River Terrace Mapping of Rush River, Sibley County, MN

By

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Abstract

Approximately 10,000 years ago, Glacial River Warren carved out the modern Minnesota River Valley. When the Minnesota River later occupied that valley, it worked to achieve a state of equilibrium. During this process, the features of the river begin to reflect the amount of water and the amount of sediment being transported. The Minnesota River's tributaries in turn responded to the new base level of the deepened Minnesota River valley. The tributaries carved down through the substrate, producing terraces that were left behind high on the stream valley walls. Rush River, about 3 miles south of Henderson MN, is one such tributary. In this study, three separate terrace levels were located and mapped within the Rush River ravine. The mapping of these terraces along the Rush River Valley can tell us about past events, like the timing of base level changes of the Minnesota River or the Glacial River Warren. The terraces can also serve mining and excavating companies. By mapping these terraces and noting their consistency, we can help companies determine if the area is worth excavating for earth materials for construction purposes.

Acknowledgements

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Introduction

At the end of the most recent glacial interval, Glacial Lake Agassiz contained enormous volumes of glacial melt water, trapped against the retreating ice sheet to the northwest (Ojakangas and Matsch, 1982). When the moraine dam containing the lake failed, the release of water carved a channel and created the Glacial River Warren (Figure 1). Glacial River Warren is the ancestor of the Minnesota River. Over time Glacial River Warren and its tributaries carved through till into bedrock, creating a wide channel and associated floodplains (Johnson, 1998).

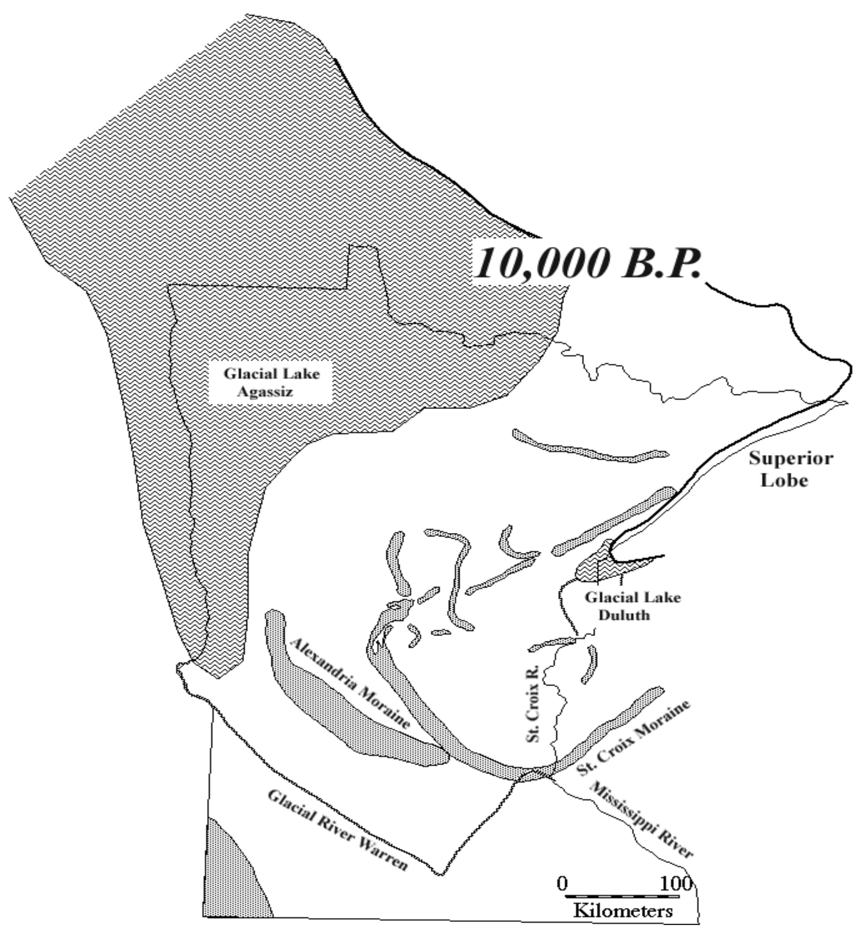

Figure 1. Glacial Lake Agassiz with a Southern outlet created by the loss of a natural ice dam draining water which created the Glacial River Warren which is the present day Minnesota River. (The Institute for Minnesota Archaeology)

Rush River is located in Sibley County (Figure 2.) about 3 miles south of Henderson, Minnesota (Figure 3). The river is estimated to have formed 10,000 years ago after melt waters from the Laurentide Ice Sheet formed Lake Agassiz. When the lake broke through a natural dam, a massive outflow of water – The Glacial River Warren – carved the landscape of southern Minnesota creating a huge valley that was ultimately occupied by the Minnesota River (Fisher 2003). When water accumulates in uplands, it will flow to the lowest spot possible or base level due to gravity. The base level of a river is the lowest point to which water can flow. For example, if there were a period of massive amounts of flow in the Minnesota River, more and more sediment would be moved downstream causing more incision. In turn, tributaries to the Minnesota River would also begin to down-cut and incise in response to the base level change of the Minnesota River. This period of increased incision could then be recorded by terraces, where information about past events can be obtained.

Figure 2. Sibley County highlighted in red.

Terraces composed of sand and gravel are remnants of former floodplains; they manifest geomorphically as step-like features at the edges of river valleys. Because base level dropped as the river incised its valley, high terraces are typically older and the youngest terraces have lower elevation and sit close to the modern river channel. Over time as water flowed down tributary streams, headward erosion lengthened the ravines upstream, eventually developing new tributaries and ravines. When Glacial River Warren caused local base level to drop these tributaries would similarly have cut downward, leaving terraces at the edges of their paleochannels (Bock, 2010).

One example of a tributary with terraces is Seven Mile Creek, a tributary to the Minnesota River that is located about 5 miles south of Saint Peter, Minnesota. That creek and its ravine system have been extensively studied in the past and present in hopes to better understand issues of hydrology and pollution. This area of Minnesota is heavily used in agriculture so issues of sediment supplies and runoff from fertilizers make this tributary a fit candidate for pollution control studies in order to learn more about why pollution and sediment supplies are so heavy in the Minnesota

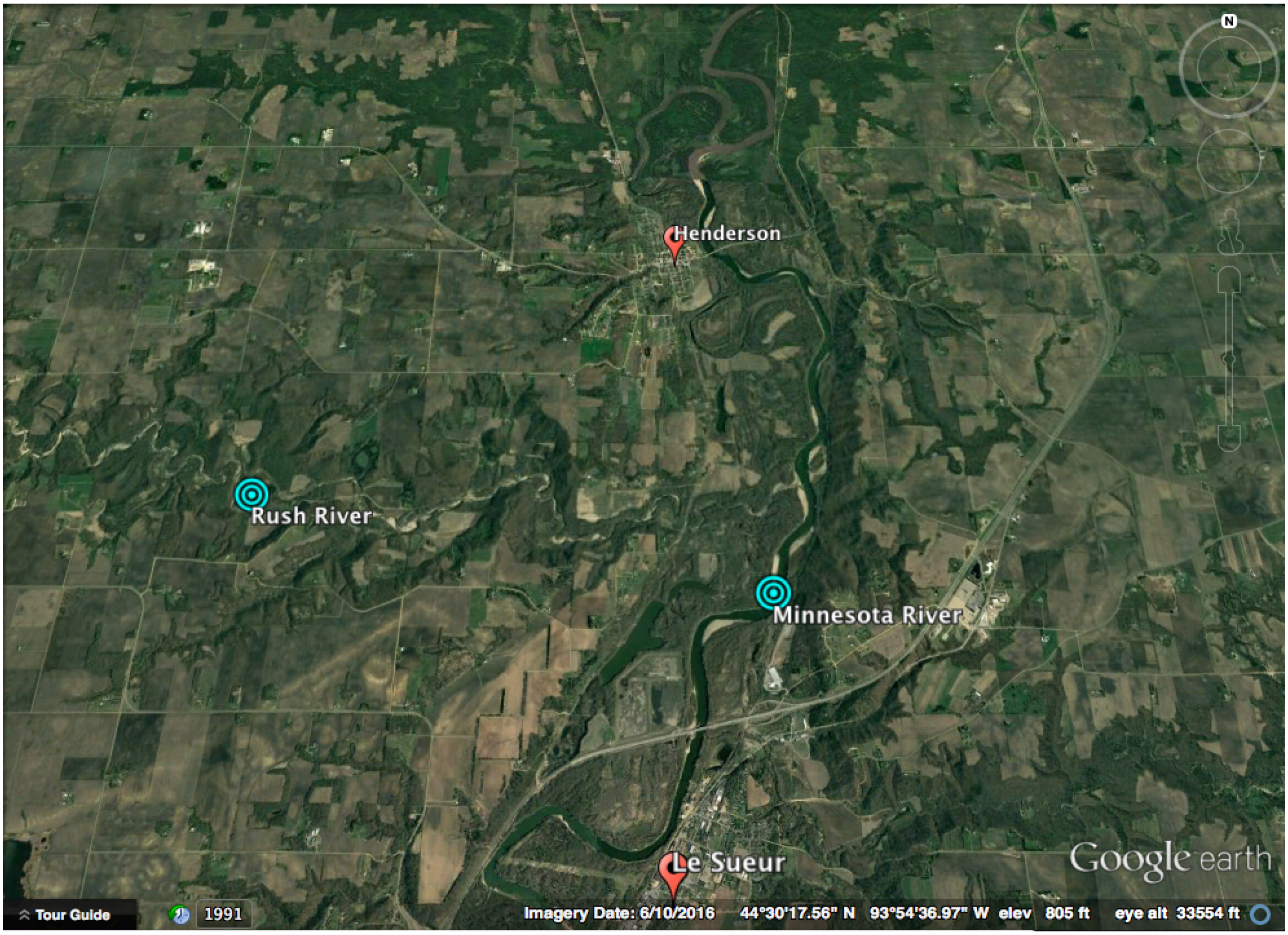

Figure 3. Shows the location of Henderson, MN in relation to Rush River and the Minnesota River

River, Mississippi River, and ultimately into the Gulf of Mexico. Rush River, located in Sibley County about 3 miles south of Henderson, Minnesota, is an analogous system to Seven Mile Creek also leading into the Minnesota River.

The Rush River area has not yet been studied as extensively as Seven Mile Creek. Locating and mapping river terraces at Rush River will open a window into the past and give us knowledge of the evolution of the tributary ravines of the post Minnesota River. River terraces are important landforms because they can provide deposits of aggregate used for construction purposes as well as sand deposits. They can provide information about hydrology for flood management and planning purposes as well as longer-term environmental changes driven by combinations of climate and anthropogenic changes.

In Bock's thesis about Seven Mile Creek, he wrote that we need to add data from other ravines much like Seven Mile Creek(2010). I wish to add to the data collected by mimicking his study at Rush River. Then, the two tributaries can be compared.

Over the course of this study, using methods from previous studies of river terraces, I made various trips to Rush River to locate terraces and confirm their compositions in order to map the various levels of terraces within the Rush River Ravine.

Geologic Setting

When glaciers came through this area of Minnesota for the last time, ending around 10,000 years ago, they left thick deposits of glacial till on top of Paleozoic sedimentary bedrock. The till is spatially heterogeneous, with various stratigraphic layers and units as described by Lusardi et al. (2012). Because the glacial till is so clay rich it is able to hold together much stronger than if it were rich in sand-sized particles. Since it is so clay rich, the Rush River ravine is able to keep its steep valley walls intact. This is important as it also helps keep terraces intact and well preserved. Also located within the Rush River valley are units of quaternary alluvium, quaternary colluvium and alluvial terrace deposits. Alluvium is a sand a gravel unit with silt and clay that have been deposited by the modern Rush River in channels and floodplains. Colluvium is a unit that consists of clay to boulders. This unit is deposited on steep slopes by weathering and gravitational processes (Jennings et al. 2012). The alluvial terrace deposits are comprised of a sand and gravelly sand unit with silt and clay. This unit is well sorted and they form a nearly level surface with some areas of streamlined bars and shallow channels (Jennings et al. 2012). The unit lies above the modern floodplain.

Watershed Characteristics

Since the Glacial River Warren came through this area, Rush River and its tributaries have been slowly incising through the glacial till and underlying rock layers, trying to reach base level. In more recent years in advancements of agriculture and drainage techniques, floodplains and wetlands have been altered or lost their ability to store floodwaters. Because drainage tiling speeds up the process of draining water flushed out into drainage ditches or rivers at a high rate of speed causing increased flooding, erosion and sediment loaded water (Fennessy et al).

Research Methods

The data collected came from a mixture of fieldwork and observations made at outcrops and landforms within the park. Information was gathered in a field notebook and photographs were taken for visualization. Information from the field such as the composition of the terraces as well as gathered from maps from the Minnesota Geologic Survey for Sibley County (Jennings et al. 2012) was used to verify locations of terraces. This information was recorded on a field base map. These maps are contour maps that are derived from Light Detection and Ranging (LiDAR) taken from the Minnesota Geospatial Commons for Sibley County (MNDNR). The map gives details of different elevations; terraces at different elevations can distinguish separate units. Throughout Rush River County Park, terraces were identified and their location was recorded on the base maps. Sand distribution models from the Minnesota Geospatial Commons determined their extent for Sibley County (Lusardi et al. 2012). Once the initial field data was input into ArcMap, additional terrace regions were interpreted based on their similar appearance to known terrace structures in ArcMap as well as using information of different units from the Surficial Geology of Sibley County Map from the Minnesota Geologic Survey (Jennings et al. 2012) From the data collected, maps of terraces along Rush River were made using ArcGIS to visually show the location and what unit each terrace belongs to. Because there is no time scale of the events that happened to create the terraces, they were broken down by location and elevation. Intervals of around 50 ft. were noted for each terrace level. Further studies of Rush

River are required in order to better date the terrace levels. Hypotheses of events that occurred over time are the best dating methods used in this study.

Results

By using a combination of ArcGIS, DEM data, contour elevation maps, the Surficial Geology map from the Minnesota Geological Survey (Jennings et al. 2012), and fieldwork, terraces were located and their extent was mapped. Three terrace levels were identified along the Rush River ravine. The three terrace levels are distinct from each other from elevations of 970-740 ft. above sea level.

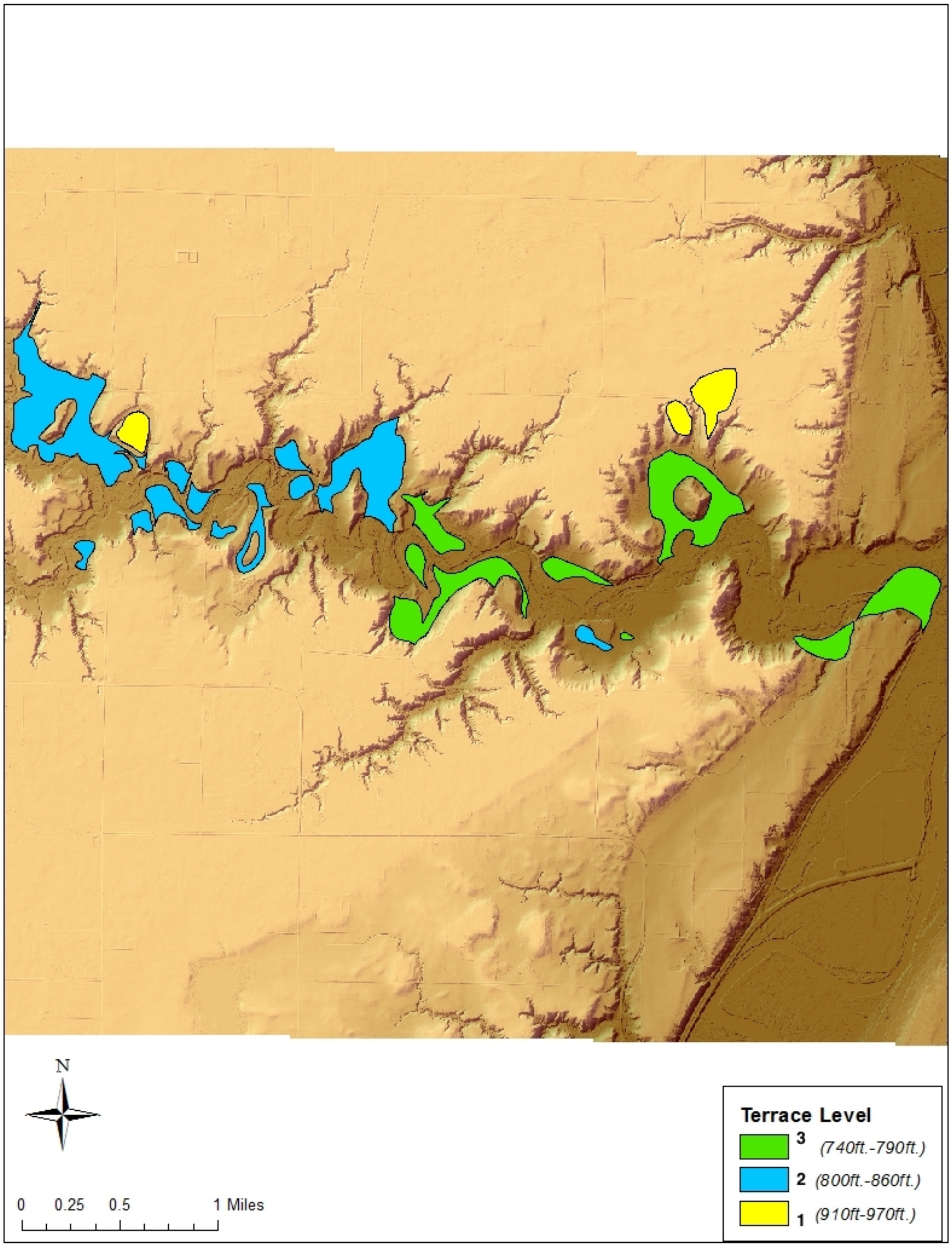

Figure 4. The colored sections are the locations of terraces within the Rush River ravine. Terrace levels are measured in elevation above sea level.

Located within all of the terrace units in the previous page (Figure 4.) are sand and gravelly sand units with silt and clay. These units are well sorted, fining upward. The terrace levels form a nearly level surface with some areas of streamlined bars and shallow channels. There are locations filled with fine-grained sediment, which lie above the modern floodplain.

Terrace Level 1- this terrace level is mapped yellow in color. The elevation at which these terraces are located is 970 ft. in elevation above sea level. This terrace level sits at or near the top of the Rush River ravine

Terrace Level 2- this terrace level is mapped blue in color. The elevation of the surface of the terrace is 860 ft. in elevation above sea level.

Terrace Level 3- this terrace level is mapped green in color. The elevation of the surface terrace is 790 ft. above sea level.

Although we do not have dates of when these terraces were formed, we do have geologic information of what types of materials that water from Rush River has had to carve through for thousands of years. Below is a rough sketch of a Cross Section of Rush River.

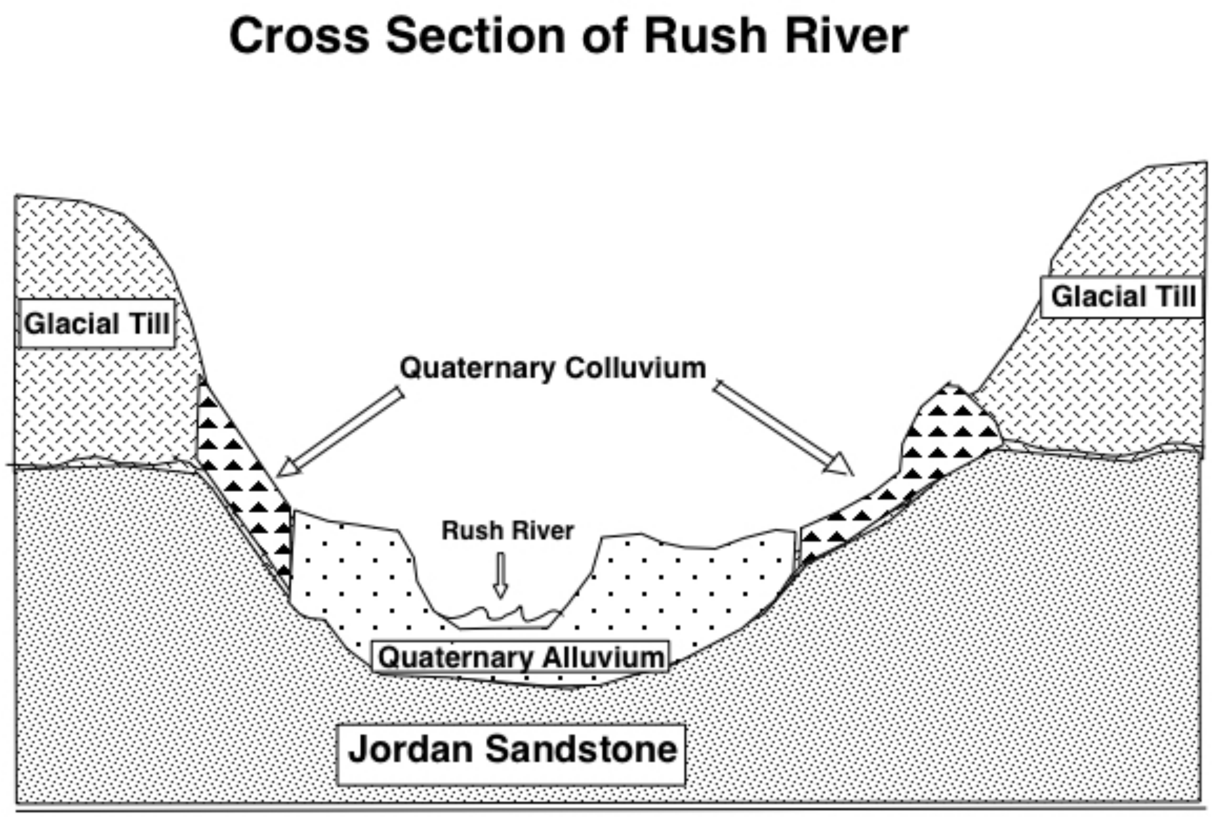

Figure 5. A rough sketch of the cross section of the Rush River Ravine. (Not drawn to scale)

The cross section sketch of Rush River (Figure 5.) gives a general description of the materials that Rush River has eroded or deposited during its ~10,000 year evolution.

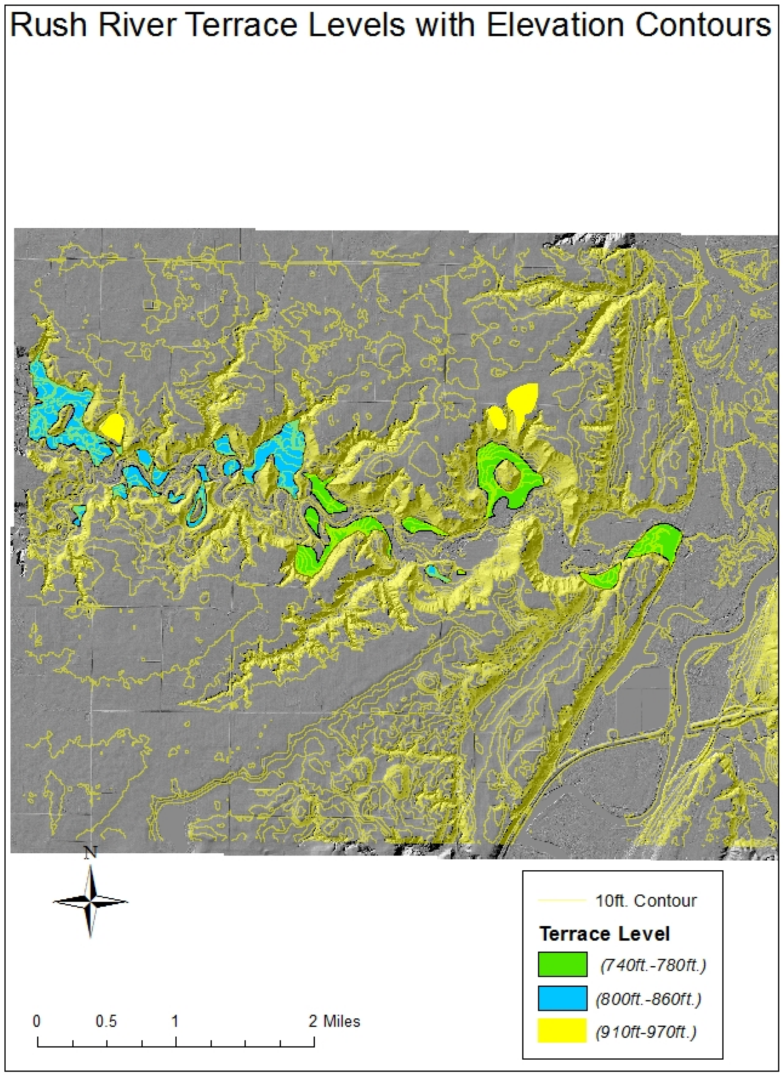

Figure 6. Three distinct terrace levels shown with 10 ft. contour lines. Terrace levels are measured at elevation above sea level in feet.

The elevation contours are shown at 10 ft. intervals (Figure 6). From the top of the oldest terrace levels to the bottom of the youngest terraces levels there is a distance of about 230 feet, within that 230 feet terraces were mapped based on points of equal elevation. Based on these elevation differences between terrace levels, it is possible to begin to interpret previous environments, such as when periods of higher or lower amounts of down cutting and incision were occurring within the area.

Rush River Terrace Levels with Quaternary Alluvium & Colluvium

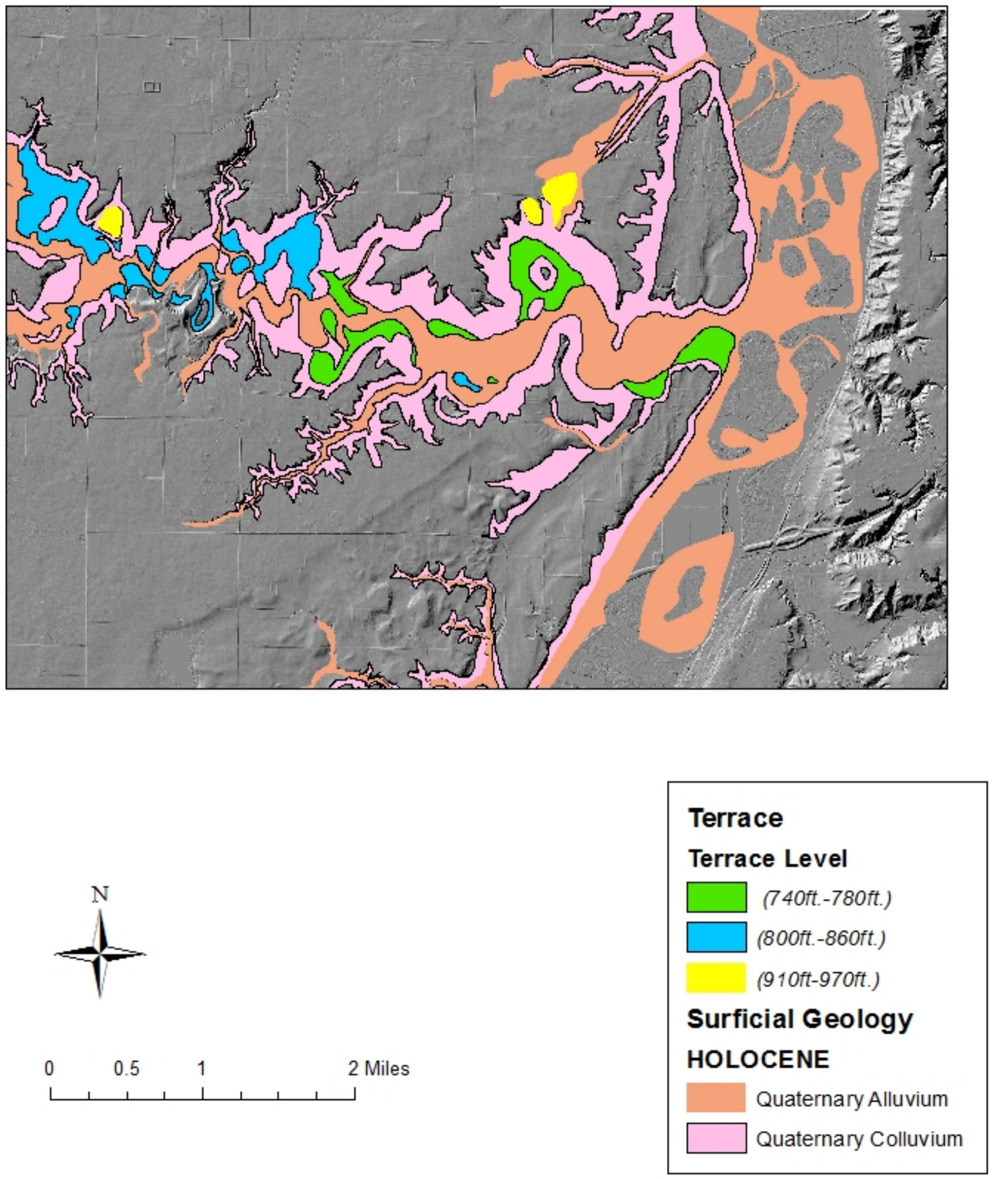

Figure 7. Alluvium and Colluvium mapped with the 3 distinct terrace levels of the Rush River ravine. Showing relation of terrace levels and units of alluvium and colluvium.

Alluvium (Figure 8.) is a unit consisting of sand and gravel with silt and clay. Fine-grained sediments, which are deposited by modern streams in channels and floodplains.

Figure 8. Example of quaternary alluvium deposits in the floodplain of Rush River. Rush River is located on the left in this picture.

Colluvium (Figure 9.) is a unit that consists of clay to boulders. This unit is mostly fine-grained sediment to sand and gravel. Deposited on steep slopes by weathering processes.

Figure 9. Example of quaternary colluvium within the Rush River ravine. There is soil along with other fine grained sediments and larger gravel size particles deposited on a slope of the ravine due to weathering and gravitational processes.

Level surfaces located below 740 ft. and sloping hills with colluvium deposits are not considered terraces in this study (Figure 7.). Although they have similar characteristics of terraces, locations below 740 ft. within the ravine are considered to be within the modern floodplain or have ended up in the area due to weathering processes.

Discussion

The numerous terraces present within the Rush River valley suggest that the stream has gone through many periods of down cutting. When did these periods of down cutting occur and what factors controlled them? One hypothesis of mine is that terrace level 1 is different from the others. This terrace level is interpreted to be the oldest terrace level within the Rush River Ravine. I believe that this terrace level was formed during periods of post-glacial melt, but prior to the Glacial River Warren carving through this area. Because these terrace levels lie above the Rush River ravine, it is possible that there were pre-Glacial River Warren flows of water in this area. During this time, there was little to no vegetation due to the glaciers that had just reshaped the landscape. After the glaciers melted away, they left massive deposits of glacial till. This loose sediment with no vegetation to hold it together would have been easily shaped by fluvial processes. Elevations decrease from the west to the east, which is the same direction, that Rush River drains in to the Minnesota River, leading one to believe that the natural flow of water prior to Rush River being formed is the similar west to east direction. These terrace levels were preserved while Rush River or other erosional processes washed out other terraces within this level during the draining of Glacial Lake Agassiz.

Terrace level 2 reflects a higher base level that existed as the Glacial River Warren was still carving the valley shortly after deglaciation. A terrace height of around 50 ft. is a significant distance. Geologists do not know how long it took Glacial River Warren to carve the entire depth of the Minnesota River Valley. There may have been multiple phases of outburst floods and down cutting with associated pauses between flood events. During those pauses, tributaries like Rush River would have had time to develop floodplains that would later become terraces. Thus, this terrace level may indicate a period, however short, during which Glacial River Warren – and, thus, the local bas level for Rush River – was stable at a higher elevation.

Terrace level 3 was formed in more recent years, sometime after the final draining of Lake Agassiz. This terrace level is interpreted to be the youngest of terrace levels within the ravine. Older terraces were controlled by natural factors but younger terrace development may have been influenced by anthropogenic events. One hypothesis would be with more and more drain tile being placed underground, water draining from these tile reach the river much faster causing higher rates of erosion and flooding. Relative to normal flow of Rush River, there is evidence of large scale flooding events that cover these low areas. This terrace level could tell us more about erosion rates as well as the effects that these practices have been having on our river systems and the amount of water being drained in the area.

Although we do not have ages of these terraces and are thus limited in what we can interpret, we can compare these terraces with those of Seven Mile Creek. Bock also located three terrace levels. And, is similar in both tributary valleys, one terrace level of around 59 feet in Seven Mile Creek is similar to Terrace 2 in the Rush River valley, which is at about 50 feet. Having a correlation in terrace levels in both Seven Mile and in Rush River is strong evidence that there was a period of stability of the Glacial River Warren at this terrace elevation: these two streams had time to develop floodplains at that elevation.

Because the ages of these terrace levels as well as the factors controlling their development are unknown it is difficult to pinpoint the times that these terraces were formed. However, I believe my interpretations correlate with Bock's, physically exploring the area to identify terrace levels was helpful in ensuring accuracy. Further investigation could help determine if human interaction has in fact been affecting terrace development, and a valuable future effort would be to collect dates of the terrace materials to determine if human development affected terrace processes.

Conclusion

By mapping the terrace levels within the Rush River valley a better understanding of the current and historic hydrology of the area has been obtained. The mapping shows evidence of post-glaciation but pre-Glacial River Warren flows where there is alluvial sediment lying above the ravine. There is also evidence of the period where Rush River was trying to reach base level with the Minnesota River during the draining of Glacial Lake Agassiz when the Glacial River Warren carved through the area. Finally, I believe there is evidence of anthroprogenic influence to younger terrace development within the ravine due to higher amounts of water being discharged from drainage tiling.

References

AeroMetric, Inc. LiDAR Elevation, Minnesota River Basin, Southwest Minnesota, 2010 Minnesota Department of Natural Resources (MNDNR)

Bock, Jeremy. "Geology and Geomorphology of Seven Mile Creek Park."Thesis. Gustavus Adolphus College, 2010. *Geology and Geomorphology of Seven Mile Creek Park*. Web.

Fennessy, Siobhan, and Christopher Craft. "Agricultural Conservation Practices Increase Wetland Services in the Glaciated Interior Plains." (n.d.): n. pag. Ecological Society of America. Web. 3 Dec. 2015. <http://www.indiana.edu/~craftlab/publications/09-0269.1.pdf>.

Fisher, T. (2003). Chronology of glacial Lake Agassiz meltwater routed to the Gulf of Mexico. *Quaternary Research, 59*(2), 271-276. doi:10.1016/S0033-5894(03)00011-5

Jennings, Carrie E., Barbara A. Lusardi, and Angela S. Gowan., 2012,"Surficial Geology." *County Atlas of Sibley County, Minnesota*. Vol. C-24. N.p.: The U.S. Geological Survey, n.d. N. pag. Print. Part A.

Johnson, Mark D., Davis, David M., and Pederson, Joel L. Terraces of the Minnesota River Valley and the Character of Glacial River Warren Downcutting. Minnesota Geological Survey. p. 121-130 1998

Lusardi, Barbara A., R. S. Lively, and Angela S. Gowan., 2012, "Sand Distribution Model." *Geologic Atlas of Sibley County, Minnesota*. Vol. C-24. N.p.: The U.S. Geological Survey, n.d. N. pag. Print. Part A.

Matsch, C. L., 1972, Quaternary geology of southwestern Minnesota, in Sims, P.K., and Morey, G. B., eds., Geology of Minnesota: a centennial volume: St. Paul, Minnesota, Minnesota Geological Survey, p. 548-560

Ojakangas, Richard W. and Matsch, Charles L. (1982) *Minnesota's Geology.* ` Minneapolis, MN: University of Minnesota Press

"Upper Mississippi Glacial Landscapes." The Institute for Minnesota Archaeology, 1999. Web.