs' input and output. After measurements were taken, they were plotted, mapped, and compared with flow data from the past as a proxy for high flow aquifer conditions. Similar measurements were last taken in 2013 during a low flow drought period. The purpose of this project is to determine how the groundwater dynamics have changed from the previous drought conditions. It is expected that an increase in discharge will be found, suggesting a greater contribution from spring systems that are fed by recently recharged aquifers.

## INTRODUCTION

The Hill Country of Central Texas is prone to intermittent periods of extreme drought. Most decades experience substantial drought for at least a year, often several (Smith et al. 2015). For more than a decade prior to 2013, Central Texas experienced one of the most severe and intermittent long lasting droughts since the decadal drought of 1947 to 1956 (Kocis 2014). Drought conditions caused water bodies in the region to reach record lows, and flow ceased in many springs. In 2000 the well-known artisanal spring Jacob's well quit flowing for the first time in recorded history (Broun et al. 2008). The decrease in water volume was the result not only of a decrease in precipitation, but a decrease in input of groundwater from underlying springs and aquifers as well. The relationship between the surface water in the region's water bodies and the groundwater in aquifers beneath is complex, and is dependent not only on rainfall or drought, but the karst features that allow water to either enter or discharge into the surface water. Rainfall in the area can either flow into the rivers or creeks directly, or can infiltrate the soil and underlying karst features to recharge the aquifers (Smith et al. 2015). Aquifers are thus the source of inputs or outputs for the overlying surface water, depending on the geology of the setting and precipitation trends through time. As we observed through this study, even periods of significant rainfall, if experienced during severe drought conditions, can result in no appreciable increase in flow (Smith et al. 2011). On Halloween of 2013, in stark contrast to the dry conditions of the decade previous, Hays County experienced a flash flood with over ten inches of rain in one night. Discharge measurements along the gaining stretch of the Blanco River in the Wimberley area were taken just prior to this event. Less than two years later on Memorial weekend of 2015 the same region experienced even more severe rainfall, resulting in the largest flooding event of the Blanco River in over 100 years. These major events combined with periodic precipitation caused the region to emerge from the prolonged drought conditions. When yet another flood of lesser magnitude occurred in 2016, the Blanco River experienced high-stand, non-drought conditions. The first measurements of this study were taken in late June of 2016, just after this period of heavy rainfall. The second set of measurements were taken two months later, on September 1<sup>st</sup> after a summer of moderate rainfall in which the Blanco River experienced non-drought, base level conditions. These measurements were compared with data taken in November of 2013, post flood yet still low stand due to drought. The focus of this paper is the comparison of groundwater and surface water interactions under these different climactic conditions. To understand and quantify how groundwater inputs via springs and aquifer systems change under varying conditions, discharge measurements taken at high, medium, and low stand have been recorded and compared.

### County Lines:

The data downloaded for the county lines was sourced from the [Texas Natural Resources Information System \(TNRIS\)](#) website. The specific dataset used was “[Political Boundaries](#)”. Within the downloaded data files, the txdot\_2015\_county\_detailed\_tx shapefile was used. Its original coordinate system was GSC\_North\_American\_1983.

## Description

The political boundaries Texas dataset contains the most up to date political jurisdictions, boundaries (state, county, city), and parks. Each of the boundary datasets are derived from various sources such as the Texas Department of Transportation, Texas Parks and Wildlife, and local jurisdictions to create the most comprehensive datasets available.

Within the download you will receive.

- StratMap County Polygon
- StratMap County Seats
- StratMap Cultural
- StratMap Parks
- TxDOT City Point (End of Year)
- TxDOT City Polygon (End of Year)
- TxDOT County Detailed Polygon
- TxDOT County Generalized Polygon

## Data Details

Category:

Boundary

Available Formats:

Shapefile

*Fig. 1: Description (left) and Details (above) of the Political Boundaries dataset from the TNRIS website.*

### Texas Rivers:

The data downloaded for the Blanco River was sourced from [Texas Parks and Wildlife \(TPW\)](#). The specific file was the “[Significant Stream Segments](#)” file. Its coordinate system was NAD\_1983\_Texas\_Statewide\_Mapping\_System, its datum was D\_North\_American\_1983.

## SignificantStreamsSegments

Shapefile



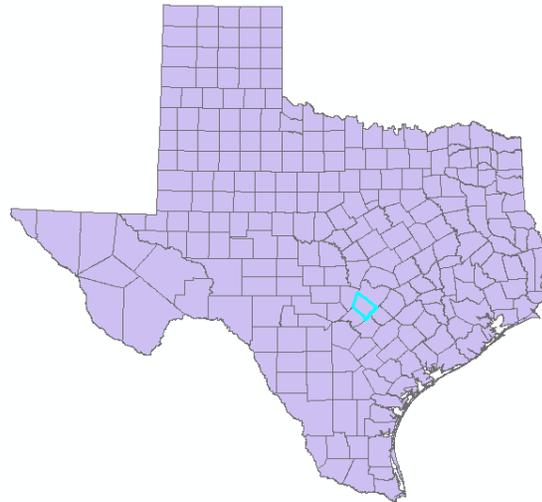
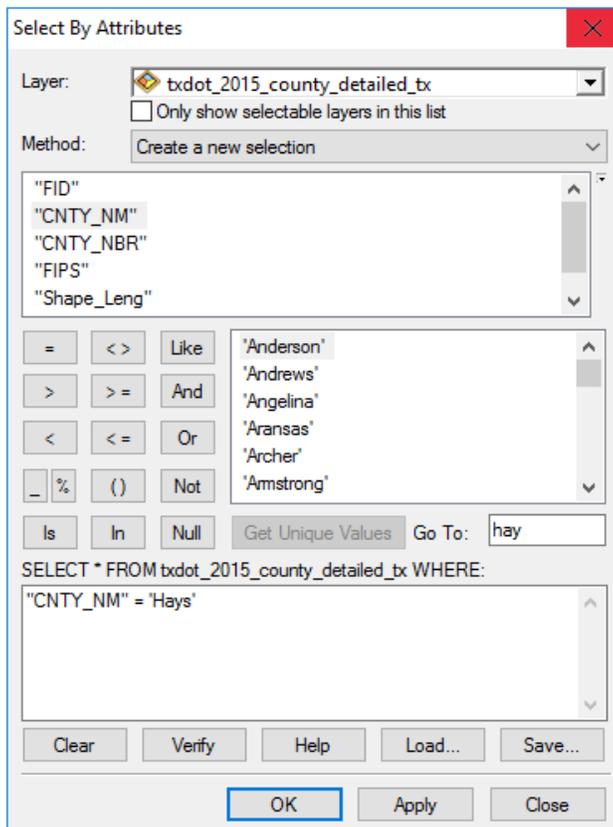
Tags

United States, inlandwaters, Texas, biota, environment

*Fig. 2: Overview of the downloaded Significant Streams Segment dataset from TPW.*

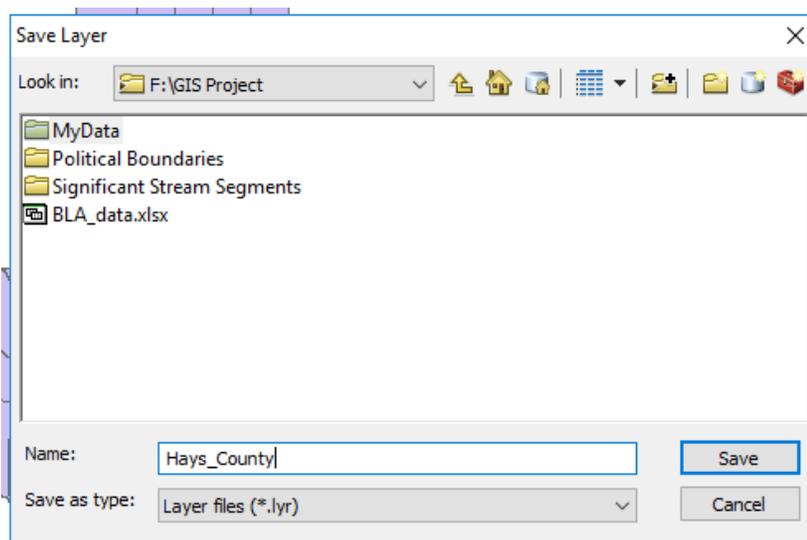
## Selecting for Hays County

The first step in pre-processing was the selection of Hays County from the txdot-counties polygon within the Political Boundaries file. This was done within ArcMap using a selection by attribute query (fig. 3)



*Fig. 3: Selection by attribute query (left) and resulting selection (above). Hays County is the selection outlined in blue.*

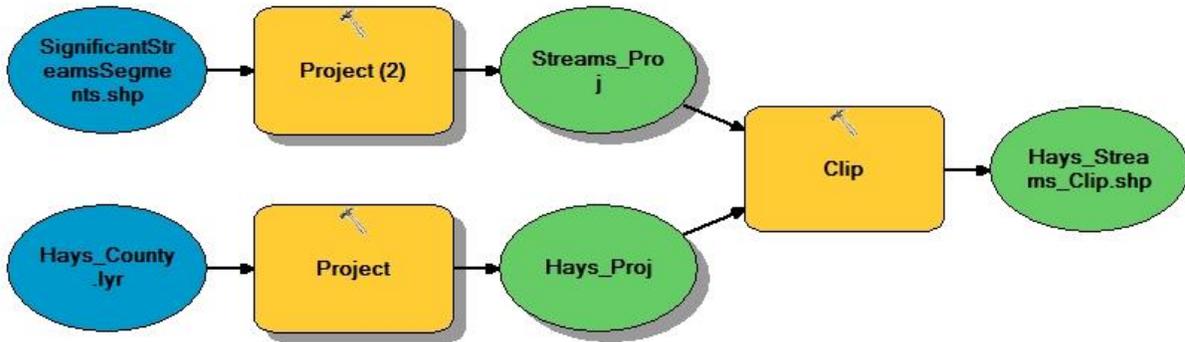
A layer was created from the selection using the Selection → Create Layer from Selected Features tool. The layer was then saved from the new selection and called Hays\_County (fig. 4)



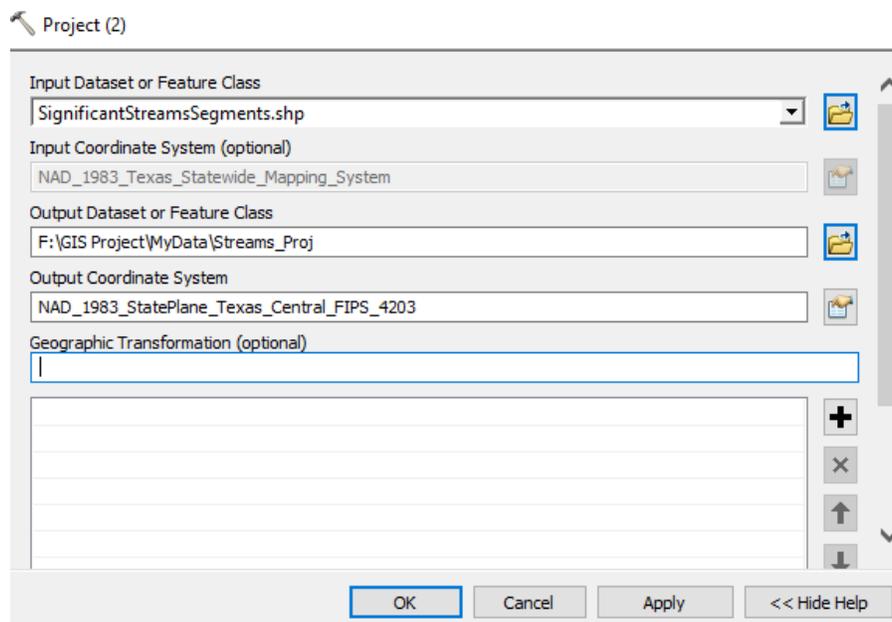
*Fig. 4: Save layer tool used to save the selection as a new layer file called Hays\_County*

## Model Builder

The remainder of the pre-processing for this project was completed using model builder. This is a useful tool for creating a visual work flow. The process by which the Significant Stream Segments and Hays County shapefiles were projected to the same coordinate system are outlined below (fig. 5). As both files had different coordinate systems, both were projected to the NAD\_1983\_StatePlane\_Texas\_Central\_FIPS\_4203 coordinate system (fig. 6). The Streams projection was then clipped to the Hays County projection so that only the water bodies within Hays County remained from the original Significant Streams Segments dataset.



*Fig. 5: Model builder workflow showing the projection of the Significant Streams Segments and Hays County files to the same projection. The resulting projections were then clipped so that only the streams within Hays County remained.*



*Fig. 6: Projection of Significant Stream Segments shapefile to NAD\_1983\_StatePlane\_Texas\_Central coordinate system. Hays County was also projected to this coordinate system.*

Once the model was run, two useful shapefiles were created: the Hays Streams Clip and the Hays County polygon. Both were ready for manipulation in ArcMap. This concluded the work performed in ArcCatalog. The remainder of the project was concluded using ArcMap.

## Importing GPS Coordinates

Once the streams and river polylines were appropriately clipped to the Hayes County polygon, GPS points were imported for the discharge sample sites. Before doing so, the data frame had to be set to GCS\_WGS\_1984 because that was the coordinate system in which the GPS Coordinates were measured. In order to import, an excel csv file with just the latitude, longitude, and names of the measurement points was created. It was then added in ArcMap using the File→Add Data→Add XY Data Tool. Once that tool was opened, the GPS.csv file was selected and the X and Y fields specified as Longitude and Latitude (fig. 7). This was possible because the latitude and longitude within the excel file were recorded in decimal degree, the appropriate unit for import.

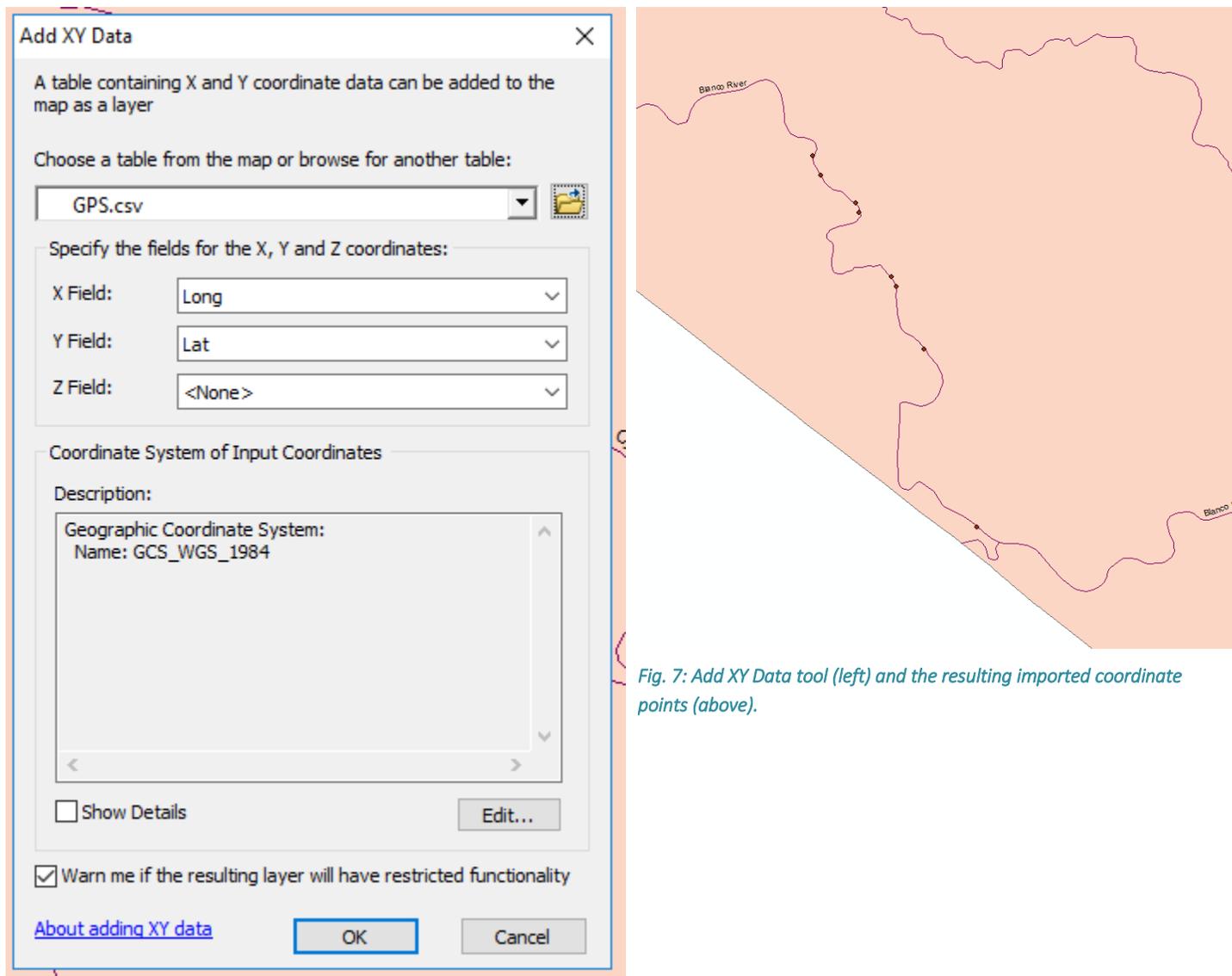
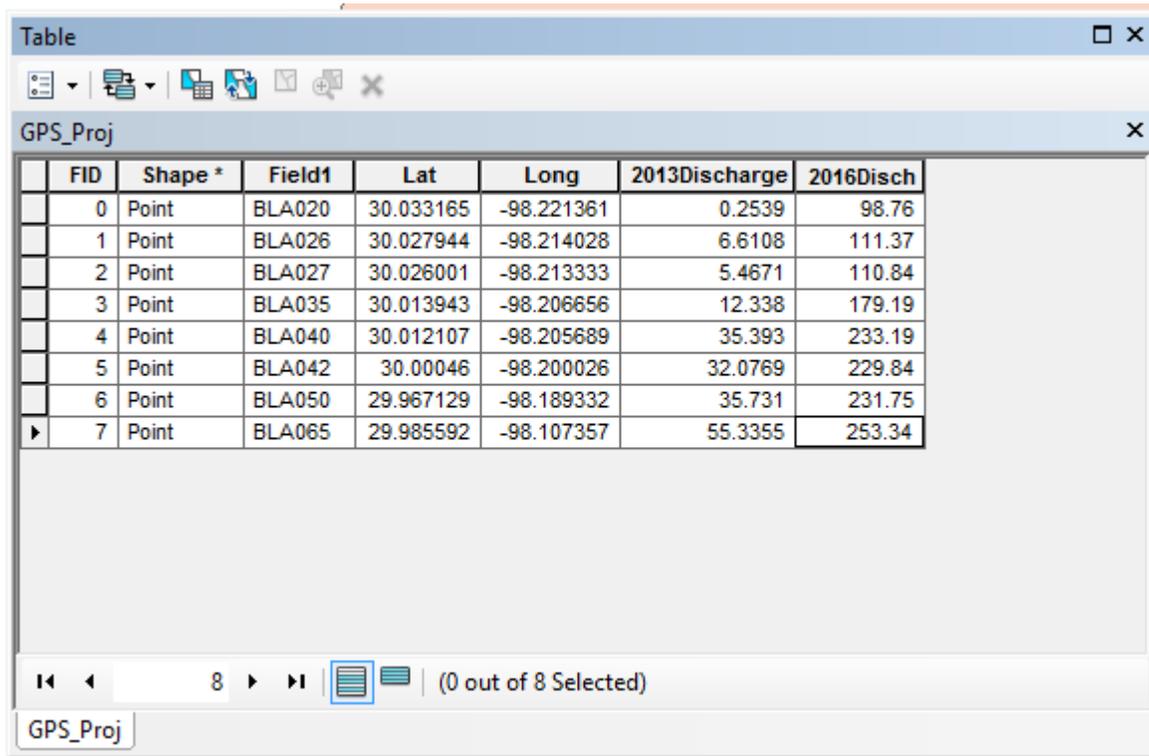


Fig. 7: Add XY Data tool (left) and the resulting imported coordinate points (above).

Once the discharge cite coordinate points were imported, the data frame was changed back to the Texas Central State Plane Coordinate System to which the streams and county shapefiles were created. The GPS points were then projected to this coordinate system as well. Although the points were imported within a reasonable distance to the Blanco River polyline, they did not directly intersect it. Additionally, the original excel file did not include discharge data from 2013 or 2016. In order to properly display this data, the points were first moved to intersect with the river polyline. Fields were then added to the attribute table so that discharge measurements for the two sample years could be manually added.

## Adding Discharge Data

In order to add discharge data, the Add Field was used within the attribute table. The columns 2013 Discharge and 2016 Discharge were created, storing double values with a precision of 7 and a scale of 4. To add values to the created fields, editor was turned on and the data was entered manually (fig. 8).



FID	Shape *	Field1	Lat	Long	2013Discharge	2016Disch
0	Point	BLA020	30.033165	-98.221361	0.2539	98.76
1	Point	BLA026	30.027944	-98.214028	6.6108	111.37
2	Point	BLA027	30.026001	-98.213333	5.4671	110.84
3	Point	BLA035	30.013943	-98.206656	12.338	179.19
4	Point	BLA040	30.012107	-98.205689	35.393	233.19
5	Point	BLA042	30.00046	-98.200026	32.0769	229.84
6	Point	BLA050	29.967129	-98.189332	35.731	231.75
7	Point	BLA065	29.985592	-98.107357	55.3355	253.34

Fig. 8: The discharge in cfs of the measurement sites recorded in separate fields for 2013 and 2016.

## Moving GPS Points to Intersect with the River

Because the GPS points did not import to directly intersect with the river, they had to be manually moved using editor. The GPS points layer was made to be selectable using Selection → Make This the Only Selectable Layer. The Intersect function within the Snapping toolbar was turned on for a precise intersect. Each point was then selected and moved until it snapped to the Blanco River layer (fig. 9).

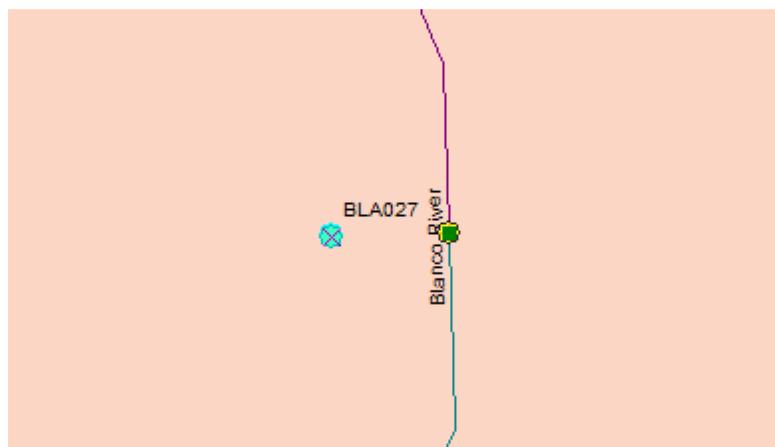


Fig. 9: Measurement point BLA027 snapping to the Blanco River layer. This movement was repeated for all imported GPS points representing discharge measurement sites.

## Splitting Stream Segments at Sample Points

The first step in creating an appropriate display of the Blanco River was to split the Stream Segments layer where it was intersected by discharge measurement points. To begin this process, Editor→Start Editing was selected and the Hays\_Streams\_clip layer was selected as the editable layer (fig. 10).

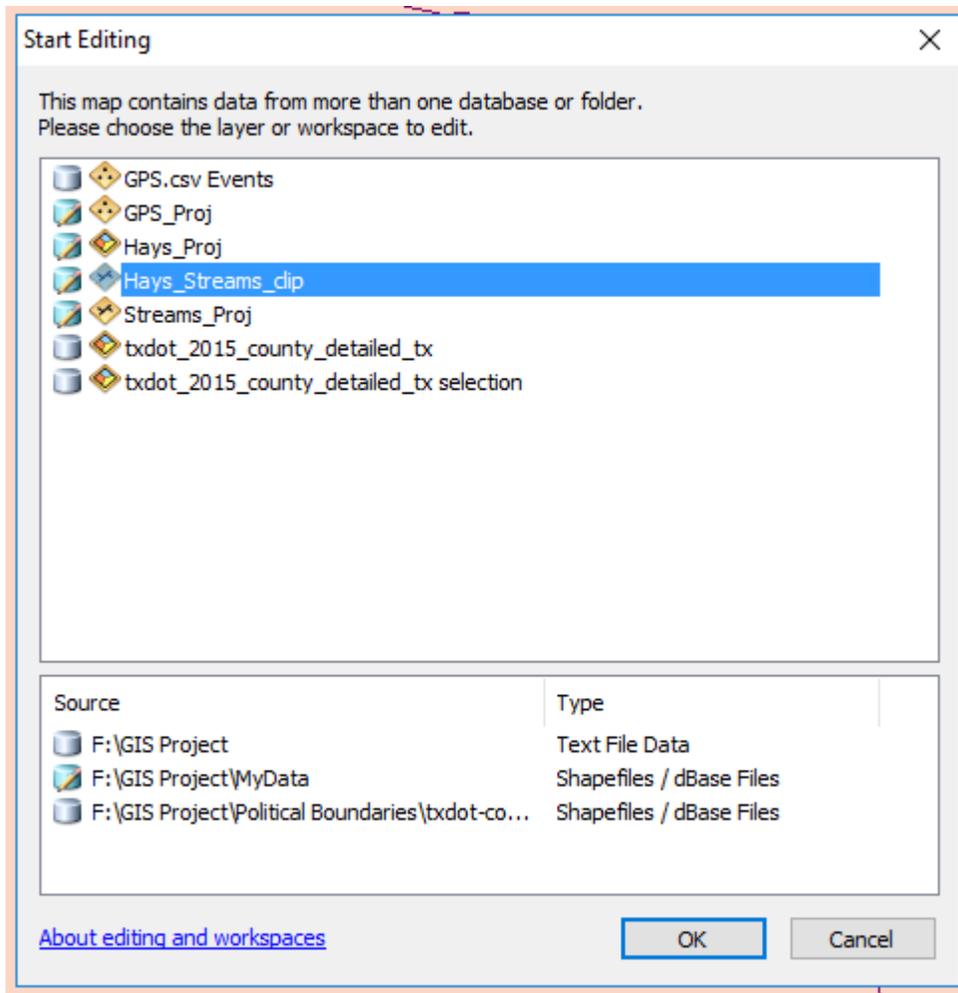


Fig. 10: The Hays Streams layer was selected as the editable layer within the Start Editing tool.

## Combining Multi-Line Segments Between Sampling Sites

With the Intersect function within the Snapping toolbar still turned on, the river segments were selected and split at each point at which they were intersected by a point within the GPS layer. This part of the editing process was fairly straightforward. The intention of splitting the streams into segments was to create unique, continuous lines in between each sample site. Cumulatively, these lines would create a study area reach from sample sites BLA020 to BLA065. The downloaded stream files were broken up into segments that did not coincide with the sampled points however. Although the segments could be split appropriately, the stretches between several neighboring points held two lines, each with their own FID in the attribute table (fig. 11). In order to merge and display the stretches appropriately, each segment between the points needed to have only one FID. The only way I could think to do this was to create a selection of the two lines between neighboring points and dissolve the layer based on a common field. The GNIS\_NAME field was chosen for this dissolve command, as both shared the same name “Blanco River” (fig. 12). The result of this dissolve command was a continuous line between adjacent points with only one FID.

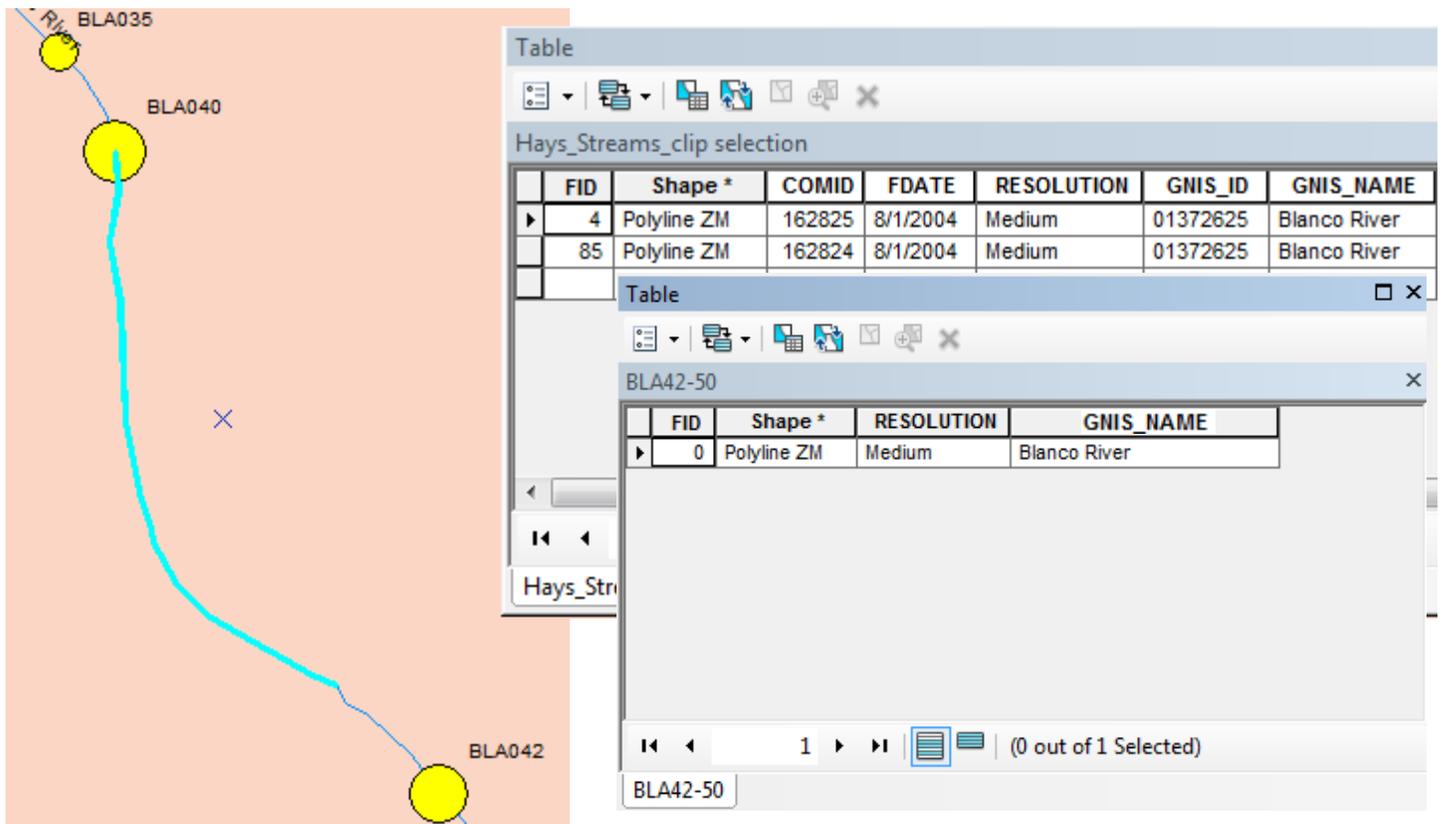


Fig. 11: The multi-line stretch between BLA040 and BLA042 (left). The original attribute table of this segment consisted of two FIDs (top-most Table). After the Dissolve tool was used, the two lines were combined into one (bottom-most table).

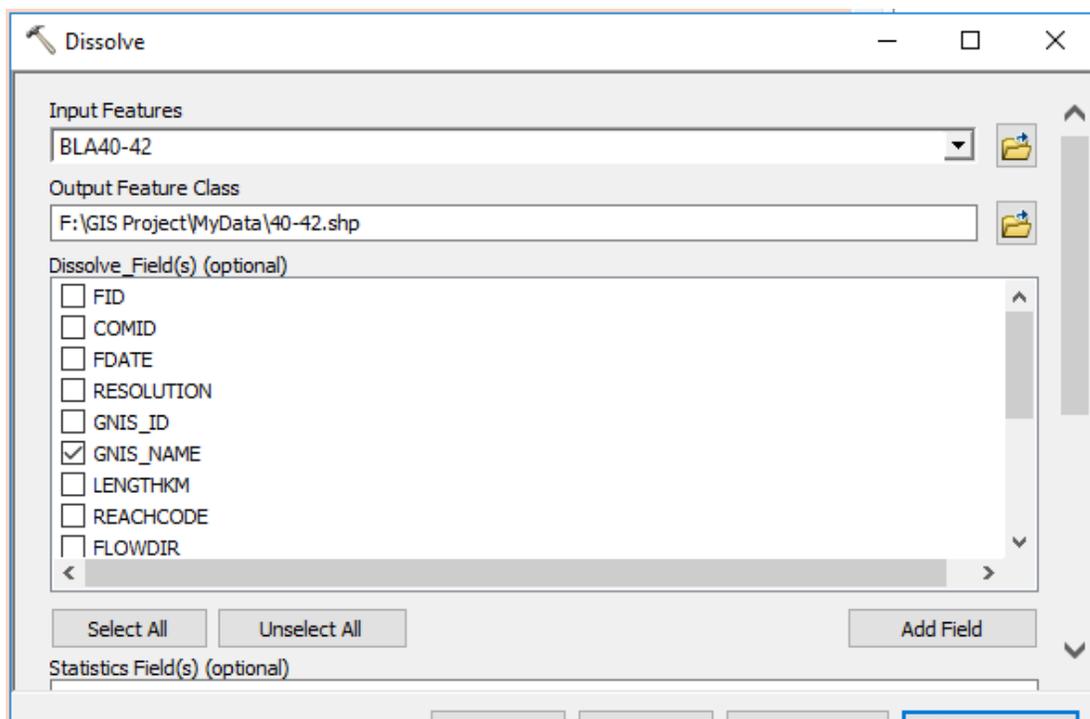
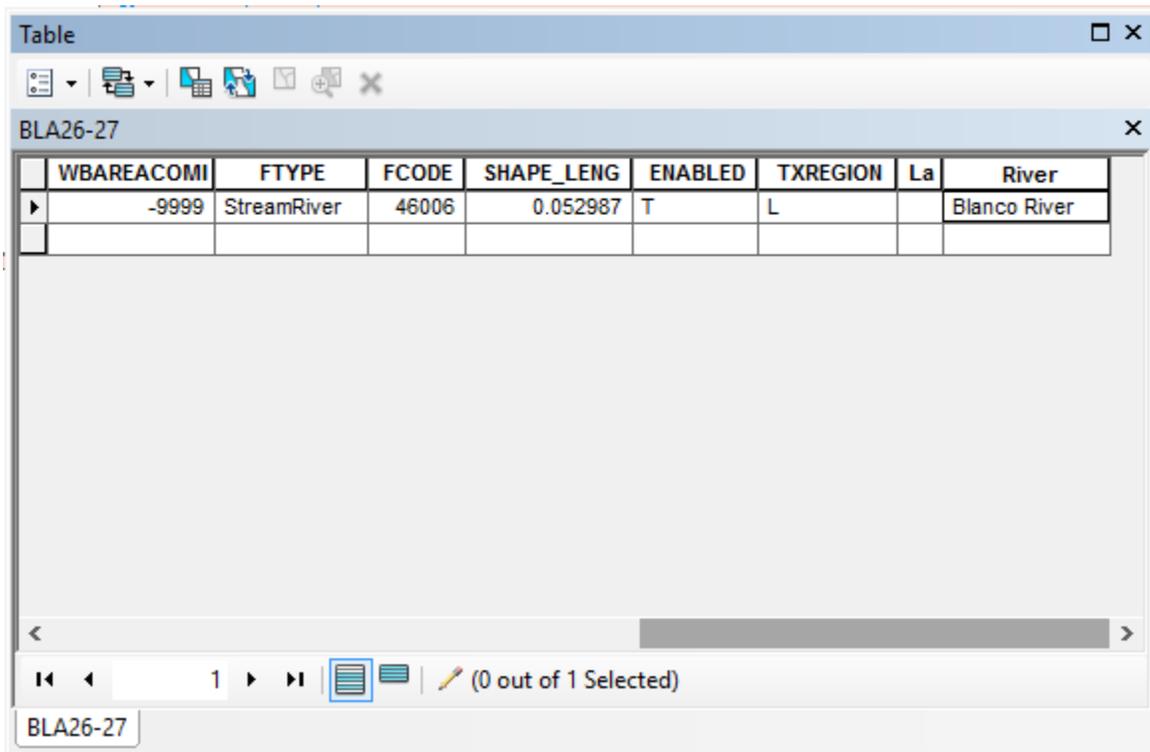


Fig. 12: The Dissolve tool was used to combine the two lines within the river selection stretching between BLA040 and BLA042. GNIS\_NAME was used as the dissolve field, resulting in a single line called 40-42 with only one FID.

## Merging Stretches between Sampling Sites into a Cumulative Reach

Once each stretch was appropriately dissolved or split to be a continuous line with only one FID, the five lines between the six measurement points were merged into one shapefile. To ensure that this was done correctly, a new field called “River” was created within each stream segment layer. The text “Blanco River” was entered for all of the layers using editor (fig. 12). This ensured that all segments shared a common attribute by which they could be merged.



	WBAREACOMI	FTYPE	FCODE	SHAPE_LEN	ENABLED	TXREGION	La	River
▶	-9999	StreamRiver	46006	0.052987	T	L		Blanco River

Fig. 13: The new “River” field within the BLA27-27 stream layer was filled out as “Blanco River” using editor. The same process was used for each of the five stream segments.

The merge tool was then used to combine the five river segments between the six sampling sites, comprising a cumulative reach from the first sample site, BLA20, to the last, BLA50. This new line was called “Merge” (fig. 14).

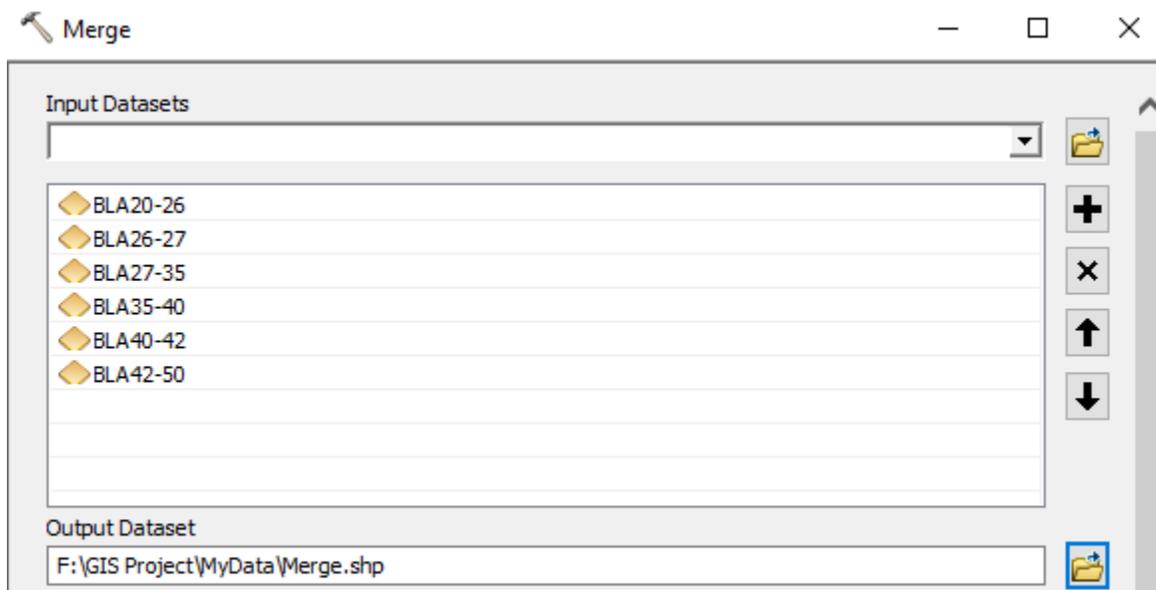
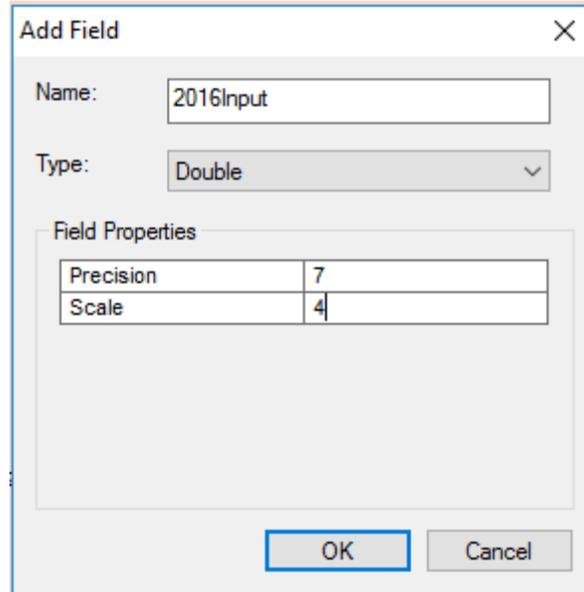


Fig. 14: Each of the five segments between the six sampling sites were merged to a new shapefile called “Merge”.

## Adding Input and Output of Groundwater within Each River Segment

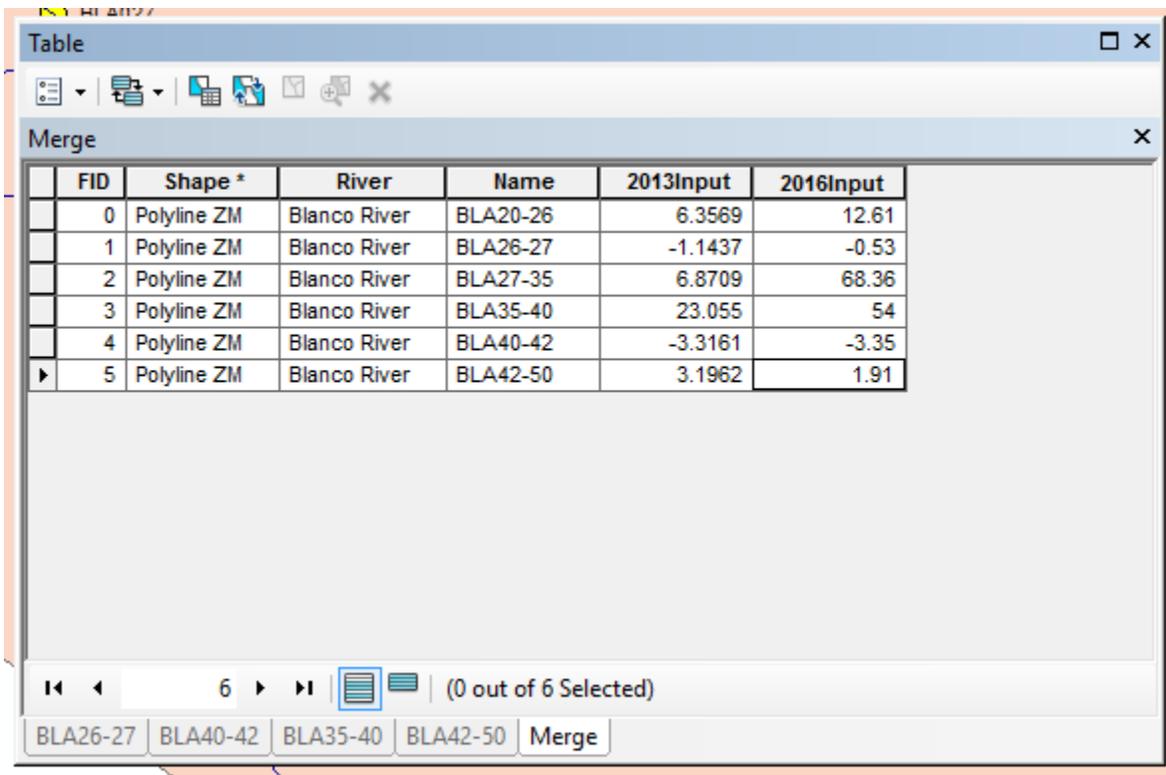
The point of having each of the five stretches between the sample points be their own unique FID was so that the groundwater input or output for each segment could be calculated and added to the attribute table. The calculations were performed in excel, and involved subtracting the discharge of each sample site to be subtracted from the discharge of the sample site immediately upstream (ex. discharge of BLA26 – discharge of BLA20 = input or output between BLA20 and BLA26). Once these values were calculated for 2013 and 2016, two new fields were created within the attribute table of the Blanco River Merge file to input them (fig. 15). These were then added to the table using editor (fig 16).



The 'Add Field' dialog box shows the following configuration:

- Name: 2016Input
- Type: Double
- Field Properties:
  - Precision: 7
  - Scale: 4

Fig. 15: New fields called 2013Input and 2016Input were created as Double values with a Precision of 7 and a Scale of 4.



FID	Shape *	River	Name	2013Input	2016Input
0	Polyline ZM	Blanco River	BLA20-26	6.3569	12.61
1	Polyline ZM	Blanco River	BLA26-27	-1.1437	-0.53
2	Polyline ZM	Blanco River	BLA27-35	6.8709	68.36
3	Polyline ZM	Blanco River	BLA35-40	23.055	54
4	Polyline ZM	Blanco River	BLA40-42	-3.3161	-3.35
5	Polyline ZM	Blanco River	BLA42-50	3.1962	1.91

Fig. 16: The calculated input and output for 2013 and 2016 were added to the Merged Blanco River attribute table.

There were two different ways to visualize the discharge data recorded along this stretch of the Blanco River. The first involved looking at the point data for 2013 and 2016 individually. To do this, the GPS points layer needed to be proportionally symbolized based on their associated discharge values (see “Symbolizing Discharge Data”). The second analysis involved displaying the gaining and losing stretches of the stream segments within the measurement reach. The negative input values associated with each segment represented losing sections, meaning the river loses water to infiltration and groundwater recharge. The positive input values represented gaining sections, meaning the groundwater is added to the surface water. To best visualize these differences, the losing sections were coded red and the gaining were coded green (see “Symbolizing Input and Output” section)

## Symbolizing Discharge Data

The measurement point data needed to be both symbolized and labeled. To create an informative visual, the points were symbolized by size relative to their discharge values: the points with the greatest discharge were represented by the largest circles, the points with the smallest discharge were represented by the smallest circles. This was done using the Layer Properties→Symbology→Quantities→Proportional Symbols function, with value field set to “2013 Discharge” (fig. 17).

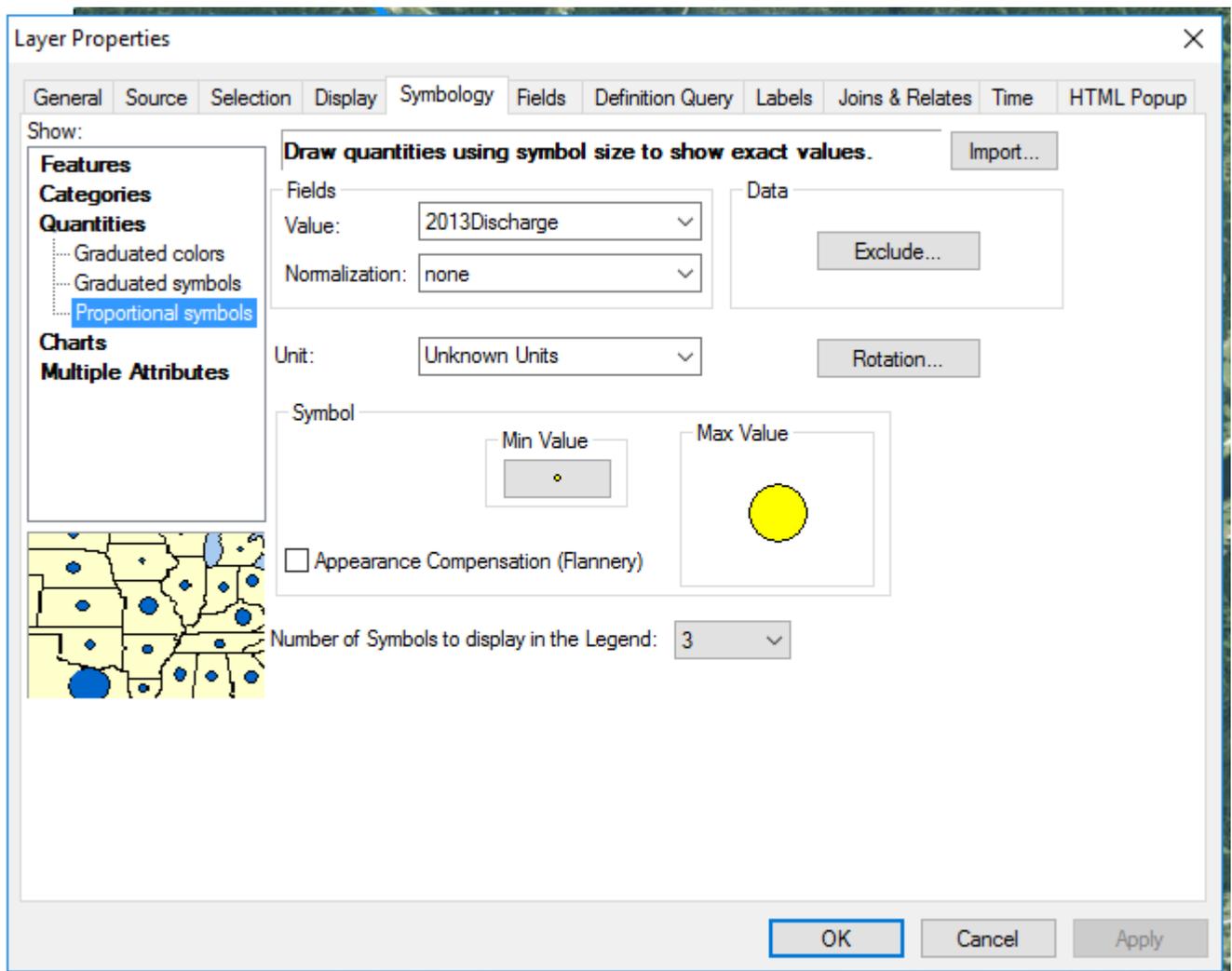


Fig. 17: The Symbology tab for the 2013 Discharge Measurements map. The 2013Discharge value field was represented by proportional symbols.

Although proportional symbols worked very well for displaying the 2013 data, the discharge data for 2016 did not display well using this symbology tool. Graduated symbols using manual classification were used instead (fig. 18).

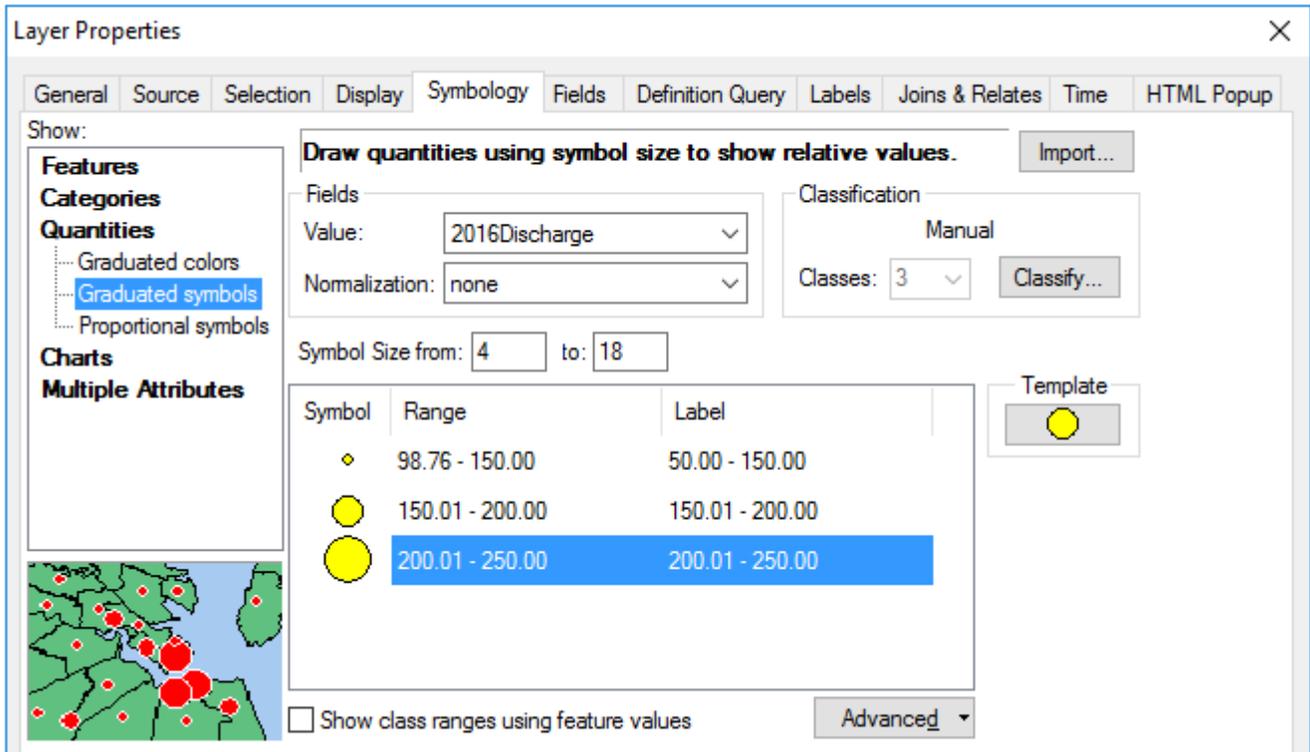


Fig. 18: The symbology tab showing the manual classification of the graduated symbols representing 2016 Discharge data. Ranges and labels were input manually to ensure the best visual display of the point discharge measurements.

The next step was to label the points. To do this, a halo was added to the text and the placement was set to prioritize a right side, horizontal placement of the 2013 Discharge measurements (fig. 19). This was done for the 2016 map as well.

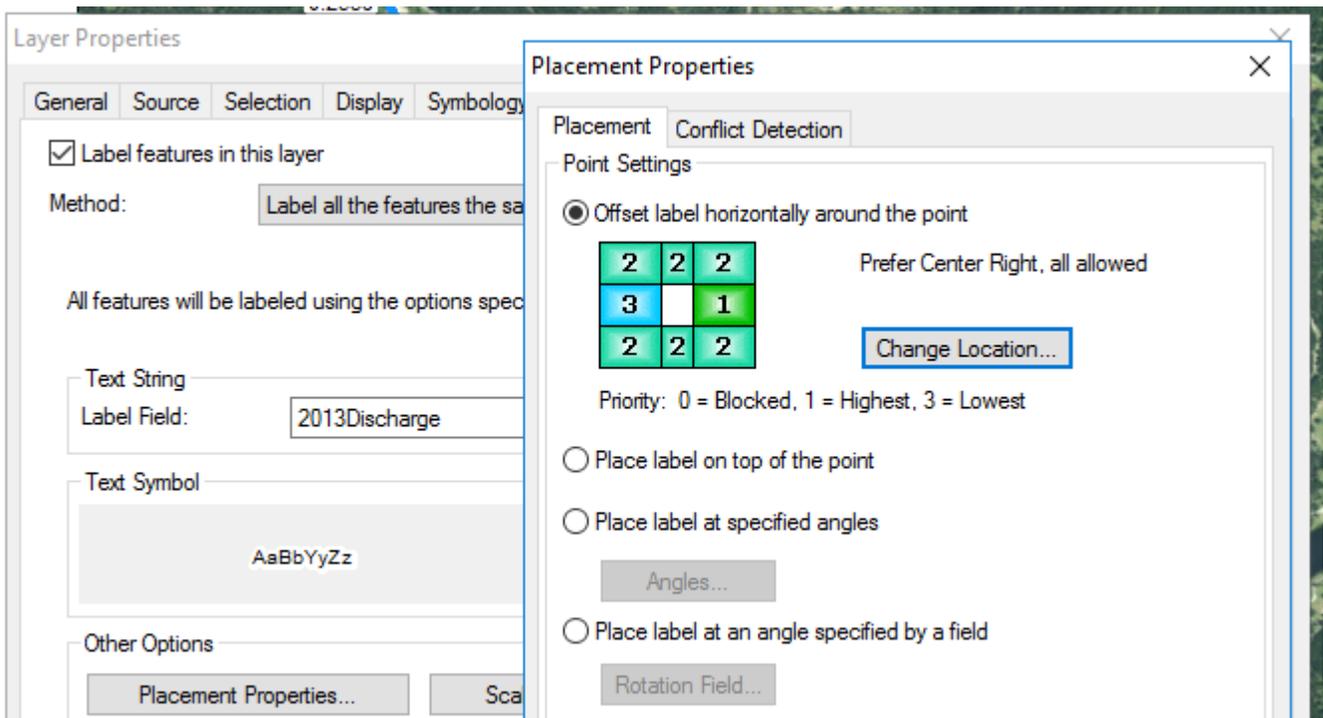
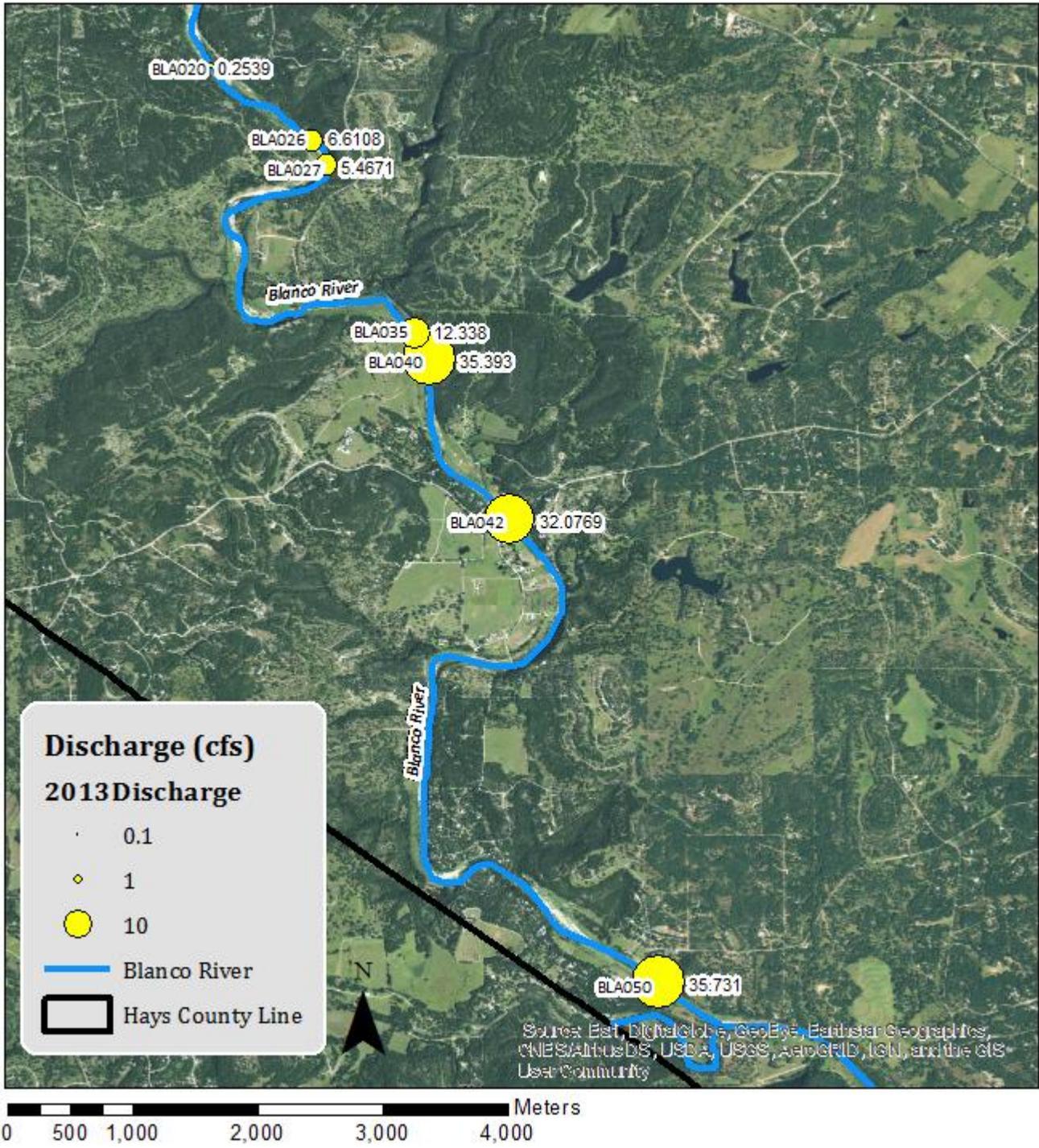
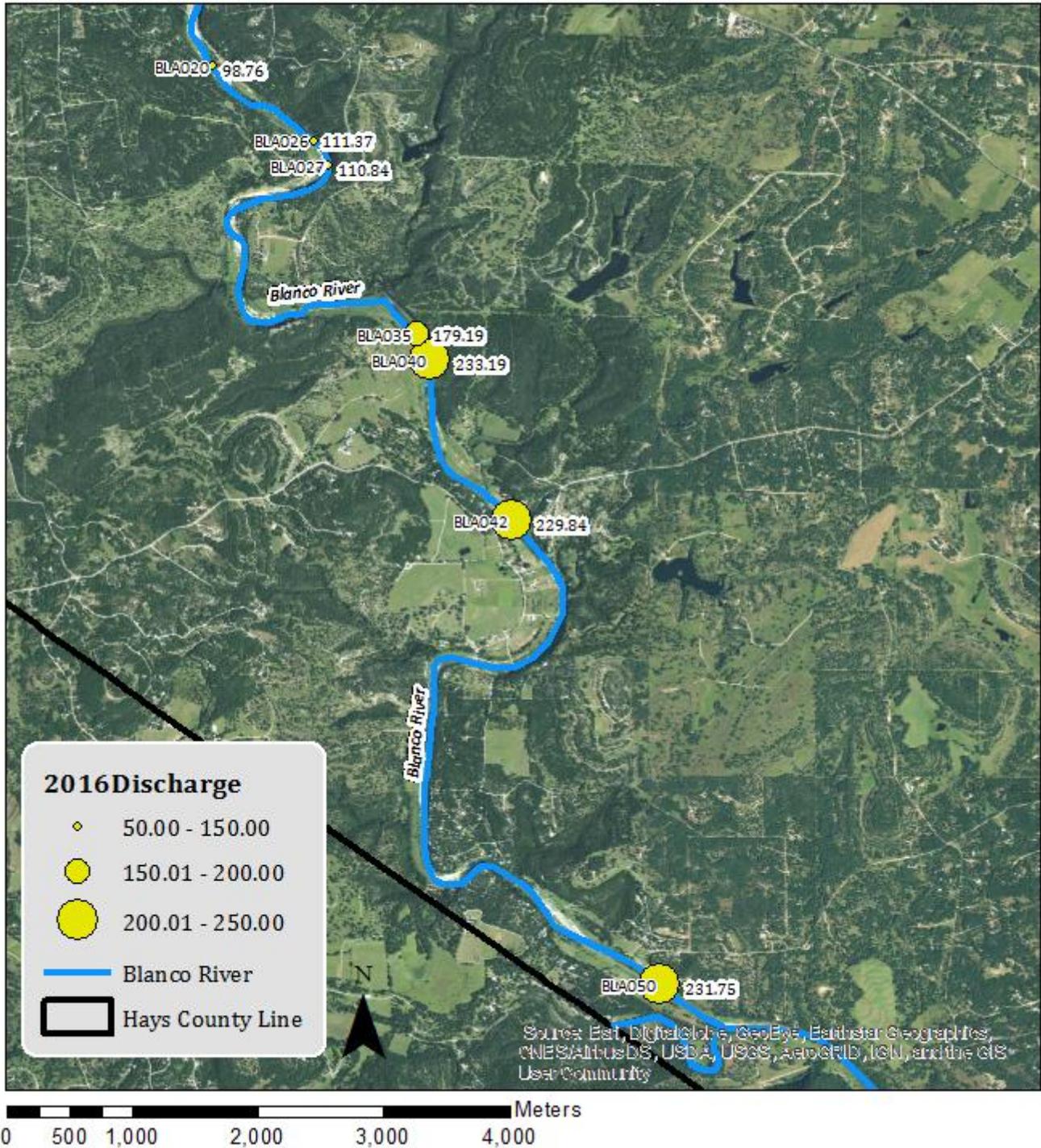


Fig. 19: The placement properties for the 2013 Discharge data labels. A right-side priority offset was selected and a text halo added for visibility.

# Blanco River Discharge Measurements from 2013



# Blanco River Groundwater Contributions from 2016



## Symbolizing Groundwater Inputs and Outputs

The input data for each segment of the Blanco River reach from BLA020 to BLA050 needed to be represented visually as well. Because each segment between the neighboring points had its own input value, a manual symbology was used to represent this data as well. To do this, the Layer Properties→Symbology→Quantities→Graduated Colors tool was used. The Field Value was set to 2013 Input with two manual classes. The upper most range for the first category was set to 0 to divide the values between positive and negative. A red color was assigned to the created negative category, and the label was changed to read “Losing Section”. A green color was assigned to the remaining positive range, and its label was changed to “Gaining Section” (fig. 20).

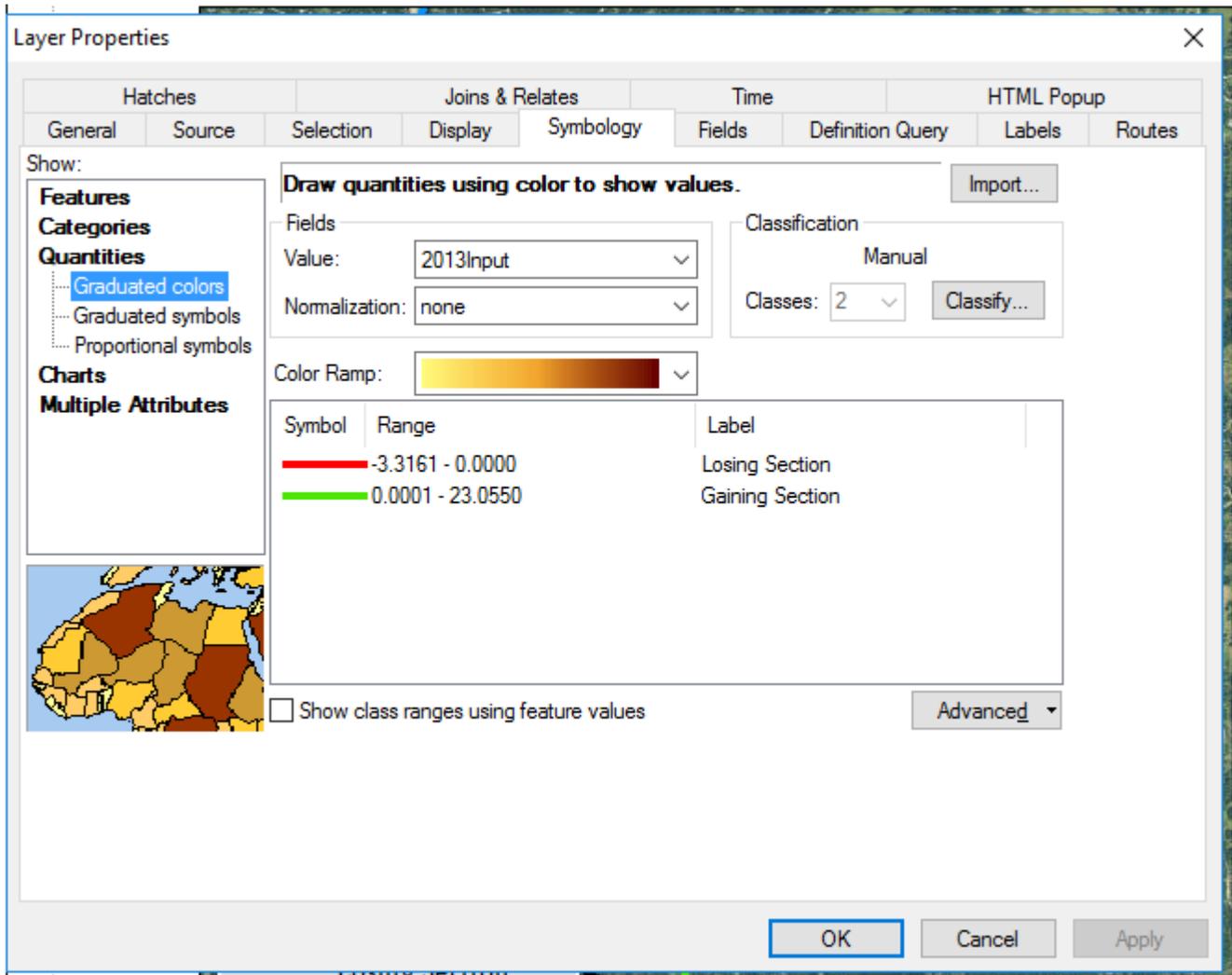
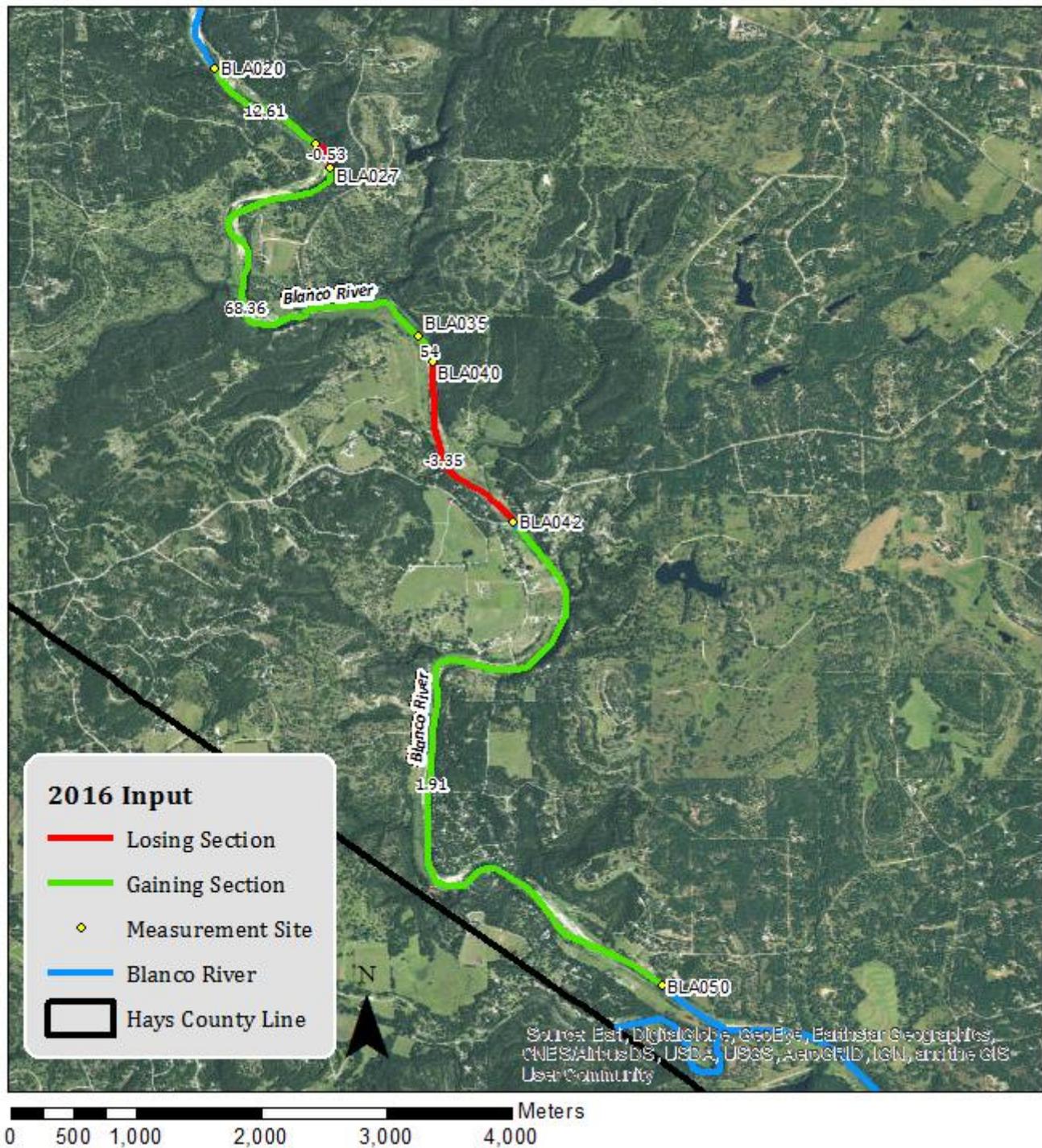


Fig. 20: The symbology tab for the Blanco River measurement reach. A manual classification was used to create two classes, one negative (the red, Losing Section) and one positive (the green, Gaining Section).

The segments were labeled using the 2013 Input field, with a halo added for visibility. The symbology of the measurement points was changed back to the “feature” type so that it did not distract from the visualization of groundwater contributions. Labels for the points were kept for data analysis purposes. Once a map was created for 2013, the same steps were repeated using the 2016 Input field. As with the Discharge Data Point data, two maps were created to contextualize groundwater inputs and outputs. Both groundwater contributions maps are included below (see “Resulting Maps for 2013 and 2016 River Segment Data”).



# Blanco River Groundwater Contributions from 2016



## CONCLUSION

A comparison of discharge at each site during each period of data collection quantifies the amount of input that can be attributed to underlying springs. The four major springs fall between the point sites BLA020 and BLA050 and the total change in discharge from each site can be attributed to volumetric input from the springs. Comparing the total reach discharge with the discharge attributed to the springs contextualizes the magnitude of the springs' contribution to the river system. Underlying spring systems contribute significant amounts of discharge into the Blanco River. The volumes are not generated by short term fluxes in rainfall, but by long term precipitation trends. Discharge increases require multi-year precipitation increases, and discharge will decline if rainfall is not sustained. Periods of prolonged drought will reduce groundwater contributions as the underlying springs and aquifers are fed by less runoff and precipitation. Surface water flows are influenced by groundwater contributions, which can account for high volumes of input as evidenced by the four major springs along the studied reach.

## CITATIONS

Broun, A.S. et al. (2008). The Geology of Cypress Creek Watershed, Wimberley Area, Texas. Austin Geological Society Bulletin. 4: 23-34.

Kocis, T.N., 2014. Understanding Surface Water—Groundwater Interactions on the Blanco River, Hays Count, TX. B.S. Honors Thesis, Jackson School of Geosciences. Austin, TX.

Smith, B.A., Hunt, B.B., Andrews, A.G. et al. (2015) Environ Earth Sci. 74: 7633-7642.

Smith BA, Hunt BB, Beery J (2011) Final report for the Onion Creek recharge project, northern Hays County, Texas. Barton Springs/ Edwards Aquifer Conservation District, Austin, TX, prepared for the Texas Commission on Environmental Quality.