Agricultural Water Use Compared to Discharge into the Great Salt Lake from the Bear River Basin

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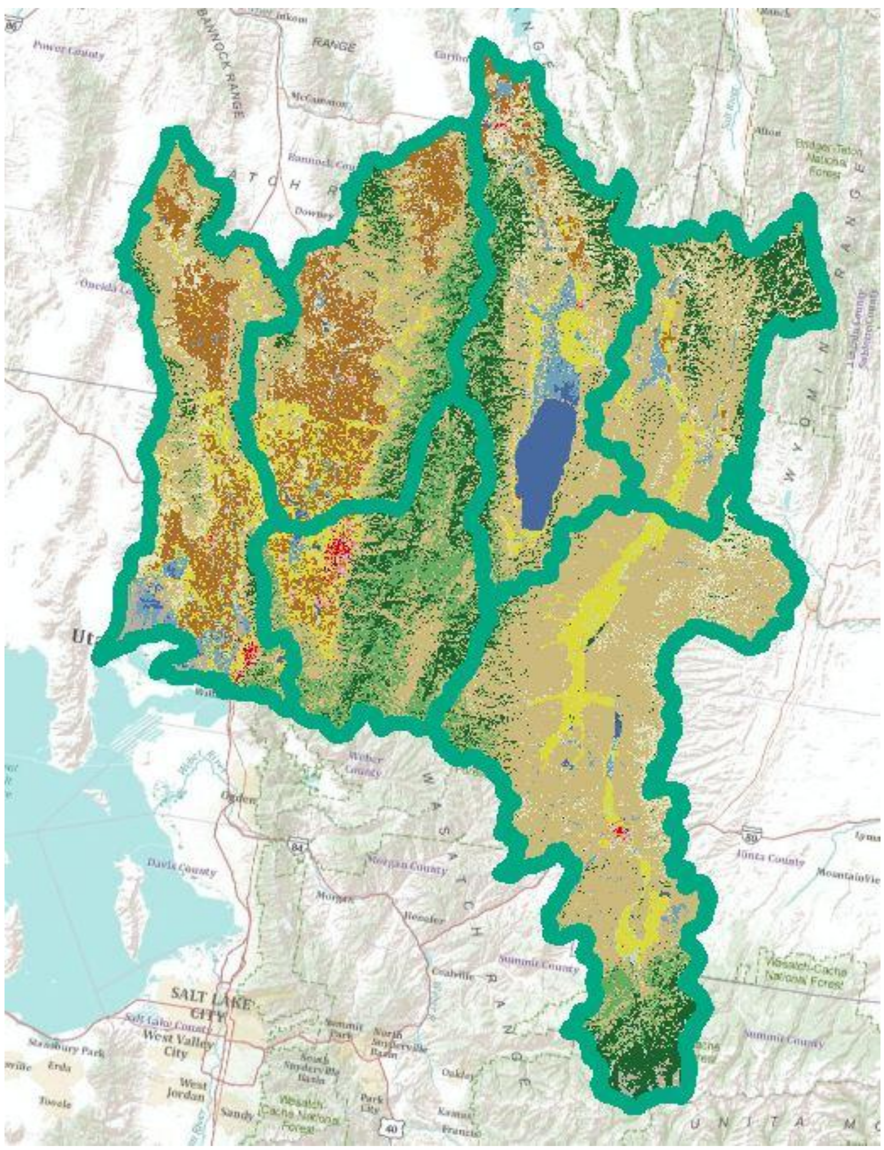

Executive Summary

This project covers a portion of the Great Basin known throughout the paper as the Bear River Basin. This basin is located at the most North-Eastern part of the Great Basin and is comprised of six different HUC-8 watersheds. These six watersheds were used to create a basemap of the area in ArcGIS for the purpose of determining what the ratio of water used by agriculture in the Bear River Basin to discharge of the Bear River into the Great Salt Lake. This basemap was the backbone to determining what the discharge of the river into the lake. This was done using two different methods. The first method was to use data obtained from the National Hydrography Dataset (NHDPlus 16). The second method was to find the USGS gages located on the river to obtain this discharge. A comparison of the two values was made and the observed values for the discharge were to be used to calculate the ratio. The basemap was also set up to calculate the amount of precipitation that typically falls on the agricultural lands located in the basin. The area of land covered by agriculture was also found using this basemap. Through literature, the Crop Water Requirement (CWR) required by the crops in the basin was found, but the accurate CWR was not able to be calculated. This is critical in finding the ratio. Due to time constraints, this value was not able to be calculated and will be finished later.

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Chapter 1 – Introduction

This project encompasses a region that covers a portion of Northern Utah, Southwestern Wyoming and Southeastern Idaho. This region is a part of the Great Basin. It is known as the Bear River drainage. The Bear River's headwaters are located in the high Uinta mountain range near the corner of the Wyoming-Utah border. It proceeds northward weaving in and out of Utah and Wyoming. It then proceeds in a northwestern direction with a branch going south into Bear Lake. As it continues its course, it enters Idaho, where it changes direction and begins its trek back into Utah through Cache Valley. It exits Cache Valley through Cutler Reservoir and continues its journey toward the Great Salt Lake. It discharges into the Great Salt Lake through the Bear River Wildlife Refuge in Northern Utah. Shortly before it discharges, it is joined by the Malad River from Idaho. It is one of three major tributaries that feed into the Great Salt Lake and is by far the longest and provides the most inflow to the lake. The other two main tributaries are the Weber River and the Jordan River. This project, as mentioned, will cover the Bear River and its tributaries. The focus of this project will be to determine the ratio of water used by agriculture to discharge of the Bear River into the Great Salt Lake. A map of the course that the Bear River takes is shown in Figure 1.

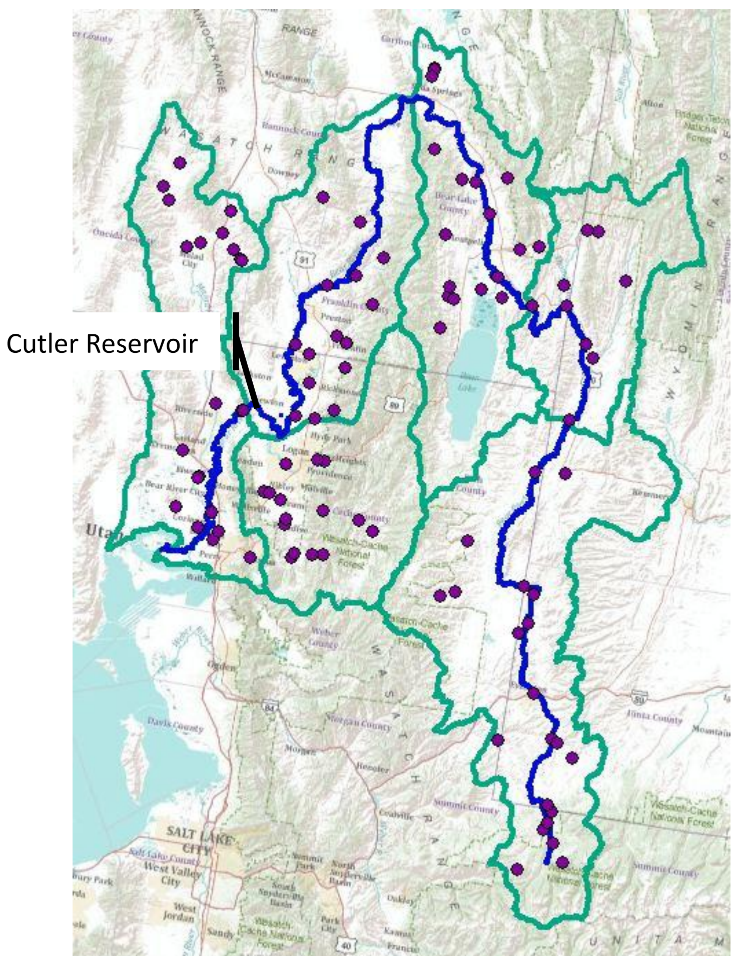

Figure 1 - Path of the Bear River

This ratio will help determine the effect that water diversion has on the level of the lake. If this amount is a small amount, for instance 2 %, then this effect is minimal. However, if the ratio is fairly significant, for example being greater than 25 %, then the effect cannot be ignored. The limit for this project will be 25%. Greater than this will result in an effect that cannot be ignored, and less than this would result in the need for further investigation.

In order to accomplish the task of finding this ratio, data regarding the drainage area needed to be downloaded and consolidated. The consolidation of this data was accomplished using ArcGIS 10. A discussion of the data that was retrieved will be given in Chapter 2. The data was used to build a basemap in ArcMAP which was used to determine the discharge of the Bear River into the Great Salt Lake and also the area of land that is used for agricultural purposes. The process that this was done will be given throughout this paper as well as the results from the basemap in Chapters 3 and 4 respectively.

Chapter 2 – Data Retrieval

There was a lot of data that needed to be downloaded in order to complete this project. There were three main sources from where this data was downloaded. These three sources are the NHDPlus 16, the USGS and the NLCD 2006 websites. A discussion of each of these sources and the data that was downloaded from them will occur in this chapter in the order mentioned above.

The NHDPlus website was by far the source where the majority of the data came from. This data included Flowlines, Basin, Flowline Attributes, Elevation, Flow Accumulation, Flow Direction, and Watershed feature classes. The Flowline, Basin, and Watershed feature classes were used to develop the basemap that will be discussed in Chapter 3. The remainder of the feature classes mentioned above were used as part of the analysis of the project. A discussion of each of these feature classes will follow.

The Flowline feature class contains the data for each of the streams in the Great Basin. This provided the backbone of the streams for the Bear River drainage area. This delineates each river or stream, including the main branch of the Bear River as well as the Malad, Logan, Blacksmith Fork, and Little Bear Rivers. All of the named rivers are main tributaries to the Bear River and supply a significant amount of water to the main stream.

The data for the Basin feature class provided the boundaries for the drainage area. There were six main sub-basins that make up the Bear River basin. Each of these basins had their own Hydrologic Unit Codes (HUC-8) which made it impossible to completely combine them into one main basin.

The data for the Flowline Attributes provided some important attributes associated with the Flowline feature class. Two attributes in particular are the Mean Annual Flow (MAF) and the stream type. The MAF provided annual flows for each of the rivers which aided in finding the discharge of the Bear River into the Great Salt Lake. The stream type allowed for locating and determining USGS gages that were located on either canals or streams, the gages will be discussed later.

The Elevation dataset was used to get an idea of how the terrain looks. It was also used to determine the flow direction for the basin. This allowed for the creation raster datasets for the Bear River. This helped to determine if the streams lined up well with the flowline feature class.

The data for the Flow Accumulation was input into GIS as a raster. This allowed for classes to be formed as to how much flow accumulated throughout the basin.

The data for the Flow Direction was input in the same way that the Flow Accumulation was inputted. This provided direction that the flow would take to eventually discharge into the Great Salt Lake.

The data for the Watershed feature class provided the names of each of the watersheds in the Bear River Basin. These names made it possible to get a glimpse at the general flow direction of the Bear River. These names also made it possible to get the correct data for stream gages that were accessed from the USGS website.

Another source where data was retrieved from was the USGS website for stream flows. From this site, the stream gages for the Bear River Basin were obtained. This was needed to determine the discharge of the Bear River into the Great Salt Lake. Table 1 below shows a sample of what was included as part of the USGS Gages information.

Table 1 - Sample of USGS Gage data from Website

Object ID	SiteID	SiteNAME	LatDD	LongDD	coord_acy_cd	dec_coord_datum_cd	HUCID	basin_cd
1	10010400	EAST FK BEAR RIVER NR EVANSTON, WYOMING	40.87	-110.78	F	NAD83	16010101	10
2	10010500	HILLIARD-E FK CANAL NR ST LINE NR EVANSTON, WYO.	40.92	-110.82	F	NAD83	16010101	10
3	10011200	WEST FORK BEAR RIVER AT WHITNEY DAM, NR OAKLEY, UT	40.84	-110.93	F	NAD83	16010101	10
4	10011400	WEST FK BEAR RIVER BL DEER CR NR EVANSTON, WYO	40.94	-110.86	F	NAD83	16010101	10
5	10011500	BEAR RIVER NEAR UTAH-WYOMING STATE LINE	40.97	-110.85	F	NAD83	16010101	10

The last source that was used to collect data was the National Land Cover Dataset (NLCD) for the year 2006. This was the most recent land cover dataset that was found for the area. This dataset was used to determine how much land area was covered by agricultural lands. Through the Metadata file that came with the image file, it was possible to determine what codes to look for to isolate the agriculture related land cover. An area was then able to be calculated to determine the irrigated area for agriculture. Figure 2 below shows what the image looks like that was downloaded from NLCD 2006.

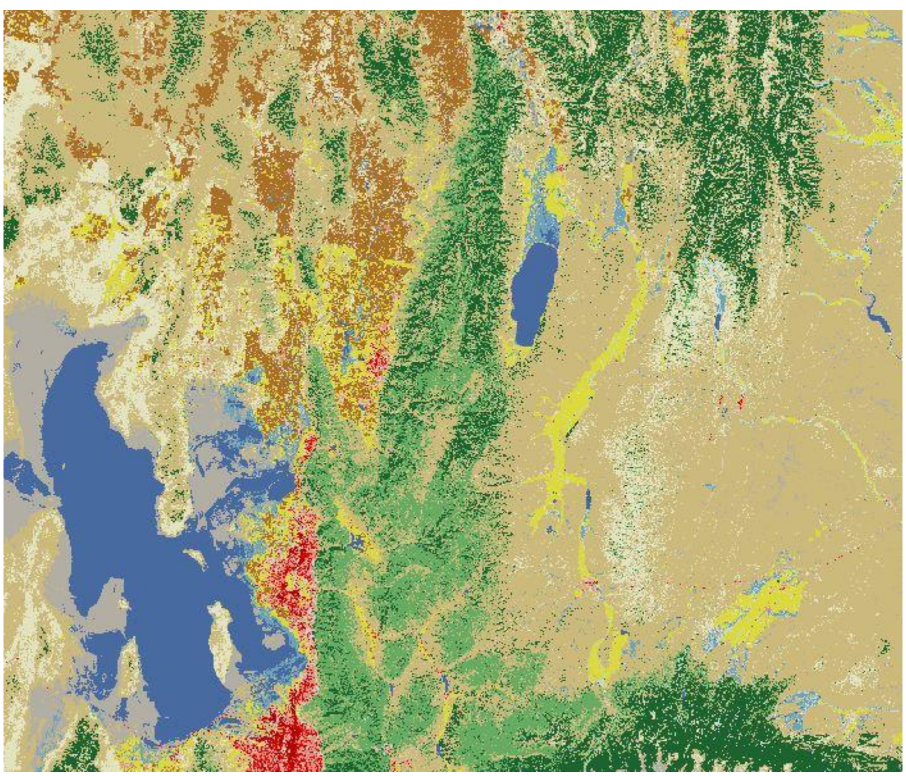

Figure 2 - Example of the Image from NLCD 2006

Chapter 3 – Basemap Development

The basemap for the Bear River Basin was straightforward to create. It was first necessary to download the flowline shape file, shown in Figure 3, and the basin dataset, shown in Figure 4, from NHDPlus 16.

Figure 3 – The Shapefile for the NHD Flowlines

Figure 4 – The Basin dataset for the Great Basin

As can be seen in these two figures, these datasets give all the flowlines and the subbasins for the entire Great Basin hydrologic unit. Since the Bear River Basin is a small portion of the Great Basin, it was necessary to locate and isolate the subbasins that make up the Bear River Basin. To do this, it was necessary to view the attribute table for the basin dataset and select those HUC-8 regions associated with the Bear River. These were identified as being in the upper right corner of the Great Basin. Using the "Select by Attributes" tool in ArcMap, it was possible to select the subbasins associated with the Bear River. These subbasins were then exported and added to the Basemap Feature Dataset created for the purpose of creating the Basemap. This Feature Class was then named Basin to match what it represents. Figure 5 below shows this addition to the basemap.

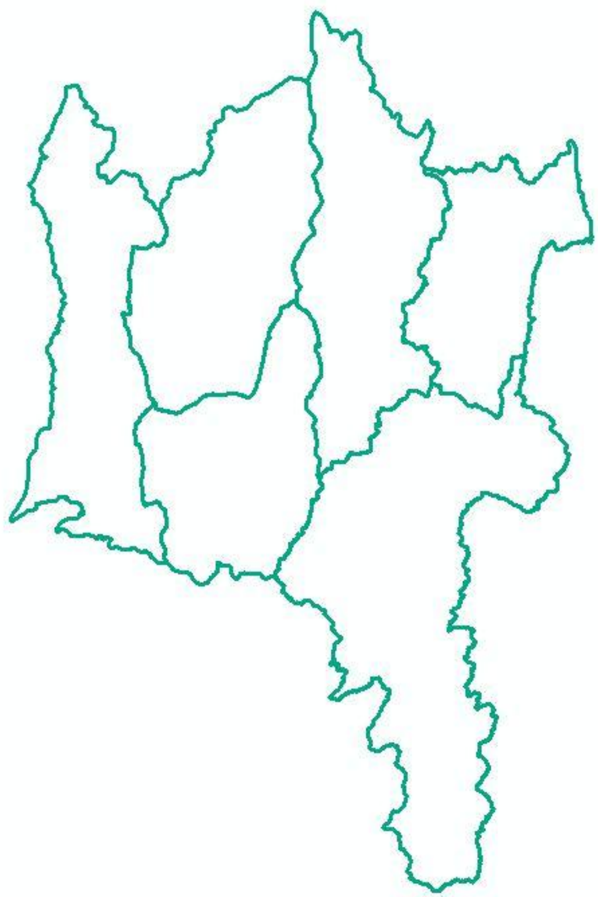

Figure 5 – The Basin Feature Class

It is important to point out that these basins were not able to be joined into one because there are three different HUC-8 identifiers for the six subbasins. This prevented the join from successfully running. Thus all six of the subbasins make up the Bear River Basin.

After the basin was outlined, it was necessary to input the Watershed Shapefile. The same situation occurred for this file as that for the basin dataset. The watersheds that were desired were selected using the "Select by Attribute" tool and selected the HUC-8 identifiers associated with the basin. These were then exported to the basemap and named Watershed. As was mentioned earlier, this layer came with the name of each of the subbasins. Figure 6 below shows what this layer looks like in the basemap.

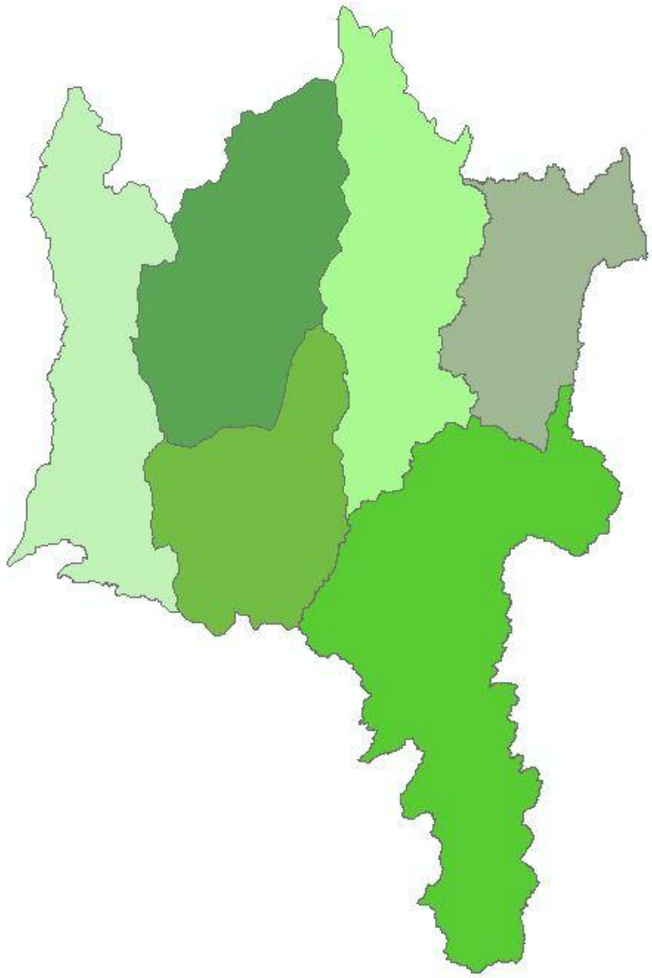

Figure 6 – The Watershed Feature Class

With the Basin and Watershed Feature Classes created, it was then necessary to add the flowlines to the basemap. This was done in a similar fashion using the “Select by Location” rather than the “Select by Attribute” tool in ArcGIS. This made it easier to select all the reaches in the basin without worrying about each reach code to select. Figure 7 shows the end result for the Flowline Feature Class that was added to the basemap.

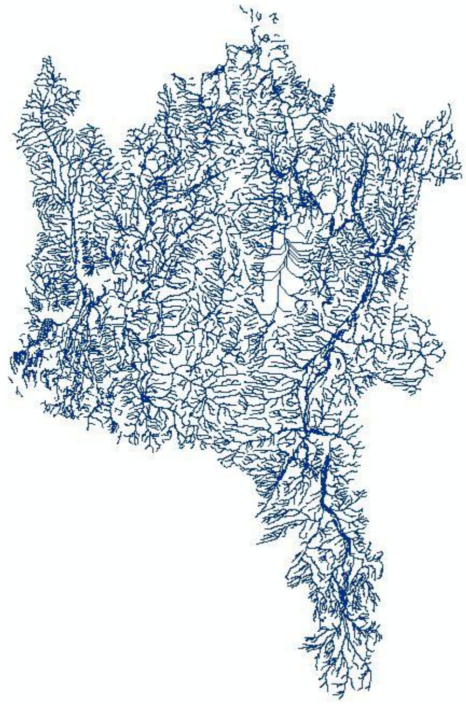

Figure 7 – The Flowline Feature Class

As can be seen in the figure, it is possible to guess the flow direction that the Bear River takes through the Bear River Basin. With all three of these feature classes created, the basemap was completed. The backbone for the main project was completed and now the analysis could be completed.

Chapter 4 – Analysis

The analysis for this project was the part of the project that took the longest to complete. There were a lot of trial-and-error processes that were done in the process of doing the analysis. A brief description of the problems that occurred during the process of the analysis will occur followed by the description of the steps that were done to complete the analysis portion of the project.

Several setbacks were experienced while trying to complete the analysis of this project. The Gages, Flow Accumulation (FAC), Flow Direction (FDR), and Elevation (ELEV) feature classes were loaded onto the basemap only to find out that the data was incorrect or the area covered was insufficient for the area. The Gages was by far the most confusing. When these gages were loaded onto the basemap, it was very difficult to determine which gages were used for the outlet gages to each of the subbasins. Since there were about 1892 different gage stations, as shown in Figure 8, it was necessary to seek some further guidance as to what could be done to reduce this number.

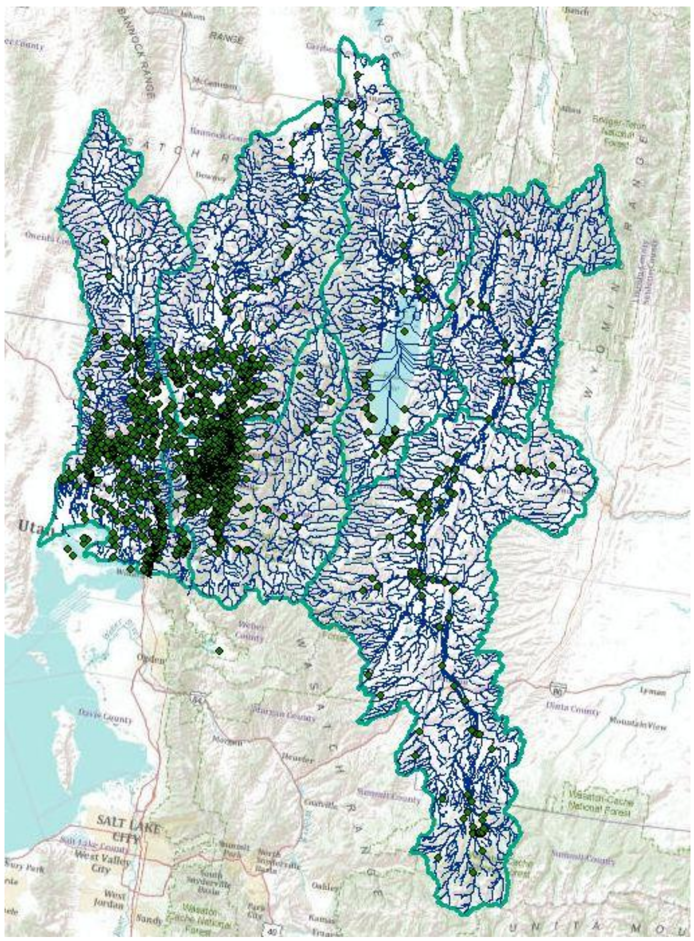

Figure 8 – The 1892 gage stations for the area. Each gage is depicted as a green diamond

After some consultation with Dr. Tarboton concerning the difficulties that were occurring, it was determined that the data from USGS needed to be filtered some more to include the attribute named Type for the gages and the MAF (mean annual flow) for the reaches. Along with this minor setback, there were others happening with the FAC, FDR, and ELEV feature classes. The problem with each of these was the same in that isolating the features to the Bear River Basin only seemed to be impossible. It was then discovered that it wasn't completely necessary for these to be isolated as they were used to make sure that the river continued on its course in a logical manner. There was another problem that occurred while getting this set up for the final analysis. It came with the Land Cover image from the NLCD 2006 website. Trying to isolate the land cover for the Bear River Basin only seemed to not work. It wouldn't allow for a selection of the image to be selected using the "Select by Location" tool. It was only after consulting with Dr. Tarboton that the "Clip" tool was discovered and used. This created an abbreviated version of the image for the Bear River Basin as shown in Figure 9.

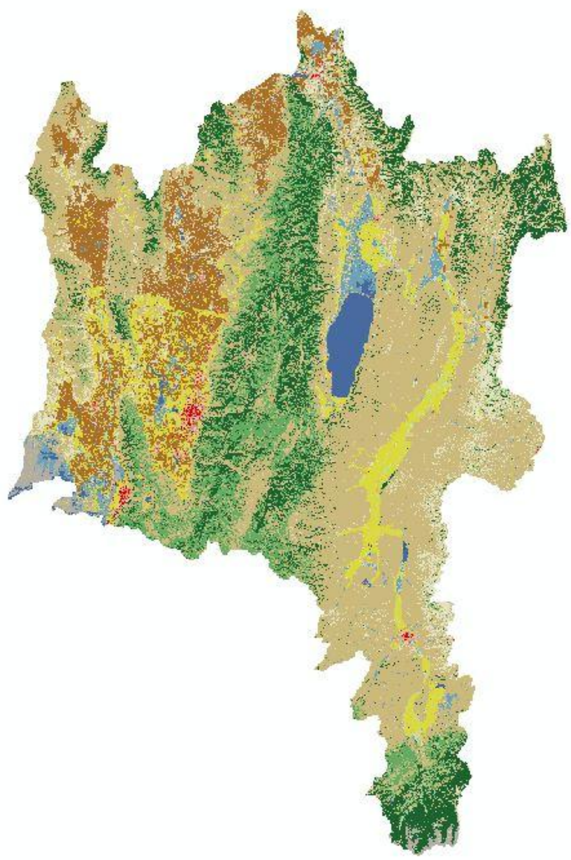

Figure 9 – The land cover image for the Bear River Basin

With all these setbacks listed and discussed, it is now possible to discuss the steps that were taken to create the map used for the analysis of the project. The order that these will be discussed will be as follows: the Land Cover image and data associated with it, the USGS Gages, and then the MAF for the Flowline feature class.

As was mentioned previously in this chapter, the Land Cover image was clipped to be confined to the Bear River Basin. Finding the area associated with agriculture from this image proved to be difficult. Along with this image came information regarding what each of the different colors meant. This information was found in the Metadata file. While perusing this file, the layers that were associated with agriculture were found and are shown in Figure 10. The layer values were found to be 81 and 82.

```
    Enumerated_Domain_Value_Definition: Moss- Alaska only areas dominated by
    Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class D
  Enumerated_Domain:
    Enumerated_Domain_Value: 81
    Enumerated_Domain_Value_Definition: Pasture/Hay  - Areas of grasses, legu
    Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class D
  Enumerated_Domain:
    Enumerated_Domain_Value: 82
    Enumerated_Domain_Value_Definition: Cultivated Crops - Areas used for the
    Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class D
  Enumerated_Domain:
    Enumerated_Domain_Value: 90
    Enumerated_Domain_Value_Definition: Woody Wetlands - Areas where forest o
    Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class D
  Enumerated_Domain:
```

Figure 10 – Sample of the Metadata file

With knowing these values, it was then possible to select these two layers and find the area associated with them. Originally it was desired to know the areas associated with each state that the Bear River runs through, but since the data for all the states was not found, a general irrigated area was found to be 444024800 Acres. This value will be used later in this report to find the water requirements for the irrigated area of agricultural land for the basin.

With this area found, it was then time to determine both the measured discharge of the Bear River into the Great Salt Lake and the predicted discharge that the NHDPlus data says should occur. The latter was found first in this process. In order to find the discharge of the Bear River into the Great Salt Lake according to what the NHDPlus data says, it was necessary to join the Flowlines attribute table with the Flowline Attributes attribute table. This allowed for the creation of a new field labeled MAF_cfs_, as shown in Figure 11, for the Flowline attribute table. After this join was done and the new field created, the Field Calculator was used to assign the new field values to those from the Flowline Attributes attribute table.

Table

BearRiver

FTYPE	FCODE	SHAPE_LENG	ENABLED	MAF_cfs_	Shape_Length
ArtificialPath	55800	0.015041	T	4785.8477	1390.695176
ArtificialPath	55800	0.026069	T	4643.6665	2590.254045
StreamRiver	46006	0.000538	T	4642.5508	59.876621
StreamRiver	46006	0.05798	T	4642.4966	5752.963558
StreamRiver	46006	0.00773	T	4640.625	732.28924
StreamRiver	46006	0.068604	T	4611.8711	6736.066546
StreamRiver	46006	0.003574	T	4608.0122	333.70382
StreamRiver	46006	0.01082	T	4607.689	1061.069894
StreamRiver	46006	0.018872	T	4605.9985	1748.786016
StreamRiver	46006	0.00563	T	4605.5806	546.336434
StreamRiver	46006	0.019173	T	4603.4971	1874.59766
StreamRiver	46006	0.005668	T	4593.6235	507.837294
StreamRiver	46006	0.030835	T	4593.5083	2898.655663

15 (1 out of 455 Selected)

BearRiver

Figure 11 – The created MAF field for the Bear River

From this table, it was possible to sort the data in descending order to easily find the maximum amount of flow that was being discharged into the lake. From inspection of the gages on the map, it was determined that in order to have a good comparison for discharge, the reach where the last USGS gage is located on should be the same reach that is selected for the maximum discharge . This turned out to be different then what the maximum discharge in general was because the reach is fifteen reaches upstream of the outlet into the lake. This reach, and its associated MAF, are shown in Figure 11 being highlighted in blue.

With this discharge value found, it was desired to compare this with the observed value from the gage itself. In order to do this, it was necessary to download the correct gage stations for the Bear River from the USGS website. This was done by selecting the Great Basin area with the Type attribute selected. After this was done, a file was allowed to be downloaded for use. It was then easy to find the gages associated with the Bear River Basin. The next filtration that occurred was to find the gages that were associated with the streams in the basin. This narrowed the number of gages down significantly from the 1892 to just 107 gages, as shown in Figure 12.

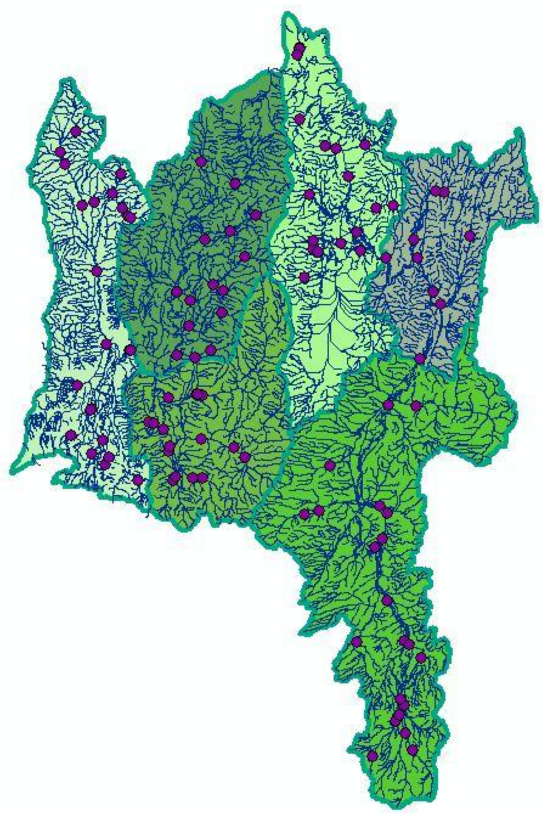

Figure 12 – The 107 USGS gages in the Basin

With creating a layer that was made up solely of the reaches that make up the Bear River, it was easy to find the most downstream gage located on the river, as shown in Figure 13. Knowing the site number of this gage made it easy to go onto the USGS website and locate the stream gage recordings for that gage. The average annual values were downloaded which contained data for the last 40 years. These were input into an excel file and the average for these years was taken. This value was found to be 1660 cfs which is significantly less than the value determined by NHDPlus at 36.13% of that value.

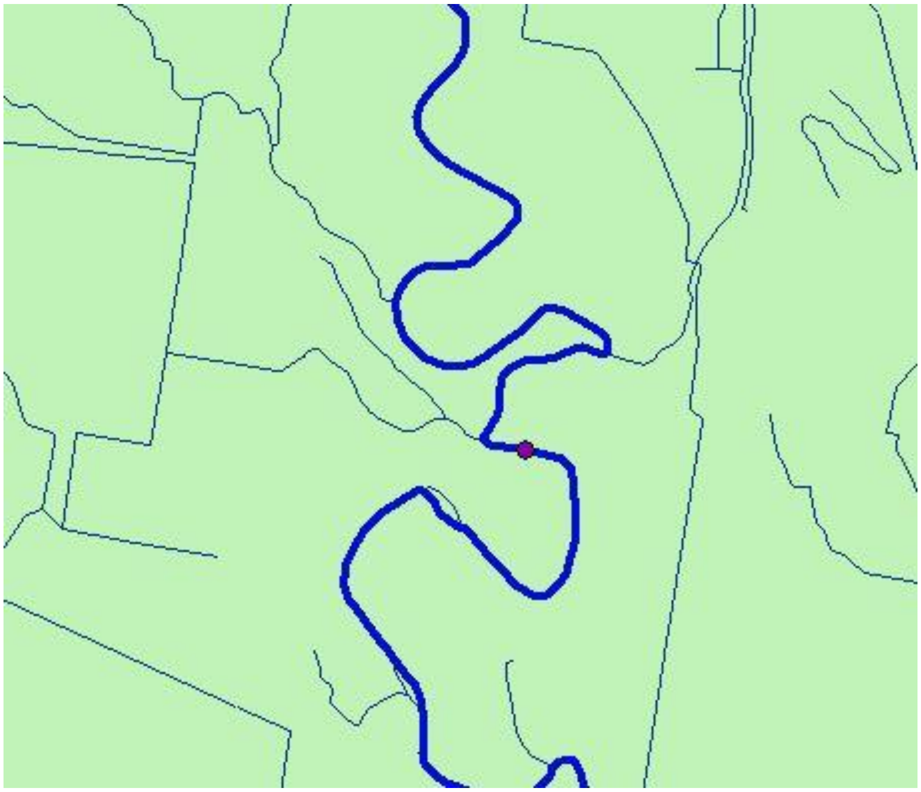

Figure 13 – The most downstream gage on the Bear River denoted as the Dot

For the purpose of this project, the discharge from the Bear River that is from the observed value from the gage was used as the discharge for the ratio mentioned in the first chapter. This was chosen because it is the value that is actually being seen at the outlet of the basin.

The next step in determining the ratio of water used by agriculture to the discharge of water into the Great Salt Lake from the Bear River Basin was to determine the Crop Water Requirement (CWR) of the agricultural area in the basin. This turned out to be more difficult than originally thought. It was necessary to download the precipitation data from Prism for the area to start with. When this file was input into GIS, there was no special reference to go along with it. This was remedied by re-projecting the data using the NAD-83 datum. With this projection, the precipitation data was properly projected over the country, as shown in Figure 14. This then made it possible to isolate the precipitation over the basin. This was needed to help determine the average amount of precipitation that would be expected to fall on the agricultural land. This value would be used to subtract the amount of water that would be taken out of the Bear River to supply water to the agricultural lands to supply the necessary water to their crops.

Figure 14 – The precipitation raster projected correctly. The Bear River Basin is shown where it needs to be.

The next step was to determine the crop coefficient for the agricultural crops in the basin. This was mostly attempted by searching the internet for any information. A site was found that went into detail about the coefficients and how to calculate the CWR. This website is www.fao.org/S2022E/s2022e07.htm. The base evapotranspiration value that was used was that for alfalfa. It was attempted to find and average growing period for the crops and also an average crop coefficient, however, an accurate value was unable to be calculated at the writing of this report. It should be noted that this value will be pursued until it is found so that an accurate ratio can be determined.

Chapter 5 – Conclusion

In conclusion, the area of the Bear River Basin that is covered by agricultural land was found to be 444024800 Acres. This is the main value that will be used to multiply the CWR to find the total amount of water that is being used by agriculture. This would then be divided by the discharge of the Bear River into the Great Salt Lake according to the USGS gage located on the Bear River near Corrine, UT. This discharge value was found to be 1660 cfs, which is 36.13% less than the predicted amount from the NHDPlus data.

There is still some work to do to complete this project, however, with the deadline for this report already here, this is how much is done. Better time management and preparation would have helped in fully completing this project on time. As they say, there is always a lesson to be learned with everything.