

# **Post Settlement Alluvium (PSA) in the Rush River Valley**

By  
DEVIKA MOHABIR

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DEVIKA MOHABIR

Under the supervision of Mark Johnson

## **ABSTRACT**

The impact of land use changes following European settlement is evident in the sediments of the Rush River valley floodplain. A layer of well-developed pre-settlement soil is buried by sandy alluvium as much as 2 feet thick. This paper examines the depositional history of post settlement alluvium (PSA) in the Rush River valley floodplain and relates it to land use changes since the time of settlement in the early 1800's. The PSA sediments of the floodplain were measured at a transect consisting of 8 cores. Sediment analysis was done on 4 of the 8 cores. The cause of PSA on the floodplain is difficult to determine due to coinciding changes in both land use and stream character since the time of settlement. The spatial variation of PSA in the Rush River valley is unknown due to the analysis of sediments from only one transect. However, based on previous studies on PSA in the Midwest it can be assumed that PSA distribution in the Rush River valley is influenced by drainage area of the watershed, stream power, and valley width and slope. The extent to which each of these factors play a role can only be determined from a more extensive study of the watershed.

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## **Introduction**

Accelerated soil erosion is a major environmental problem that can have two possible explanations: (1) a change of climate affecting the vegetation cover of an area, or, (2) human interference in the natural ecosystem. Virtually all such erosion today is the result of human interference (Butzer 1974). One way to examine the extent of increased soil erosion is by studying overbank sedimentation and flood plain evolution. A key indicator of accelerated soil erosion in the Midwest is the existence of post settlement alluvium (PSA) on floodplains. In this paper, the major objective of researching PSA is to document the history of floodplain sedimentation in the Rush River Valley in southern Minnesota and to relate the sedimentation history to cultural and natural environmental factors. Although little previous work has been done in Minnesota on PSA, Beach (1994) studied three watersheds in southern Minnesota looking for the existence of PSA. He found that there existed a buried soil indicating a period of stability or equilibrium, and a layer on top indicating either increased erosion of the land, increased discharge in the river, or both. He states that the Rush River floodplain contains deposits of PSA. Anderson (1998) investigated PSA in the Rush River Valley in relation to ditching and mentioned that lighter layers of sand above a darker, organic-rich layer of sediment indicate the presence of PSA. The presence of PSA indicates that there have been changes, and that ditching would contribute to these changes by increasing flood magnitude and frequency (Anderson 1998).

## **Previous Work on PSA**

PSA is a layer of alluvium found on many valley floodplain surfaces in the upper Midwest and is associated with overbank flooding due to land use changes following European settlement in the early 1800's. Beach, Knox, and Lecce, have done the most extensive studies of PSA in the Midwest and all have related it to land use changes following settlement. PSA is typically described as a layer of lighter colored sand. In many cases there is a distinctly darker, richly organic pre-settlement soil (PSS) horizon underlying the PSA. In many Minnesota valleys, the overlying sediment is frequently interspersed with anthropogenic materials (Beach 1990). PSA has been investigated in a number of areas in the Midwest. Ruhe and Daniels (1965) conducted a study of side valleys in Iowa. A side valley is a short, theater-like depression that descends between ribbed interfluvies from a summit to a trough valley (Ruhe and Daniels 1965). The side valleys studied were incised in Kansian glacial till, which is mantled by Wisconsin loess. Ruhe and Daniels (1985) found that the alluvium near the axis of a certain side valley in Adair County had two distinct layers. The upper 22 inches was lighter colored and bedded and contained 14 percent sand and 1.8 percent organic carbon. They refer to this layer as post settlement in age. They also describe the top of a sub-adjacent layer, which exists to a depth of 4 feet. This layer is darker colored, 2 % sand, and contains 2.5 to 3% organic carbon. They refer to this soil as the A horizon buried by the post settlement deposits. Below the A horizon is another buried soil layer which is highly organic, and exists to a depth of 12.5 feet. Similar lithologies indicate the loess on the bounding side and head slopes was the sediment source for the buried soil. Higher sand content in the post settlement deposits indicates this sediment derived in part from the till slopes. Ruhe

and Daniels (1985) found the average thickness of the post settlement deposits to be 6 inches. In this side valley, the rates of valley filling and slope erosion have been three to ten times greater, respectively, in post-settlement times than in pre-settlement time (Ruhe and Daniels, 1965).

Knox (1972, 1987) researched valley alluviation in southern Wisconsin and historical valley floor sedimentation in the upper Mississippi Valley. In southern Wisconsin, a basal unit of coarse-textured debris in valley alluvium is thought to represent bed load sediments of a prior channel active near the end of the mid-Holocene about 6000 years B.P. A silty clay series over the coarse layer is interpreted to have been derived by vertical accretion on the paleo-floodplain during a climatic shift toward more humid climate conditions during the late Holocene. Distinctly laminated silt loam sediments produced by vertical accretion extended from the middle series to the current surface, and mainly result from increased flooding related to modern land use practices (Knox 1972). Knox (1972) demonstrates that the lower and intermediate series are products of channel and floodplain responses to Holocene climatic fluctuations, whereas the upper series is primarily the consequence of deforestation and cultivation practices since 1830 (Figure 1).



Figure 1. Bank and bed sediment in a high-energy tributary near Dickeyville, Wisconsin. The fine textured light colored sediment at the top is PSA (Knox, 1987).



Valley floor sedimentation in the upper Mississippi valley is similar to that in southern Wisconsin. Here, overbank sedimentation rates rose rapidly in both tributary and main valley floodplains in the late nineteenth century in response to poor agriculture land management (Knox 1987). The effects of accelerated sedimentation are most clearly revealed in the region's floodplains where eroding channel banks expose relatively thick accumulations of sediments that were deposited by historical overbank flooding. Knox (1987) describes pre-settlement soils as being very organic-rich. These soils range from very dark brown to grayish brown in color. In most localities with good drainage, a black to very dark brown mollisol with an A horizon that is often 10-30 cm thick occurs at the top of the underlying sediment, indicating that pre-settlement overbank vertical accretion was very slow. Prominent characteristics of the historical sediments, or post settlement sediments, relate to sedimentology. The historical

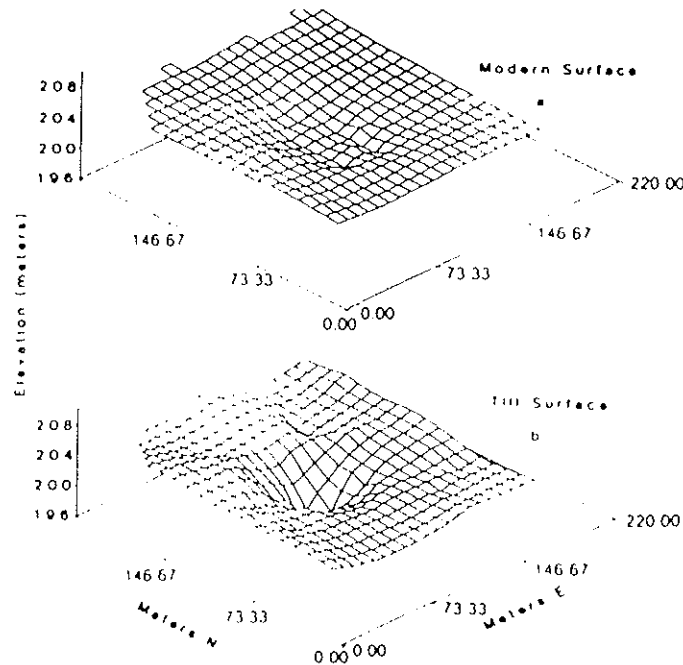
sediments usually appear yellowish brown (10YR 5/4) to dark brown (10YR 3/2) and display prominent stratified bedding whereas pre-settlement overbank sediment usually appears massive because there was sufficient time for bioturbation to destroy former bedding structures (Knox 1987). Bedding structures are also more prominent in historical sediments because they typically contain higher percentages of sand and silt and lower percentages of clay than do pre-settlement overbank sediments. Since settlement, the deposition of overbank sediments have resulted in an overall flattening of the valley floor. Knox (1987) also found that the mean depth of historical sediments tends to increase gradually in the down-slope direction for most valleys. The thickness of PSA typically ranges between 30 to 50 cm in tributaries draining less than 50 km<sup>2</sup> and between 50 and 80 cm in main valleys draining more than 50 km<sup>2</sup>.

Norton (1985), studied erosion and sedimentation in a closed drainage basin in northwest Indiana in order to determine the amount of erosion that has occurred since cultivation of the land began, and to determine the spatial relationship of the erosion-sedimentation process that has occurred during 145 years of agriculture. Detailed studies of the sediment provides insight into the erosion and sedimentation processes that have taken place (Norton 1985). Norton (1985) found that many of the cultivated basins that are completely closed contain organic soils buried by light-colored, silty, inorganic sediments deposited after cultivation began. He refers to these inorganic sediments as post settlement alluvium (PSA).

In his detailed field study of PSA along with other geologic sediments and the original till surface, Norton (1985) demonstrated that there had been a reduction in the original relief of the watershed. The reduction in relief was due to a combination of

filling in with PSA and removal of soil from surrounding slopes. The amount of PSA deposited over the organic soil can be attributed to erosion of the mineral soils on the peripheral slopes (Norton 1985). This overall smoothing of the topography can be seen in a comparison of the present day landscape to the original till surface (Figure 2), and is similar to the flattening of the valley floor described by Knox (1987).

**Figure 2. Diagram comparing (a) the modern soil surface and (b) the original till surface (Norton, 1985).**



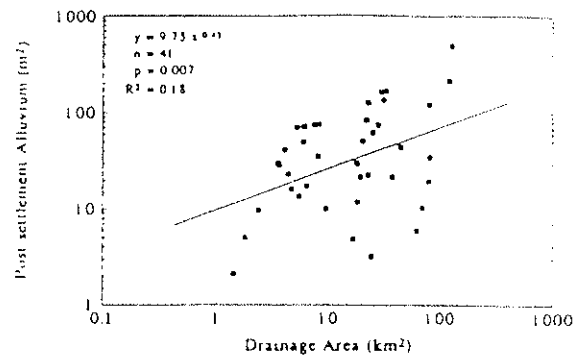
Beach (1990) studied the utility of soil surveys to assess the investigation of floodplain storage in southern Minnesota. Data about accelerated sedimentation collected from field cores was compared with information derived from three county soil surveys in southeastern Minnesota. Soil Conservation Service county soil surveys are the most widely distributed information sources for studying soil and sediment storage in drainage basins. These surveys, if reliable, could aid research on accelerated erosion and sediment storage, and thus help elucidate regional denudation rates, drainage basin

response to land use, rates of soil development, and, indirectly, sediment pollution of water. Information on soil erosion is particularly important because soil erosion is a major source for water pollution (Beach 1990). Two attributes described in many soil surveys of the upper Mississippi valley are erosion class and depth to buried soils. As interpreted by Beach (1990), the buried soils are thought to represent the pre-settlement floodplain surface. The range of depths to these buried soils therefore indicates the range in thickness of accumulated historical alluvium. Information derived from soil surveys along with measurements from field transects and surveys showed that buried soils commonly have mollic epipedons. They have A horizons that are very dark, silt loam, loam, or sandy loam, and have granular structures. Based on soil combustion in a carbon analyzer, these buried soils contain at least 5% organic carbon in their upper A horizons. The overlying sediments, however, are lighter in color, silt loam to sand in texture, horizontally laminated, and have lower amounts of organic matter (usually less than 2%) (Beach 1990).

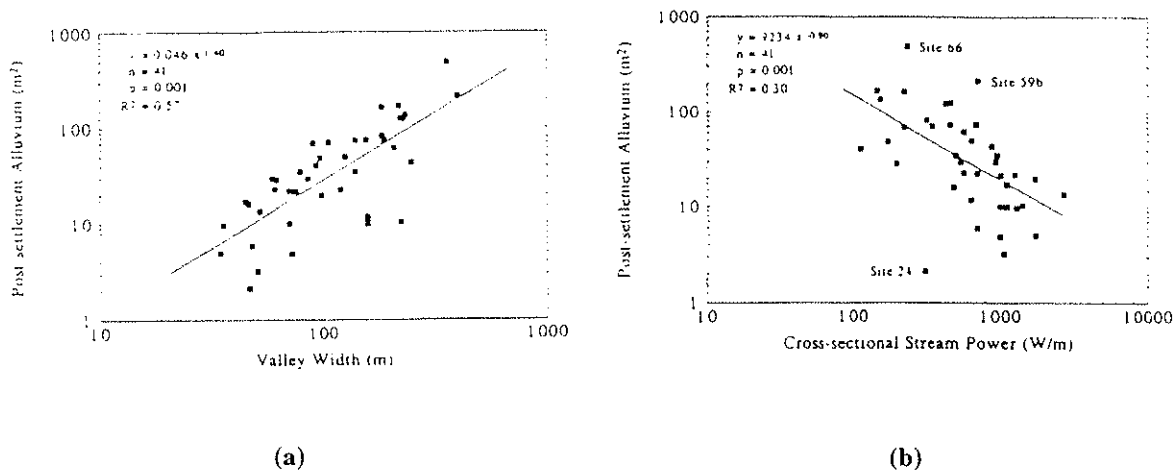
Lecce (1997) studied processes influencing spatial variations in the storage of post settlement vertical accretion alluvium and the impact of floodplain evolution in the Blue River watershed, Wisconsin. Lecce (1997) provides a further examination of the effects of land use changes following European settlement. Although human impacts on hydrology and accelerated soil erosion and sedimentation have been documented, the patterns of sediment storage have not been. Eroded soils from uplands only travel a short distance before they are deposited and stored (Lecce 1997). It has been thought that these patterns of sedimentation are influenced by valley width, downstream changes in stream power, and the development of meander belts (Magilligan, 1985, 1992a), (Graf, 1983),

(Knox, 1987a), and (Lecce, 1997). To better understand historical floodplain sedimentation, Lecce (1997) looked at valley bottoms along 41 cross-valley transects and calculated PSA thickness. He found that the pre-settlement soil was easily identified by its dark brown to black color and high amount of organic matter. The overlying sediments were typically much lighter in color (yellowish-brown) and well laminated. After careful examination of the cross-sectional transects, it was found that the PSA increased downstream with the drainage area (Lecce 1997). Although, due to the weak relationship of the two as seen in Figure 3, influences of valley width and cross-sectional stream power were examined ( Figure 4).

**Figure 3. Relationship between the cross-sectional area of post settlement alluvial storage and drainage area (Lecce, 1997).**



**Figure 4. Relationship of cross sectional area of post settlement alluvium with (a) valley width and (b) cross sectional stream power (Lecce, 1997).**



Magilligan (1992) found that valley width influences floodplain storage indirectly through its control of flood power while Graf (1983, 1990) found that sediment transport and deposition is controlled by down stream changes in cross-sectional stream power. Lecce (1997) found that valley width and cross-sectional stream power explain 57% and 30%, respectively, of the variance of PSA in the Blue River watershed. Not only are valley width and cross-sectional stream power important factors in floodplain sedimentation but the development of meander belts is also influential.

In his study, Lecce (1997) found that lateral migration produces an enlarged channel, or meander belt, that is capable of containing floods much greater than the bankfull discharge. The increase in channel capacity associated with the development of meander belts promotes the transport of sediment to channels that lack meander belts. These downstream channels have low channel capacities and low values for stream power and thus have little capacity to contain flood flows and insufficient energy to

enlarge the channel. These qualities allow for significant historical overbank sedimentation (Lecce 1997).

Anderson (1998) investigated PSA in three heavily ditched watersheds in southern Minnesota. Rush River, High Island Creek, and Buffalo Creek were chosen based on the respectively decreasing areas of their watersheds. All three watersheds lie mostly within Sibley County, Minnesota and are significantly ditched systems. Open ditches extend the original natural river systems and underground tiling extends the system even further. The effects of ditching on the rivers creates a concern involving both river discharge and added pollution (Anderson 1998). Several approaches were taken to look for changes in the stream systems, one being the study of PSA in the floodplain. Lighter layers of sand above a darker, organic-rich layer of sediment was found and interpreted to be PSA. Land clearing, vegetation changes, and ditching, however, occurred in a similar time frame. Therefore, the amount of PSA associated with increased discharge alone could not be measured (Anderson 1998). The three streams in the system were measured and found to be third order streams prior to ditching. After ditching, Buffalo Creek remained a third order stream while High Island Creek became a fourth order stream and Rush River a sixth order stream. Overall, the stream systems investigated were greatly changed by ditching. The total length of each stream increased between 300% and 400%, the overall slope greatly decreased, and the order of two streams decreased. Increased magnitude of flooding due to ditching predicted by empirical equation was 6 to 13 times the original natural flow (Anderson 1998). These changes caused by ditches are indicated by the presence of PSA.

## **Study Area**

The Rush River is a tributary of the Minnesota River that flows north from Mankato to Minneapolis/St. Paul (Figure 5). The river lies within Sibley County, Minnesota and has a watershed area of 383 square miles (Anderson, 1998). The river is located in an area that has been extensively ditched (Anderson, 1998) as well as farmed since European settlement. Prior to European settlement in the early 1800's, this area was covered with vegetation and unaltered by agricultural practices (Marschner, 1930). Changes in land use practices have altered the landscape there by increasing sedimentation on the valley floor. This area was chosen for study because increased sedimentation often coincides with the existence of PSA.

## **Field Methods**

In order to characterize the sediments of the valley floor and determine the presence of PSA, a transect was taken across the valley bottom in the Rush River Wayside, T. 112.N. R. 26.W (Figure 6). With a bucket auger, 8 cores were taken at intervals of 42 feet, starting from the edge of the flood plain and continuing along towards the edge of the river. Initially, layers in each core were separated in terms of color (using the Munsell color chart) and texture.



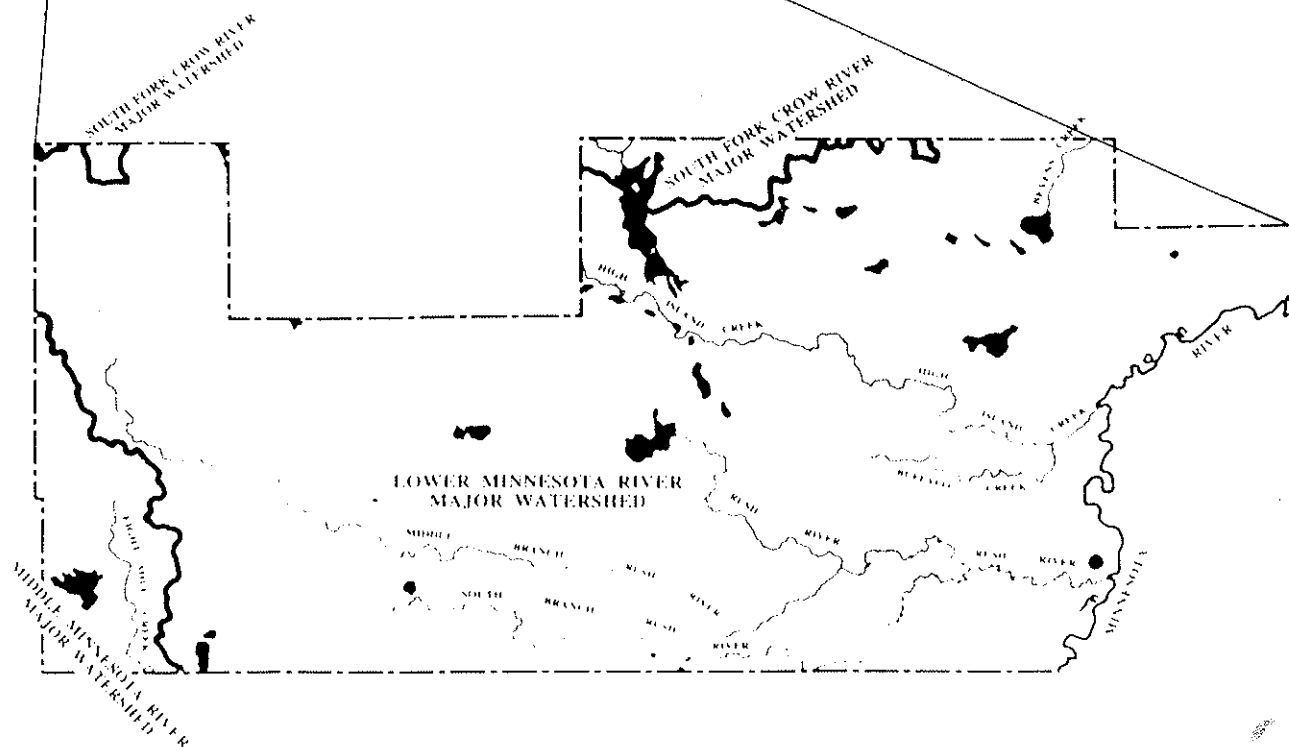
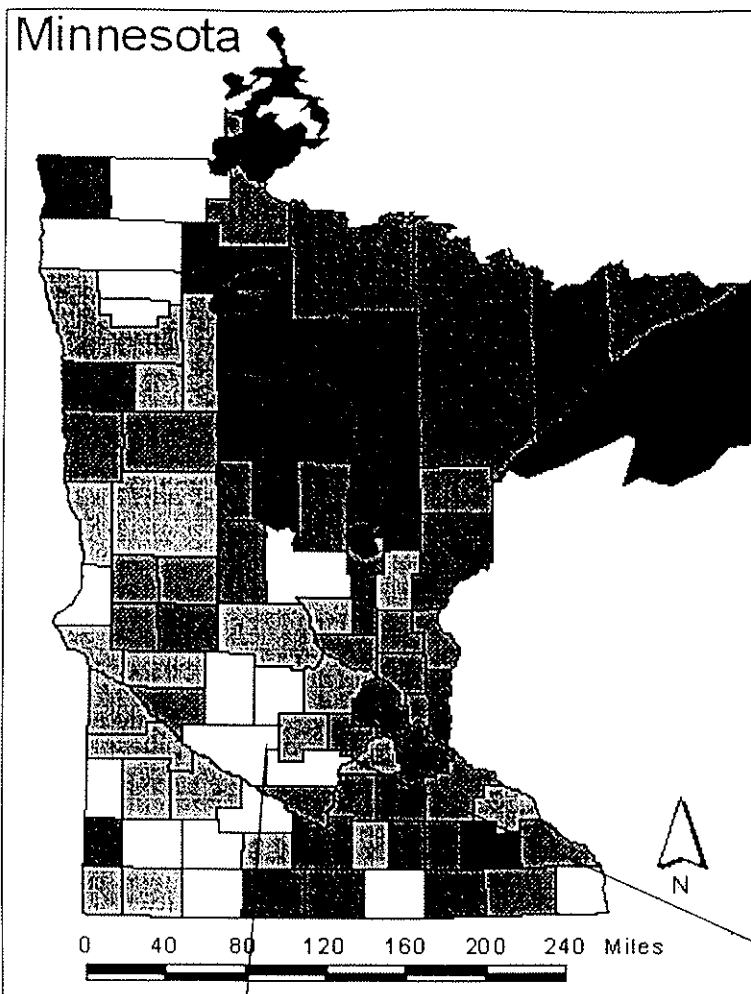
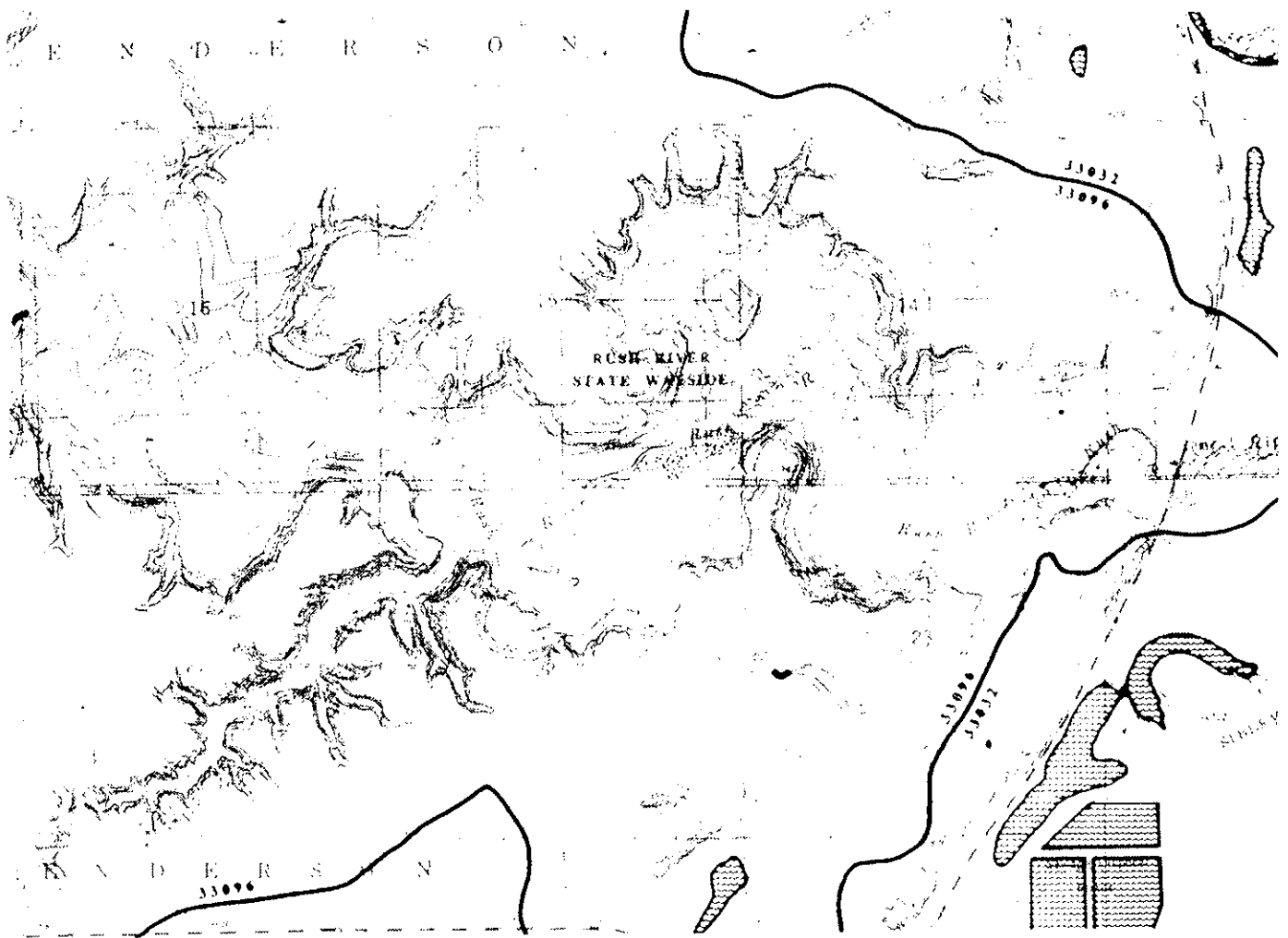
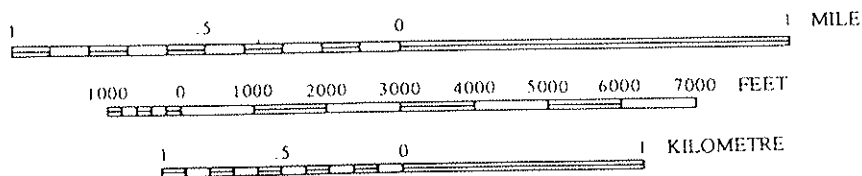


Figure 5. Sibley County, MN. The Rush River is located in Henderson, MN (indicated by the dot). The Rush River is a tributary of the Minnesota River.

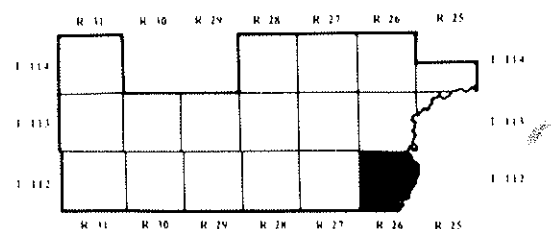
Figure 6. Topographic map of the Rush River State Wayside and a location map of the area (Surface Water Hydrology Atlas, Sibley County, 1993).



SCALE 1:32,000



LOCATION DIAGRAM



After careful examination of the samples from all 8 cores, correlations between adjacent cores were made and from there a rough cross-section of the valley floor was created to help get an idea of the general pattern of sediments below.

Although color and texture are important in the correlation of sediments, further methods were needed to determine if PSA existed along the floodplain. PSA is most often described as being sediment in a floodplain that has a relatively low percent of organic matter and a higher percent of sand than silt or clay. In order to construct a more accurate cross section of the area, the samples were more thoroughly analyzed in the lab.

## **Lab Methods**

Four out of the eight cores were analyzed in terms of organic matter and percent sand, silt, and clay.

### **Organic matter Analysis**

The determination of organic matter was by loss of ignition (Dean 1974, Smith and Atkinson, 1975). The concentration of organic matter in a sediment layer can be used in the determination between PSA and pre-settlement sediments or the "buried soil". In general, floodplain surfaces that are characterized by slow rates of sedimentation tend to accumulate organic matter in an incipient A soil horizon, whereas floodplain surfaces experiencing rapid alluviation normally accumulate relatively small amounts of organic matter in the profile (Knox, 1987). The procedure involves placing a pre-weighed crucible containing 5g of soil into a convection oven for 12 hours at 105<sup>0</sup> C to remove excess water. Once dry and cooled to room temperature, the sample and crucible are weighed. The crucible and sample are then placed in a muffle furnace at 395<sup>0</sup> C for 12 hours to burn off any organic matter. The sample and crucible are cooled

in the convection oven and then to room temperature and re-weighed to determine the loss of organic matter.

### **Percent Sand, Silt, and Clay**

The determination of the percent of sand, silt, and clay in the samples was by pipette analysis (Folk, 1974). For each of the 4 cores tested, a 30-70 g sample from each layer was placed in a beaker with 125 ml of dispersant and let sit for 24-48 hours. The sample was then wet sieved into a 1000ml cylinder. Sand that remained on the sieve was transferred back into the beaker and dried in a convection oven. After the sand had dried, it was dry sieved at one-phi intervals and weighed, placing the fraction remaining in the bottom sieve into the cylinder. The temperature of the water was taken to determine the A value and withdrawal times were computed. After all withdrawals had been taken, the samples were dried and weighed in order to compute the percent sand, silt, and clay in the cores. After completion of the textural analysis, variations of the sand, silt, and clay were plotted, (Figure 7 and Figure 8) and used to construct the final cross section of the channel.

Figure 7. Percent sand, silt, and clay along with percent organic matter in (a) core 2 and (b) core 3.

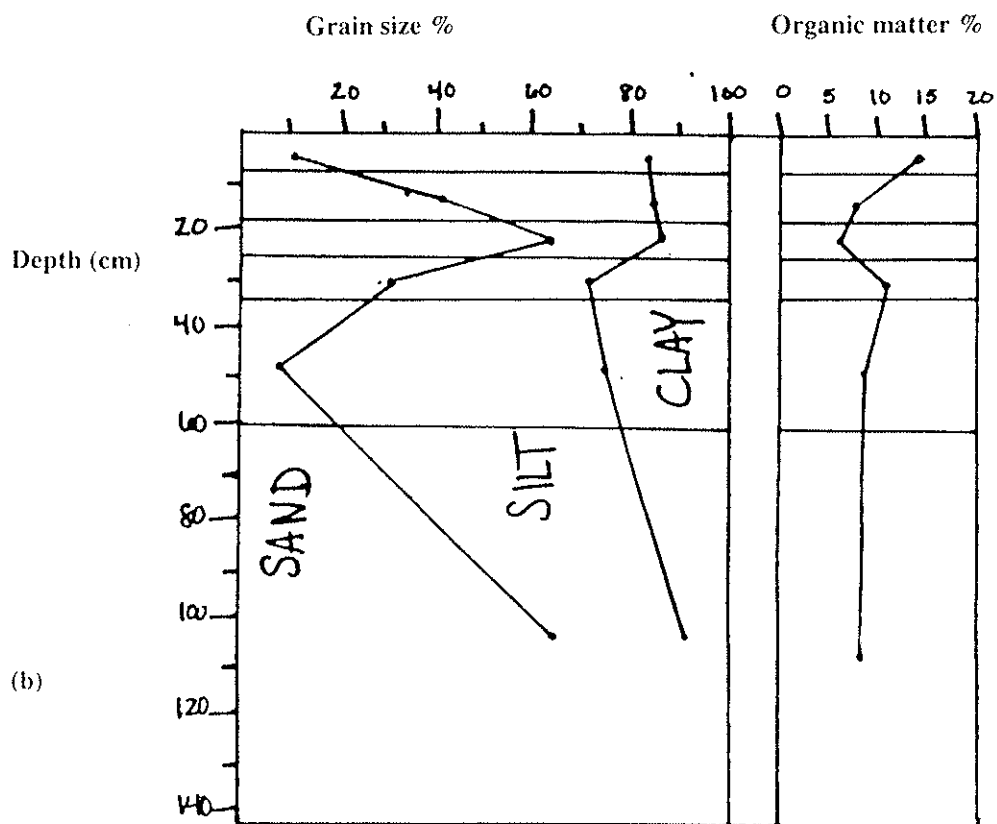
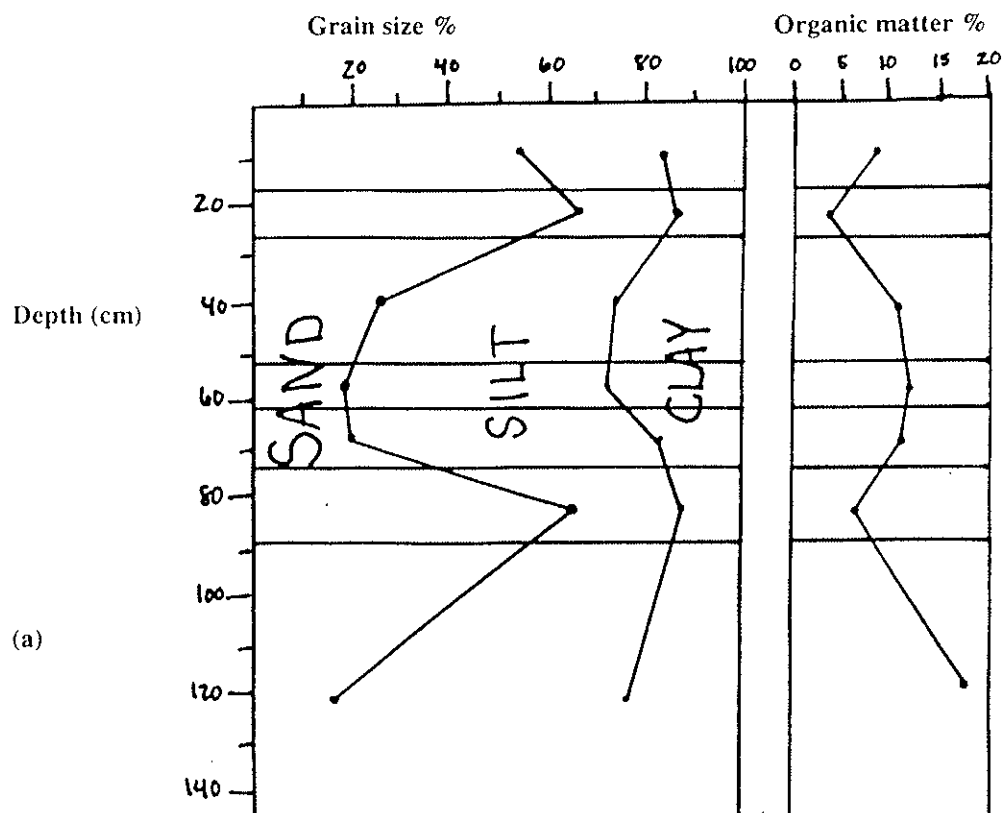
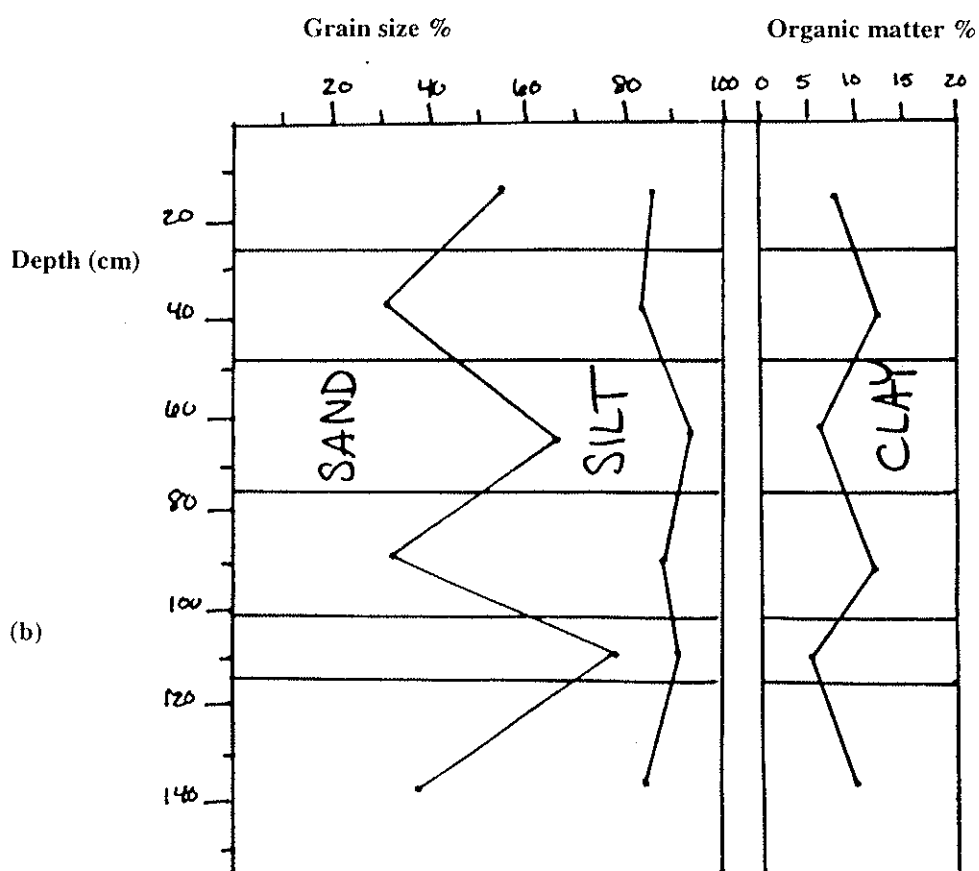
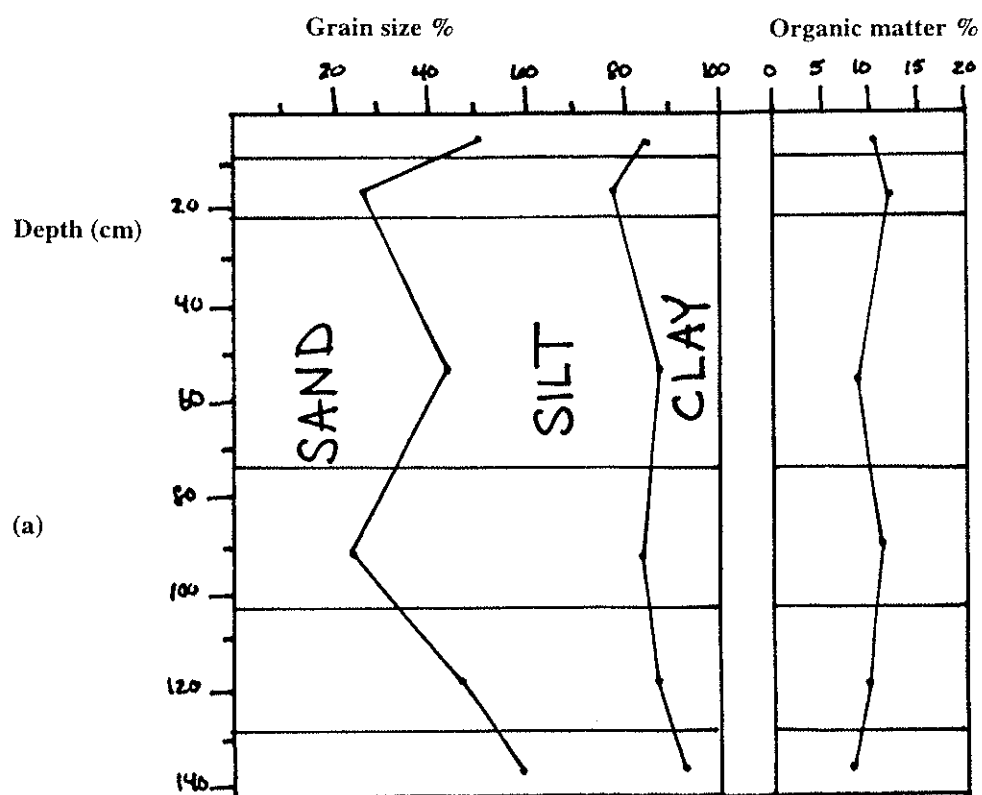


Figure 8. Percent sand, silt, and clay along with percent organic matter in (a) core 4 and (b) core 5.



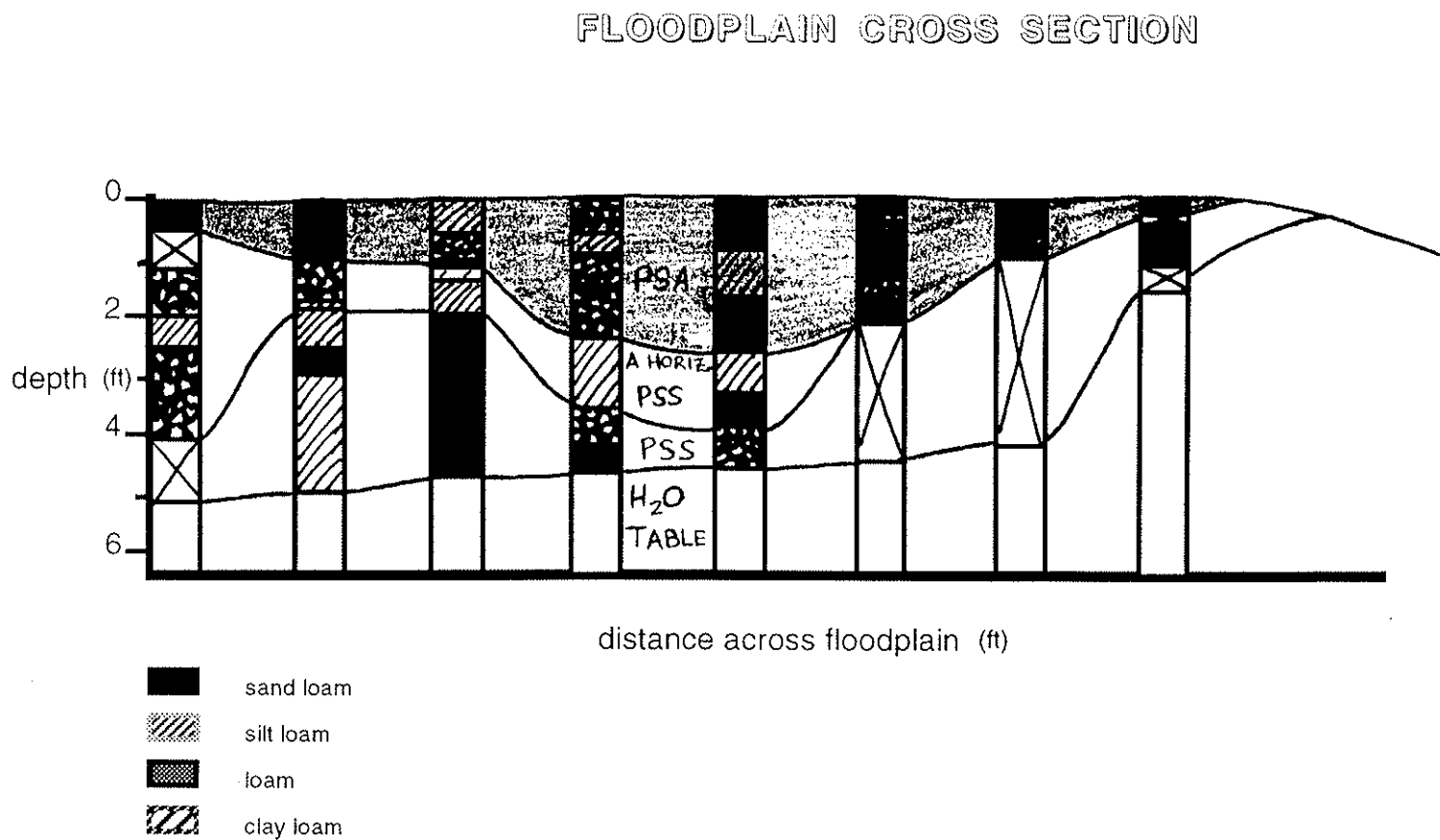
## Results

The variations in particle size and texture of the sediments are indicative of changes in stream character since the time of settlement (Knox, 1987). A change in stream character is related to its capability to transport sediments, which is directly related to sedimentation rates on the floodplain.

The sediments across the flood plain of the Rush River represent a distinction between pre-settlement and post settlement sedimentation rates. Of the 4 cores analyzed, the sediments ranged from sand and silt loam to loam layers with greater than 30% sand and less than 10% organic matter to sediments of clay loam, silt loam, and sand loam with less than 30% sand and greater than 10% organic matter (Figure 7 and Figure 8). The layers with higher percentages of sand and less organic matter are interpreted to be PSA and the underlying layers with lower percentages of sand and more organic matter are the buried or pre-settlement soils. The boundary between the two is illustrated in the floodplain cross section (Figure 9). The top layer is PSA and the underlying 2 layers are the buried soil and its A horizon.

Higher sand percentages in the PSA indicate that the stream has been disrupted or changed in such a way that its equilibrium has changed, therefore altering the sediment load. Knox (1987) states that large floods, typified by high magnitude turbulent stream flows, are required to transport sand-textured sediments from the channel to an overbank depositional position. While PSA is deposited by an increase of flooding onto the floodplain, the buried soil represents a time when there were not as many floods and the floods that did occur were of a much lesser frequency.

Figure 9. Cross section of Rush River valley floodplain showing PSA and buried soil with A horizon. The shaded region is PSA. The X areas indicate the layers of sediment from the cores that were not analyzed and were not correlated to other sediments in the transect that had been analyzed.





The buried soil across the floodplain is recognized by its silt loam to clay loam texture with very low sand percentages. It contains greater than 10% organic matter, due to a slow overbank sedimentation rate, and ranges in color from black to olive black.

### **Sediment Distribution**

PSA across the floodplain ranges from 1-2.5ft in depth and thickens towards the center of the floodplain between cores 3 and 6 which is approximately between 92 and 230 ft into the transect. The buried soil ranges from 1 to 5 ft with a 1-3ft A horizon. The buried soil thins towards the stream and disappears near the 6<sup>th</sup> core (about 100 ft from the stream). The sediments beneath the A horizon and down to the water table range from a sand loam to loam and contain greater than 30% sand and greater than 10% organic matter. This possibly indicates an area that contained an old channel bed which, after the stream had migrated, was allowed to collect organic material while retaining its high sand content. The average thickness of PSA in the floodplain is 1.5 ft (.46 m). With a floodplain width of 1000 ft (305 m), the cross-sectional area of PSA storage is 1500 ft<sup>2</sup> (457 m<sup>2</sup>).

### **Discussion**

Although PSA is found in the Rush River Valley floodplain, it cannot be determined from this study the exact cause of deposition. It can be said, however, that PSA deposition is probably the result of an increase in flood frequency and magnitude due to a combination of land use changes and changes in channel characteristics since the time of settlement. Lecce (1997) found drainage area, valley width, stream power, and the development of meander belts to be influential in the storage of PSA because all three

are related to flood frequency and magnitude. For valley widths close to 300 m, Lecce (1997) found that the cross-sectional area of PSA storage was on average between 100 and 500 m<sup>2</sup>. In the Rush River floodplain, with a valley width of 305 m, the cross-sectional PSA storage was 457 m<sup>2</sup>. The drainage area of the Rush River is 980 km<sup>2</sup>. When plotted against the cross-sectional area of PSA, the results are again similar to those found by Lecce (1997). Because their land areas are so different, the strong similarities in PSA storage in relation to valley width and drainage area between the Rush River and the Blue River are very interesting.

The Blue River watershed has a local relief ranging between 30 and 120 m and is not a ditched area. The Rush River watershed, however, has a local relief of approximately 70 m and is a heavily ditched area. Although Anderson (1998) found the construction of artificial drainage ditches to drastically influence channel characteristics and increase in the maximum peak flow and mean annual flood in the Rush River valley watershed, the extent to which ditches have influenced PSA storage is still questionable.

From the study in this paper, it can be said that it is both naturally occurring changes in the channel and changes in land use that have influenced the deposition and storage of PSA on the Rush River valley floodplain.

## **Conclusion**

The amount of post settlement alluvium found in the Rush River Valley floodplain is interpreted to reflect changes in stream character related to post-European settlement land use practices such as increased farming and the creation of drainage ditches. These changes include an increase in flood frequency and magnitude which both lead to high rates of deposition of channel sediments onto the floodplain. The upper layer

of sediments deposited on the floodplain were analyzed and found to be high in sand content and low in organic matter content, indicating rapid sedimentation rates of sediments from within the channel bed. This layer is post settlement alluvium (PSA). Beneath the PSA is a buried soil. It is a rich organic layer containing less than 30% sand and represents a time of slower sedimentation. This layer represents pre-settlement time in which there was less land use and also less flooding.

A change in land use practices throughout the last century has undoubtedly had an impact on sediments. However, the extent to which each is responsible varies from area to area and is sometime difficult to differentiate from natural processes that occur. A more detailed study in the area would need to be done in order to better understand and distinguish the events that created the floodplain sediments of today.

### **Suggestions for Further Research**

This study solely dealt with one small area of the floodplain to look for the existence of PSA. PSA was found and could be correlated to changes in the stream character, however, a clear idea of the spatial relationship of the PSA could not be interpreted from such a small amount of data. To fully understand the distribution of PSA over the floodplain and therefore the possible history of the Rush River valley, transects would need to be taken at various localities across the watershed and analyzed in the same manner that has been done for this single transect.

## References

- Anderson, K. 1998. Changes of hydrologic geometry in streams due to ditching. Senior research thesis, Department of geology, Gustavus Adolphus College, St. Peter, Minnesota.
- Beach, T. 1990. The utility of soil surveys to assess floodplain sediment storage in southeastern Minnesota. *Annals of the Association of American Geographers*. 42: 170-181.
- 1994. The fate of eroded soil: sediment sinks and sediment budgets of agrarian landscapes in southern Minnesota. *Annals of the Association of American Geographers*. 84: 5-28.
- Butzer, K.W. 1974. Accelerated Soil Erosion: A problem of man-land relationships. In *Perspectives on Environment*, ed. I. R. Manners and M. Mikesell, pp.57-75. Association of American Geographers, Commission on College Geography Publication No. 13. Washington D.C.: AAG.
- Dean, W. E. 1974. Determination of Carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: Comparison with other methods. *Journal of Sedimentary Petrology*. 44: 242-248.
- Folk, R. L. 1974. Pipette analysis of silt and clay. In: *Petrology of sedimentary rocks*, The University of Texas, Geology 370K, 383L, 383M. Hemphill Publishing Co., Austin, Texas, pp. 37-43.
- Graf, W.L. 1983. Downstream changes in stream power in the Henry Mountains, Utah. *Annals of the Association of American Geographers*, 73: 373-378.
- 1990. Fluvial dynamics of Thorium-230 in the Church Rock event, Peurco River, New Mexico. *Annals of the Association of American Geographers*. 80: 327-342.
- Knox, J.C. 1972. Valley alluviation in southwestern Wisconsin. *Annals of the Association of American Geographers*. 62: 401-410
- 1987. Historical valley floor sedimentation in the upper Mississippi valley. *Annals of the Association of American Geographers*. 77: 224-244.
- Lecce, S.A. 1997. Spatial patterns of historical overbank sedimentation and floodplain evolution, Blue River, Wisconsin. *Geomorphology*, 18: 265-277.
- Magilligan, F. J. 1985. Historical floodplain sedimentation in the Galena River basin, Wisconsin and Illinois. *Annals of the Association of American Geographers*. 75: 583-594.
- 1992. Threshold and the spatial variability of flood power during extreme floods. In: J.D. Phillips and W. H. Renwick (Editors), *Geomorphic systems*. Elsevier, Amsterdam, pp. 373-390.
- Marschner, F., 1930, Original vegetation of Minnesota: North Central Forest Experiment Station, Forest Service, U.S. Department of Agriculture, 1: 5000,000.
- Norton, L.D. 1986. Erosion-sedimentation in a closed drainage basin in northwest Indiana. *Soil Science Society of America Journal*. 50: 209-213.

Rongstad, Berg, and Quade, 1993, Surface water hydrology atlas, Sibley County, Minnesota: Water Resources Center, Mankato State University, 1: 32,000.

Ruhe, R. V., and R.B. Daniels. 1965. Landscape erosion - geologic and historic. *Journal of Soil and Water Conservation*. 20: 52-57.

Smith, R. T., and Atkinson, K. 1975. Techniques in pedology. London: Uwin Bros. The Gresham Press.