LEADING THE JAMES: THE MORPHOLOGICAL CHANGES
OF THE MISSOURI RIVER AND THE
SUBSERVIENT JAMES RIVER

by:

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Presented to the Faculty of the Graduate School of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE IN GEOLOGY

THE UNIVERSITY OF TEXAS AT ARLINGTON

December 2010

ACKNOWLEDGMENTS

I would like to thank Dr. John Holbrook for not only encouraging me to pursue an M.S. in Geology, but also providing me with invaluable field opportunities and mentoring me throughout my time at UTA. Also to Dr. John Wickham and Dr. Harold Rowe for offering their time and support while serving on my master's committee. I would also like to thank the UTA Geology Department faculty and fellow students for their support, encouragement, and comradery. Special thanks should be given to all who offered time and insight with regards to my thesis: Tim Cowman for assisting with the cost of my field work, purchase of hand augers, and providing historical maps through the Missouri River Institute, Dr. Mark Sweeney for assisting with additional information on the James River, Eli Erickson for his hard work in the field. I would also like to thank Ronald Goble for processing my OSL samples and offering professional insight to the OSL procedure. I would also like to thank Scott Lundstrom, with the USGS, for taking the time to discuss his work in the Missouri River Valley with me.

The extent of the mapping project could not have been completed without the hard work of the other REU and NSF students. I would like to thank Neal Alexandrowicz for providing a detailed map of the Gayville quadrangle (07') and also spending a few days in the field during the summer 2008 field season, Jordan Garrett for providing a detailed map of the Saint Helena quadrangle (07'), and Scott Stoner for offering a few days out of his summer to assist with the Mission Hill and Menominee quadrangle mapping. I would like to offer a special thanks to my husband, Dustin E. Ward, for not only providing a detailed map of the Gayville NE quadrangle (07'), but also for serving as my mapping partner on the Meckling quadrangle (07'). I also want to thank Dustin for providing assistance in the digital compilation of the Meckling, Mission Hill, and Menominee quadrangles and for giving his professional opinion on graphics. I would also like to thank him for his physical, mental, and emotional support throughout my M.S. career

Finally, I would like to thank my parents for always encouraging me to pursue education. I owe them so much for the sacrifices they have made to provide me with the opportunity to find a field of study that I love. And to my son, Grey Evans Ward, I can't wait to meet you next year.

December 10, 2010

ABSTRACT

LEADING THE JAMES: THE MORPHOLOGICAL CHANGES

OF THE MISSOURI RIVER AND THE

SUBSERVIENT JAMES

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The University of Texas at Arlington, 2010

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The James River flows into the Missouri River east of Yankton, SD. The degree to which the morphological changes of the Missouri River had an impact on the course of the James River is debatable. After mapping the Mission Hill and Menominee quadrangles, surficial maps have been made showing the preserved allounits of the area. Hand augers were used to ground-truth surface features located through the use of aerial photographs, topographic maps, and to confirm features on the surficial maps made. OSL samples were taken from both quadrangles and also from Meckling and Saint Helena; the latter two were mapped during the summer of 2007. A chronology of preserved fragments of the Missouri River valley in the study area was made based on OSL dating; this will aid in building a clear sedimentological picture of the study area. The main question that has been answered is the chronology of where the James joined the Missouri throughout the Holocene and how the interaction of both rivers evolved during this time period.

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CHAPTER 1

INTRODUCTION

River geomorphology is complex and variable. There are a variety of aspects that affect river behavior such as discharge, vegetation, climate, etc. Because of the multi-faceted characteristics of rivers, surficial mapping becomes important in answering many questions that researchers may have (i.e. land use, affects of climate on fluvial systems, etc.). Surficial mapping focuses on surface features; in this study these surface features are synonymous with paleo-features such as channels, splays, bars, and floodplain deposits. In order to map the allounits in the study area, their characteristic surficial geometry have to be identified using various maps such as aerial photographs, topographic maps, and also color infrared satellite imagery. Surficial mapping can be used to make a chronology of river morphology over time; using optically stimulated luminescence dating we can narrow the range of time in a particular reach. These maps can be verified against any historical maps that may exist, such as the Lewis and Clark expedition maps and the 1800's maps provided to us by the Missouri River Institute. Based on these maps, some have argued that the confluence of the James and Missouri Rivers fell somewhere west of where it is today. The determination of the confluence will be made using the surficial mapping of the Mission Hill quadrangle in combination with the OSL dates.

The study area includes the Missouri River floodplain from Yankton to Meckling; two quadrangles were studied during the summer 08' field season while the remaining four included in this study were mapped during the summer 07' field season (Figure 1.1). All six quadrangles are located within the Missouri National Recreational River floodplain which totals 98 miles along the eastern boundary of South Dakota and Nebraska. The MNRR begins at Gavins Point Dam and ends near Ponca, Nebraska. A river classified as recreational contains esthetic characteristics, but access is readily available and there may be some shoreline development (Berry and Young 2004). The purpose of this paper is to evaluate the interaction of the Missouri and the James Rivers over the span of the late Pleistocene through the Holocene. There are three overall questions that this study will strive to answer: 1) Are the large paleo-loops seen on the aerial and topographic maps remnants of the Missouri River or the James River 2) Where was the confluence of the James and Missouri during Lewis and Clark's expedition and 3) What was the chronology of the interactions of the James and Missouri rivers during the last portion of the Holocene.

The larger portion of this study will piece together the chronology of the two rivers through all six quadrangles included in this study. The chronology will be made using the surficial maps and the corresponding OSL dates, as well as relative dating of the remaining paleo-loops with respect to those OSL dates. The final maps will have the potential to answer the above mentioned questions and also may be used with existing soil maps to determine future land use in the Missouri River valley.

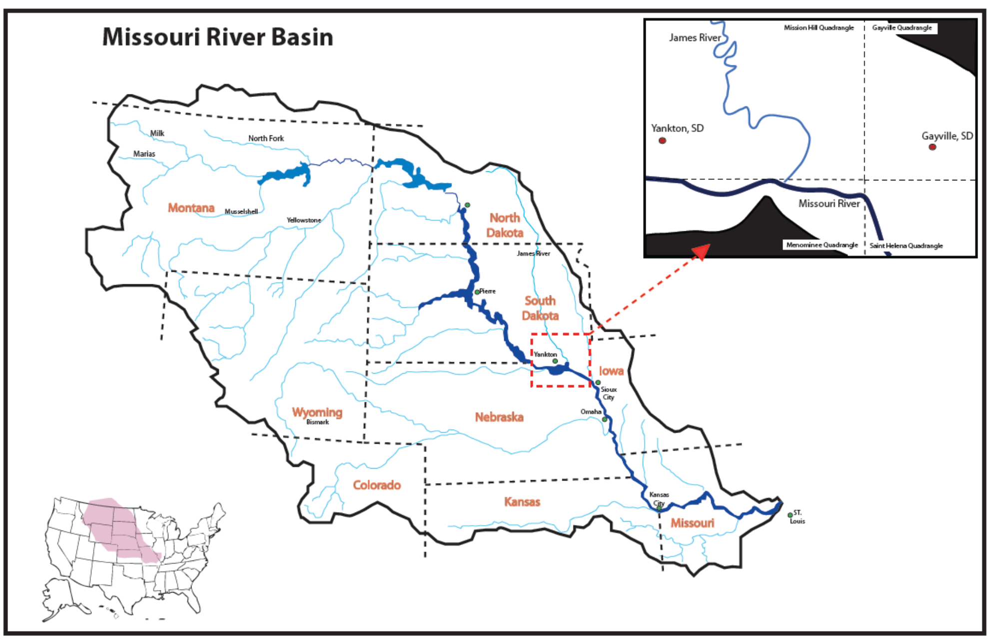

Figure 1.1: Missouri River Basin. (Modified from U.S Bureau of Reclamation Dept. of Interior, U.S. Government Printing Office 1945, 0-629774).

CHAPTER 2

BACKGROUND

2.1 Lewis and Clark and the Missouri River Drainage Basin

The Missouri River basin measures over 1000 miles long and at its widest measures approximately 700 miles. The Missouri River drains more than 1,300,000 km^2 (Jacobson 2006) and is the nation's longest river twisting and bending for nearly 2465 miles from Three Forks, Montana to St. Louis, Missouri (Baumhoff 1951). The basin includes ten states and a small portion of Canada. Some of the main tributaries of the Missouri River within South Dakota are: the Moreau River, the Cheyenne River, the Bad River, the Niobrara River, the James River, the Vermillion River and the White River.

In 1803, President Jefferson commissioned Meriwether Lewis, born near Charlottesville, Virginia on August 18, 1774, to explore the Missouri River. Lewis chose William Clark, born near Charlottesville, Virginia on August 1, 1770 to accompany him on this expedition. Lewis served as the expedition's biologist and botanist and Clark served as the expedition's cartographer and riverman (Moody, 2003). The expedition reached the Yankton area between August 18 and August 28, 1804 (Lewis and Clark 1965, edited by Elliot Coues). They recorded the James River as being on the NE side of the Missouri River and measured it at 90 yards wide and measured the confluence of the James and Missouri Rivers at 950 miles upstream from the Mississippi River. The expedition lasted from 1804-1806 and stretched from Camp Dubois near present day Hartford, Illinois to the Pacific Ocean. The two captains followed the Missouri River to its headwaters near Lemhi Pass. The pass is located on the Montana-Idaho border in the Rocky Mountains. They thought that the crossing of the Rockies would take one day and that they would then be able to resume their journey to the Pacific Ocean by river. The Lewis and Clark's expedition served to provide the first detailed information on the lands west of the Mississippi (Figure 2.2). They not only recorded information about the Missouri River and its tributaries, but also the plants, animals, and indigenous people who inhabited this uncharted land. Based on first hand observations and information provided by the natives, Clark was able to provide the first detailed maps of this region. Using instruments such as protractors and index[1], circumferentors[2], logline and reels[3], pocket compasses[4], spirit level[5], and two-pole chains[6], he was able to provide surprisingly accurate maps. According to Moody (2003), Clark measured the magnetic bearing of the Mississippi River shoreline at S 74º W and the Ohio at N 52.5º W making the angle between the shorelines at 53.5º. The 1978 U.S. Geological Survey's measurements at the Wyatt quadrangle come in at N 52º W and S 77.5º W making the angle between the two at 50.5º.

The Missouri River is split between the upper and lower portions of the river. The LMOR (Lower Missouri River) begins at Gavins Point Dam and continues to its confluence with the Mississippi River near St. Louis, Missouri.

Anthropogenic alterations of the Missouri River began in the 1800's and consisted of clearing, snagging, and stabilization of the river for steamboat navigation (Chittenden, 1903). Major changes began on the Missouri during the 1930s with the construction of Fort Peck Dam in

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[1] for measuring and plotting angles on paper.
[2] is a magnetic compass that measures the horizontal angle between magnetic north and a landmark.
[3] at the end of the line was a log or flat, triangular piece of wood weighted along one edge so that it would be partially submerged in the water. A bridle of three short lines connected each corner of the wood log to the line. Knots were tied in the line or attached to the line like an appendage, at intervals of 7 fathoms. The line was wound around a reel. The log was cast over the side into the water and the line was pulled off the reel by the motion of the boat moving relative to still water. Similarly, if the boat was anchored in a river, then the water moving downstream pulled the line off the reel. By counting the number of knots that came off the reel during a specific time, the speed of the boat or the speed of the water could be calculated.
[4] is a small version of the Circumferentor.
[5] is similar to present-day carpenter levels with a bubble of air trapped in a tube of liquid to determine when a surface is horizontal.
[6] consisted of 50 links. Each link was 7.92 inches long so that the two-pole chain was 33 feet long.
(Moody, 2003)

Montana. The Missouri River is now home to six major dams and serves as the largest water management system in the U.S. with nearly 92,500 km^3 (73.4 million acre feet) of water storage (U.S. Army Corps of Engineers, 2004). The management of the river was to serve to improve navigation, flood control, recreation, etc. The majority of the rock dikes and revetments found within the river are a direct result of the Pick-Sloan plan. The result of bank stabilization has created a narrower, swifter, and deeper channel from what was a shallow, shifting braided river in the historical past (Jacobson 2006).

Figure 2.1: 1890's map of partial study area, Missouri River Commission.

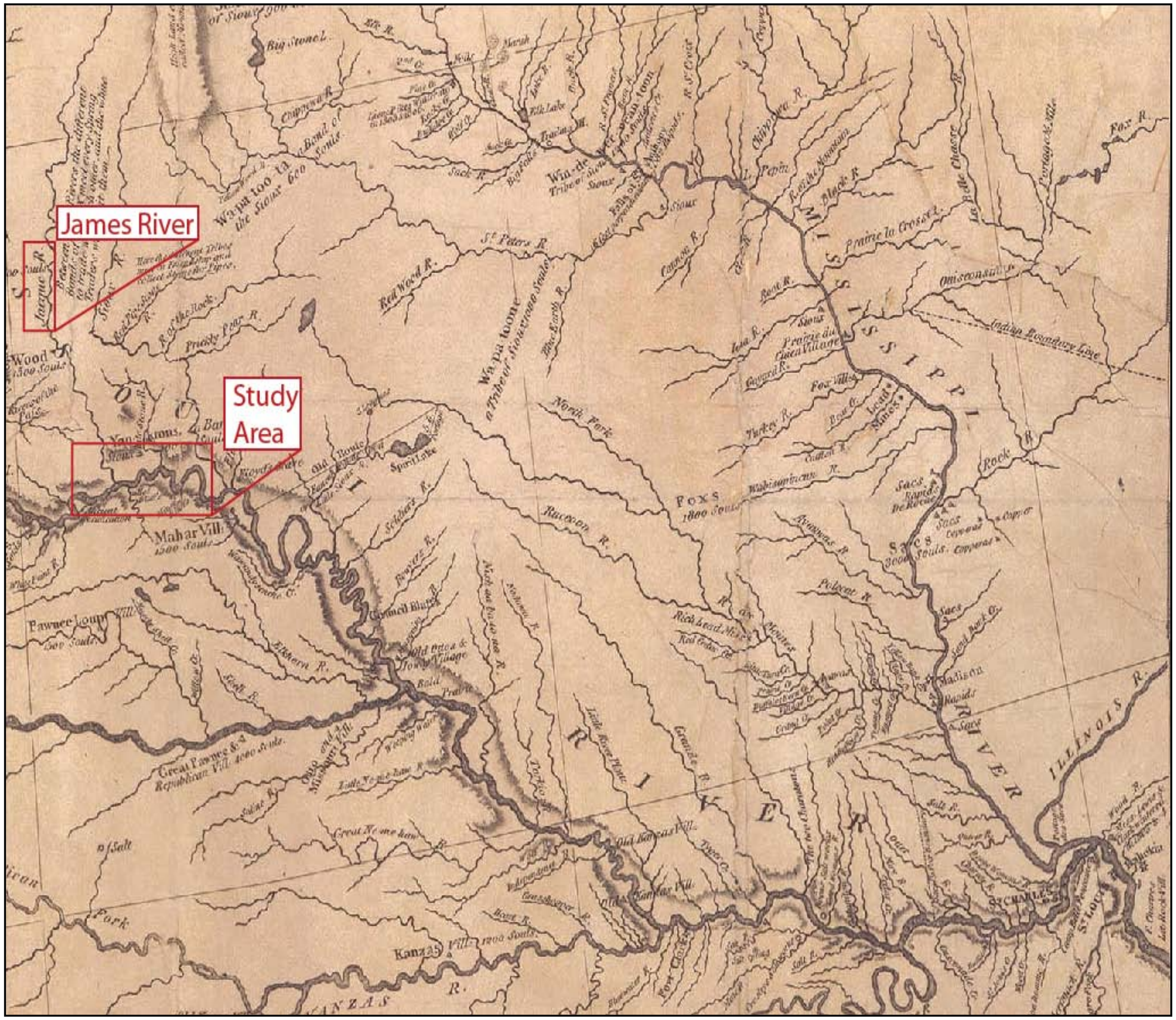

Figure 2.2: 1814 Lewis and Clark map provided by the Missouri River Institute. Library of Congress Geography & Map division, Call Number [G4126.S12 1814 .L4](G4126.S12 1814 .L4).

2.2 Pick-Sloan Plan

Water allocation issues within the Missouri River Basin is split between the upper basin and the Lower basin. The upper basin was concerned with irrigation while the lower basin was plagued by flooding. Both the Corps of Engineers and the Bureau of Reclamation had plans on how to best harness the water resources within the basin.

William Glenn Sloan joined the Bureau of Reclamation in 1936 and in 1939 was selected to make a plan allocating basin wide water resources. His plan focused on the concerns of the upper basin population and focused on not only irrigation, but also hydroelectrical power through the creation of 17 power plants. He also sought to preserve natural habitat and recreation. Lewis A. Pick represented the Corps of Engineers and focused his plan on flooding and navigation (Ferrell, 1993). Pick had three main groups of projects: 1) 1500 miles of levees on both sides of the Missouri stretching from Sioux City to the mouth of the river 2) reservoirs on the tributaries, and 3) five more dams on the main stem of the river (Reuss 1982).

According to Lawson (1982) there were several flooding events that helped to stimulate the development of the Pick-Sloan Plan: April 12, 1943 the Missouri flooded to 1881 flood stages in Nebraska and southern South Dakota inundating 70,000 acres, May of 1943 brought flooding to 1844 flood levels inundating over 540,000 acres, the second week of June 1943 brought seven inches of rain per day flooding an additional 960,000 acres, and the following spring the Missouri floods inundated 4.5 million acres of farmland bringing the two year flood damage to over $100 million dollars. Because both plans focused on the needs of a portion of the basin, a combined plan was practical. The combined Pick and Sloan plans were to include 107 dams with five Corps of Engineers dams to be included: Oahe, Big Bend, Fort Randall, Fort Peck and Gavins Point Dam. Along with the dams, several levees and concrete floodwalls were proposed. More than a hundred dams of varied purposes were constructed on the Missouri River and likewise many of its tributaries (Baumhoff 1951, Ferrell 1993). These dams play an important role in shaping the morphological activity of the rivers they are built on and likewise on subsequent tributaries.

According to the Missouri River Recovery Program fact sheet (2007), construction of the artificial levees in the floodplain fixed the Missouri River in its present day location and has locked overbank sediment in its place since 1960.

2.3 Gavins Point Dam

Gavins Point Dam, located west of Yankton, SD, was constructed during the period from 1952 to 1957, and confines the current Lewis and Clark Lake. Gavins Point Dam is located approximately 1300 km upstream from the confluence of the Missouri River and the Mississippi River (Heine and Lant 2009). The portion of the Missouri River abruptly downstream of the dam and continuing to Sioux City, IA is the last stretch of the Missouri River to be considered "natural" as it is not artificially channelized. The alteration of channel load and discharge imposed by the dam, however, has impacted not only the morphology of the Missouri River since the 1950's but also the subsequent tributaries that flow into the Missouri River, including the James River. These tributaries will incise or aggrade to match the Missouri River, which serves as a buttress. According to Holbrook (2006), river profiles will incise or aggrade to match a down dip physical barrier (e.g. sea level or in this case the tributaries are anchored to the Missouri River level: Figure 2.3). Any shift in the buttress serves as the primary control on the base level and dictates maximum incision and aggradation, referred to as the buffer zone (Holbrook et. al. 2006).

The change in water surface elevation of the Missouri River is documented for the interval from the 1940's till 1996 at Yankton, SD. The two meter elevation change, from 353 meters to 351 meters marks incision in the Missouri River that also caused incision in its tributaries. This incision persists beneath the dam to Sioux City and is triggered by decreased suspended sediment load and decreased flow imposed by the upstream dam (Jacobson 2009). Suspended sediment load may have been reduced to as little as seventeen percent of pre-dam loads and incision may be as great as 3.5 m just downstream of Gavins Point Dam. Current stream flow is influenced by release from Gavins Point Dam. The seasonal release is at least 25,000 cfs, except during periods of flood discharge from the James, Vermillion, or other tributaries. During years of normal water supply flows vary between 35,000 cfs during the spring, summer, and fall months, and 15,000 cfs or less during the winter. The Gavins Point to Ponca park segment is free from any impoundments and other structures which might impede flow.

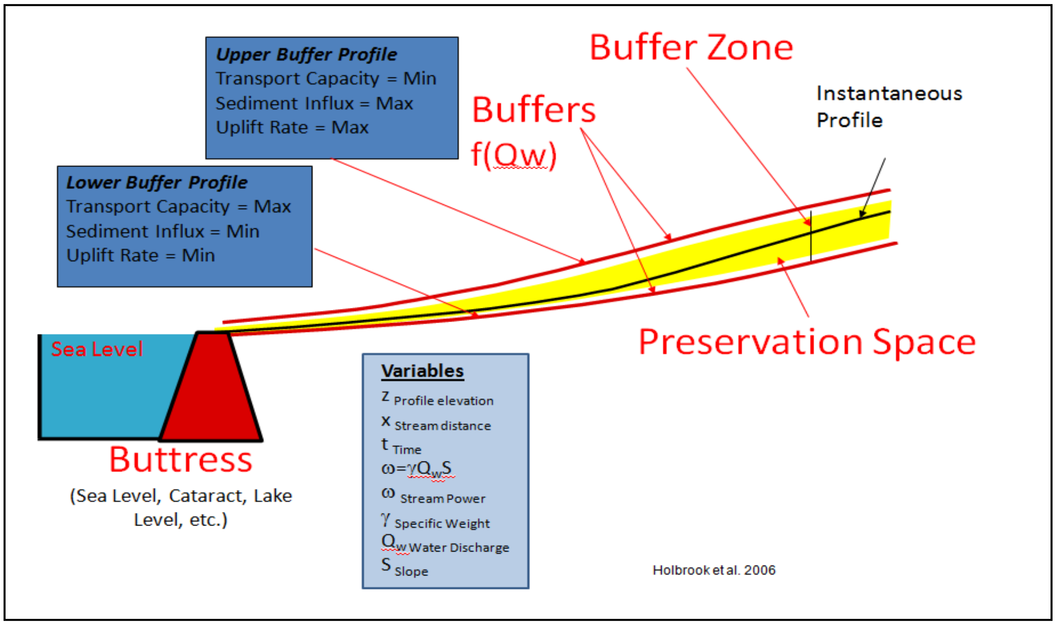

Figure 2.3: Buffer and buttress model. Buttress in the study area is the Missouri River with the buffers referring to the incision or aggradation of the tributaries.

The damming projects promoted incision in some areas of the lower Missouri and aggradation in others due to changes in sediment load (Jacobson 2009); inherent issues are present in both instances. In incisional areas, the river is sediment starved, while aggrading areas are supplied with sediment from other sources (i.e. tributaries) and may be at risk for flooding due to small increases in river discharge (i.e. spring storms). Another risk factor in both occurrences involves the water table. Incision will cause a drop in water table, while aggradation will raise the water table. A rise in water table adds to the possibility of having damaging floods while incision may hinders reconstruction of sandbars, for example. Within the study area, the sandbars are pivotal to the survival of certain endangered bird species.

Rahn (1981) conducted a study on the incision and erosion caused by the Gavins Point Dam. His study included a 55 mile stretch of river, below Gavins Point Dam, where he estimated that erosion totaled 2,200 acres. He concluded that this loss of suspended sediment and change in river equilibrium caused erosion of “both inner and outer sides of its meanders” and also observed erosion “along both sides of crossings between meanders”.

This incision below Yankton serves to increase the sediment supply within the water column and has a direct affect on discharge and velocity. One might speculate that the overall net effect is the pattern change observed currently in the river. Large paleo-loops form a meandering river in the northern sections of the valley, while tracing the rivers southwest path we begin to approach a pattern change towards the active braided morphology. However, it is important to note that while this pattern change may be attributed to the construction of the dam, this pattern change can be seen throughout the valley and was in place well before dam construction. Some change in pattern may be attributed to damming and other anthropogenic inputs, however, we cannot accurately hypothesize what percentage of the changes can be attributed to natural processes of the Missouri River and what percentage can be attributed to anthropogenic sources at this time.

Blevins (2007) finds that large changes in suspended sediment and turbidity in the lower Missouri River below Gavins Point Dam have occurred in response to extensive structural changes imposed on the Missouri River and its watershed during the last two centuries, specifically damming, implementation of levees and channelization. The large historical decrease in suspended sediment and turbidity seems inconsistent with the common assumption that the Missouri River flows much faster than it did before bank stabilization. However, comparison of modern velocity measurements with available measurements made before bank stabilization indicate that while mean velocities are similar, maximum velocities in the lower Missouri River were substantially larger before bank stabilization than maximum velocities measured today (Blevins 2007).

Damming caused a distinct change in suspended sediment load in the Missouri River (Table 2.1). According to the 2007 Army Corps of Engineers update, the suspended sediment load was reduced from 320 million tons per year to a mere 20-25% of this pre-dam figure.

Channelization of the Missouri River also played an important role in changes of sediment transport. In 1879, the estimated amount of sediment carried past St. Charles, Missouri was 11 billion cubic feet (Missouri River Environment Assessment Program). Pre-dam suspended-sediment load near the mouth of the Missouri River was estimated to be 320,000,000 tons per year (Keown and other, 1986) while post dam suspended sediment load was estimated at 86,000,000 tons per year (Moody, 2003).

While the damming efforts were emplaced to allow for irrigation, navigation, and to control damaging floods, it had a direct affect on sediment load. Annual sediment load is essentially zero at Gavins Point Dam and increases to approximately 68 million metric tons per year sediment load at Hermann, Missouri (Horowitz, 2003). According to Elliot and Jacobson (2006), any increase in sediment load can be attributed to bank erosion and sediment input from tributaries.

Table 2.1: Annual suspended sediment loads

ANNUAL SUSPENDED SEDIMENT LOADS CALCULATED FOR LOCATIONS AND TIME PERIODS INDICATED															
a. CALCULATED FROM CONCENTRATION DATA FOR THIS REPORT															
	1994-2006*					1981-1993*				1968-1980*				1949-1952*,[†]	
	Suspended load (Mg x $10^{6/yr)}$		Sand Load (Mg x $10^{6/yr)}$			Suspended load (Mg x $10^{6/yr)}$		Sand Load (Mg x $10^{6/yr)}$		Suspended load (Mg x $10^{6/yr)}$		Sand Load (Mg x $10^{6/yr)}$		Suspended load (Mg x $10^{6/yr)}$	
Gauge	Load	S.E.[§]	Load	S.E	Sand Percentage	Load	S.E	Load	S.E	Load	S.E.	Load	S.E.	Load	S.E
Yankton	0.24	0.03	0.01	0.002	3%	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Sioux City	7.3	0.1	N.A	N.A	N.A	9.9	0.9	4.0	0.6	15.6	0.7	13.2	1.7	N.A	N.A
Omaha	18.6	2.2	6.5	0.4	35%	16.4	1.1	6.4	0.4	18.9	1.0	11.6	0.6	N.A	N.A
Nebraska City	20.6	0.3	N.A	N.A	N.A	41.1	13.7	8.4	0.7	29.4	1.2	16.3	0.9	N.A	N.A
St. Joseph	27.6	1.9	10.0	0.7	36%	77.6	32.1	16.6	3.4	63.6	4.6	N.A	N.A	270.2	12.0
Kansas City	41.9	3.0	13.2	1.1	32%	53.0	8.4	16.7	4.5	61.0	2.8	N.A	N.A	280.2	39.7
Hermann	55.2	4.4	13.6	1.3	25%	72.9	4.8	42.8	3.3	77.0	121.2	23.2	4.0	326.4	11.6

Table 2.1 cont.

B. COMPILED FROM OTHER REPORTS				
Suspended Load (Mg x $10^{6/yr)}$				
Gauge	1940-1952 (USACE, 1951,1957)**	1948-1952 (USACE, 1957)**	1929-1931 (Secretary of War, 1934) ††	Pre-dams (MBIC, 1971) §§
Yankton	125.0	121.0	N.A	120.7
Sioux City	N.A	N.A	64.0	N.A
Omaha	148.6	233.4	71.3	148.8
Nebraska City	N.A	N.A	N.A	N.A
St. Joseph	N.A	233.4	N.A	233.1
Kansas City	N.A	299.8	118.8	297.6
Hermann	N.A	289.1	N.A	295.7

Note: USACE- U.S. Army Corps of Engineers; MBIC- Missouri Basin Inter-Agency Committee.
* Loads calculated using rating curve models in LOADEST; details in text.
† Loads calculated from unpublished concentration data, U.S. Geological Survey.
§ S.E. - Standard estimate of prediction
N.A. – not available
** Calculated from daily loads; methods are documented in reference.
†† Calculated from daily loads; methods are documented in reference; samplers may not be comparable to later samplers.
Average 1 July 1929 to 30 June 1931.
§§ Annual Loads given 1940-1952; 1949-1952; methods of calculation unspecified.
From Jacobson et al. 2009.

2.4 Pleistocene deposits

The Laurentide ice sheet covered a large portion of North America during the Pleistocene and according to Flint (1971) may have been near 500 M thick in eastern South Dakota. It appears that glaciation may have reached its southern expansion at approximately 20,000-17,000 yr. B.P. (Mickelson et. al 1983). According to Andrews (1987), the glacial dome of the Laurentide Ice sheet began traveling from northern Canada through South Dakota at approximately 14,000 years ago. The main ice sheet, during the late Wisconsin period, was split into two main lobes, the James and the Des Moines, by what is today referred to as the Coteau des Prairies (Figures 2.5 and 2.6). The James Lobes, and subsequently the James Basin, is confined between the Coteau des Prairies and the Coteau du Missouri. Radiocarbon dates of Des Moines lobe ice margins in Minnesota indicate multiple advances of the Laurentide ice sheet during the late Wisconsin (Patterson, 1997a). In northeastern South Dakota, five end moraine complexes were deposited by the Des Moines lobe and three end moraine complexes were deposited by the James lobe (Gilbertson, 1989). During this time, according to Johnson and McCormick (2005), the James River may have formed due to constraints on the melt waters by ice or perhaps either a crevasse or simply as by serving as a subglacial drainage path.

Figure 2.4: Loess deposits Gayville NE quadrangle

The James lobe of the Laurentide Ice sheet may have reached its southern most extent at approximately 20 ^{14}CKa B.P. before retreating at approximately 14 ^{14}CKa B.P. and stretched from Hudson Bay down the James River Valley to the Missouri River, SD (Carlson 2007). The James Lobe of the Laurentide ice sheet formed the James River in stages during its retreat. The Missouri River, likewise, was altered by glaciations (Bluemle, 1972). These alterations happened several times due to ice blockages. Evidence of this activity can be found by examining more than 300 miles of abandoned channel systems that stretch from eastern Montana to Bismarck, ND (Flint 1947). Evidence of Pleistocene deposits from these glaciations can be seen throughout the study area.

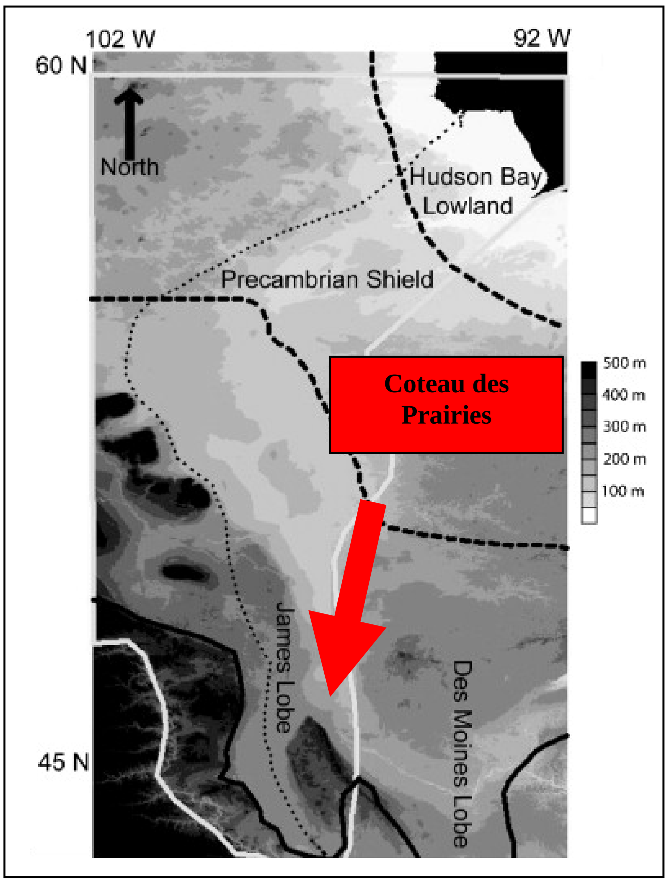

Figure 2.5: Map of the James Lobe (west) and Des Moines Lobe (east). The James lobe stretches from the Hudson Bay to the Missouri River. Carlson et. al. 2007.

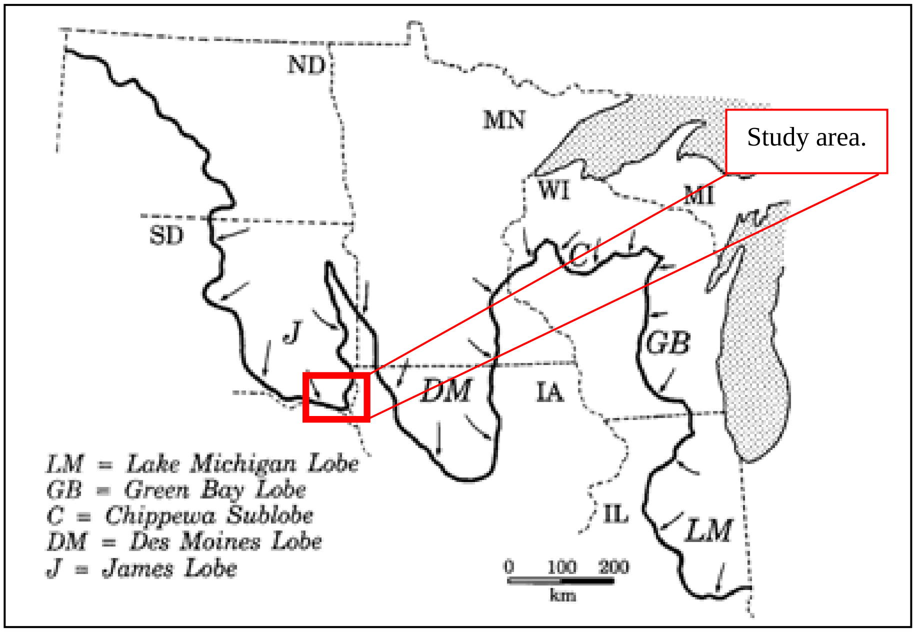

Figure 2.6: Major lobes along the southern margin of the Laurentide Ice Sheet between Illinois and Montana. Clark 1992

Large deposits of loess found on the north bluffs of the Missouri River valley, Gayville NE quadrangle, were mapped in the 2007 field season by Dustin E. Ward and April D. Moreno. According to field work done by Muhs and Bettis (2000), approximate loess thickness within our study area is < 3meters (Figure 2.4) (other sources, Grimley 2000). Pleistocene gravel/till was also mapped at several locations within the Gayville NE quadrangles during the 07' field season. Other studies have also found and dated Pleistocene deposits within Yankton County. Johnson and McCormick (2005) used Carbon^{14} to date two wood samples yielding dates of 12,880 ±170 and 12,540±170 yrs.

During the summer field season of 2008, two undergraduate students participating in an NSF-REU project mapped the Vermillion quadrangle which lies just east of the study area. Two OSL dates were taken from this quadrangle and returned dates that suggests that sedimentation in this area falls within the 16Ka to 10 ka range (G. Calvert et al. 2009: Figure 2.7). This range corresponds to late Wisconsin glacial activity; these glacial cycles led to flooding due to melt water and outwash. These cycles also had a direct impact on the formation of the James River valley and the James River.

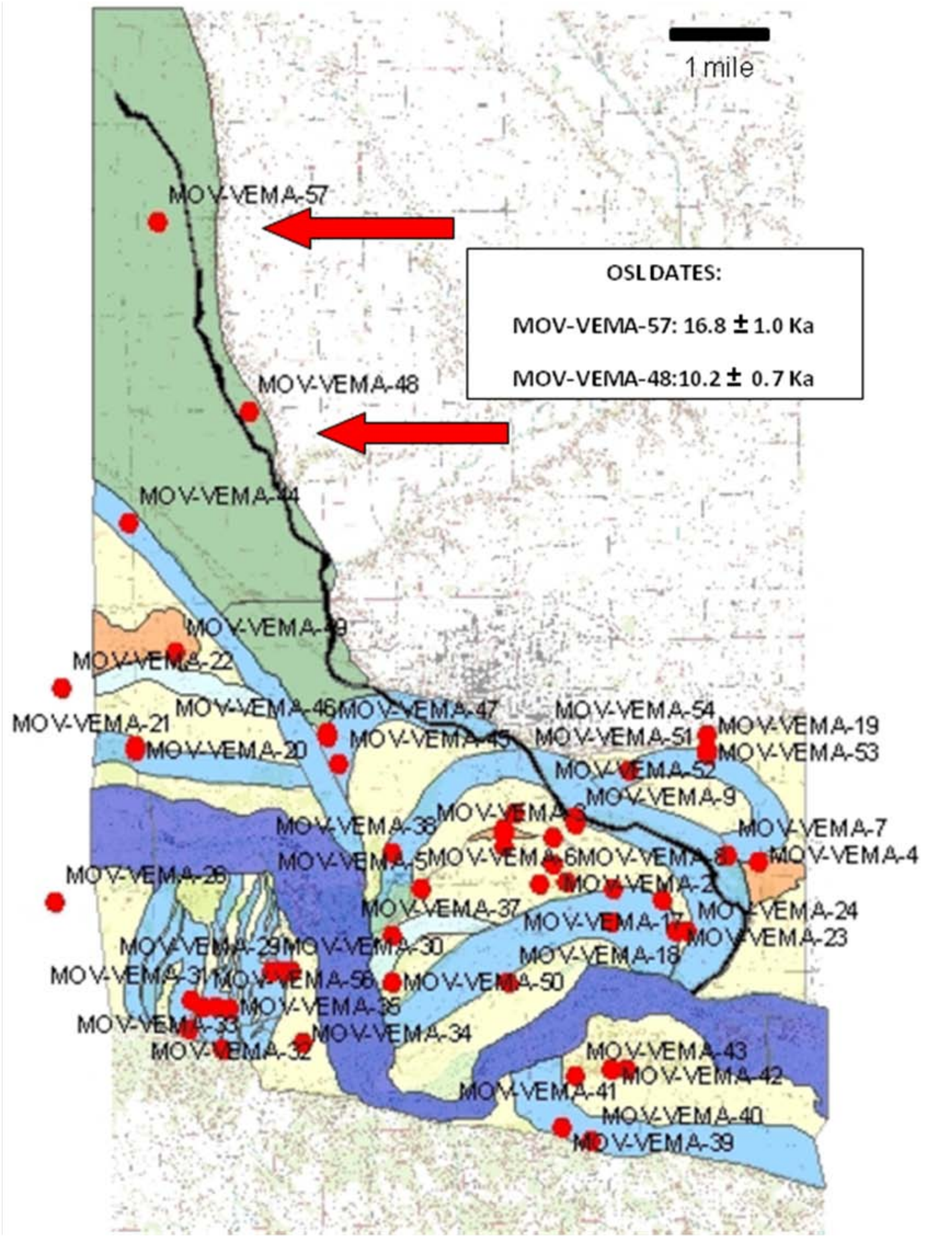

Figure 2.7: OSL dates in the Vermillion Quadrangle. Calvert et al.

2.5 James River and its background

The James River is the principal tributary of the Missouri River; it is approximately 747 miles long (Benson, 1983), and flows from North Dakota through South Dakota until it reaches the Missouri River east of Yankton, SD. The James River serves as a main drainage for the regions between the Coteau du Missouri and the Coteau des Prairies. It is considered to be one of the longest un-navigable rivers in North America (Flint, 1955; Johnson and McCormick, 2005). This low lying area between the two plateaus was carved by glacial activity during the last ice age.

The James River Basin has an approximate area of 21,100 square miles. Two thirds of it, 14,900 square miles, can be found in South Dakota alone. Due to its low slope, dropping approximately 130 ft in SD, the James is a fairly stable River. It has a high suspended sediment load and is relatively slow moving. According to the Garrison Diversion Unit (1989), it is the only north-south corridor in SD that has continuous woodlands and also serves as a migration route and breeding area for passerine birds; the woodlands are inhabited by a large population of whitetail deer.

"Overall, the James River has a surface gradient of 0.75 ft/mile in the Yankton area. During the low water stage (approximately December) the James River is anywhere from 75-250 ft. wide and 3-6 ft. deep, however, during the high water stage (approximately April) the water surface is up to 15 ft. higher than during low water stages" (Simpson 1960). The width varies little from low water to high water stages unless overbank flooding occurs. During the summer of 08' (field season) high rain caused the James River to flood almost the entirety of the low lying areas of its valley (Figure 2.8).

Figure 2.8: James River overbank flooding.

2.6 Prior Mapping

2.6.1 *Surficial mapping*

During the summer of 2007, two undergraduate students and two graduate students from the University of Texas at Arlington, under the supervision of Dr. John Holbrook, began mapping a portion of the Missouri National Recreational River. Four quadrangles were mapped on the South Dakota side of the Missouri River: Meckling (mapped by April D. Moreno), Gayville NE (mapped by Dustin E. Ward), Saint Helena (mapped by Jordan Garrett), and Gayville (mapped by Neal Alexandrowicz). These four quadrangles are important for understanding the Missouri during the last (approximately) 10,000 yrs. Two of the quadrangles, Saint Helena and Gayville, hold additional importance when understanding the morphology of the James River. Paleo-loops of the James can be found across both quadrangles, after first passing through the Mission Hill quadrangle. By combining all six quadrangles, a pattern begins to emerge supporting the hypothesis that the paleo-loops are Missouri River in origin and the James River does indeed follow theses abandoned loops of the Missouri River.

2.6.2 Soil Mapping

Soil surveys have been completed in the study area and can be found for each county (http://soils.usda.gov/). The Yankton county soil survey was completed in 1976, approved in 1977, and published in 1979. The economy in Yankton County relies heavily on cropland and rangeland; 84 percent of the county is cropland, pasture, and hayland while the remaining 16 percent is rangeland (Ensz, 1979). There are many specific uses for surveying the soil, including but not limited to land-planning programs, predicting possible soil behavior in conjunction with specific land uses and also determining any limitations or hazards that the soil conditions may have on a planned use. These surveys prove helpful when discussing not only the development or uses of certain areas, but also when issues of conservation come to light. Before responsible land uses can be determined, maps need to be made to show what kinds of soils are present and where they are; based on their properties the best use for that area can be determined to avoid any mishaps associated with soil-related failures. Because soil horizons can change over short or long distances, surveys need to be completed to determine if a specific soil is seasonally wet or subject to flooding, may be shallow to bedrock, is too unstable to be used as a foundation for buildings or roads, and determine where there might be high water tables making underground installations impractical (Ensz, 1979). During these surveys, scientist pay particular attention to things like erosional qualities, how different soils act during droughts/flooding and the effect on crops, and flooding. These scientists also want to note overall slope and drainage patterns. Once these observations have been made, the scientist classify and name the soils using correlations with nearby counties or other areas that have already been classified to ensure a uniform naming and description process. They then use aerial photographs to draw the boundaries between the individual soils horizons.

How are these soil surveys useful for my study? Using the soil map in conjunction with the aerial photographs and topographic maps, etc., we were able to pick out patterns of soil distributions and determine if those patterns match surficial features we have already marked.

2.6.3 Other mapping projects

Other mapping projects have been done in my study area. Scott Lundstrom, with the USGS, has been completing mapping in the Missouri National Recreational River (Figure 2.9). Looking at his mapped units, patterns associated with large scale channel meanders can easily be picked out. While more detailed units such as splays and bars are not individually accounted for on his map, we were able to compare the large scale meanders we mapped in this area with his. We also know that glaciation played an important role in shaping the study area. While my study focuses on mapping surficial units within the river valley, we can look at other maps, such as Lundstrom's, for mapped glacial units on the adjacent bluffs. The deposits can be correlated to the Pleistocene deposits that we mapped at various locations and depth in the Missouri River Valley and nearby tributaries.

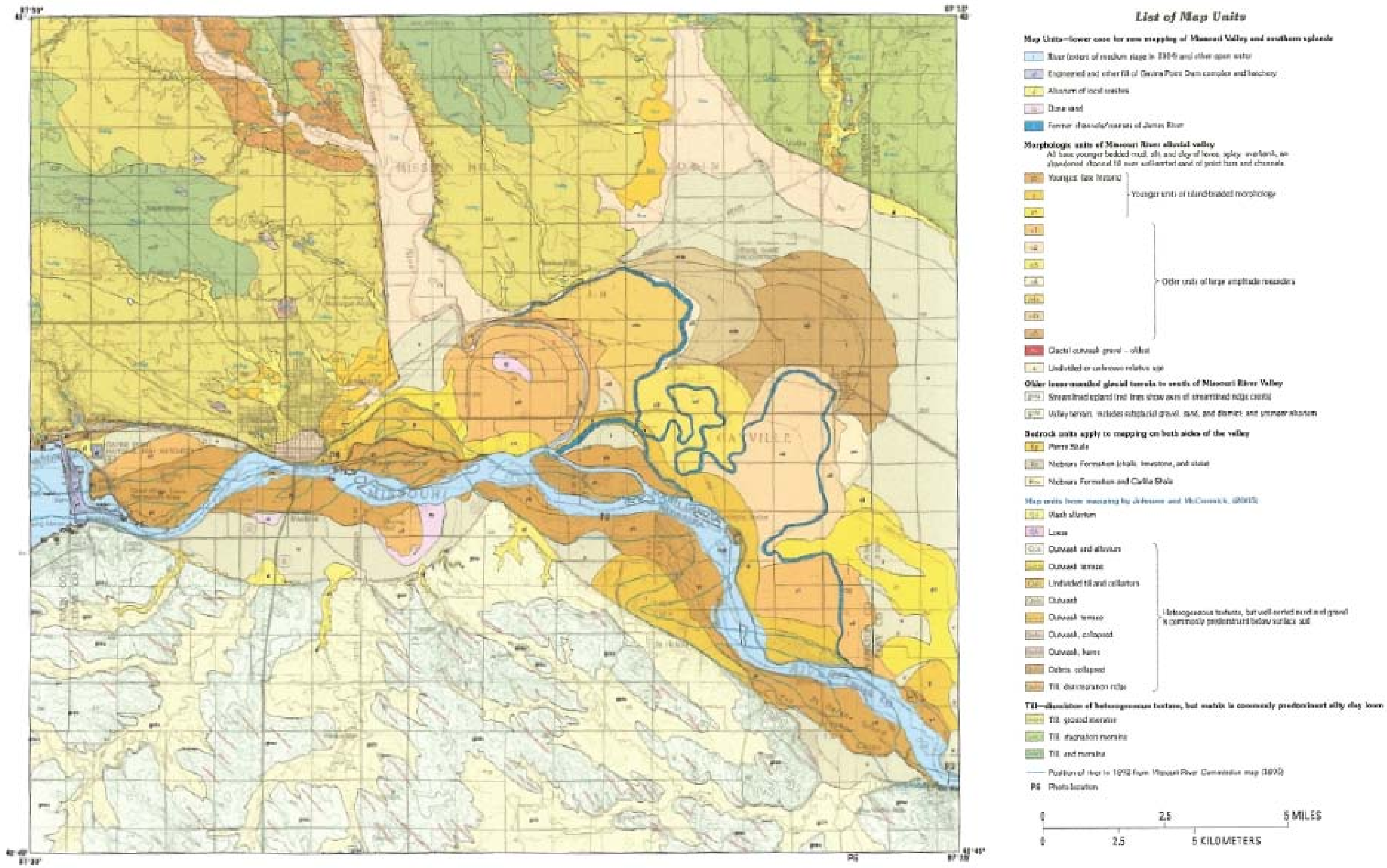

Figure 2.9:Lundstrom et. al 2006

CHAPTER 3

METHODS/DATA ACQUISITION

The methods used in this study are based on previous field work techniques completed by Dr. John Holbrook and his students. The primary goal of surficial mapping is to define the allostratigraphic units within the study reach and to provide a practical means for subdivision of mapable surficial deposits. Allostratigraphy defines map units based on recognition and delineation of their bounding discontinuities (e.g., channel scours, valley scours, traceable soil horizons, etc.) (NACSN, 1983). Mapable units used in this study include: ox-bow lake/channel fills, individual channel belts, splays, point bars, and undifferentiated flood basin strata.

The initial step in field mapping requires evaluation of topographic maps, aerial photographs, digital elevation models, any existing satellite imagery, soil maps, and any existing historical maps (Figure 3.4 and 2.1) for surficial features indicative of mapping units as predicted from established sedimentary architectural models (e.g. Miall 1996).For example: "channel fills are generally floored with the coarse material carried by the active river. If the channel is abandoned abruptly, and active flow does not return, the remainder of the channel will fill with clay and silt deposits in an ox-bow lake setting. If the channel is periodically reoccupied by the main channel, fill may be of any grain size carried by the river, and will alternate in grain size in direct proportion to flow strength during reoccupation" (Miall 1996). The next step includes marking boundaries of proposed units on the topographic and aerial maps, the primary paleo feature seen on the Mission Hill quadrangle aerial map is a large arc shaped polygon. This arc shape can be interpreted as a paleo loop, however, ground-truthing is required to ensure that the sediment column is consistent with the predefined architectural models. Ground-truthing is accomplished with the use of Dutch hand augers (Figure 3.2). These consist of 1 meter bars, the T-bar (handle) and various auger heads which are switched out depending on the sediment conditions (i.e. the sand auger for use in sand and the gravel auger for use in gravel). Augurs are advantages over larger mechanical drilling rigs because of their lower expense, higher safety, easy transportability, greater acceptability by private land owners, and the ability to access small sites lacking road access. Each borehole is sampled and logged in 10cm increments. Samples are each logged based on grain size, sediment color, and presence or absence of organic material (Figures 3.1, 3.3, and 3.5). Facies are interpreted based on these characteristics. Given that the sedimentary samples taken adhere to the precedent, channels tend to contain fine-grained fill compared to the adjacent sandier point bar deposits, splays should be thin heterogeneous veneers over the top of point-bar deposits, there will be no need to take more than two to three samples per feature other than to trace the feature out to its fullest extent.

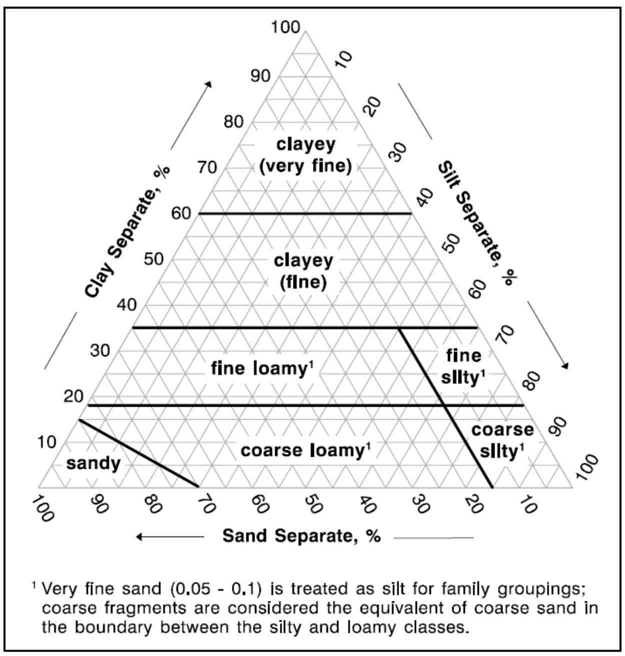

Figure 3.1: (Schoeneberger et. Al. 98)

Sediment classification is based on grain size (Figure 3.3) and on the percentage of sand, clay, and silt content in the sample (Figure 3.1). Sediment is defined as sand if it contains 70-100% of sand sized particles, clay if it contains 40-100% clay size particles, and silt if it contains 65-100% silt size particles. Clay is predominantly found on the floodplain, while sand is found at the base of channels and throughout bars. Mixtures of these three sediment types can also be found with respect to particular features and energy inputs. For example, loam, may be found in channel fill and is associated with an active channel fill. Sediment classification in the field is based on a smear test. A portion of each 10cm increment is smeared between the thumb and pointer finger to determine relative grain size. In some instances when the grain size is difficult to determine, a second test may be employed. The second test requires a portion of the sample to be chewed. Once the borehole confirms the hypothesis we can classify the map unit. If the borehole does not confirm the hypothesis, we re-evaluate the hypothesized feature.

Mapping was initiated and completed during the 2008 summer field season in both the Mission Hill and Menominee quadrangles by April D. Moreno and Eli Erickson. The four other quadrangles used in this study, Meckling, Gayville NE, Gayville and Saint Helena, were mapped during the 2007 summer field season as part of a USGS EDMAP project conducted by April D. Moreno, Dustin E. Ward, Neal Alexandrowicz, Jordan Garret and supervised by Dr. John Holbrook. All OSL sample discussed in this study were taken during the 08' field season.

Figure 3.2: Dutch Auger system: picture shows handle, two 1 meter bars, gauge, and two different auger heads.

	U.S standard sieve mesh	Millimeters	Phi φ units	Wentworth size class
Sand	12	2	-0.75	Very coarse sand
	14		-0.5	
	16		-0.25	
	18	1	0	
	20		0.25	Coarse sand
	25		0.5	
	30		0.75	
	35	0.5	1	
	40		1.25	Medium sand
	45		1.5	
	50		1.75	
	60	0.25	2	
	70		2.25	Fine sand
	80		2.5	
	100		2.75	
	120	0.125	3	
	140		3.25	Very fine sand
	170		3.5	
	200		3.75	
	230	0.0625	4	
Silt	270	0.053	4.25	Coarse silt
	325	0.044	4.5	
	NA	0.037	4.75	
	NA	0.031	5	
	NA	0.0156	6	Medium silt
	NA	0.0078	7	Fine silt
	NA	0.0039	8	Very fine silt
Clay	NA	0.002	9	Clay
	NA	0.00098	10	
	NA	0.00049	11	
	NA	0.00024	12	
	NA	0.00012	13	
	NA	0.00006	14	

Figure 3.3: Wentworth grain-size scale.

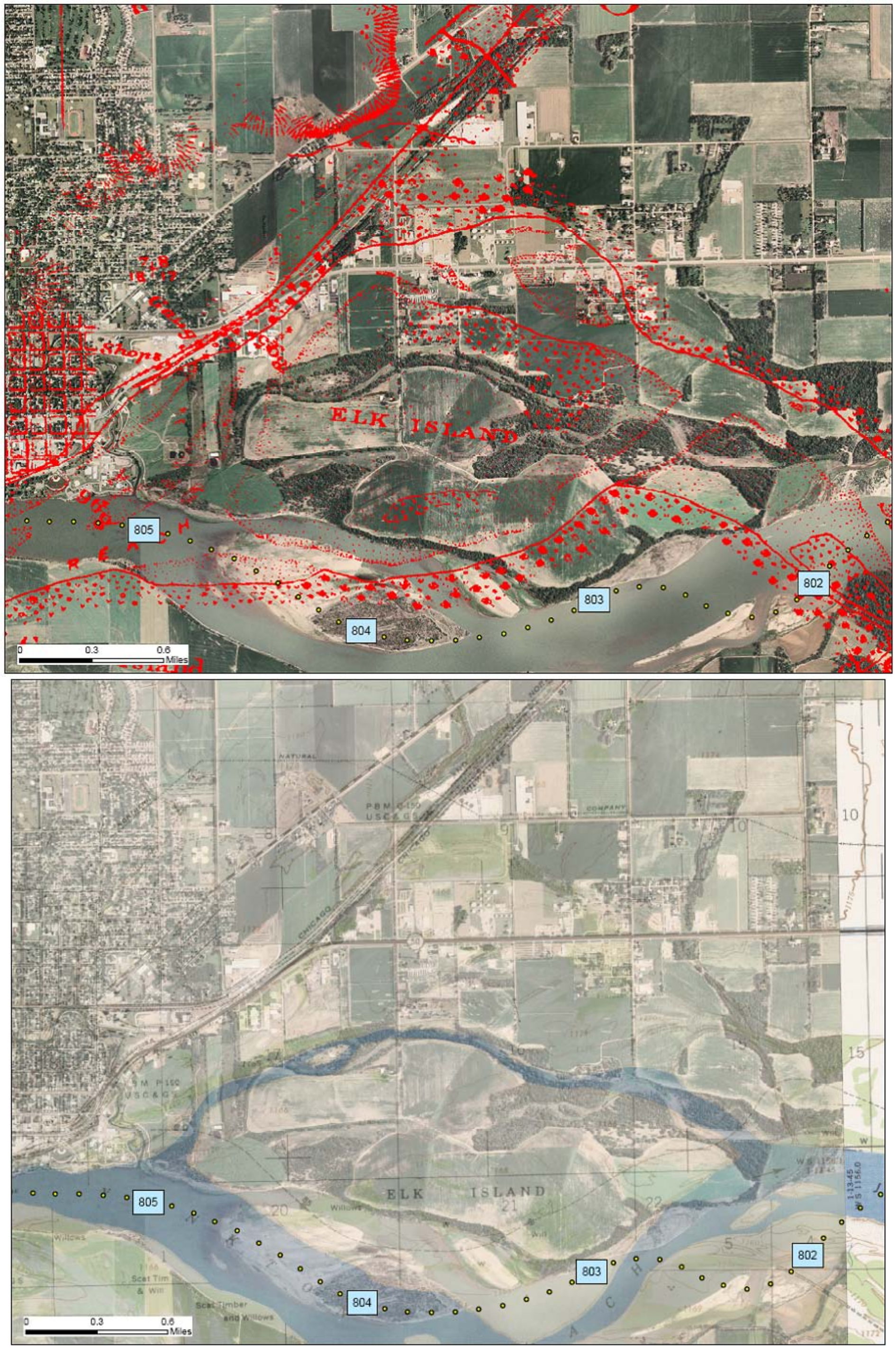

Figure 3.4: Aerial photographs overlain with 1800's maps, provided by the Missouri River Institute.

Core # Mov-MH-001 Date 06-13-08
Landscape position ___ Land Use ___
Elevation ___ Desc & drilled by ___
Slope ___ Location 0640138/4750100
Water table depth ___ Quad ___
Facies sequence possible splay sequence; inner channel bed off of point bar

depth	tex	Munsell color		ox	stains & conc		om	features & comments
meters		matrix	mottle		oxides	salts		
10	L	10yr 5/2	-	ox	fe	-		
20	L	10yr 5/2	-	ox	fe	-		
30	LS	10yr 5/3	-	ox	fe	-		
40	LS	10yr 5/3	-	ox	fe	-		
50	LS	10yr 5/3	-	ox	fe	-		
60	L	10yr 5/2	-	ox	fe/Mn	-		
70	LS	10yr 5/3	-	ox	fe/Mn	-		
80	S	10yr 4/3	-	ox	fe	-		medium sand
90	S	10yr 4/3	-	ox	fe	-		medium sand
3.0	S	10yr 6/3	-	ox	fe	-		medium sand terminal depth
10								
20								
30								
40								
50								
60								
70								
80								
90								
4.0								

SiC = silty clay
SiCL = silty clay loam
SiL = silty loam
L = loam
SL = sandy loam
C = clay
LS = loamy sand

Figure 3.5: Example log sheet.

OSL (optically stimulated luminescence) samples were taken at key point bar locations. In order to constrain dates of James River channels relative to the Missouri River, nine samples were taken from the Mission Hill, Meckling, and St. Helena quadrangles. Each sample was taken from the upper portion of a point bar and used to estimate the approximate time of abandonment and channel position at the time of point bar deposition. Point bars are preferred sample site due to the homogenous nature of the sand content. The sampling tool used was built by Dr. John Holbrook and consists of a PVC pipe and check-valve (Figure 3.6). The check-valve closes once the sand has been collected forming suction within the PVC pipe and retaining the sand as the device is extracted from the borehole. The overall apparatus is constructed to fit onto the bottom of the auger and samples are collected at 10 cm depth accuracy as in the case of the other auger heads.

Figure 3.6: OSL sampler; shows check valves and tip to attach PVC pipe to.

OSL samples are tested by Ron Gobble at the University of Nebraska OSL lab using a single aliquot method. Referred to as SAR (single aliquot regenerative-dose method), each sample contains approximately 100-1000 grains. Murray and Wintle (2000), found in their study that the SAR protocol is the technique of choice for determining the quartz equivalent dose using the main OSL trap based on the following table (Figure 3.7).

Step	Treatment[a]	Observed[d]
1	Give dose, D_i	–
2	Preheat[b] (160–300°C for 10 s)	–
3	Stimulate[c] for 100 s at 125°C	L_i
4	Give test dose, D_t	–
5	Heat[b] to 160°C	–
6	Stimulate for 100 s at 125°C	T_i
7	Return to 1	–

[a] For the natural sample, $i = 0$, and $D_0 = 0$ Gy.
[b] Aliquot cooled to < 60°C after heating. In step 5, the TL signal from the test dose can be observed, but it is not made use of in routine applications.
[c] The stimulation time is dependent on the stimulation light intensity.
[d] L_i and T_i are derived from the initial OSL signal (0.3 or 0.8 s) minus a background estimated from the last part of the stimulation curve.

Figure 3.7: Generalized single-aliquot regeneration sequence: (Murray and Wintle 2000). This cycle is then repeated as many times as desired from step 1; for instance, in the next cycle (the first regeneration cycle) a regeneration dose D_1 is given, and the first regenerated OSL signal, L_1, and the corresponding test dose OSL signal, T_1, are measured. The test dose is kept constant throughout the experiment.

OSL is one of the main techniques used to date morphological features. Time-span for dating is up to ~100,000 to 500,000 b.p. OSL calculates radiation dosimetry, which is the amount of radiation absorbed by matter, organic or inorganic from either direct or indirect ionizing radiation (when subatomic particles are energetic enough to detach electrons from atoms, ionizing them) (Botter-Jensen et. Al.,2003). In sediments, the source of radiation comes from alpha, beta, and gamma radiation emitted during the decay of ^{235U}, ^{238}U, ^{232}Th, ^{40}K, and ^{87}Rb, and their non-stable daughter products, both within the mineral grains and in the surrounding sediments (Lian, 2007).

The technique is used to date the last exposure of sediment to sunlight prior to burial; this exposure provides the energy needed to release the trapped electrons. The dating technique focuses primarily on quartz and feldspars. Quartz is the more desirable of the two because feldspar ages tend to underestimate the true age (Figure 3.8).

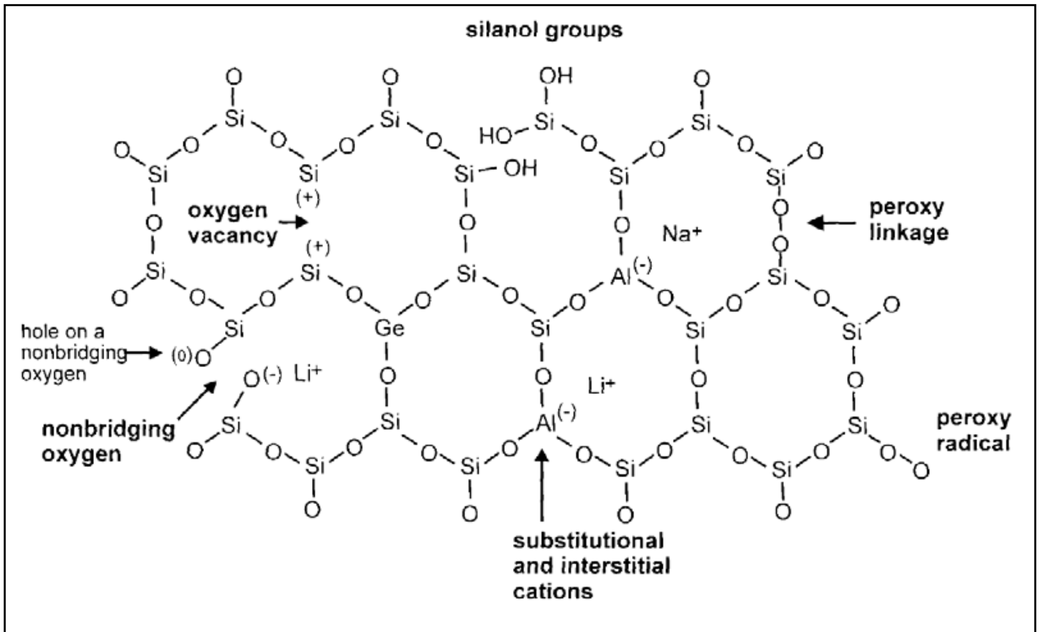

Fig. 5.1. Schematic of quartz lattice showing common defects (from Götze et al., 2001).

Figure 3.8: Quartz lattice

OSL measures the release of free electrons, which become trapped within the defects of the crystal lattices of either quartz or feldspars, as luminescence. The intensity of the luminescence is directly correlated to the number of electrons absorbed by the sample, which is directly proportional to the duration of burial and exposure to burial radiation. Optically stimulated luminescence sampling process consists of multiple steps: 1) irradiation causing the valence electrons to become ionized creating electron holes 2) pre-existing defects act to localize the free electrons using non-radiative trapping 3) any exposure to light leads to absorption of energy by the trapped electrons 4) recombining the freed electrons with the localized holes results in luminescence (the OSL signal) (Botter-Jensen et. Al.,2003).

In order to process the obtained sample in the laboratory, there must be exposure to heat and a steady light source of known wavelength and intensity to determine natural OSL signal.

D_e is determined on the OSL reader by comparing the signals from known lab radiation doses to the signal from the natural sample. D is found using calculations based on concentrations of K, U, Th, water content, and calculation of the cosmic contribution from burial depth, location, elevation and age. D_e, the equivalent dose, is the laboratory dose of beta or gamma radiation in gray, Gy, needed to induce luminescence equal to that acquired by the sample subsequent to the most recent bleaching event, while D, the dose-rate in Gy/Ka, is the dose of alpha, beta, gamma, and cosmic radiation per unit time that the sample received while buried (Ronald Goble personal conversation). The age then is found using the following calculation: Age= D_e/D= Gy/ (Gy/Ka) = Ka (Figure 3.9).

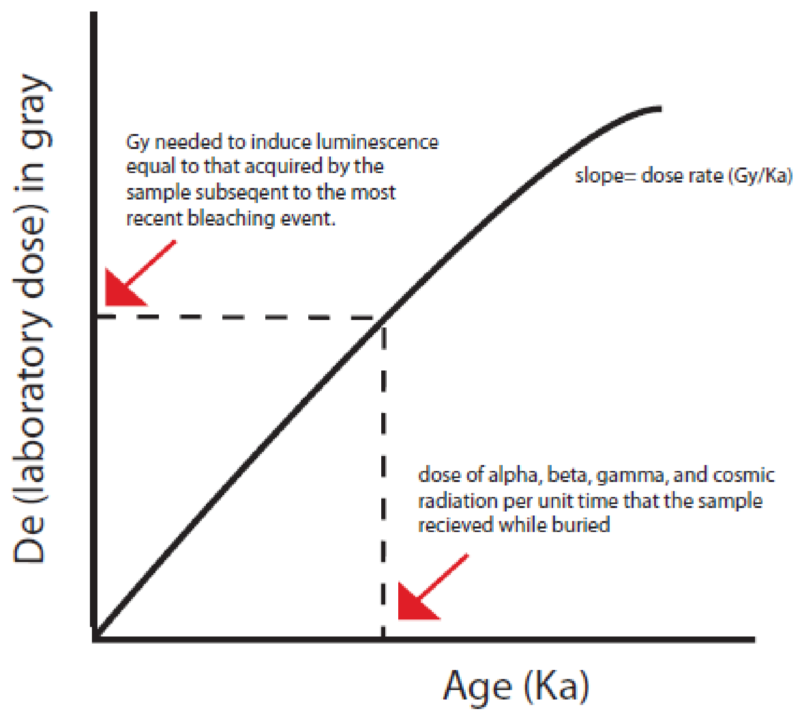

Figure 3.9: Example graph for hypothetical sample to determine age. "The paleodose (Gy) increases with increased age (ka), and the dose rate is the slope (Gy/ka). Different dose rates would plot as different lines. A similar relationship exists between the equivalent dose (Gy) and the elapsed time for a given laboratory regenerative dose (s), with the slope being the laboratory Sr-90 source calibration (Gy/s)" (Ronald Goble personal conversation).

OSL sample retrieval does have its own set of inherent problems. The researcher needs to ensure that the sample is taken in a location with pure sand about 0.3 meters on either side of the preferred sample to ensure consistency during analyses. Consistency is important due to the differences in radiative properties between minerals, such as quartz and feldspar. The researcher also needs to ensure that the PVC pipe is correctly attached to the OSL sampler. Incorrect attachment could lead to loss of PVC pipe down sample hole, or loss of sample from inside of the PVC pipe. Loss of sample sand means mixing of sediment, a new hole would need to be dug to ensure that mixing is avoided or the hole might be salvaged if dug deeper. Sample processing may return inaccurate dates if, the sample was reset due to exposure during fluvial transport, incomplete resetting of the signal due to inadequate light exposure in the fluvial environment, and due to the fact that quartz signals reset more rapidly than feldspar signals again making quartz the desired mineral (Wallinga, 2002).

CHAPTER 4

RESULTS

4.1 Process of borehole identification

Borehole logging is based on sediment characteristics (Figure 4.1). Each facies can be identified based on sediment texture and grain size, and includes coarse, fine, and heterogeneous textural lithofacies. Coarse grained sand can be correlated to Missouri River sand bars. Fine grained clays can be correlated to overbank fines and passive channel fills, and heterogeneous mixtures can be identified as splays or active channel fill. Other characteristics that are used are matrix coloring, mottle, and stains (Figure 4.2 and 4.3) which are useful to identify whether the environment was rich in oxygen or depleted in oxygen. An example of a low oxygen environment in this study can be associated with oxbow lakes. Organic material is common in oxbow lake fills.

Figure 4.1: Example of fluvial sediments

Figure 4.2: Silty Loam vs. Clay

Figure 4.3: Iron staining

Figure 4.4: Size distribution of glacial deposits within northern bluffs

The Missouri River deposits range from clay rich overbank fines which are densely packed and cohesive to coarse grained bar sands which lack cohesion. Within the C horizon (the C horizon is the lower soil zone that contains partially weathered parent material) of the Missouri deposits, Simpson (1960) has classified a secondary horizon called the Cca horizon. Sediments within this horizon are represented by accumulations of secondary calcium carbonate precipitations. This Cca horizon ranges from a few inches thick to approximately 3 feet thick and can be found from several inches below to approximately 5 ft. below the ground surface. Flint (1949 a, pg. 298) offers two reasons for the calcium carbonate accumulations 1) ordinary evaporation within the permeable soils and 2) evaporation by transpiration of soil moisture by plants.

Each borehole is sampled and described in 10cm increments. Vertical changes in the lithofacies can be detected based on the above characteristics. A total of 188 boreholes were sampled across six quadrangles (Figure 4.5). Average penetrated thickness of channel fill are as follows: Menominee 3-5 meters, Mission Hill 2-6 meters, Meckling 3-7.8 meters, Gayville 2-9.1 meters, and Saint Helena 4-9.4 meters. Average backswamp depths are as follows: Mission Hill 5.9-7 meters, Gayville NE 1-9 meters, and Gayville 1-9.2 meters.

Three example boreholes from the Mission Hill quadrangle are discussed here; these boreholes correspond to the main paleo-loop in this quadrangle (Figure 4.6). MOV-MH-002 does not show a distinct fining upwards trend (i.e. 2.1-2.9 meters is oxidized, well sorted, medium grained sand while 0.1-2.0 meters alternates between L, SL, LS, and S; plant matter was found in the upper 0.3 meters). MOV-MH-018 does show a general fining-upward trend with a few 10cm increments showing facies not within the upward fining pattern. This borehole is oxidizing throughout and plant matter was found in the following increments: 0.1-0.7, 1.2, and 2.1-2.5 meters. MOV-MH-019 does not show a typical fining-upward trend, however, its location is unique. It is located directly below the adjacent bluff. 5.7-5.9 meters are distinctly a mixture of mud and very coarse sand, 1.9-5.6 meters shows a fining up pattern from Loam to Clay, while 0.1-1.8 meters shows a separate mostly fining up pattern. This borehole is an oxidizing environment throughout and plant matter was found in the following increments; 0.1-0.8, 1.5-1.6, 1.8, 2.3, 2.5, 3.2, 3.5, 3.7, 4.1, and 5.0 meters (Table 4.1).

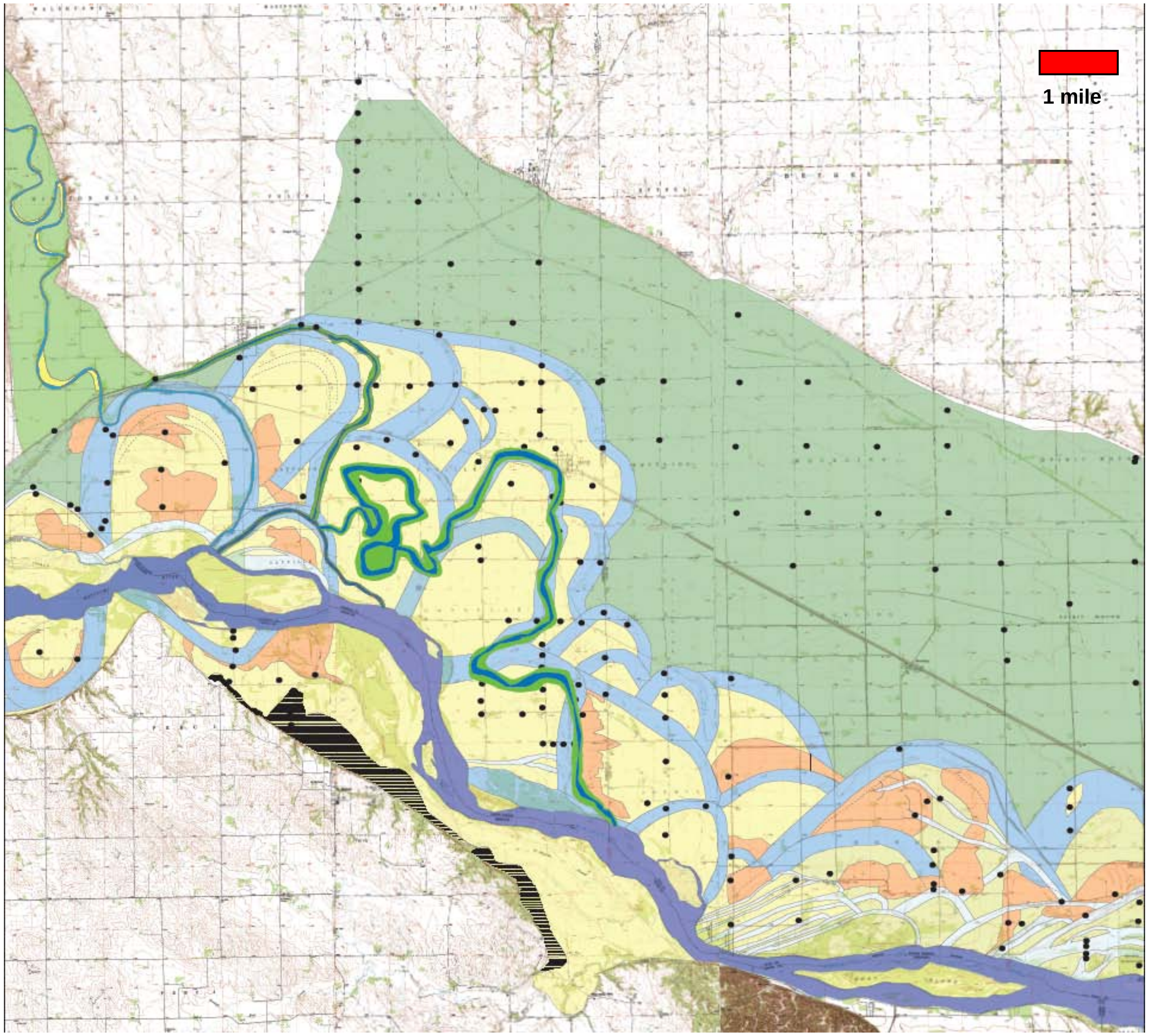

Figure 4.5: Distribution of Boreholes

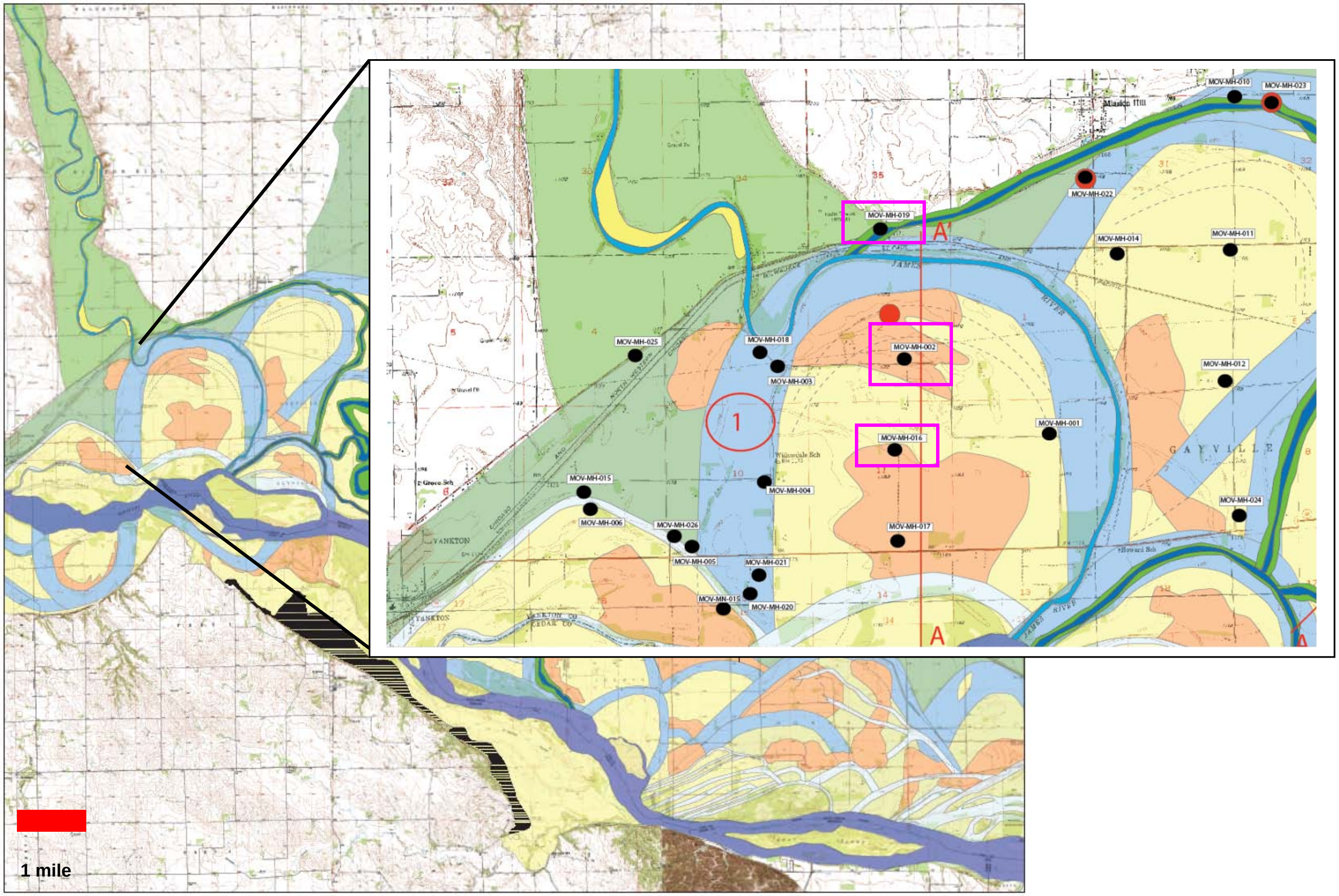

Figure 4.6: Mission Hill quadrangle showing select borehole IDs.

Table 4.1 Borehole Interpretation

Depth	MOV-MH-018		MOV-MH-002		MOV-MH-019	
	FACIES	INTERP.	FACIES	INTERP.	FACIES	INTERP.
0.1	SiC[7]		L		SiC	
0.2	SiC		SL		SiL	
0.3	SiC		SL		SiL	
0.4	SiC		LS		SiC	
0.5	SiC		S		SiC	
0.6	L[8]		S		SiC	
0.7	SiC		LS		SiC	
0.8	SiC		LS		SiL	
0.9	SiL		LS		SiL	
1.0	SiC		LS		L	
1.1	C[9]		LS		L	
1.2	SiC		LS		L	
1.3	SiC		LS		L	
1.4	C		S		L	
1.5	SiC		S		SiL	
1.6	SiC		S		L	
1.7	SiC		SL		L	
1.8	SiL		LS		L	
1.9	SiC		LS		C	
2.0	SiC		LS		C	
2.1	SiC		S		C	
2.2	C		S		SiC	ACF[10] James
2.3	C		S		C	
2.4	SiL		S		C	
2.5	SL		S		C	
2.6	SL		S		C	
2.7	SL		S		C	
2.8	L		S		C	
2.9	L		S	Splay	C	

[7] Silty Clay
[8] Loam
[9] Clay
[10] ACF: Active Channel Fill

Table 4.1 cont.

Depth	MOV-MH-018		MOV-MH-002		MOV-MH-019	
	FACIES	INTERP.	FACIES	INTERP.	FACIES	INTERP.
3.0	L				C	
3.1	L				C	
3.2	SL[11]				C	
3.3	LS[12]				C	
3.4	LS				C	
3.5	LS				C	
3.6	S[13]				C	
3.7	S				C	
3.8	S				C	
3.9	S				C	
4.0	S	ACF			C	
4.1					C	
4.2					C	Floodplain
4.3					SiC	
4.4					SiC	
4.5					SiC	
4.6					SiC	
4.7					SiC	
4.8					L	
5.0					L	
5.1					L	
5.2					L	
5.3					L	
5.4					L	
5.5					L	
5.6					L	Outwash
5.7					Mud/vcS	
5.8					Mud/vcS	
5.9					Mud/vcS	Glacial

[11] Sandy Loam
[12] Loamy sand
[13] Sand

4.2 Surficial geologic maps: Mission Hill to Meckling reach of the Missouri River Valley

4.2.1 Pleistocene

Detailed maps were made of the six quadrangles directly associated with the study area: Mission Hill (08'), Menominee (08'), Gayville (07'), Saint Helena (07'), Gayville NE (07'), and Meckling (07'), as well as the Vermillion quadrangle (08') which provides dating on the Pleistocene deposits. Pleistocene deposits are mapped in the study area in Gayville NE, Gayville, and Mission Hill at varying depths along the north bluffs. Depths of Holocene deposits in the Gayville NE quadrangle are based on Isopach lines from borehole data and map a depth range of 2 meters to 8 meters beneath Holocene backswamp strata. Depth of Pleistocene deposits increased downdip (Figure 4.8). Scott Lundstrom (2006) used ^{230}Th/U dating techniques on calcite laminae found within ground moraine on the land surface within the James River valley and found dates approximately 10.5 to 12.5 Ka (Figure 4.7). These findings indicate ground-water discharge from glacial aquifers that closely followed the latest Wisconsin advance of the James Lobe (Lundstrom 2006). These dates closely follow the last Wisconsin advance of the James Lobe. An REU student associated with UTA during the field season of 2008 (Graham Calvert) dated two sand samples from the base of the moraine within the Vermillion River Valley that dated sedimentation starting prior to 16 ka and lasting through 10 Ka. These dates were established using OSL dating. This date range encompasses the Lundstrom dates for the Pleistocene deposits (Figure 2.7).

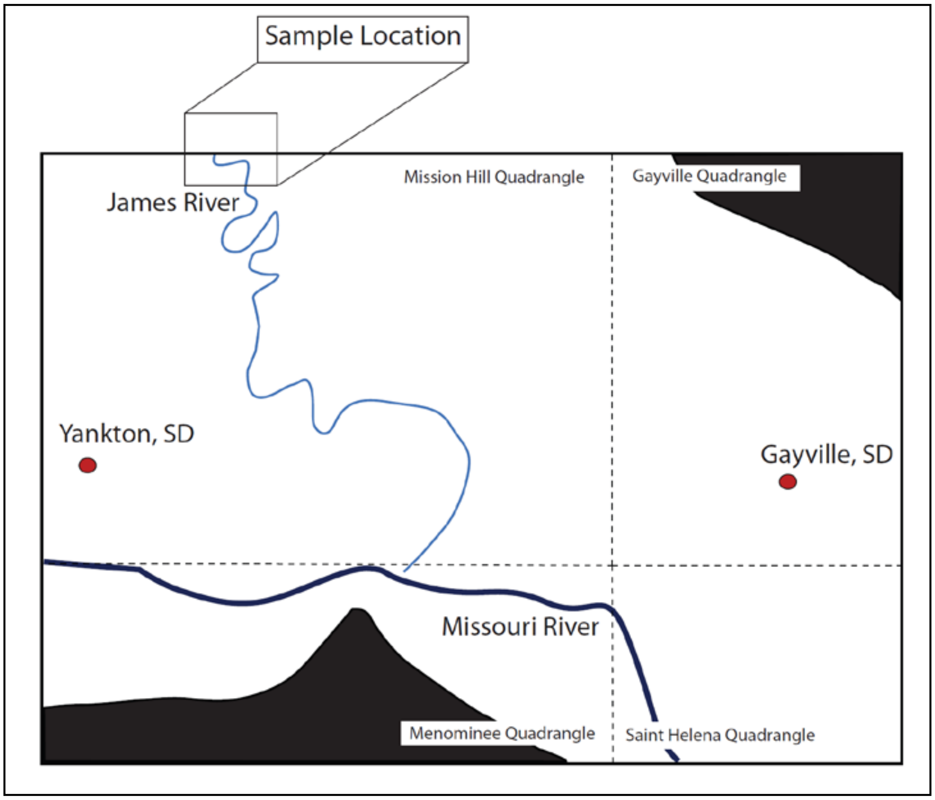

Figure 4.7: Approximate sample location for $^{230}Th/U$ date

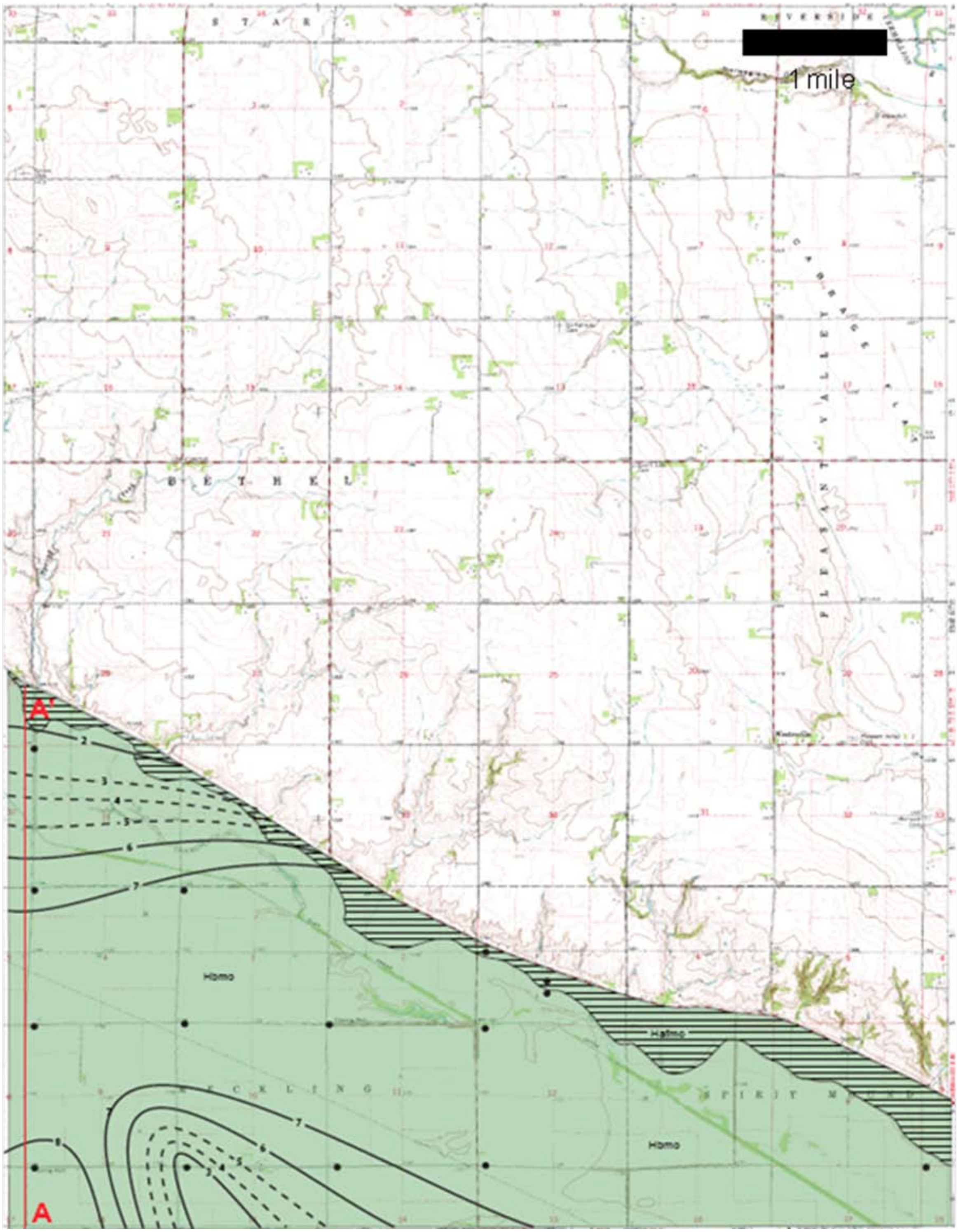

Figure 4.8: Gayville NE quadrangle showing Isopach lines of glacial till depths (Ward, Dustin E.).

4.2.2 Holocene Deposits

The Missouri River Valley widens drastically at Yankton, SD, from the 3-6 Km typical of most of South Dakota to 10-16 Km which continues downstream until the choke point at Vermillion, SD (Lundstrom et. Al. 2006). The Holocene meander loops within this 10-16 Km wide valley are large scale meander loops. The James River also enters the Missouri River Valley here. Paleo James River deposits are mapped across Mission Hill, Gayville NE, and Saint Helena quadrangles. The most upstream Holocene transition from meandering to braided morphology is mapped in the Meckling quadrangle. This transition in river morphology can be seen as far downstream as Missouri state (Holbrook et al 2006) (figure 4.9). Bar deposits mapped are large scale and proportional to the scale of the encasing paleo-channels (figure 4.10). Island-bar deposits are only mapped within the Meckling quadrangle and correlate to this braided morphology. Fine and heterogeneous fills of the large meander loops range from 4.0 meters to 8.8 meters depth across the study area (Figure 4.14).

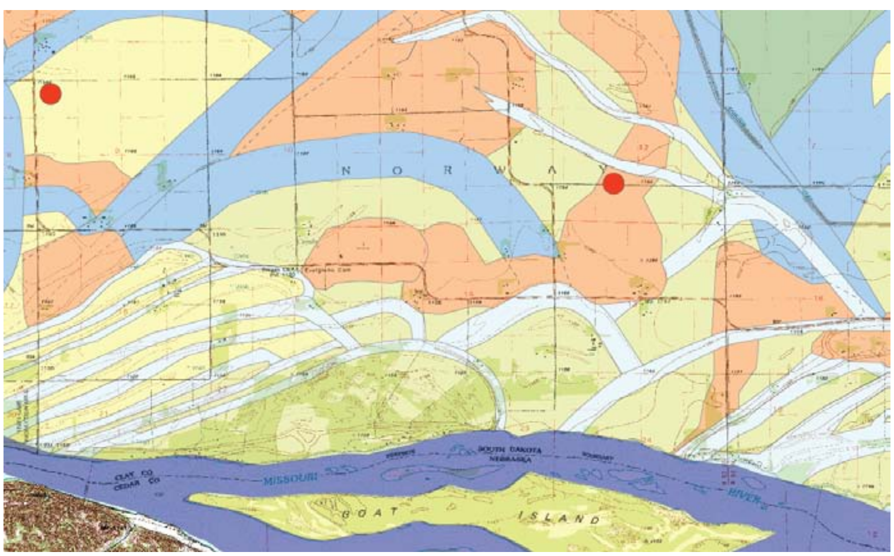

Figure 4.9: Braided river morphology within the Meckling quadrangle

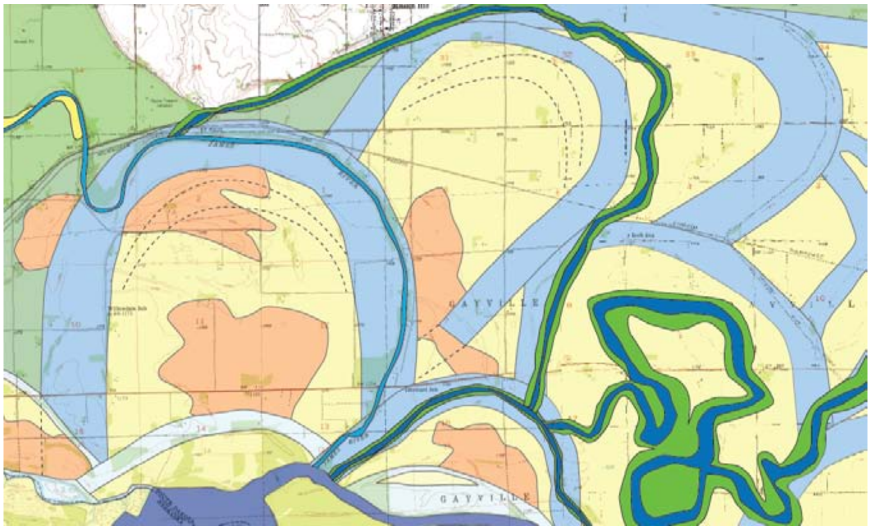

Figure 4.10: Large scale bars with encasing paleo-channels within Mission Hill quadrangle

Paleo-confluences of the James and Missouri Rivers are mapped in two locations within the St. Helena quadrangle with the modern confluence mapped in the Mission Hill quadrangle. OSL dates in the Mission Hill and St. Helena quadrangles constrain the interactions of the James and Missouri rivers between 2.59 ± 0.15 Ka and 0.82 ± 0.06 Ka (Figure 4.11). The three OSL dates within Mission Hill quadrangle constrain the three large Missouri loops at 2.59 ± 0.15 Ka, 1.83 ± 0.11 Ka, and 0.82 ± 0.06 Ka, while the OSL date within the Saint Helena quadrangle dates the James deposits here at 1.46 ± 0.10 Ka (Figure 4.12) (See Appendix C).

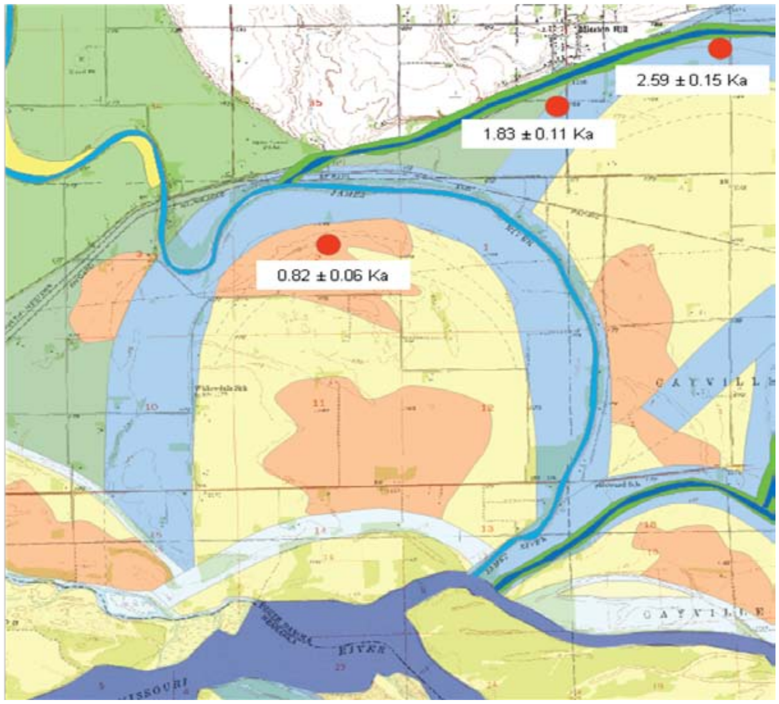

Figure 4.11: Mission Hill OSL dates

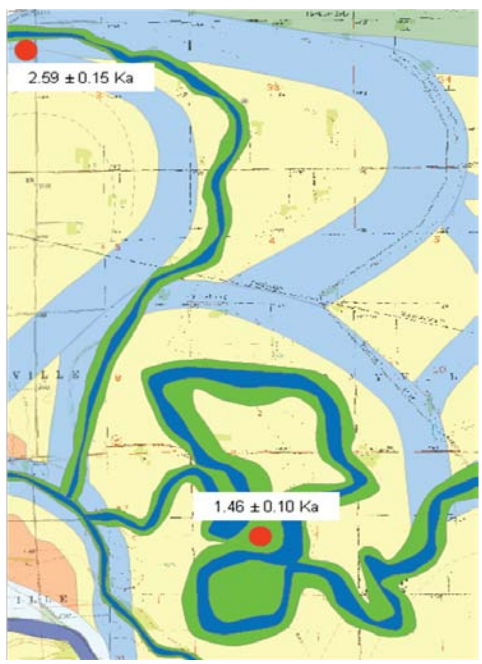

Figure 4.12: James River OSL date

4.2.3 Morphometrics of mapped allounits

Fourteen specific allounits mapped within the study area have been identified for paleohydrology, however, not all are examined here (Table 4.2, p. 63). The Missouri paleo-channels mapped can be loosely grouped based on characteristics such as width and radius of curvature. Point bar deposit geometry is directly linked to its engulfing meander loop. Splay deposits which are heterogeneous in geometry and are not discussed, and the backswamp floodplain are each references as one feature. Bridge (2003) and Williams (1986) offer equations to calculate bankfull mean depth and channel bankfull width based on a measured radius of curvature (Figures 4.13 and 4.14). Discrepancies between measured channel width and calculated channel bankfull width reflect differences between local measured channel width vs. a calculated average channel bankfull width. Measured width and depth for these channels are based on field data gathered, however, due to the nature of channels, boreholes may not be drilled through the thalweg. In order to get a sense of the maximum depth and widths of these channels, mathematical equations are used. These calculations and measurements will serve to determine discrepancies in energy and discharge between allounits of the James River size vs. allounits of the Missouri River size. The calculations will also be verified against measured width and depth of these allounits.

TABLE 2 Equations for Estimating Meander Geometry from Channel Size

Equation Number	Equation[a]	Number of Data Points	Applicable Range	Standard Error (Log Units)	r^2
(22)	$L_m = 7.5W_b^{1.12}$	191	$1.5 \leq W_b \leq 4{,}000$ m	0.219	0.93
(23)	$L_a = 5.1W_b^{1.12}$	102	$1.5 \leq W_b \leq 2{,}000$ m	0.220	0.94
(24)	$B = 4.3W_b^{1.12}$	153	$1.5 \leq W_b \leq 4{,}000$ m	0.241	0.92
(25)	$R_c = 1.5W_b^{1.12}$	79	$1.5 \leq W_b \leq 2{,}000$ m	0.182	0.94
(26)	$L_m = 30A_b^{0.65}$	66	$0.04 \leq A_b \leq 20{,}900$ m^2	0.202	0.92
(27)	$L_a = 22A_b^{0.65}$	41	$0.04 \leq A_b \leq 20{,}900$ m^2	0.246	0.91
(28)	$B = 18A_b^{0.65}$	63	$0.04 \leq A_b \leq 20{,}900$ m^2	0.194	0.93
(29)	$R_c = 5.8A_b^{0.65}$	28	$0.04 \leq A_b \leq 20{,}900$ m^2	0.234	0.93
(30)	$L_m = 240D_b^{1.52}$	66	$0.03 \leq D_b \leq 18$ m	0.391	0.73
(31)	$L_a = 160D_b^{1.52}$	41	$0.03 \leq D_b \leq 17.6$ m	0.354	0.81
(32)	$B = 148D_b^{1.52}$	63	$0.03 \leq D_b \leq 18$ m	0.339	0.81
(33)	$R_c = 42D_b^{1.52}$	28	$0.03 \leq D_b \leq 17.6$ m	0.399	0.81

SOURCE: Williams, 1986.

[a] Reduced major axis. W_b = channel (bankfull) width; A_b = bankfull cross-sectional area; D_b = bankfull mean depth; L_m = meander wavelength; L_a = meander arc distance; B = meander belt width; R_c = loop radius of curvature; r = correlation coefficient.

Figure 4.13: Morphometric equations

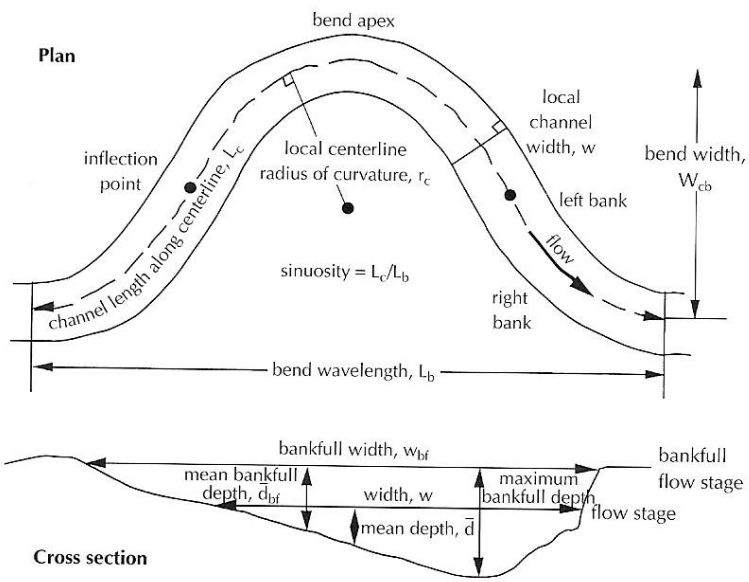

Fig. 5.15 Definition of geometrical parameters of single curved channels. Most geometrical parameters vary with flow stage, and parameters such as width, mean depth, and radius of curvature vary along the length of the channel.

Figure 4.14: Definition of common morphometric terms (Bridge, 2003).

Allounit #1 is the dominant meander loop in the Mission Hill quadrangle (Figure 4.15). The measured localized channel width[14] is approximately 724.2 meters (.45 miles) and has a

[14] Width= measured localized channel width based on drawn map and topographic scale

radius of curvature[15] of approximately 1207.0 meters (.75 miles). We calculate a predicted W_b[16] of approximately 392.92 meters and a D_b[17] of approximately 9.11 meters using Williams, 1986 equations for estimating meander geometry from channel size (equations 25 and 33). However, based on the boreholes for MOV-MH-003 and MOV-MH-018 we find channel depth to be 3 and 4 meters, respectively. MOVMH-003 was drilled on the outer edge of the channel is not representative of thalweg depth, while MOV-MH-018 was terminated at 4 meters, before reaching sand consistent with channel bottom, therefore it is not representative of thalweg depth either.
One major splay associated with allounit #1 is identified using MOV-MH-002 and a depth of 2 meters is drilled before reaching sand facies, giving a minimum of 2 M thickness for this splay. This loop has an associated OSL date of 0.82 ± 0.06 Ka; this date corresponds to MOV-MH-002 and was taken at 3.0 meters through a splay within a point bar allounit. MOV-MH-004 becomes a reducing environment at 2.8 meters; terminal depth is at 4.0 meters, however, the borehole is located at channel edge. Looking at the calculated D_b we see that channel depth should be at approximately 9.11 meters.

Allounit #2 is a shallow secondary paleo loop in the Menominee quadrangle (Figure 4.16). It has an associated splay 2.2 meters thick before reaching sand (MOV-MN-010). This loop is 2.2 meters thick before reaching sand and has a terminal depth of 3.0 meters.

Allounit #4 is a paleo loop contained within the Mission Hill and Gayville quadrangles (Figure 4.17), however, its measurements differ from allounit 1 and 3. It has a width of approximately 402.34 meters (0.25 miles) and a radius of curvature of approximately 1609.34 meters (1 mile). It has a W_b of approximately 507.99 meters and a D_b of approximately 11.01 meters. MOV-GV-018, Missouri River paleo-loop, was drilled through 8.8 meters of channel fill before refusal. Its point bar houses substantial pJd[18], with an associated OSL date of 1.46 ± 0.10

[15] Radius of curvature= measured based on drawn map and topographic scale
[16] W_b = Channel bankfull width (calculated)
[17] D_b = Bankfull mean depth (calculated)
[18] paleo James deposits

Ka; this sample corresponds to MOV-SH-001 and was taken at 4.6 meters through a pJd allounit.

Allounit #5 is a paleo loop in the St. Helena quadrangle and contains pJd (Figure 4.19). It has a width of approximately 643.74 meters (0.4 miles) and a radius of curvature of approximately 1850.75 meters (1.15 miles). It has a W_b of 575.51 meters and a D_b of 12.10 meters. MOV-SH-028 is representative of feature #5 and was drilled through 8.6 meters of channel fill.

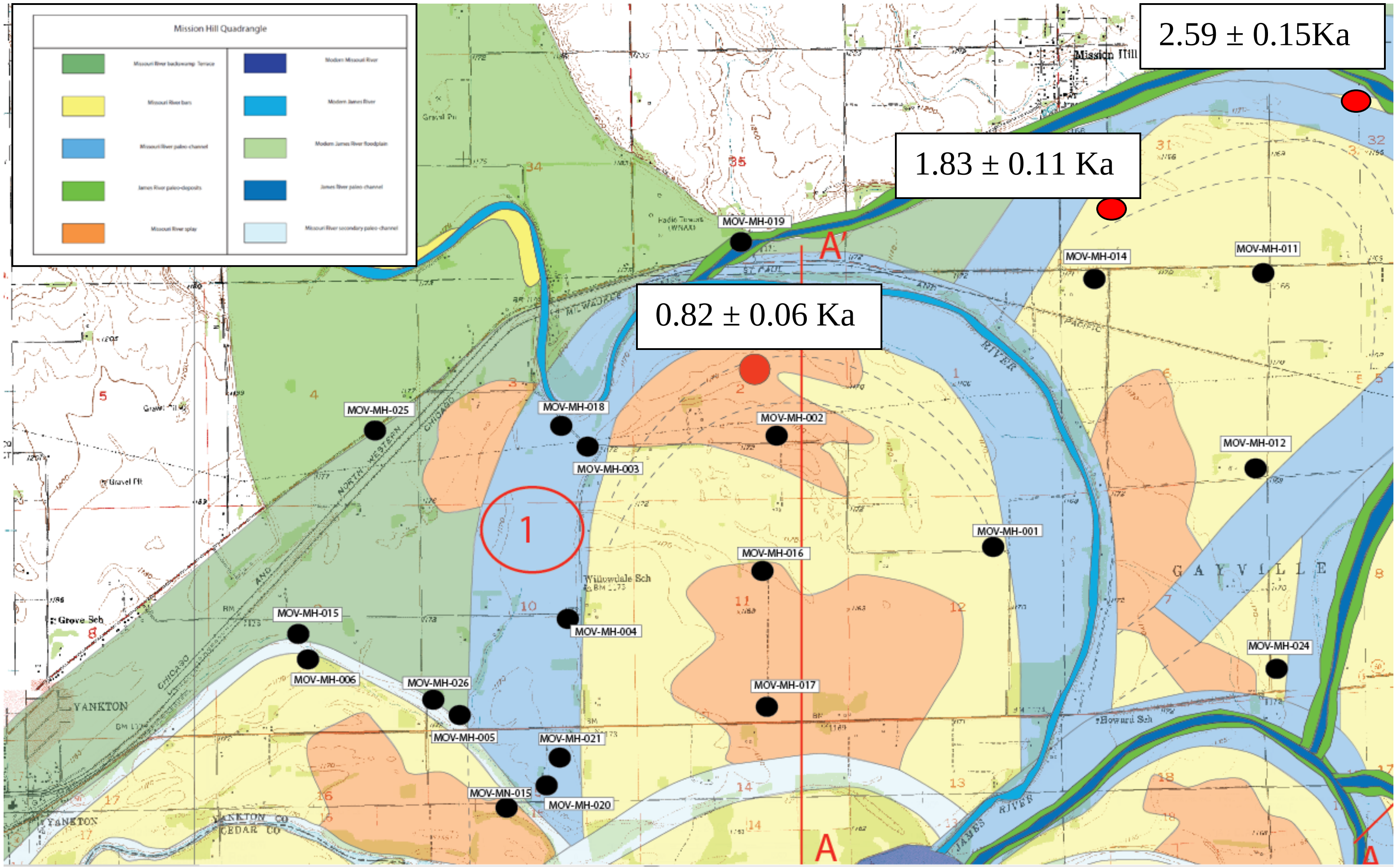

Figure 4.15: Mission Hill quadrangle showing borehole IDs and locations. For cross-section see appendix A.

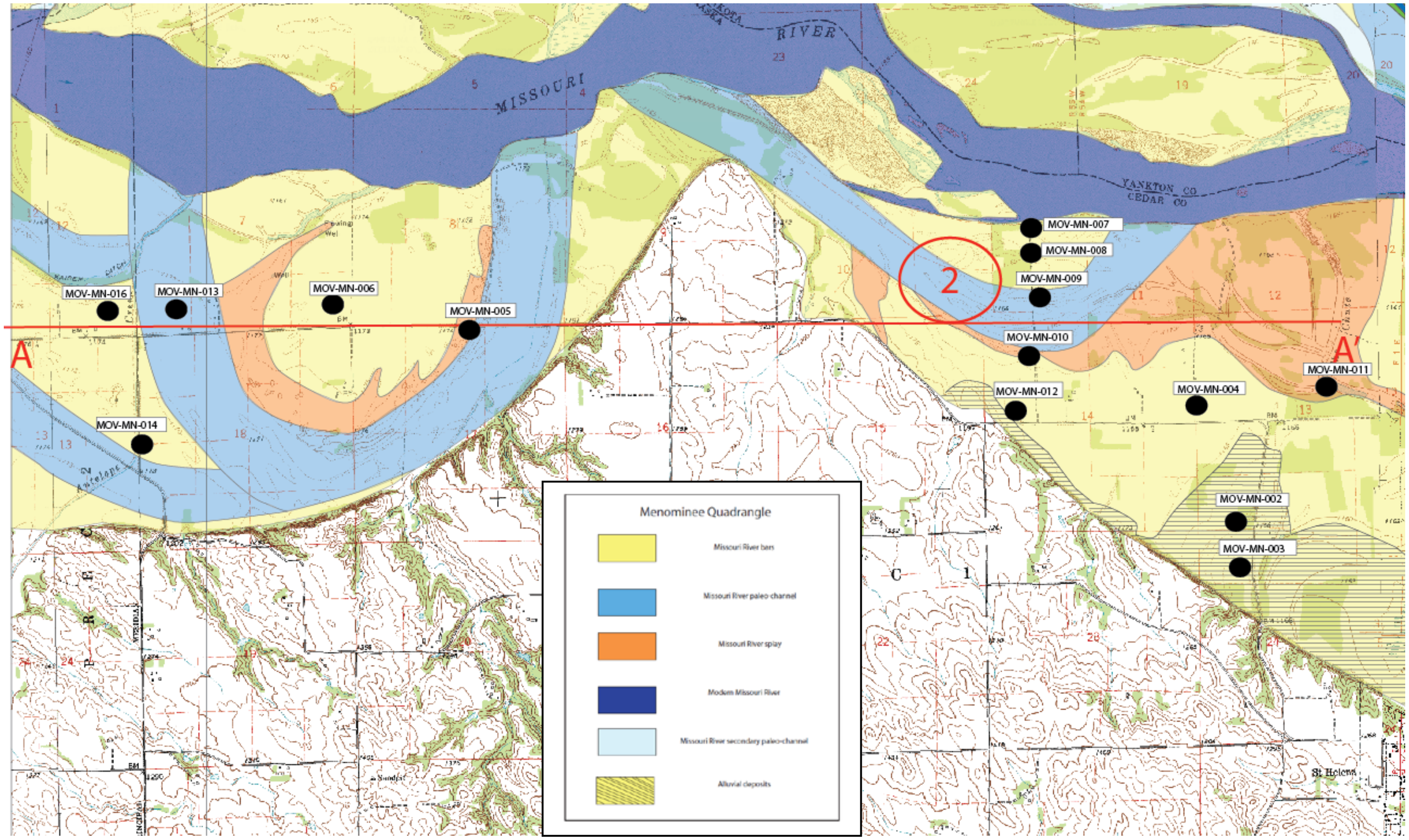

Figure 4.16: Menominee quadrangle showing Borehole IDs and locations. For cross-section see appendix A.

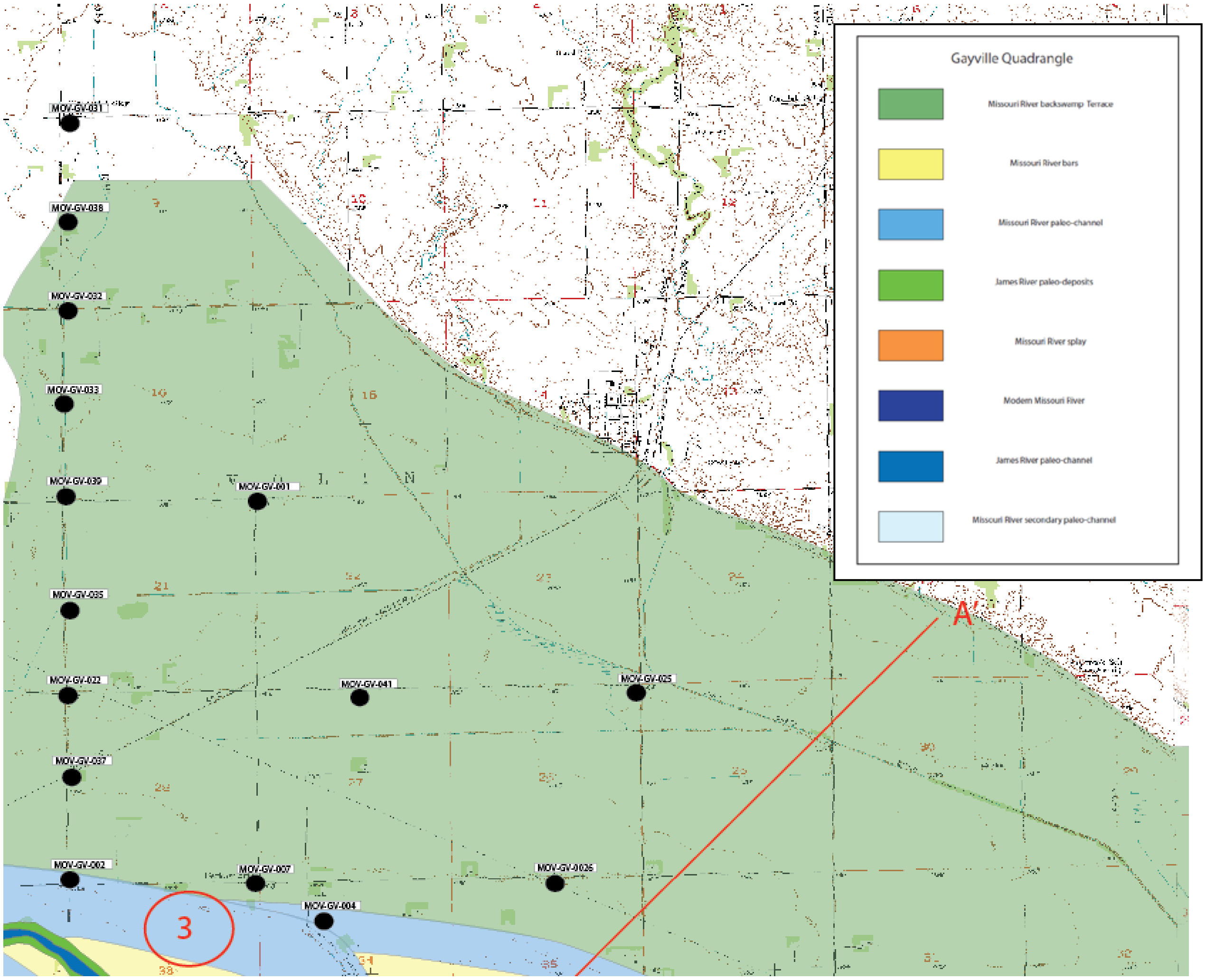

Figure 4.17: Gayville quadrangle showing borehole IDs and locations (modified from Alexandrowicz, Neal). For cross-section see appendix A.

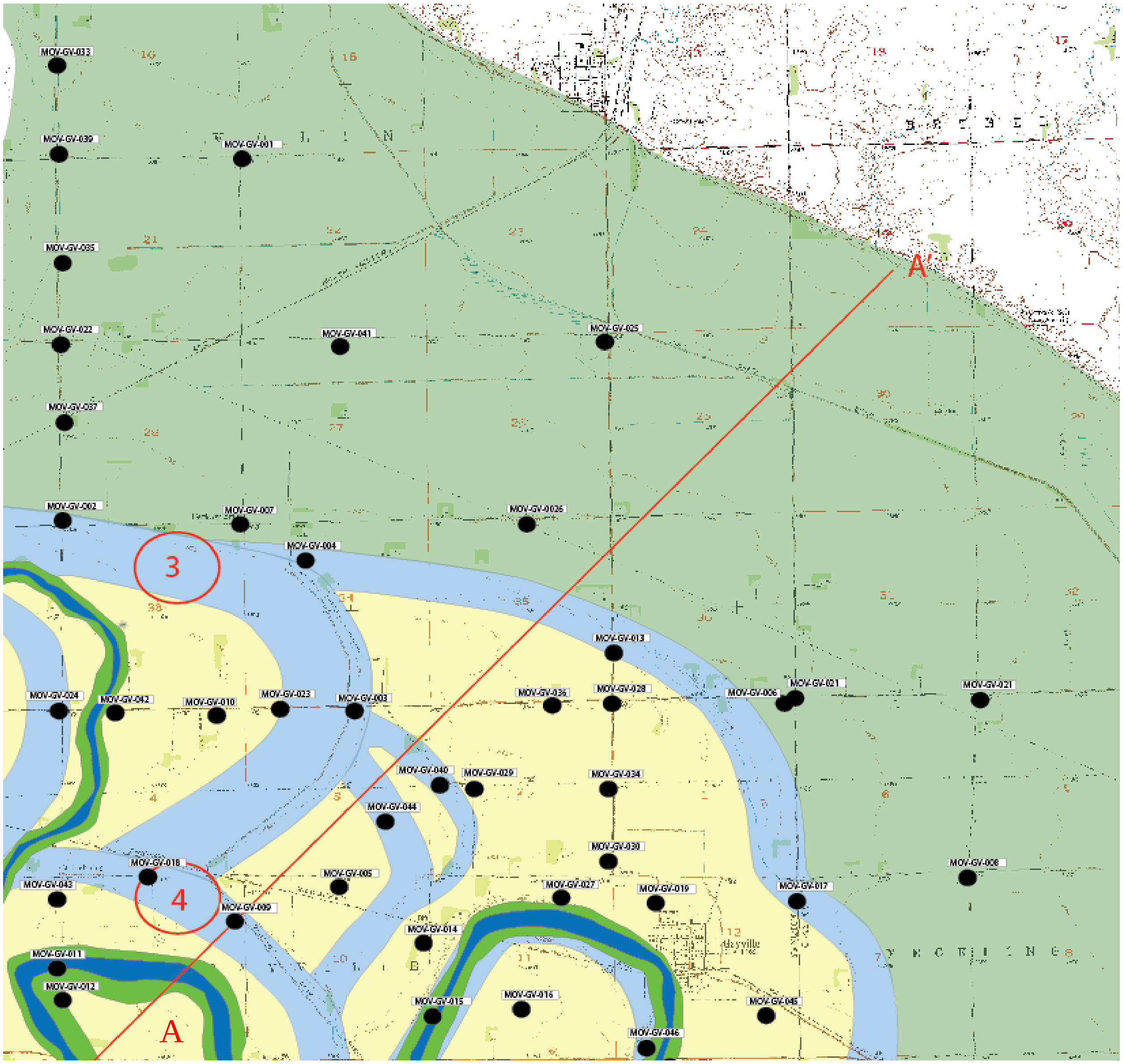

Figure 4.18: Gayville quadrangle showing borehole IDs and locations (modified from Alexandrowicz, Neal). For cross-section see appendix A.

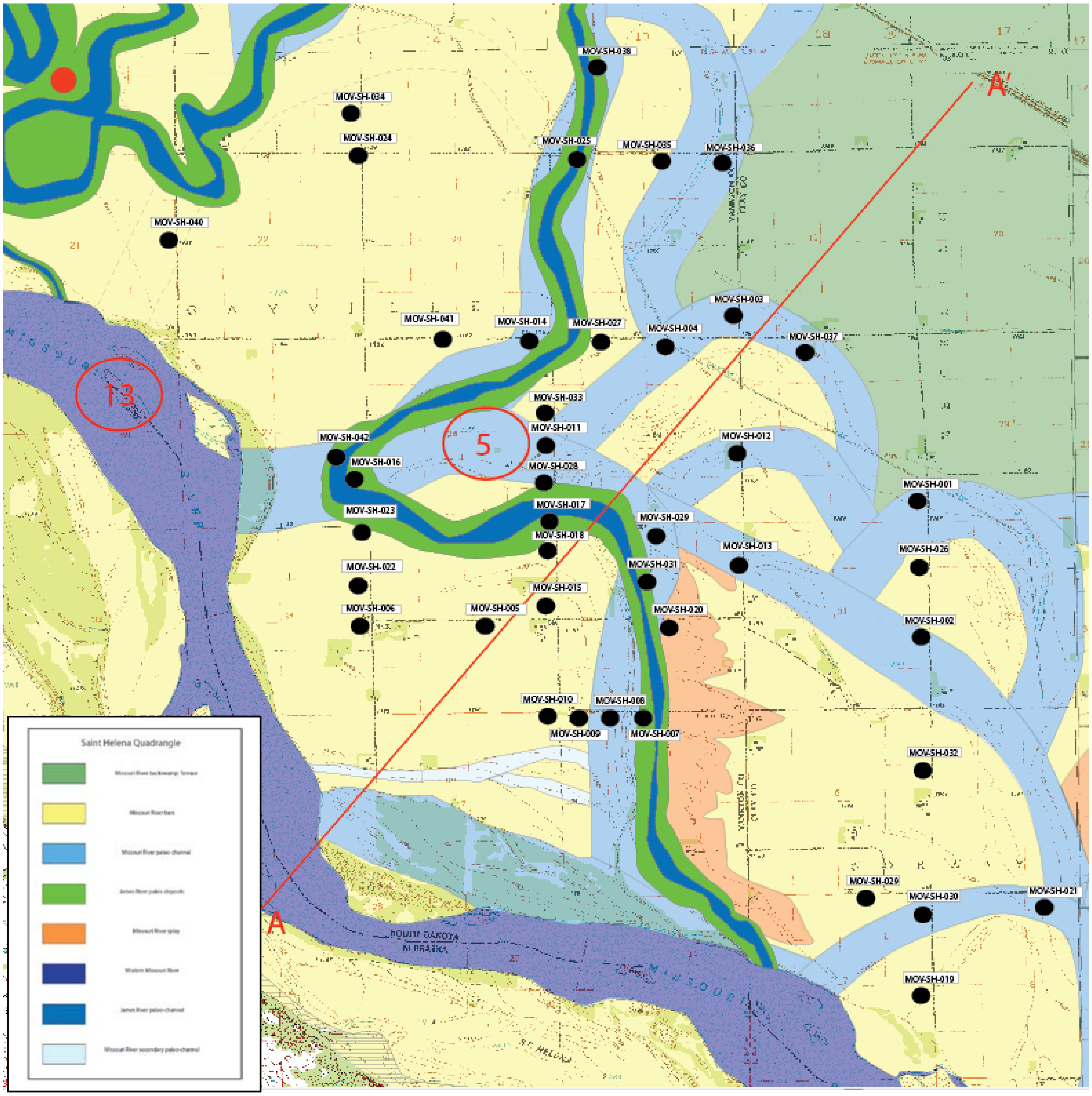

Figure 4.19: St. Helena Quadrangle showing Borehole IDs and locations (Modified from Garrett, Jordan). For cross-section see appendix A.

Allounit #6 is the floodplain backswamp veneer (Figure 4.20). Looking at the Gayville NE quadrangle Isopach map (Figure 4.8) we see thickness ranging from 2-8 meters. MOV-GN-002 has a terminal depth of 7.8 meters with refusal in Pleistocene deposits. Gayville quadrangle includes four boreholes with possible Pleistocene deposits. Along the bluffs Pleistocene deposits are found at MOV-GV-031 at 3.2 meters, MOV-GV-032 at 0.6 meters, and MOV-GV-033 at 2.0 meters. Borehole MOV-GV-001 has Pleistocene deposits at 5.5 meters, however, this borehole is not directly adjacent to the bluffs. The backswamp thickness within the Gayville and Gayville NE quadrangles increase down dip from an approximate minimum of 1 meter to 10 meters near the Vermillion quadrangle.

Allounit #9 (Figure 4.21) is a composite of many small units that collectively reveal the braided morphology seen in the Meckling quadrangle. MOV-MK-009 and 010 were drilled to a depth of between 3.0 and 4.0 meters. MOV-MK-009 has no plant matter while MOV-MK-010 has plant matter at 0.3-0.5, 0.7-1.0, 1.7, 2.3, and 2.7-2.9 meters. This shift in morphology can be seen in the Meckling cross-section (Figure 4.22). Channel width and depth vary greatly between the meandering loop and the braided section. The braided channels in the Meckling quadrangle are on average 3-4 meters thick. The braided channels thickness contrast with the larger paleo channels found within the study area; the thickest paleo-loops are found within the Saint Helena and Gayville quadrangles and range from 4.3-8.8 meters, while the shallower paleo-loops are found within the Menominee quadrangle and range from 3-5 meters.

Allounit #10 is a paleo loop within the Meckling quadrangle (Figure 4.21). It has a width of approximately 724.20 meters (0.45 miles) and a radius of curvature of approximately 2011.68 meters (1.25 miles). Its W_b is 619.99 meters while its D_b is 12.75 meters (using the Williams 25 and 33 equations). This width and depth were calculated for MOV-MK-001, however, actual depth based on drilling is 4.8 meters. Because this borehole was sampled near the edge of the channel, it is not representative of thalweg depth. This loop has two major splays associated with it, MOV-MK-029 has a borehole depth of 3.9 meters thick before reaching sand facies while MOV-MK-002 has a borehole depth of 2.7meters thick before reaching bar facies. Due to the heterogeneous nature of splays, they are indistinguishable from other allounits except those that are clay rich. On average, however, a splay sequence will be less than 1-2 meters thick. This loop also has some secondary braided channels within its bar. This loop has an associated OSL date of 2.61 ± 0.15 Ka through splay overlying point bar allounit.

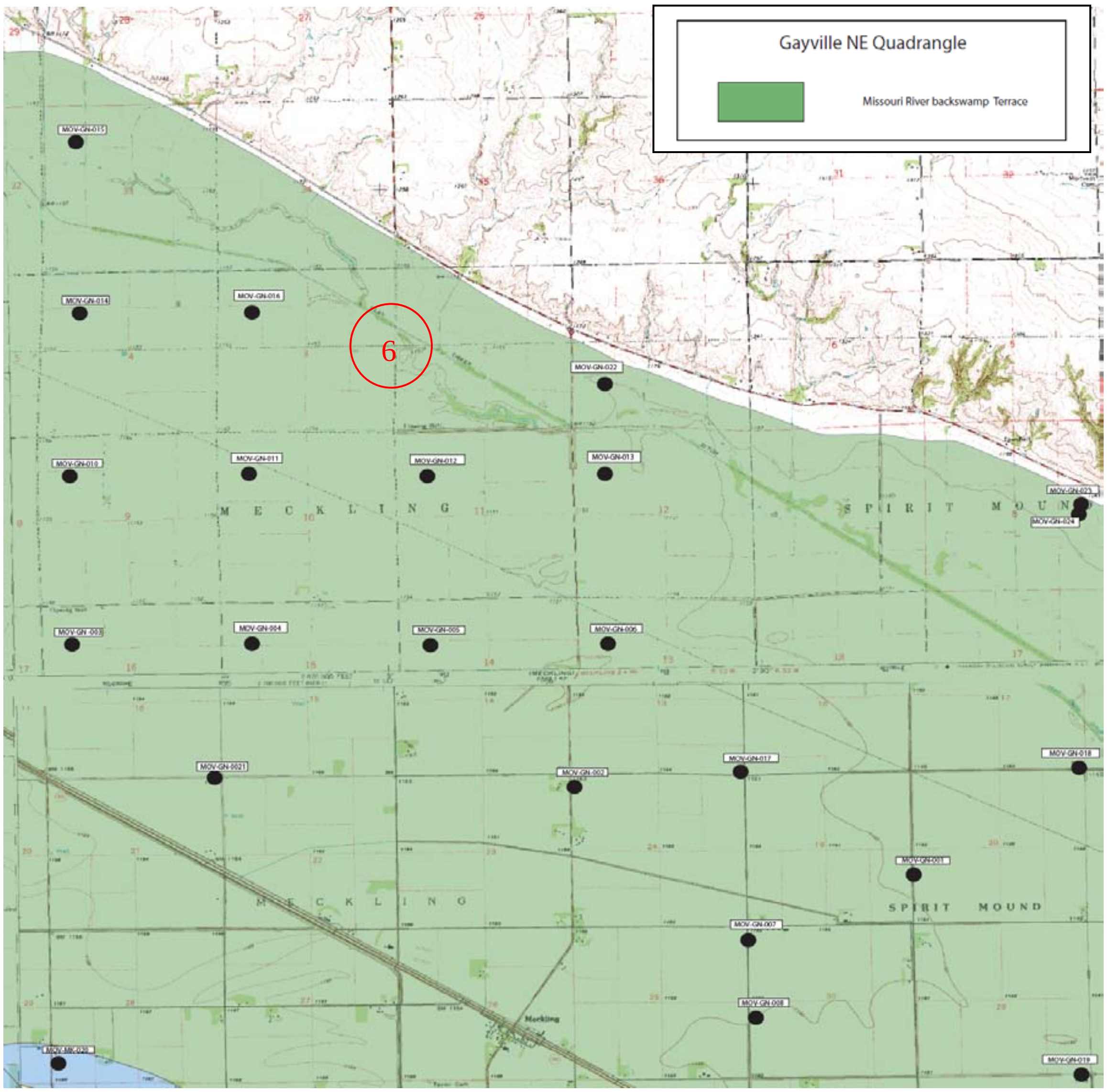

Figure 4.20: Gayville NE quadrangle showing borehole IDs and locations (modified from Ward, Dustin E.). For cross-section see appendix A.

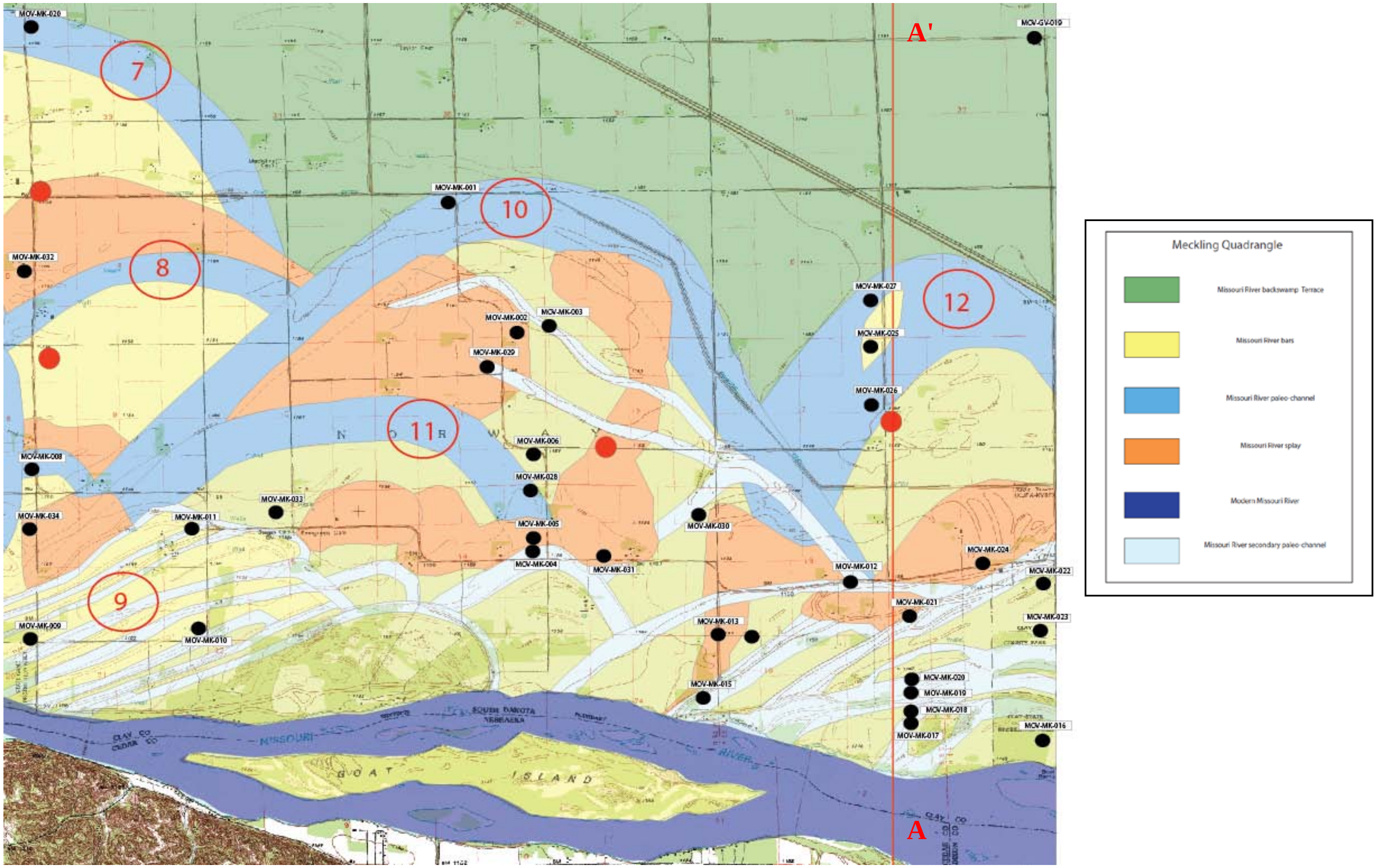

Figure 4.21: Meckling quadrangle showing borehole IDs and locations. For cross-section see appendix A.

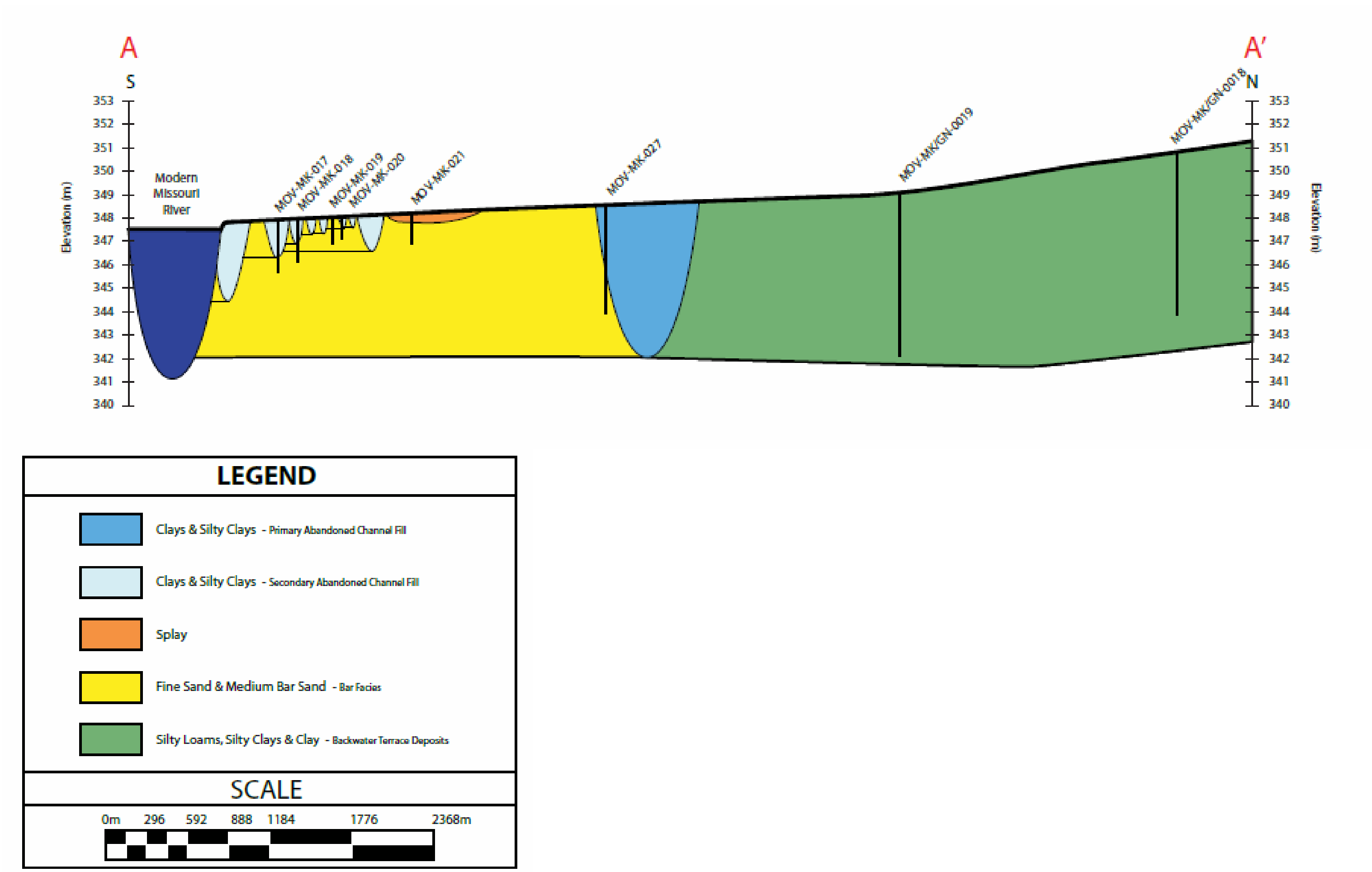

Figure 4.22: Meckling Quadrangle showing braided morphology, feature 11. Cross-section shows width and depth variations between (secondary) braided channels and main Missouri River paleo-channels. Splay sequence can also be seen over bar deposits.
(Moreno, 2007)

Allounit #11 is a paleo loop within the Meckling quadrangle. It has a width of approximately 482.80 meters (0.3 miles) and a radius of curvature of approximately 1609.34 meters (1 mile). Its calculated W_b is 507.99 meters while its calculated D_b is 11.01 meters (again using the William equations 25 and 33). Based on MOV-MK-028, we see an actual depth of 5.5 meters. Because this borehole was sampled near the edge of the channel it is not representative of thalweg depth. This loop has a splay overlain on it identified with two boreholes. MOV-MK-004 has approximately 0.5 meters of overbank fines before reaching a heterogeneous mixture of silts, loams and sands; sand facies is reached at 2.1 meters. MOV-MK-005 has approximately 0.5 meters of overbank fines before reaching a heterogeneous mixture of silts, loams, and sands; sand facies is reached at 2.6 meters. Based on borehole data from these two locations, this splay ranges in maximum thickness from approximately 1.4 meters to 1.9 meters. This loop is also cross-cut by a braided morphological shift.

Allounit #12 is the last major paleo meander loop within the Meckling quadrangle. It has a width of approximately 1207.01 meters (0.75 miles) and a radius of curvature of approximately 2011.68 meters (1.25 miles). Its W_b is 619.99 meters and a D_b of 12.75 meters. This loop shows a distinct mid-channel bar. This loop has an associated OSL date of 3.19 ± 0.15 Ka; this sample corresponds to borehole MOV-MK-042 and was taken at 3.1 M through a point bar allounit. MOV-MK-027 was drilled to a depth of 4.4 meters and MOV-MK-026 was drilled to a depth of 5.3 meters, however, both boreholes lie on the outer edges of this channel and are not representative of thalweg depth.

Allounit #13 is the Modern Missouri River. The modern Missouri is an island braid morphology river with a width of 965.61 meters (0.6 miles). Because it is no longer associated with meandering river morphology, we cannot use the same equations to determine W_b and D_b. The modern Missouri River has an approximate thalweg depth of 6.5m.

Allounit #14, the James River, has a width of approximately 209.21 meters (0.13 miles) and a radius of curvature of approximately 482.80 meters (0.3 miles). The James River has a calculated W_b of approximately 173.38 meters and a D_b of approximately 4.99 meter. The paleo

James River deposits found in Mission Hill has a measured depth of approximately 1.8-2.2 meters. Within the Saint Helena quadrangle, the James River deposits have an associated OSL date of 1.46 ± 0.10 Ka. The James deposits dated are overlying the bar of allounit #4; this sample corresponds to MOV-SH-001 and was taken at 4.6 meters through a pJd allounit. pJd associated with allounit #5 are represented by the following boreholes; MOV-SH-017 is 2.0 meters thick before reaching sand and is pJd, while MOV-SH-042 has pJd to 2.3 meters and MOV-SH-007 has pJd to 2.3 meters.

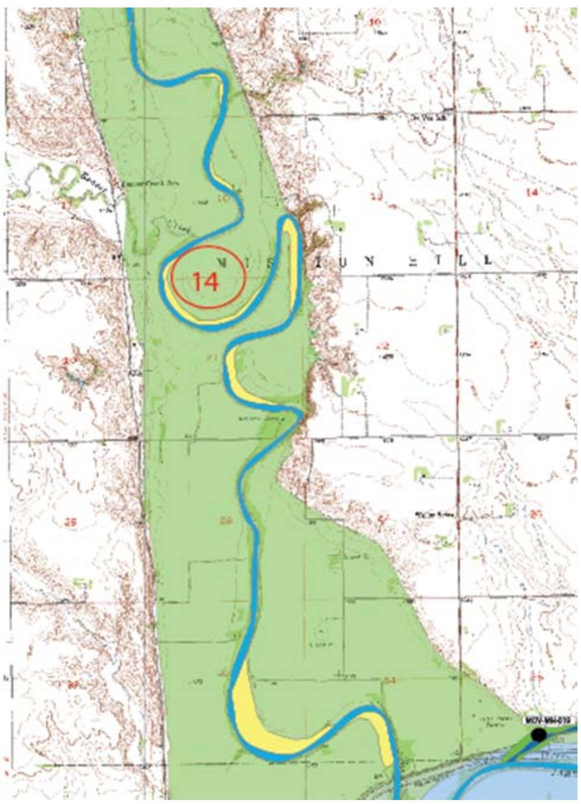

Figure 4.23: Allounit #14 found within the James River valley.

The James River takes on the characteristics of the Missouri River loops it is encased within. Examples of this can be seen in the paleo-loop southwest of allounit #2, the paleo-loop east of allounit #4, and within allounit #5. The James River is free to assume its own characteristics where it is free from the Missouri River paleo-loops, such as is seen where it crosses the bar associated with allounit #4.

The Williams calculations are a tool to determine average bankfull depth based on a measured width if field data is unavailable, however, looking at table 4.2 there is a major discrepancy between calculated D_b and drilled borehole depth. The calculated D_b values are closer to thalweg depth, while the actual field data ranges from approximate channel thalweg to shallow edge measurements and are only a measurement of channel depth where drilled. On average, deepest drilled channel depths are at 8.8 meters while deepest calculated depths are at 12.75 meters. As seen in allounit #2, if D_b were calculated from width, we would expect to have a channel with a maximum depth of approximately 11.01 meters; however, we can see from borehole data that the depth is 3 meters. The drilled depths are estimates of measured local depths while D_b is an estimate of full-calculated depths.

Table 4.2: Specific Identified features discussed

[19] Allounit #	1	2	3	4	5	6	7
Width ~	**724.20**	**402.336**	**724.20**	**402.34**	**643.74**	**NA**	**482.80**
RC ~	**1207.0**	**NA**	**1207.0**	**1609.34**	**1850.75**	**NA**	**1207.0**
W_b	**392.92**	**NA**	**392.92**	**507.99**	**575.51**	**NA**	**392.92**
D_b	**9.11**	**NA**	**9.11**	**11.01**	**12.10**	**NA**	**9.11**
IDS	**MOV-MH-018 MOV-MH-003**	**MOV-MN-009**	**MOV-GV-002 MOV-GV-003**	**MOV-GV-018 MOV-GV-009**	**MOV-SH-042 MOV-SH-016 MOV-SH-031**	**MOV-GN-002**	
Allounit	Channel	Channel	Channel	Channel	Channel	Backswamp floodplain	Channel
Drilled Depth	3-4 meters	3 meters	4.6-8.8 meters	4-8.8 meters	5.6-8.8 meters		

[19] all measurements in meters

Table 4.2 cont.

	Allounit # 8	9	10	11	12	13	14
Width ~	**321.87**	**NA**	**724.20**	**482.80**	**1207.0**	**965.61**	**209.21**
RC ~	**1287.48**	**NA**	**2011.68**	**1609.34**	**2011.68**	**NA**	**482.80**
W_b	**416.23**	**NA**	**619.99**	**507.99**	**619.99**	**NA**	**173.38**
D_b	**9.51**	**NA**	**12.75**	**11.01**	**12.75**	**NA**	**4.99**
IDS	**NA**	**MOV-MK-009 MOV-MK-010 MOV-MK-011**	**MOV-MK-001**	**MOV-MK-005 MOV-MK-004**	**MOV-MK-025 MOV-MK-026 MOV-MK-027**	**NA**	**NA**
Allounit	Channel	Braided River	Channel	Channel	Channel	Modern Missouri	James River
Drilled Depth		3-4 meters	4.8 meters		5.3 meters		

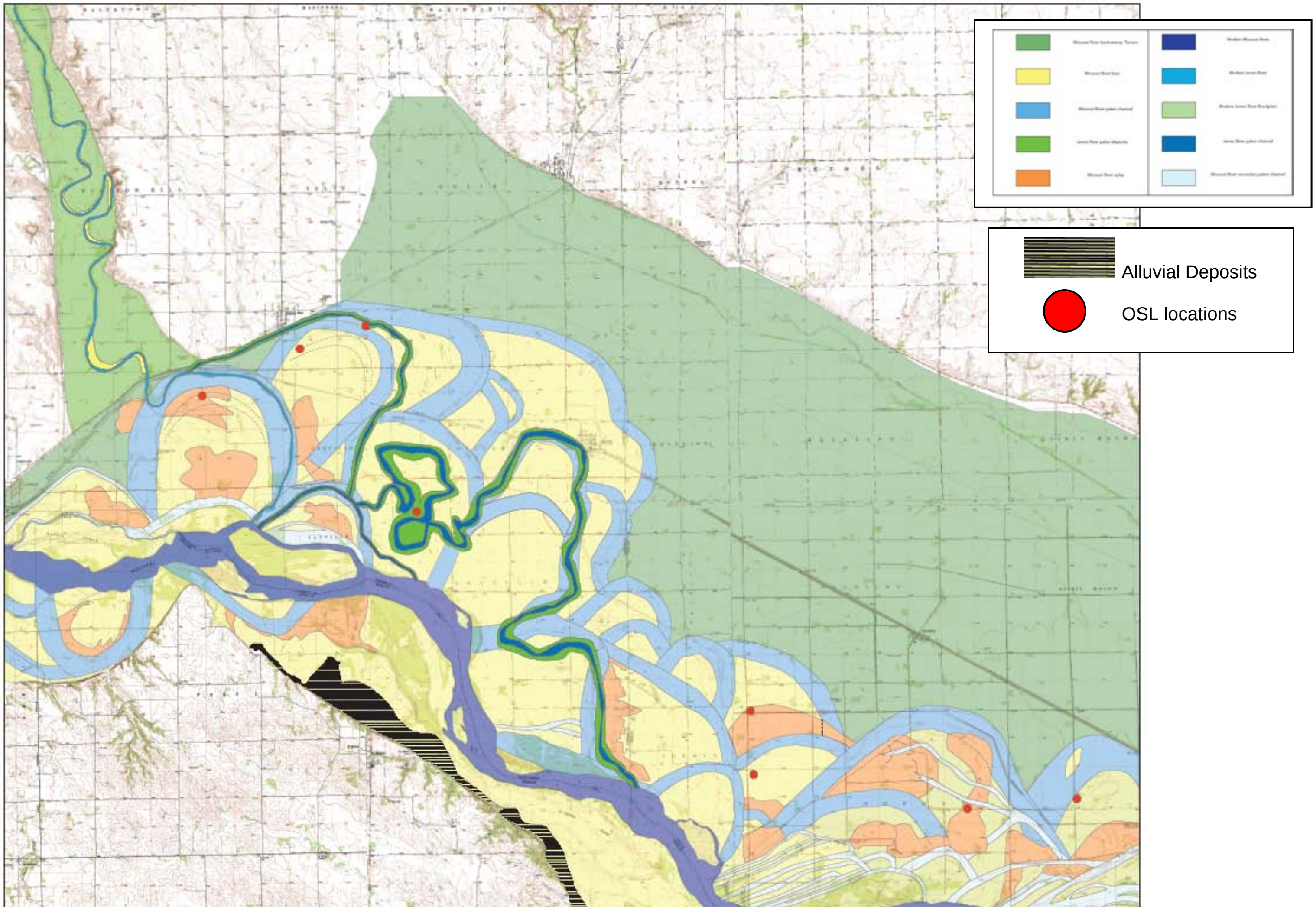

Figure 4.24: Surficial map showing Mission Hill, Menominee, Gayville, St. Helena, Gayville NE, and Meckling and subsequent OSL borehole locations.

CHAPTER 5
DISCUSSION
5.1 Deposits and Facies

The allounits mapped within the study area are defined with the intention to reflect specific fluvial depositional environments. Allounits within the fluvial environment include channel fills, recording neck and chute/avulsion cutoff, respectively, and point bars, mid channel bars, splays, and backswamp fines (Figure 5.1). Each unit is defined/described based on lithofacies sequences. Channels can be broken down into two separate units, active channel fill and passive channel fill.

Passive channel fill will trend fine upwards; the channel will grade from loam to loamy sand and/or sand at the base while the top of the channel will have a dominance of clay strata and likely originated in an oxbow lake. A field example can be seen in MOV-GV-003; this borehole is terminated at 8.8 m before reaching the expected coarse sand channel bottom. It is almost exclusively clay with exceptions at 0.4-0.9 meters SiC, 2.6-3.0 meters SiC, and 6.1-6.3 meters SiL.

An active channel fill will have a combination of sands and clays; it represents continued flow while the river finds a new path. Channel fills may contain organic materials and rooting, and may also have carbonate concretions. A field example of this can be seen in MOV-MN-005; the upper 0.1-1.3 meters contains fine grained sediments ranging from clay to loamy sand, however 1.4- 4.5 contain coarser grained sediments ranging from loamy sand to sand and are more consistent with what is expected in an active channel fill. 4.6-5.0 meters are consistent with sand expected in a channel bottom (Figure 5.3).

Point bars/ mid channel bars will have well-sorted sand at the base with possible loamy sand and will have cross-bedding throughout. Pointbars grade upward into loamy capping units.

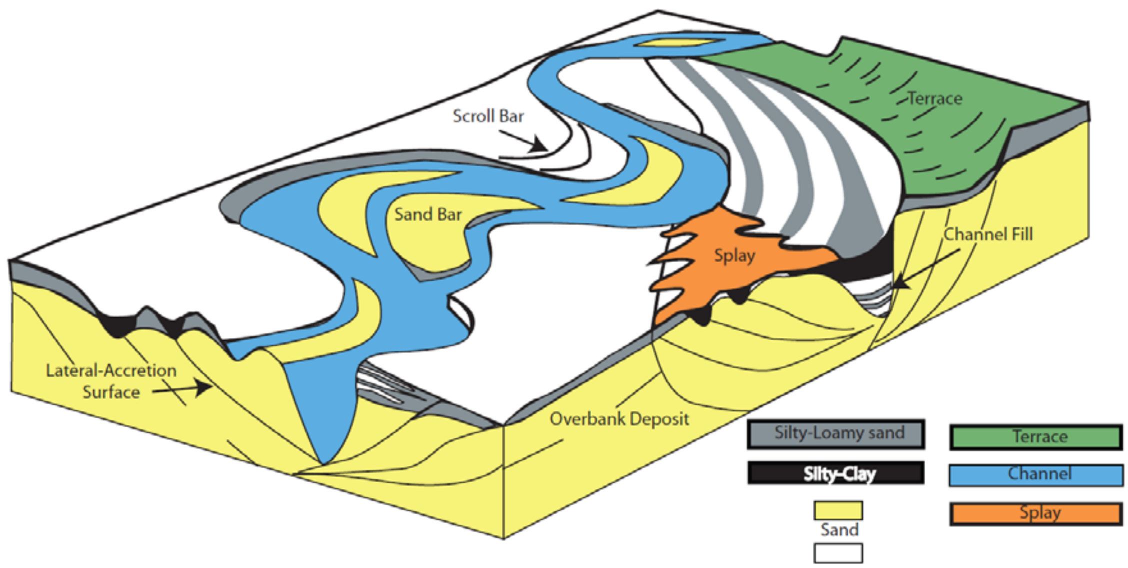

Figure 5.1: Allounit interactions. Modified from Miall (1996) and Holbrook (2006).

"Architecture of the Lower Missouri River Valley bottom, after Miall (1996). Meander loops are formed by lateral migration of point bars and smaller lateral bars that are attached to the channel boundary on the inside of meander loops. Lateral migration occurs in stages, producing a series of lateral-accretion surfaces. Point bars tend to decrease in grain size upward from sand to fine gravel at the base to silt and clay at the top because shear stress of the flow decreases up the lateral accretion surface on which the bar grows. As banks are topped by floodwaters, the coarsest part of the suspended load is deposited along the channel margins forming natural levees, and the finer part of the suspended load is deposited more evenly across the point bars as clay-rich overbank mud veneers. Sand rich parts of point bars are typically veneered by both silt-rich natural levee and clay-rich over-bank deposits. Periodically, flood waters locally breach the natural levee (or engineered levees), and suspended load and bed load sediments will escape the channel and spread out onto the adjacent point bars to form a delta-type deposit known as a crevasse splay. Point bars are typically terminated on their outer bend against a channel-fill allounit, and are defined on their inner side by a sharp surface that truncates other deposits and marks a change in ridge-and-swale trend. Channel fills record sedimentation in channels that have been abandoned from the active flow by local meander-bend cut off, or shifting of the entire channel to a new location on the flood plain (avulsion). Channels will be cut off or avulse because a new location provides a steeper and more favorable course for channel flow. Flow is strongest in the abandoned channel during the early part of the abandonment phase. Channel fills are thus generally floored with the coarse material typical of the bed load normally carried by the active river. If the channel is abandoned abruptly, and active flow does not return, the remainder of the channel will fill with clay and silt deposits in an on-bow lake setting. If the channel is periodically reoccupied by the main channel, fill may be of any grain size carried by the river, and will alternate in grain size in direct proportion to flow strength during reoccupation. Channel fills are recognized as long arcuate-to-straight swales with widths equal to or less than the forming channel. Channels with dimensions substantially less than the full size of the modern Missouri River, as well as contemporary channel fills, are identified as chute channels (Holbrook 2006)."

A field example can be seen in MOV-MH-006; the upper 0.5 meters consists of SiC, SiL, and C while 0.6-2.8 meters consists mainly of LS before reaching S from 2.9-3.8 meters. Splays consist of heterogeneous sediments. This feature will not have a clearly defined contact with underlying units if overlying any lithofacies except clay. A field example may be seen in MOV-MN-010; 1.4-3.0 meters may be consistent with underlying bar facies, however, due to the nature of splays, the contact cannot be clearly defined. 0.1-1.3 meters has sediment size ranging from SiC-LS.

Floodplain mud veneers/mud flats are defined by fine sediments that are found in suspension. These fine sediments are usually clays. This unit will be defined by a substantial amount of bioturbation (Figure 5.2). A field example can be seen in MOV-GN-001; the upper 0.1-5.3 meters consists almost exclusively of clay with some silty clay. Beginning at meter 5.4 we have a slight coarsening up consisting of sequences of silty clay, loams, and silts through 8.6 meters. These backswamps contain components of both mudflats and splays across the flood basin.

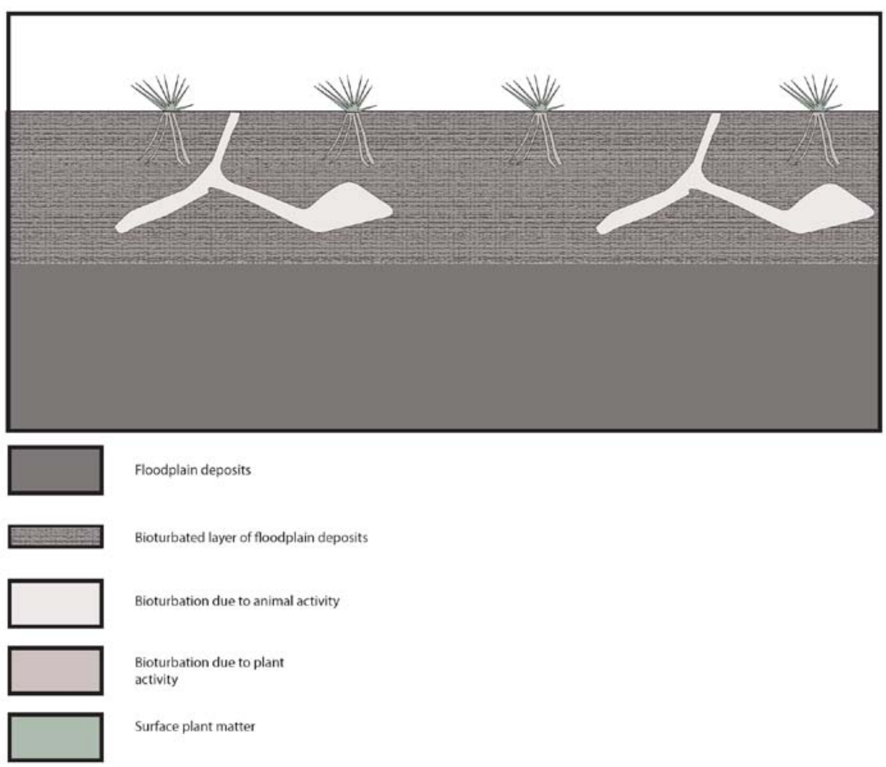

Figure 5.2: showing simplified example of bioturbation on clay-rich backswamp floodplains

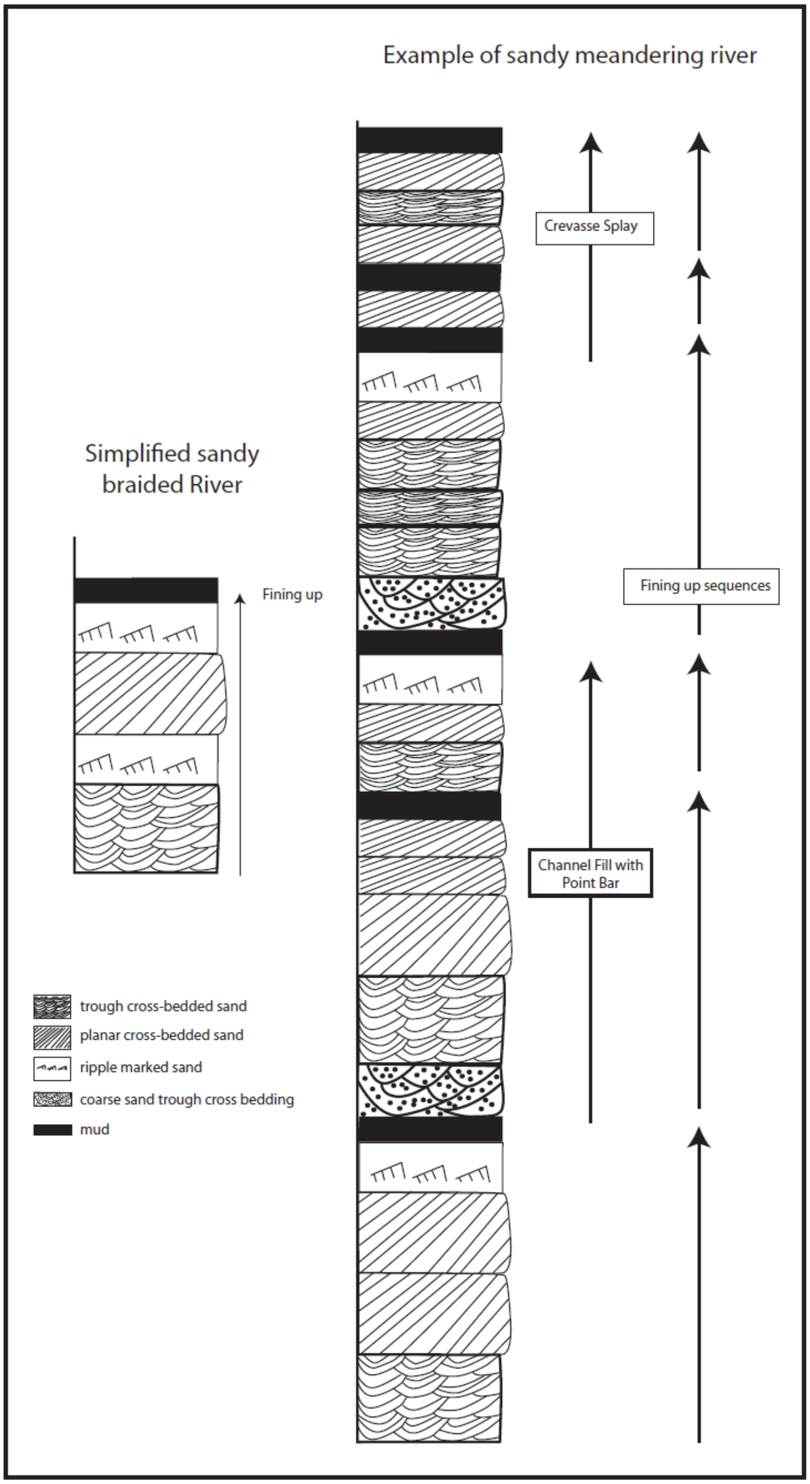

Figure 5.3: example of vertical profile for hypothetical braided and meandering sections. Modified from Boggs 2006.

Each borehole drilled is logged based on depth, coloration, oxidation state (reducing/oxidizing), organic matter presence, any other significant non-consistent features. Gley colors (gray, green, and blues) are formed due to the presence of ferrous oxides or carbonates (e.g. siderite) found in reducing environments and typically record prolonged sediment saturation more common of humid climates and high water tables (Miall 1996, Mack1993, Bown and Kraus 1987 and Kraus 1999). Yellows, reds, and oranges are formed from ferric oxides (e.g. hematite) in oxidizing environments. These colors may also be found where sediments are well drained. Coloration based on oxidation is more often determined during the early stages of diagnenesis not necessarily during deposition; thus elevation of the water table is an important factor in coloration. Environments typically associated with a lower water table include arid climates and also environments with dry periods while a reducing environment is typically associated with an area prone to saturation and higher water tables. Reduction by saturation is necessary to preserve organic material as well (e.g. plant matter). Any interbedding of coloration will offer information on the variability of the water table.

Water table levels range from .9- 4.6 meters across all six quadrangles with reduction zones corresponding to these elevations. Water table levels have remained relatively high over long periods of time. This is indicated by the consistent sampling of reducing conditions at less than 5.0 meters. The floodplain aquifer has maintained a consistent level long enough for deep strata to reduce (Figure 5.4).

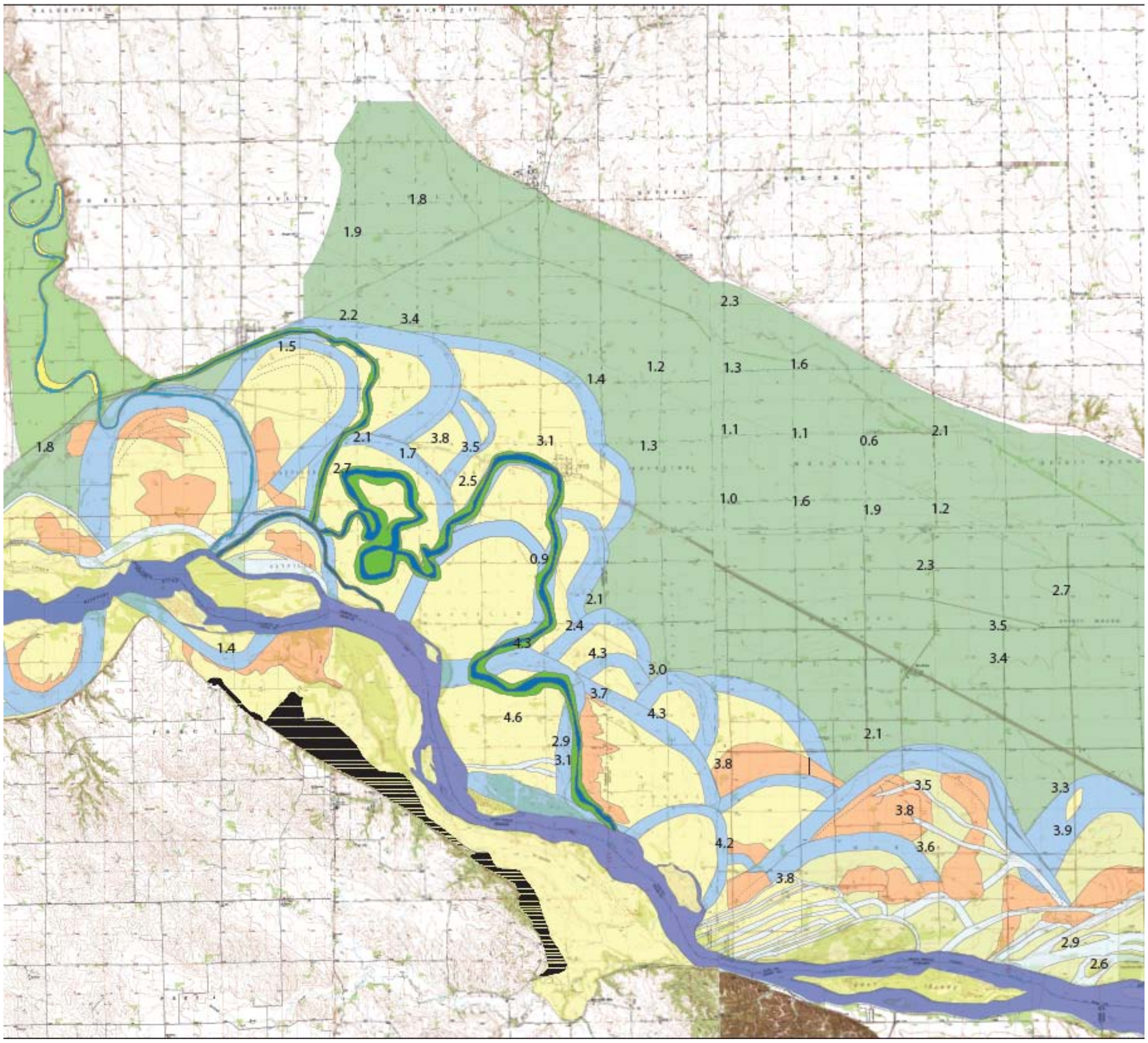

Figure 5.4: Water table distribution across study area (measured in meters).

5.2 Fluvial Morphology

Within the study area, morphology is a major part of understanding the chronology of the James and Missouri rivers. Based on the mapping of the floodplain we can see that the Missouri River has aggraded over the Pleistocene deposits with depths varying throughout the valley, however no true correlation can be made between depth and proximity to the adjacent bluffs. The only correlation can be seen with depths increasing downdip. These depth trends can be seen in the Isopach map of the Gayville NE quadrangle. Based on dating of Pleistocene deposits from OSL dating, the floodplain may have reached its current level around 7.29 ka (based on OSL dates from the 2009 field season, Sloan quadrangle). Since reaching the current level, the Missouri River has been migrating southwest on average to reach its present location along the southern valley wall. Morphologically speaking, the river has gone from large scale meanders to a slight decrease in meander size and amplitude to the present day island bar braided river (Figure 5.5). The braided morphology can be observed within the allounits of the Meckling quadrangle. Dates from the earlier large meander loops suggest that the change from meandering to braided is younger than 2.61 Ka. This change in river pattern can be seen downstream near Lexington, Missouri and has been dated between 3.5 ka and 1.5 ka (Holbrook et. al 2006).

Large scale meanders are visible within the Mission Hill, Gayville, Saint Helena and Meckling quadrangles (Figure 5.5). There are, however, examples of a decrease in size of these meanders within the Saint Helena quadrangle, eastern edge (Figure 5.5). Channel width and depth vary across the study area (Table 4.2), while secondary channels are mapped in 3 of the associated quadrangles, Mission Hill, Menominee, and Meckling.

The James River meanders within its valley range from “confined” (bound by the width of its valley) loops to hairpin turns with some sections trending towards a semi-straight morphology. Upon reaching the Missouri River Valley, the James River loops begin to mimic the large scale Missouri loops, however, within allounit #4 the James River has escaped the confines of the Missouri paleo-loop and assumes it own meander characteristics.

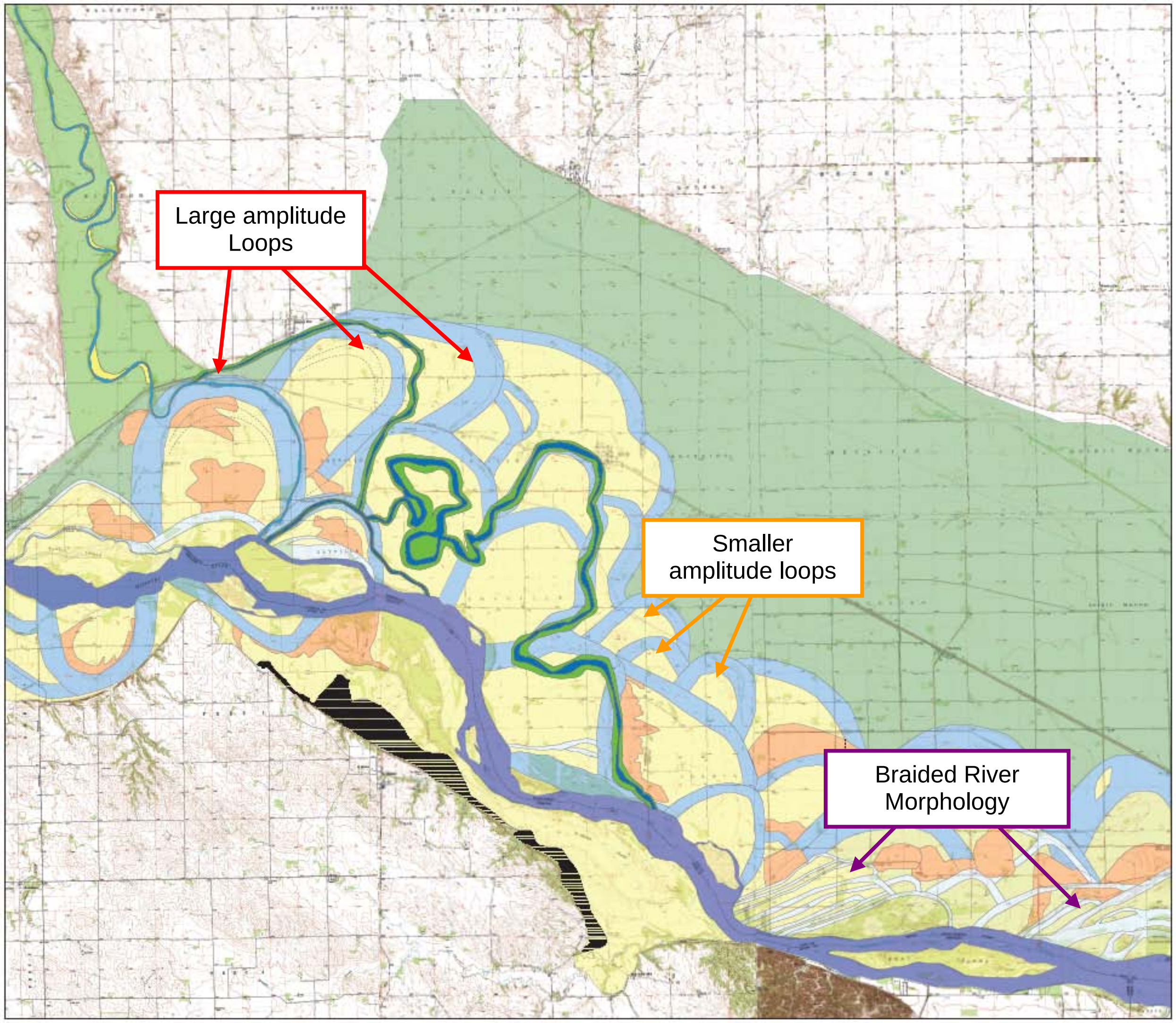

Figure 5.5: Shifts in Morphology

5.3 James vs. Missouri modern hydrology

The Missouri River has a water surface gradient of 0.85 ft/mile in the Yankton area during the low water stage (approximately December). The Missouri River is about 500-600ft wide and on average approximately 4-8 ft. deep, however, during the high water stage (approximately April) the Missouri River water surface is about 6 times wider than low water stage widths and has a water surface about 16 ft. higher (Simpson 1960). The low water stage is approximately 3 times lower than the deeper channels drilled in the study area, however, the high water stage is more consistent with field data. Discharge for both the James River and the Missouri River are monitored by the USGS.

James River near Yankton, SD (USGS 06478513) on 9/16/2010

- o Discharge 2440 cfs
- o Stage 7.20 ft

- Missouri River at Yankton, SD (USGS 06467500) on 9/16/2010
  - o Stage 16.02 ft
  - o Discharge 55600 cfs (at Sioux city, IA)

Updated discharge for both rivers is recorded on the USGS website, as well as the average flow from 1977-1986. During the period from 1977-1986 the James River north of the Yankton county line had an average flow of 375 cfs while the Missouri River during the same time period had an average flow of 26,410 cfs at Yankton, SD (Bugliosi, 1986)

5.4 Comparison of Paleohydrology of the Missouri and James Rivers

Looking at a cross sectional view, the width and depth of the James is not consistent with the morphometrics of the large amplitude paleochannels mapped in five of the six quadrangles discussed (Figure 5.6 and 5.9). It seems that it can be concluded that the Missouri River must be responsible for these larger paleochannels, based on the width, depth, and velocity of the modern Missouri River.

Several equations can be used to compare reasonable calculated discharges for these paleo-channels (Table 5.1). We can solve for A using Williams (1986) equation 29 (A_b) where we have already measured radius of curvature. We assume that the channel is a simple parabola throughout the length of the meander and solve for wetted perimeter (perimeter that is actually touched by water and affects flow through friction). Once we solve for A and P (wetted perimeter) we can calculate R (hydraulic radius). Next we solve for V (velocity) using Manning's equation. n is the Manning's roughness coefficient; after looking up the n value we find that there are three values given for an earthen channel (clean = 0.022, gravelly= 0.025, and weedy = 0.030). We will use the gravelly value as our channel bottoms trend towards coarse sand. Slope is determined from the cross sections measured for each quadrangle and elevation profiles, units will be provided in ft. /ft. Once V is solved for, we can solve for a reasonable discharge based on the assumptions and measurements made. Again, using the same calculations and sequence we can solve for the values with respect to the James River, however, because its paleo loops are affected by the Missouri River paleo-loops, except for the loops within allounit #4's point bar, using a measured radius of curvature would lead to over calculated values. Instead we used the radius of curvature from the modern James River measured within its own valley. The values calculated for features 1 and 10 offer a range based on the highest and lowest calculated bankfull width. Looking at table 5.1, we see that the projected discharge of a Missouri channel and a James channel are vastly different.

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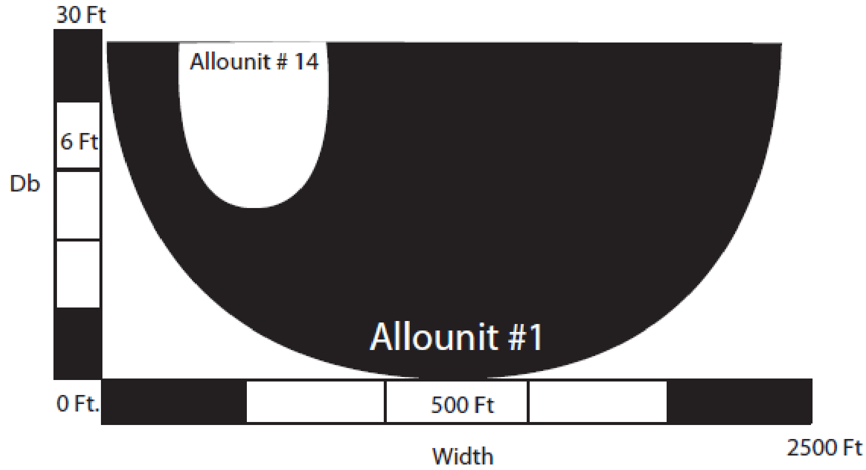

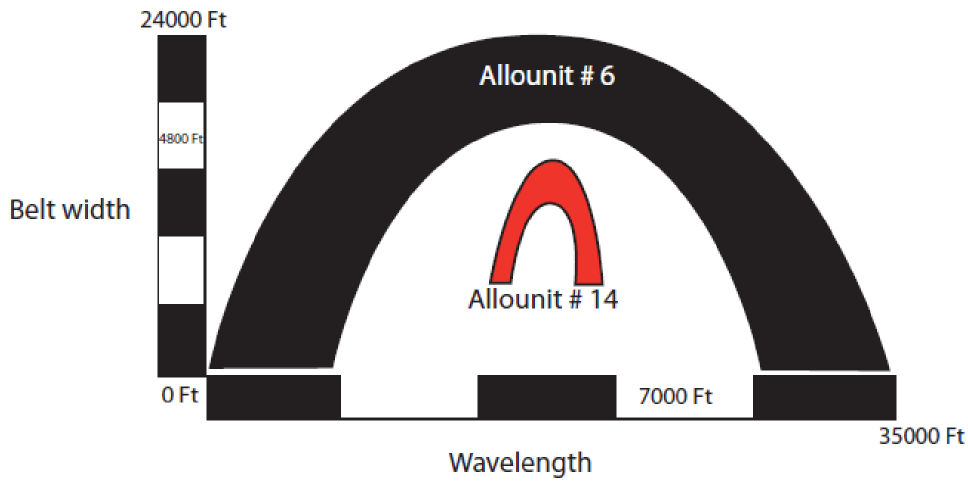

Figure 5.6: Paleohydrology comparison showing cross-section (top) and plan-view (bottom).

Table 5.1: Allounits for Paleohydrology comparison

Allounit	1	6	10	14
A	12093.67 ft		26538.48 ft	2953.54 ft
P	1309.74 ft		2085.96 ft	566.27 ft
R	9.23 ft		12.72 ft	5.22 ft
S	0.003		0.003	
V	14.36		14.52	29.48
Q	173,713.19 cfs		385,44.67 cfs	87,063.78 cfs
L_M		10058.47 meters		2414.02 meters
B		7089.85 meters		1703.63 meters
Equations used: **Q[20]=V[21]A[22]** **R[23]=A/P[24]** **V= (1.49/n[25]) (R^2/3) (S[26]^1/2)** Manning's equation				

Also using Williams (1986), we can calculate L_m[27] (meander wavelength) and B[28] (meander belt width) (allounit #14 measurements are based on localized measurements, these numbers may vary depending on where the measurements are taken within the James River valley and also in the Missouri River valley). Meander wavelength and meander belt width for the James River varies from the James River valley to the James River found within the Missouri River valley (Figure 5.6).

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[20] Discharge
[21] Velocity
[22] Cross sectional area
[23] Hydraulic radius
[24] Wetted perimeter
[25] Manning's coefficient
[26] Slope
[27] L_m= meander wavelength
[28] B= meander belt width

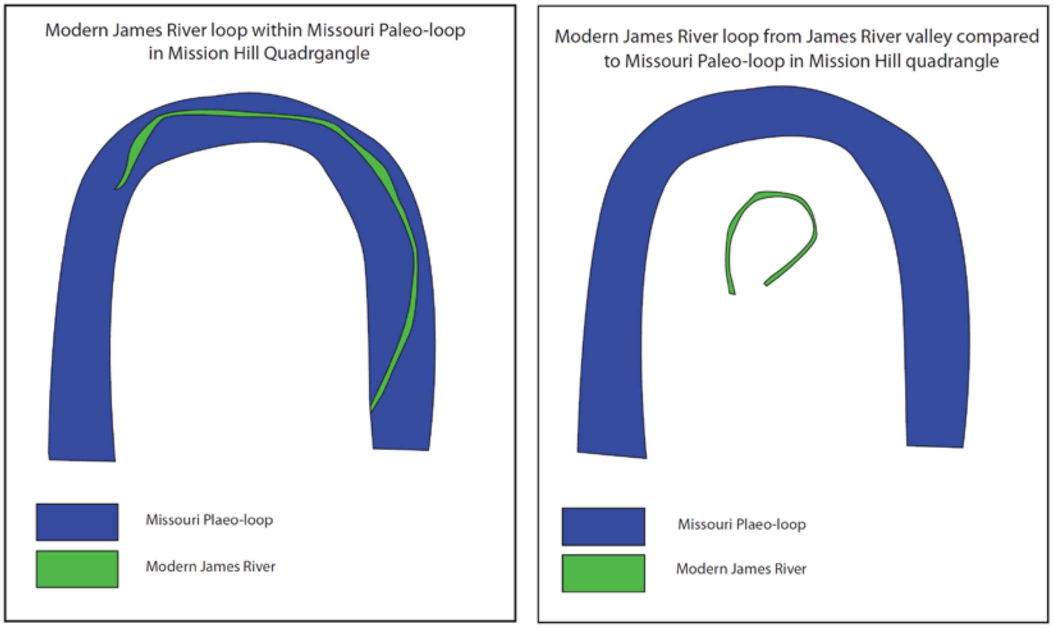


Figure 5.7: Comparison of James River loops vs. Missouri River loops

Some of the measurements of the James River within the Missouri River valley are larger and can be contributed to the fact that the James River is following abandoned Missouri meanders (Figure 5.7). B is a function of bankfull depth, however, within the Missouri River Valley, the James meander belt width is not a much a function of its depth as it is a function of the meander belt width of the underlying Missouri paleo meander. While within the James River Valley it is a function of meander belt width and also determined by the distance between the valley walls. The Missouri River measurements, however, are a direct function of bankfull width and bankfull depth within the study area. The shape of the MRV within the study area does not confine the Missouri River and allows the meanders to determine their morphology based on sediment load, discharge, slope, and velocity of flow (Figure 5.8). The shape and size of the meanders correlate to the amount of energy that is needed to be dispersed in order to reach equilibrium (Figure 5.9 and Figure5.10).

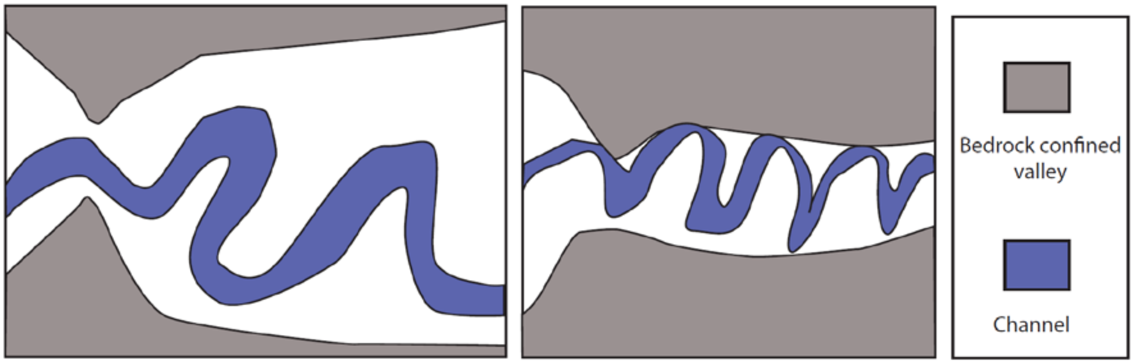


Figure 5.8: Example of how valley morphology can affect meander amplitudes. (Left) shows a bedrock valley similar to the study area valley. (Right) shows a mock bedrock valley and how a river may respond to a confined valley.

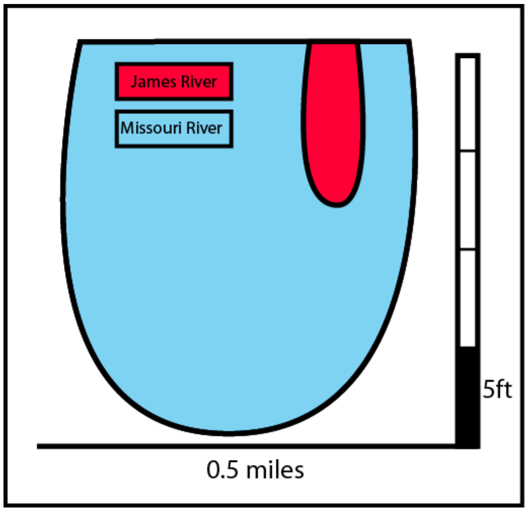


Figure 5.9: Cross section showing average width and depth differences between the Missouri River and the James River.

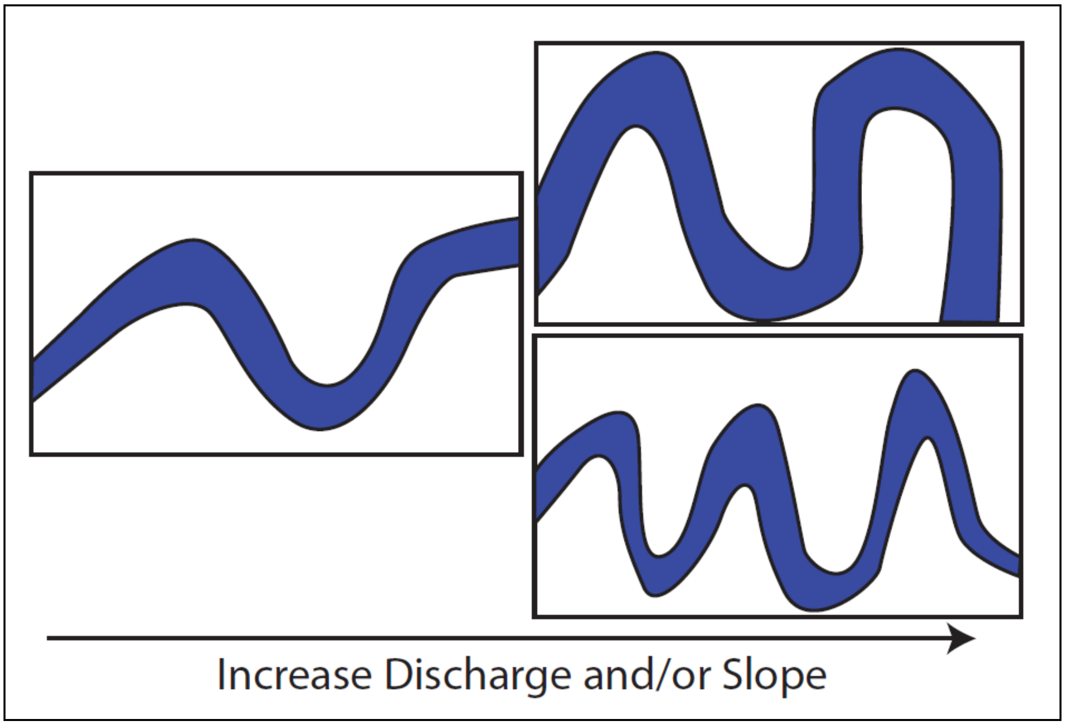


Figure 5.10: Showing two proposed reactions to increased discharge and/or slope. (Top right) shows an increase in meander amplitude while (bottom right) shows and increase in sinuosity (decreasing wavelength).

5.5 Courses of the James River relative to Missouri River paleochannels

One of the major questions to be answered at the onset of this study was to look at the paleo loops within the Mission Hill quadrangle and determine if they were from the James River or from the Missouri River. We began by looking at all maps available including the 1800's map provided by the Missouri River Institute (Missouri River Commission, 1890's map, Figure 2.1). Boreholes were drilled where they were hypothesized and access was available; the Mission Hill quadrangle proved to be a difficult quadrangle to get land owner permission to drill because it is more urban.

Looking at the Williams (1986) calculations to find channel bankfull depth and using the measured localized channel width, we find values that indicate that the mapped James River channel lacks the capacity to carry the Missouri River discharge. The most prominent feature in the Mission Hill quadrangle is the large paleochannel (allounit # 1) which currently houses the modern James River. Within the southeastern portion of this quadrangle the modern James River was cut off by a secondary Missouri channel. We can trace this most recent abandoned section of the James River across the Lower St. Helena quadrangle to a previous confluence with the Missouri River. These abandoned sections of the James River naturally follow the topographic lows left behind by the Missouri River paleo-loops. The paleo James loops deviates very little from the paleo channels of the Missouri River. Any deviation places the smaller paleo James within the Missouri River bars. The bar sands are not very cohesive and would not require much energy for a feature with proportions similar to the James loops to cut across them. Where the James is able to escape the Missouri paleo-loops, we see it take on behaviors similar to what we see within the James River valley and closer to meander activity expected based on channel proportions.

In summary, the paleo Missouri River channels are topographically lower due to difficulty in filling completely. These topographic lows naturally tend to capture the James River. These lows, combined with the cohesive clays found within the channel fills which are hard to erode, further tends to keep the river confined to the Missouri River paleochannels. Once the James River is able to escape these Missouri River paleo-channels, it resumes normal patterns across the less cohesive point bars. This pattern can be seen within the Saint Helena quadrangle and is found within the point bar of allounit #4. This "escape" is dated at pre 1.46 ± 0.10 Ka based on OSL techniques.

5.6 Chronology of the James and Missouri Rivers

The chronology of the two rivers interactions can be seen in Figure 5.11- 5.14. Figure 5.11, shows the oldest dated interactions between the James and Missouri Rivers. The OSL dates indicate that these interactions took place at less than 2.59 ± 0.15 Ka. Because of the proximity of the adjacent bluffs to this meander loop, we know that the James River would have to confluence into this loop when it was active. Once the 2.59 ka loop was cut off by the 1.83 ka loop, the James would have to confluence into the younger (1.83 ka) loop again due to the proximity of the adjacent bluffs. Once the 1.83 Ka loop was abandoned and filled, the James

River could occupy this topographic low and confluence with the Missouri River further downstream as is seen in figure 5.11. Based on the 1.46 ± 0.10 Ka for the James River deposits we can constrain this interaction at Post 1.83 Ka at least through 1.46Ka. Figure 5.12 shows the next know path of the James River. The 1.83 Ka loop is cut off by the 0.82 Ka loop. While this new loop is active, the James River would have flowed into it. Once the 0.82 ka loop is cut off and abandoned, the James River would have followed the topographic low left behind (Figure 5.13). The James River takes a hairpin turn at the location of the current confluence and continues further downstream before confluencing with the Missouri River. We can constrain the dates of this interaction by revisiting the historical 1889 map (Figure 2.1). We can see that the hair pin turn is still active when this area was mapped by the Missouri River Commission, therefore we can constrain this interaction at post 0.82 Ka through the 1880's. In order to constrain this date further an OSL date would be needed at the location marked on Figure 5.13. Finally in Figure 5.14 we see a portion of the modern Missouri River cutting off the hairpin turn and creating the current confluence. This cutoff cannot not be assigned an absolute date at this time, but can be assigned a relative date after the 1880's and before the present.

The chronology represented in Figure 5.11-5.14 is based on both OSL dates and relative dating based on cross-cutting relationships. The age range of interaction between the James and Missouri Rivers is based on the amount of OSL dates within the study area. Four of the OSL dates were taken in the Meckling quadrangle and were requested by Tim Cowman. These four dates provide an approximate relative date for a morphological change from meandering to a braided river. The other dates were taken within the Mission Hill and Saint Helena quadrangle and serve as the basis for timing the James and Missouri River interactions. Figure 5.12 illustrates a key loop to date to further minimize the range of interactions between the two rivers, however, due to funding not all paleo-loops associated directly with the James River could be dated.

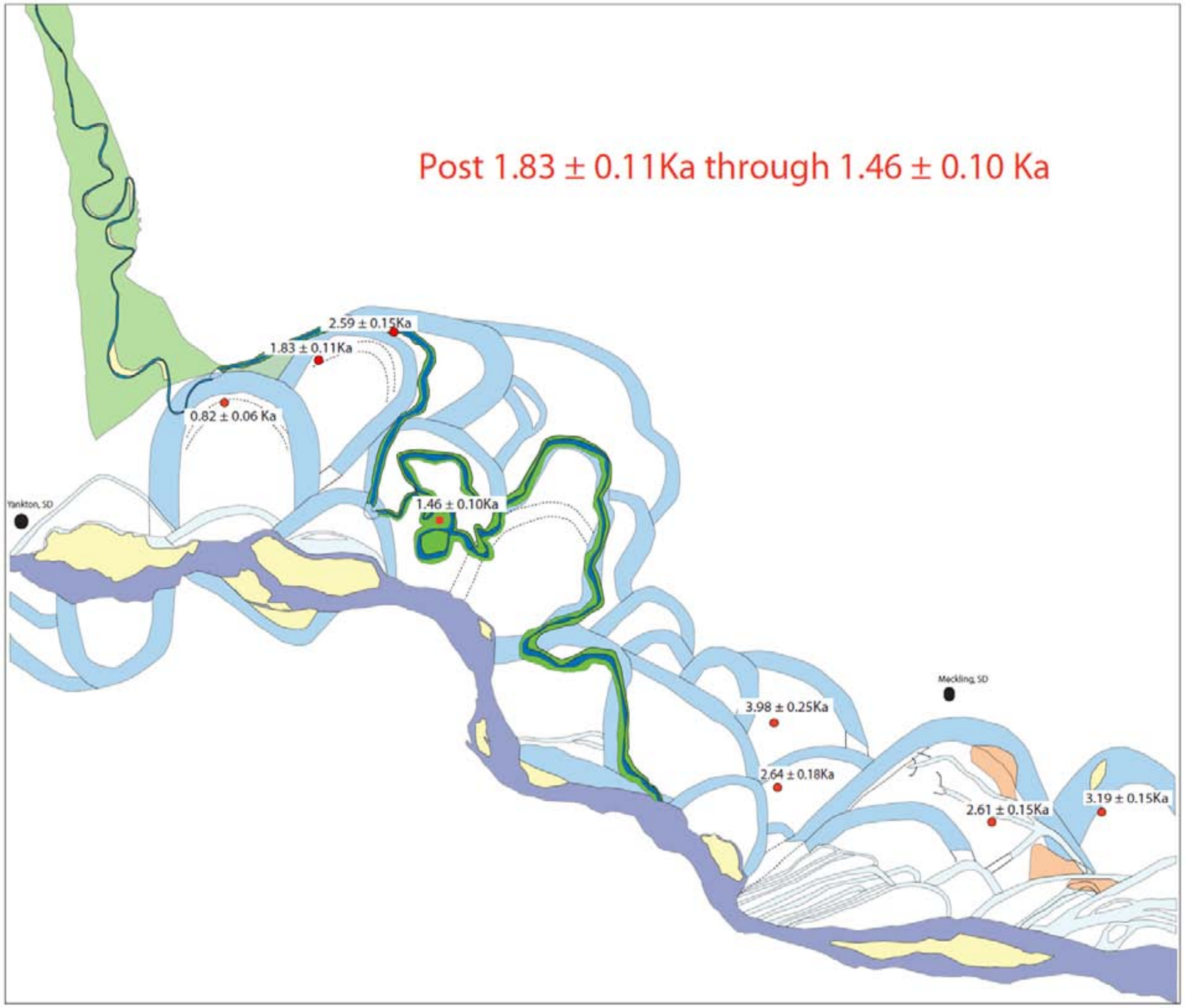


Figure 5.11: Time scale of interactions between the Missouri and James Rivers

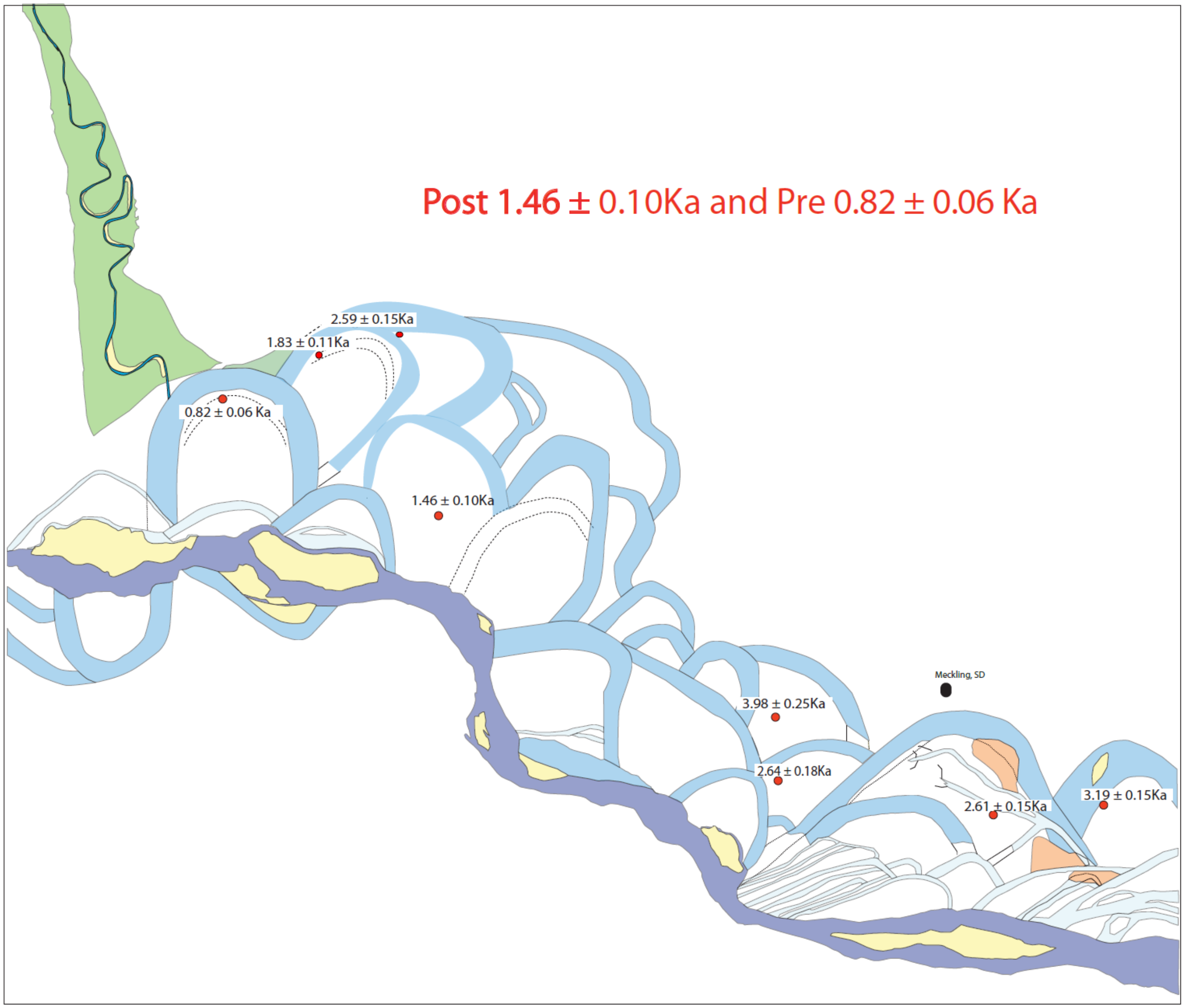


Figure 5.12: James and Missouri River**s interactions**

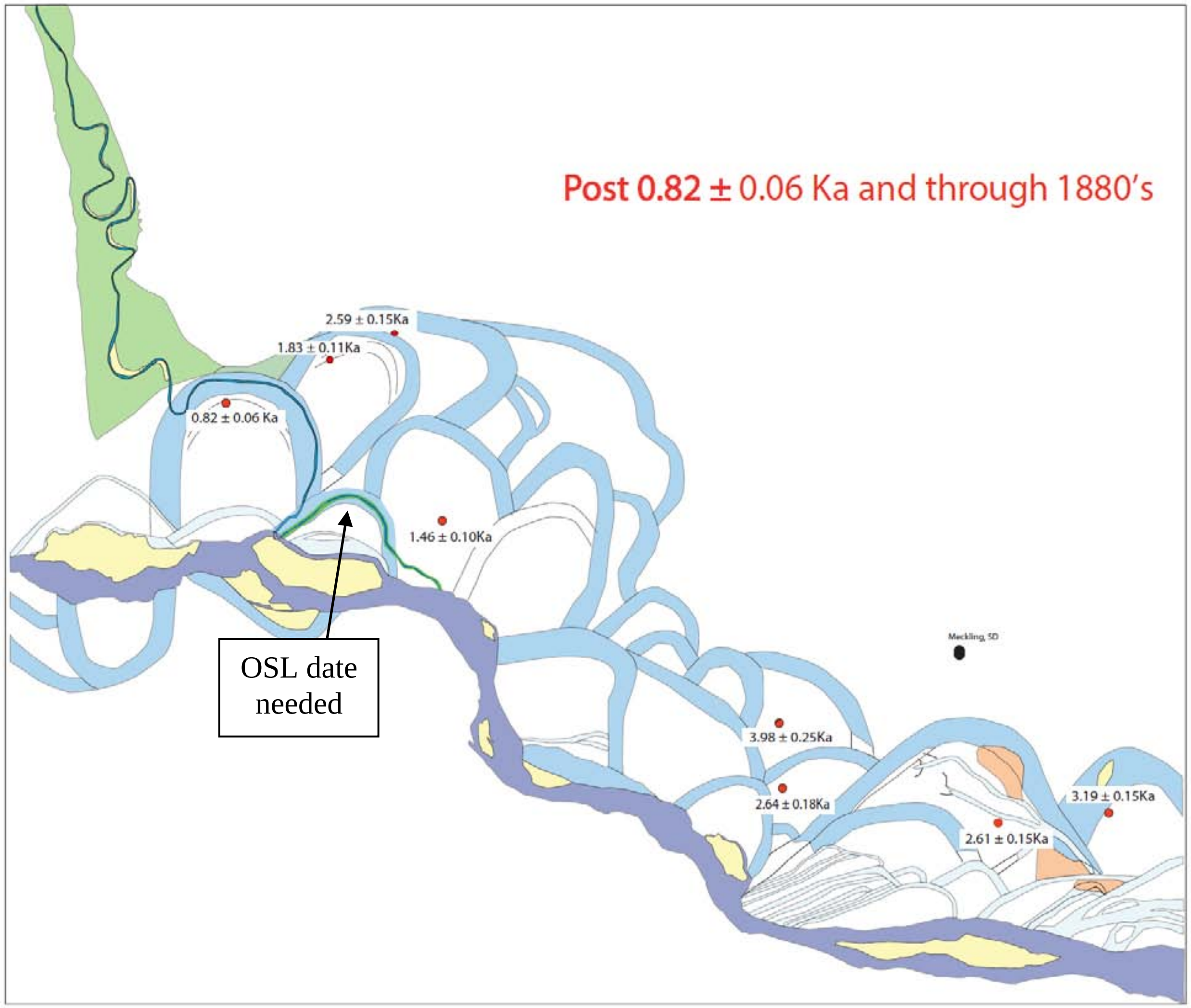


Figure 5.13: James and Missouri Rivers Interactions

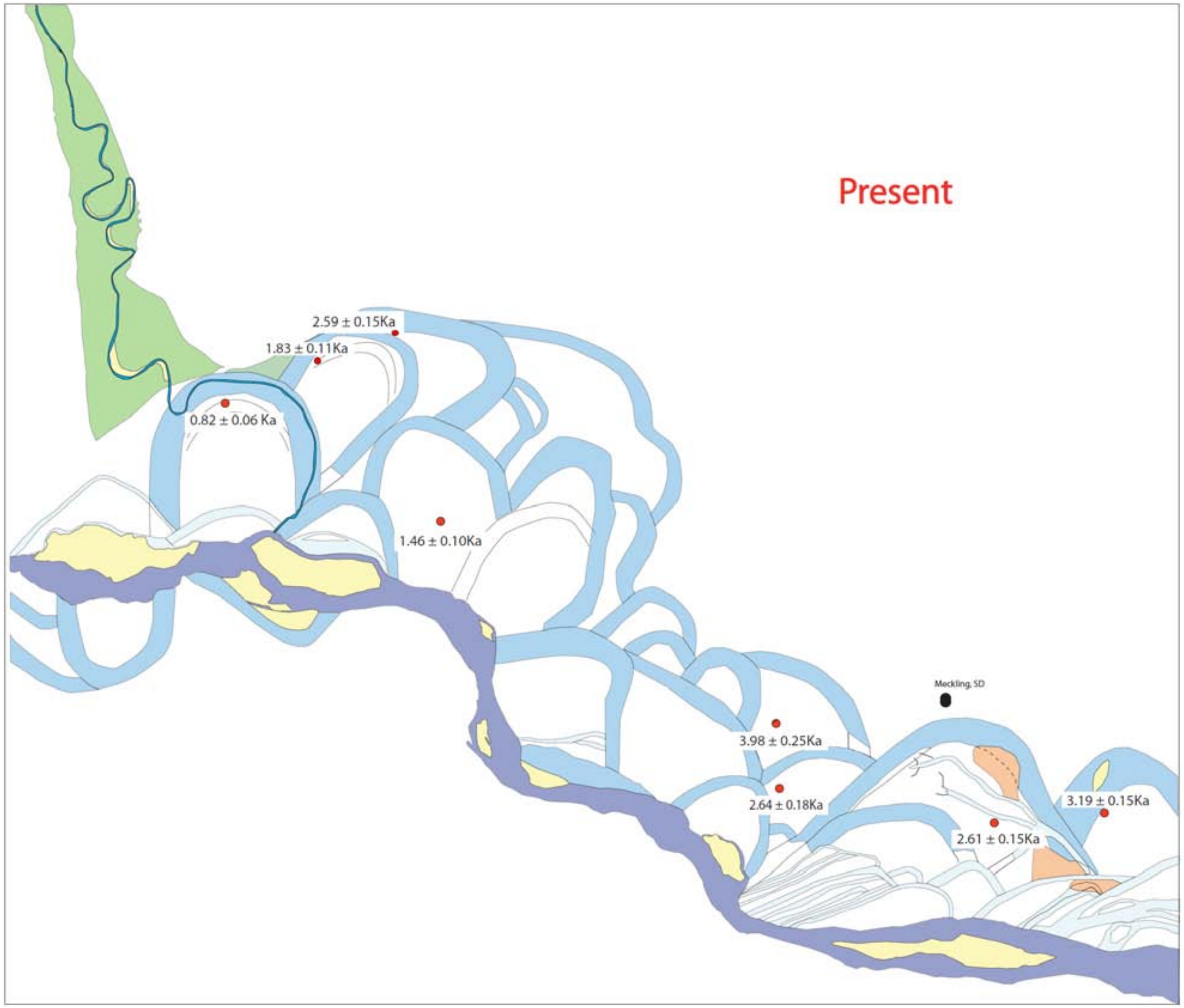


Figure 5.14: James and Missouri Rivers Interactions

CHAPTER 6

CONCLUSION

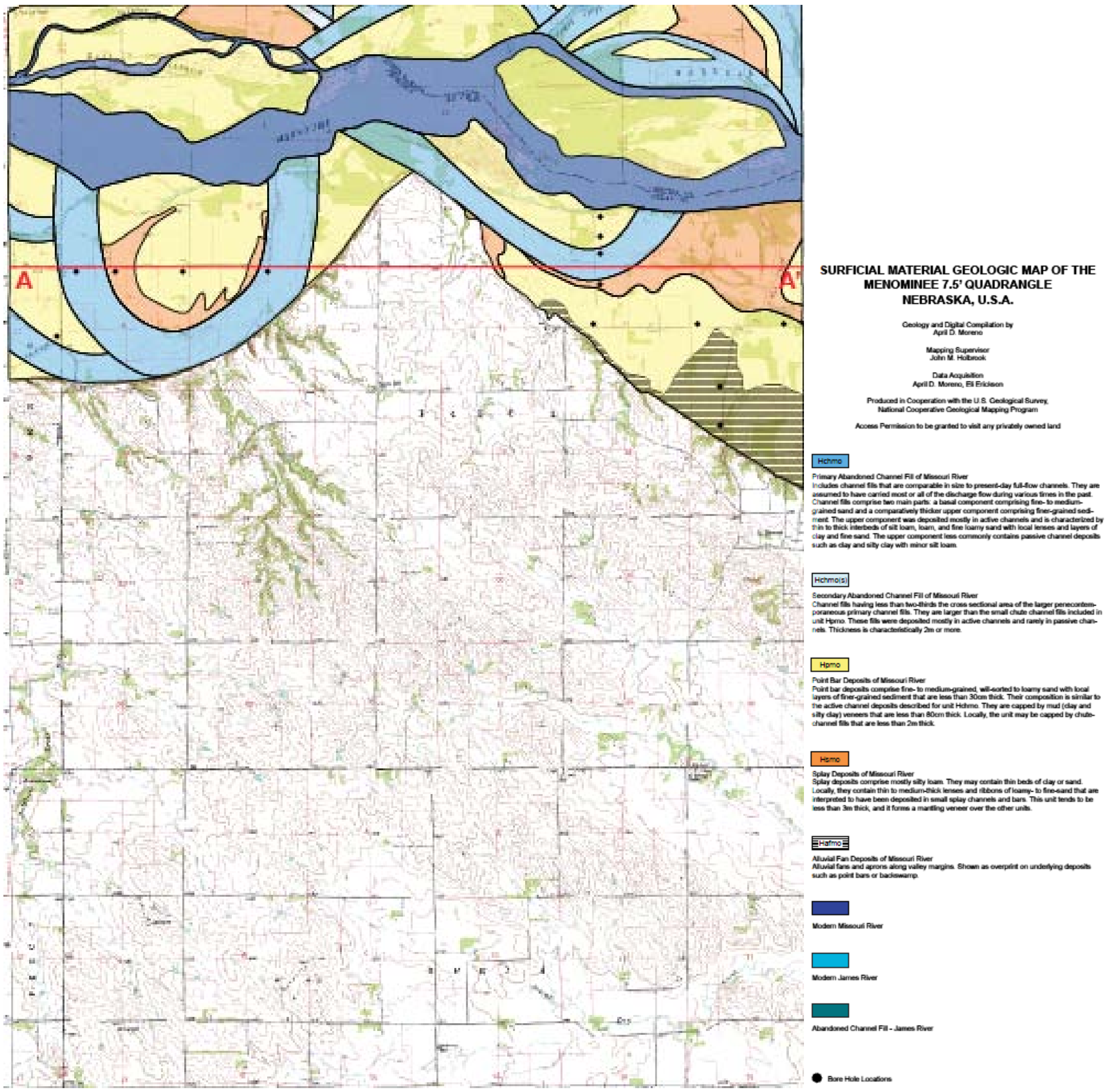
I have found, after looking at both the surficial land forms and ground-truthing with the hand augers, that the James River has followed the abandoned channels of the Missouri River for a portion of the Holocene. It appears that the Missouri paleochannels migrate by lateral point bar growth until the paleochannel is cutoff by a new channel. Once the channel is cutoff, and the subsequent oxbow lakes are filled in, the James River migrates into the topographic low. It appears that this pattern is repeated several times throughout the Holocene. Remnants of the James River have been mapped in the following quadrangles: St. Helena, Gayville, Mission Hill, and Menominee. The James River does diverge from the Missouri loops in some areas; however, these areas tend to be associated with Missouri River bars. The energy needed to cut through a bar is minimal with respect to cutting through a clay rich backswamp or channel fill.

By comparing characteristics such as width, depth, and discharge, we can conclude that the James River does not come within reach of the discharge and erosional capacity of the Missouri River, and thus does not as independently cut across the floodplain. It instead tends to follow features pre-determined by the Missouri River.

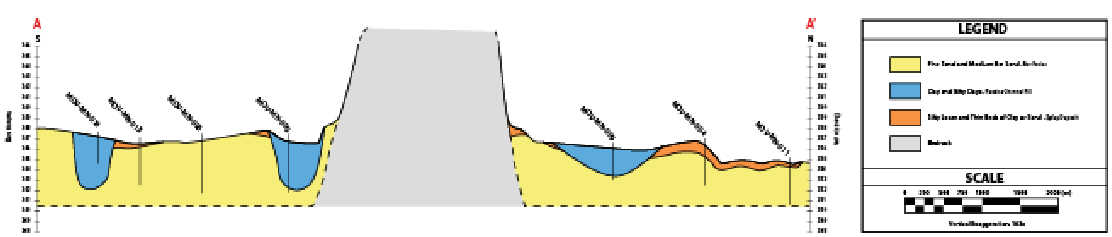
Based on the southwesterly migration of the Missouri River, it appears that the confluence of the James and Missouri Rivers was located near where it is located today or possibly just east of the present location during the Lewis and Clark expedition. The location of the confluence during Lewis and Clark's expedition depends on the timing of the secondary channel that cuts the current confluence. To further minimize the range of this secondary channel from post 0.8 ka to the present, an additional OSL date is required (Figure 5.12).

APPENDIX A

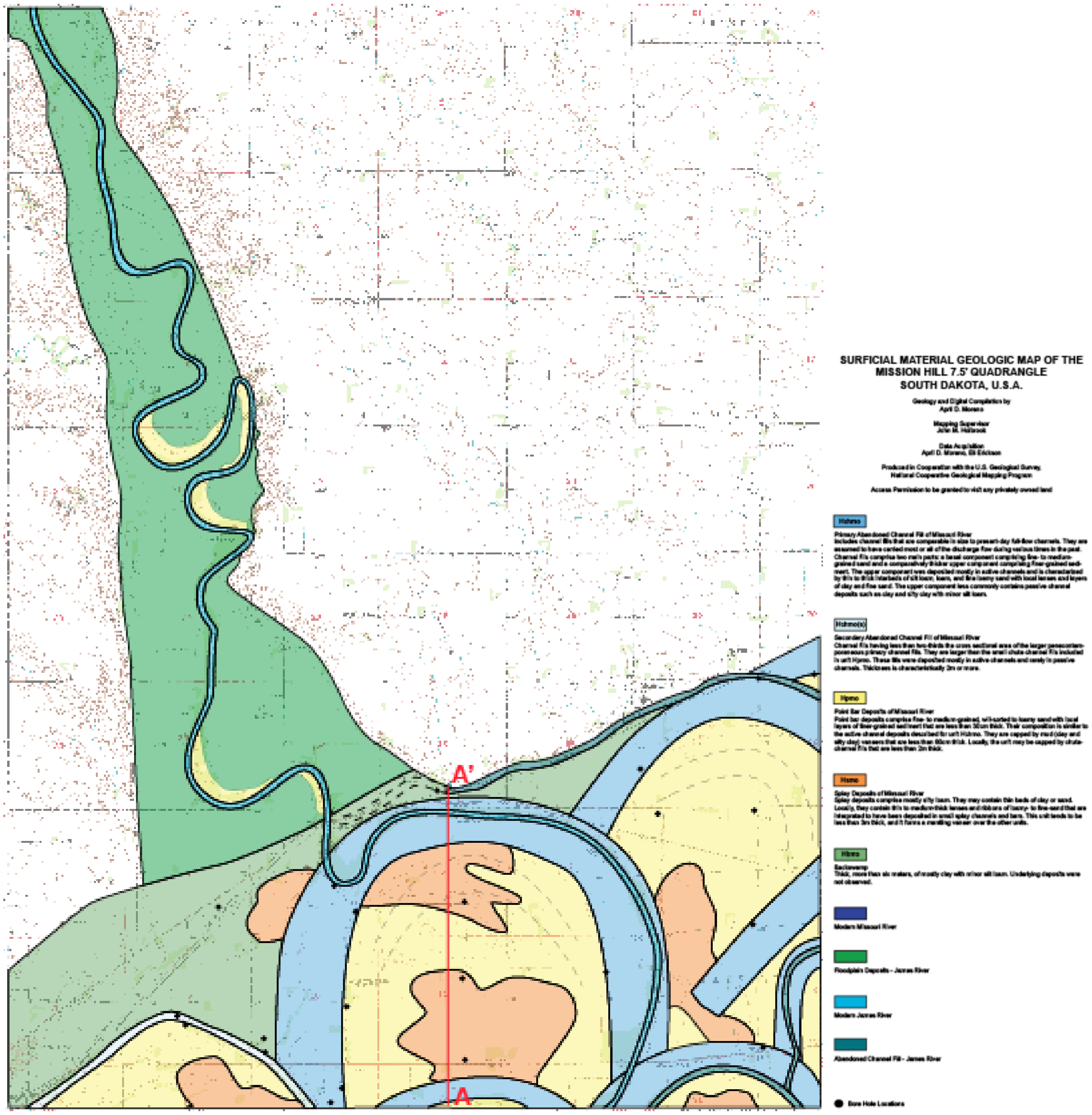
MAPS AND CROSS-SECTIONS



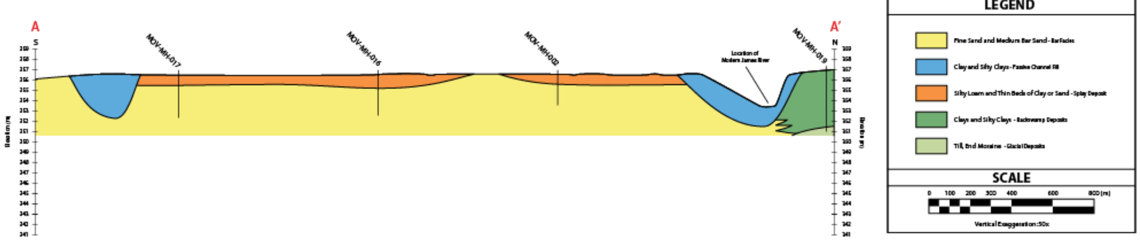
Cross Section A to A' through surficial materials of the Menominee 7.5' Quadrangle, Nebraska



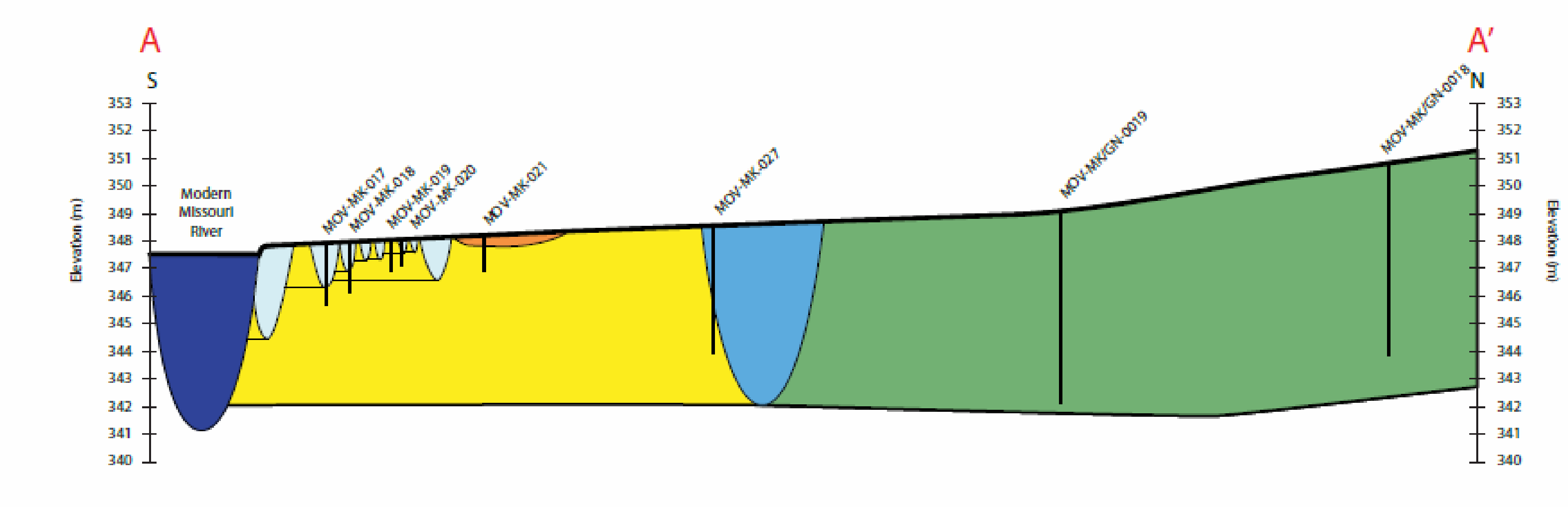
Menominee surficial quadrangle map.

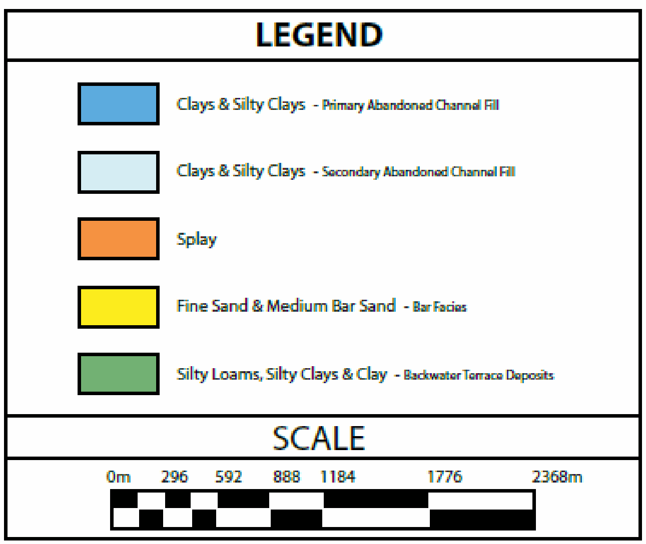


Cross Section A to A' through surficial materials of the Mission Hill 7.5' Quadrangle, South Dakota

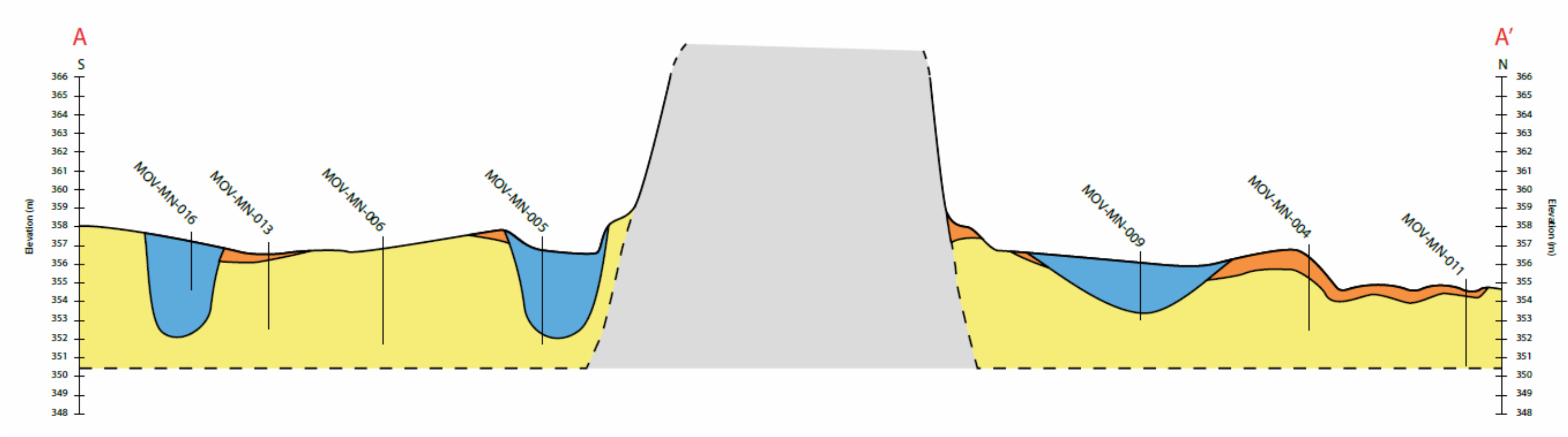


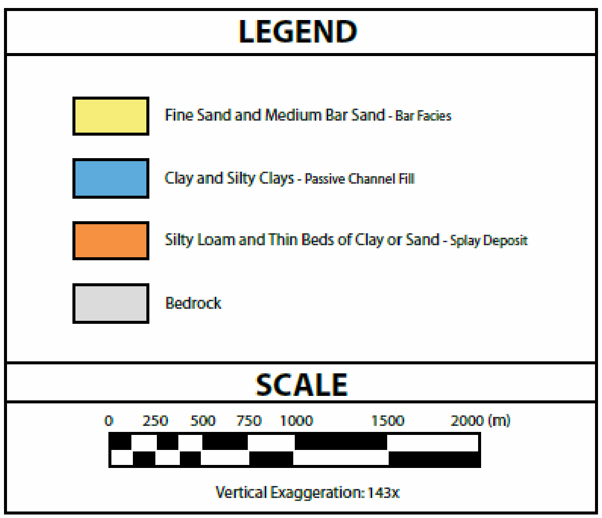
Mission Hill surficial quadrangle map.



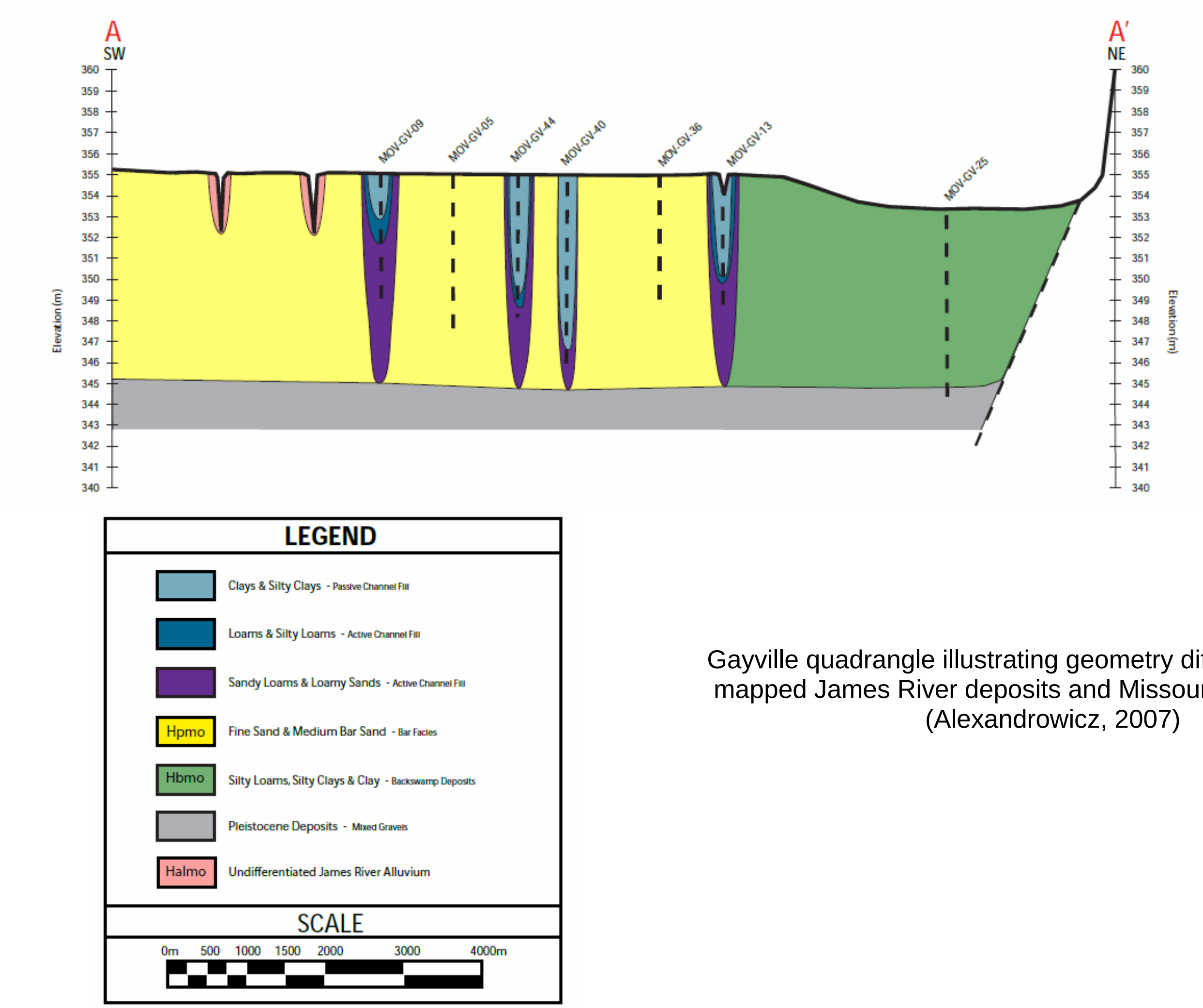


Meckling Quadrangle showing braided morphology, feature 11. Cross-section shows width and depth variations between (secondary) braided channels and main Missouri River paleo-channels. Splay sequence can also be seen over bar deposits. (Moreno, 2007)

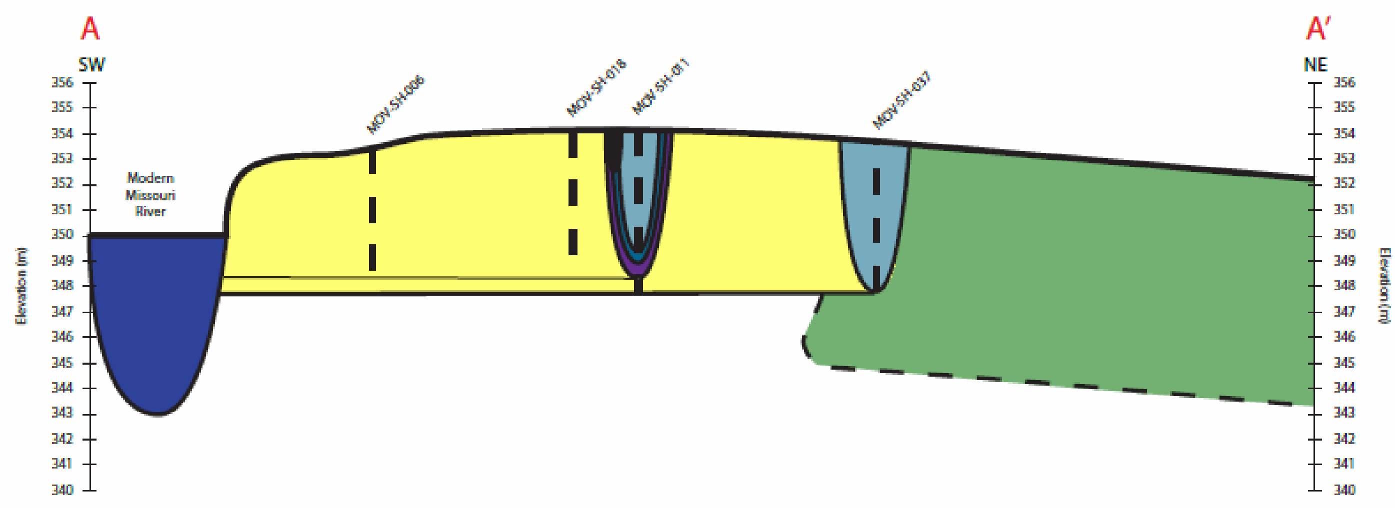


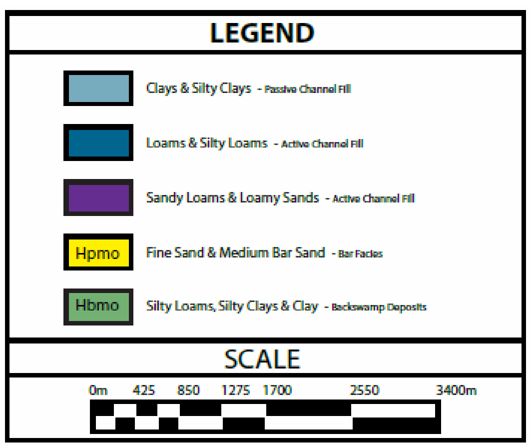


Menominee quadrangle. Cross-section illustrating depth difference between feature 9 and two other Missouri paleo-channels within quadrangle. (Moreno, 2007)



Gayville quadrangle illustrating geometry difference between mapped James River deposits and Missouri River deposits. (Alexandrowicz, 2007)





St. Helena quadrangle
(Garrett, 2007)

APPENDIX B

BOREHOLE

	MOV-MN-002		MOV-MN-003		MOV-MN-004		MOV-MN-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	Alluvial fan	SiC	Alluvial fan	C	Overbank fines	SiC	LR
0.2	SiC		SiC		C		SiC	
0.3	SiC		SiC		SiL		LS	
0.4	L		SiL		SiC		LS	
0.5	L		LS		SiC		LS	
0.6	SiC		L		SiC		L	
0.7	LS		L		SiC		C	
0.8	L		L		SiC		L	
0.9	LS		L		L		C	
1	SiL		SiL		SiC		C	
1.1	SiL		L		L		L	
1.2	L		SiL		SiC		SiC	
1.3	LS	Bar sands	SiL		SiC		L	
1.4	LS		SiL		SiC		LS	ACF
1.5	LS		SiL		SiC		LS	
1.6	LS		SL		SiL		LS	
1.7	SL		L		SiL		L	
1.8	LS		SL	Bar sands	L		LS	
1.9	LS		LS		L		SL	
2	LS		LS		SiC		L	
2.1	LS		LS		L		SL	
2.2	LS		LS		L		LS	
2.3	LS		LS		SL		LS	
2.4	LS		LS		L		LS	
2.5	LS		LS		LS	Bar sands	L	

	MOV-MN-002		MOV-MN-003		MOV-MN-004		MOV-MN-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	LS	Bar sands	LS	Bar sands	LS	Bar sands	SL	ACF
2.7	LS		LS		S		LS	
2.8	SL		LS		S		LS	
2.9	LS		LS		LS		S	
3	LS		LS		LS		LS	
3.1	LS		LS		LS		LS	
3.2	LS		LS		LS		L	
3.3	LS		LS		LS		LS	
3.4	LS		LS		LS		LS	
3.5	LS		LS		LS		S	
3.6	LS		LS		LS		S	
3.7	SL		LS		LS		LS	
3.8	LS		LS		LS		LS	
3.9	LS		LS		S	**Bar**	LS	
4	LS		LS				LS	
4.1	LS		LS				LS	
4.2	LS		LS				LS	
4.3	LS		LS				LS	
4.4	LS		LS				S	
4.5	LS		LS				LS	
4.6	LS		LS				S	CB
4.7	LS		LS				S	
4.8	LS		LS				S	
4.9	LS		LS				S	
5	LS		LS				S	**Channel**

	MOV-MN-002		MOV-MN-003		MOV-MN-004		MOV-MN-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	LS	Bar sands	L	OF				
5.2	LS	**Bar/Alluvial**	SiC					
5.3			L					
5.4			L					
5.5			L					
5.6			L					
5.7			LS	**Bar/Alluvial**				
5.8								

Sic: Silty Clay
LR: Lazy River
L: Loam
LS: Loamy sand
SiL: Silty Loam
ACF: Active Channel Fill
SL: Sandy Loam
S: Sand
C: Clay
CB: Channel Bottom
JRD: James River Deposit
vcS: Very coarse Sand
SC: Secondary Channel
cS: Coarse Sand

	MOV-MN-006		MOV-MN-007		MOV-MN-008		MOV-MN-009	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SL	Overbank fines	SiL	Overbank fines	L	OF	SiC	LR
0.2	SL		SiL		L		SiC	
0.3	SL		SiL		L		SiC	
0.4	LS	Bar sands	LS		L		SiC	
0.5	LS		C		C		SiC	
0.6	LS		SiC		SiC		SiL	
0.7	LS		L		C		L	ACF
0.8	LS		L		L		L	
0.9	LS		C		L		L	
1	LS		C		L		L	
1.1	LS		SiC		L		L	
1.2	LS		SiC		C		LS	
1.3	LS		SiC		L		SiC	
1.4	LS		L		L		L	
1.5	LS		L		S	Bar sands	LS	
1.6	SL		C		S		L	
1.7	SL		S	Bar sands	S		L	
1.8	L	Overbank fines	S		S		LS	
1.9	L		S		S		LS	
2	L		S		S		LS	
2.1	LS	Bar sands	LS		S		LS	
2.2	LS		LS		S		LS	
2.3	LS		LS		S		S	CB
2.4	LS		S		S		S	
2.5	LS		S		S	**Bar**	S	

	MOV-MN-006		MOV-MN-007		MOV-MN-008		MOV-MN-009	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	LS	Bar sands	S	Bar sands			S	CB
2.7	LS		S				S	
2.8	SiC	Overbank fines	S				S	
2.9	L		S				S	
3	L		S	**Bar**			S	**Channel**
3.1	L							
3.2	L							
3.3	L							
3.4	L							
3.5	L							
3.6	SL							
3.7	LS	Bar sands						
3.8	LS							
3.9	S							
4	S							
4.1	LS							
4.2	LS							
4.3	LS							
4.4	LS							
4.5	LS							
4.6	LS							
4.7	LS							
4.8	LS							
4.9	LS							
5	LS	**Bar**						

	MOV-MN-010		MOV-MN-011		MOV-MN-012		MOV-MN-013	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		L		SiC	Alluvial Fan	SiC	LR
0.2	SiC		LS		SiC		SiC	
0.3	LS		L		SiC		SiC	
0.4	LS		L		SiC		SiC	
0.5	LS		L		SiC		SiC	
0.6	LS		L		SiC		SiC	
0.7	LS		C		C		SiC	
0.8	LS		C		SiC		SiC	
0.9	LS		C		SiC		L	
1	LS		L		SiC		L	
1.1	LS		SL		C		L	
1.2	L		SL		L		L	
1.3	SiC		L		L		L	
1.4	LS		LS		L		SiL	
1.5	LS		LS		SL		SiC	
1.6	LS		L		SL		SiL	
1.7	LS		L		LS	Bar sands	SiC	
1.8	LS		L		LS		SiC	
1.9	LS		L		LS		SiC	
2	LS		LS		LS		LS	
2.1	LS		LS		LS		SiL	
2.2	LS		LS		LS		SiL	
2.3	S		LS		SiC	Alluvial Fan	SiL	
2.4	S		LS		SiL		SiL	
2.5	S		LS		SL		SL	

	MOV-MN-010		MOV-MN-011		MOV-MN-012		MOV-MN-013	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	S		LS		SL		SL	ACF
2.7	S		LS		SL	Alluvial Fan	SL	
2.8	S		LS		L		S	
2.9	S		LS		L		S	
3	S	**Splay**	LS		L		S	
3.1			LS		L		LS	
3.2			LS		L		LS	
3.3			LS		SL		S	CB
3.4			LS		L		S	
3.5			LS		L		S	
3.6			LS		L		S	
3.7			LS		L		S	
3.8			LS		L		S	
3.9			LS		LS	Bar sands	S	
4			LS	**Splay**	LS		S	**Channel**
4.1					SL			
4.2					SL			
4.3					SL			
4.4					LS			
4.5					LS			
4.6					LS			
4.7					LS			
4.8					LS			
4.9					LS			
5					LS			

	MOV-MN-010		MOV-MN-011		MOV-MN-012		MOV-MN-013	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1					LS	Bar sands		
5.2					LS			
5.3					LS	**Bar**		
5.4								
5.5								
5.6								

	MOV-MN-014		MOV-MN-015		MOV-MN-016		MOV-MH-001	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	SiL		SiC	OF	SiC	OF
0.2	SiC		SiL		SiL		SiC	
0.3	SiL		SiL		L		LS	Bar Sands
0.4	SiL		L		SiL		LS	
0.5	SiC		L		SL		LS	
0.6	SiC		LS		SiL		LS	
0.7	SiL		LS		SL		LS	
0.8	SiL		LS		LS	Bar sands	LS	
0.9	L		LS		S		LS	
1	L		LS		S		LS	
1.1	SiC		LS		S		LS	
1.2	L		LS		S		LS	
1.3	SiC		LS		S		LS	
1.4	SiC		LS		LS		LS	
1.5	SiL		LS		LS		LS	
1.6	L		LS		S		LS	
1.7	LS		LS		LS		LS	
1.8	L		LS		LS		LS	
1.9	SL		LS		S		LS	
2	SiC		LS		S		L	
2.1	L		LS		S		L	
2.2	SL		LS		S		L	
2.3	L	ACF	LS		S		LS	
2.4	L		LS		S		LS	
2.5	L		LS		S		LS	

	MOV-MN-014		MOV-MN-015		MOV-MN-016		MOV-MH-001	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SL	ACF	LS		S	Bar sands	L	Bar sands
2.7	LS		LS		S		LS	
2.8	L		LS		S		S	
2.9	LS		LS		S		S	
3	LS		LS		S	**Bar**	S	**Bar**
3.1	SL		LS					
3.2	LS		LS					
3.3	LS		LS					
3.4	LS		LS					
3.5	LS		LS					
3.6	LS		C					
3.7	LS		LS					
3.8	LS		LS					
3.9	C		LS					
4	C		LS					
4.1	LS		LS					
4.2	LS		LS					
4.3	LS		LS					
4.4	S	CB	SL					
4.5	S		SL					
4.6	S		SL					
4.7	S		LS					
4.8	S		LS					
4.9	S		LS					
5	S	**Channel**	LS					

	MOV-MN-014		MOV-MN-015		MOV-MN-016		MOV-MH-001	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			LS					
5.2			LS	**Splay**				
5.3								
5.4								
5.5								
5.6								

	MOV-MH-002		MOV-MH-003		MOV-MH-004		MOV-MH-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	L		S		SiC		SiC	LR
0.2	SL		SL		SiC		C	
0.3	SL		LS		SiC	LR	SiC	
0.4	LS		LS	ACF	SiC		SiL	
0.5	S		LS		SiC		SiL	
0.6	S		LS		SiC		LS	
0.7	LS		L		L		LS	ACF
0.8	LS		LS		SiL		LS	
0.9	LS		LS		SiL		LS	
1	LS		LS		SiL		LS	
1.1	LS		LS		SiC		LS	
1.2	LS		LS		L		LS	
1.3	LS		L		SiC		LS	
1.4	S		LS		SiC		LS	
1.5	S		LS		SL		LS	
1.6	S		LS		LS		S	
1.7	SL		L		SL		S	CB
1.8	LS		LS		SL	ACF	S	
1.9	LS		LS		SL		S	
2	LS		LS		SL		S	
2.1	S		LS		SL		S	
2.2	S		LS		SL		S	
2.3	S		LS		SL		LS	
2.4	S		LS		SL		LS	
2.5	S		LS		SL		S	

	MOV-MH-002		MOV-MH-003		MOV-MH-004		MOV-MH-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	S		LS	ACF	SL	ACF	LS	CB
2.7	S		L		L		LS	
2.8	S		LS		L		S	
2.9	S	**Splay**	LS		L		S	
3			LS	**Channel**	L		LS	**Channel**
3.1					L			
3.2					L			
3.3					L			
3.4					L			
3.5					SL			
3.6					SL			
3.7					L			
3.8					L			
3.9					SL			
4					SL	**Channel**		
4.1								
4.2								
4.3								
4.4								
4.5								
4.6								
4.7								
4.8								
4.9								
5								

	MOV-MH-006		MOV-MH-010		MOV-MH-011		MOV-MH-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	OF	SiC	LR	SiC	OF	SiC	OF
0.2	SiC		SiC		SiC		SiL	
0.3	SiC		SiC		SiC		SiL	
0.4	SiL		SiC		SiC		SiL	
0.5	C		SiC		SiC		SiC	
0.6	LS		SiC		SiC		SiL	
0.7	LS		SiC		SiC		SiL	
0.8	LS		SiC		SiC		SiC	
0.9	LS		SiC		SiC		SiL	
1	SL		SiC		SiC		SiL	
1.1	LS	Bar sands	SiC		SiC		SiL	
1.2	LS		SiC		LS	Bar sands	SiL	
1.3	LS		SiC		LS		SiL	
1.4	LS		SiC		LS		SL	
1.5	LS		SiC		LS		L	
1.6	LS		SiC		LS		SiL	
1.7	LS		SiC		LS		SiL	
1.8	LS		SiL		LS		LS	
1.9	LS		SiL		LS		LS	
2	LS		SiL		LS		SiL	
2.1	LS		C		LS		LS	Bar sands
2.2	LS		SiC		LS		LS	
2.3	LS		C		LS		LS	
2.4	LS		C		LS		LS	
2.5	LS		SiC		LS		LS	

	MOV-MH-006		MOV-MH-010		MOV-MH-011		MOV-MH-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	LS		SiC		LS		LS	
2.7	LS	Bar sands	SiC		LS		LS	
2.8	LS		SiC	LR	LS	Bar sands	LS	Bar sands
2.9	S		SiC		LS		LS	
3	S		SiC		LS		LS	
3.1	S		SiC		LS		LS	
3.2	S		C		LS		LS	
3.3	S		L		S		S	
3.4	S		SiC		S		LS	
3.5	S		L		S		LS	
3.6	S		L		S		LS	
3.7	S		L		S		LS	
3.8	S	**Bar**	L		S		LS	
3.9			L		S		LS	
4			L		S	**Bar**	LS	**Bar**
4.1			L					
4.2			L					
4.3			L					
4.4			SL					
4.5			SL	ACF				
4.6			SiL					
4.7			SiL					
4.8			L					
4.9			L					
5			SiC					

	MOV-MH-006		MOV-MH-010		MOV-MH-011		MOV-MH-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			SiL	ACF				
5.2			SL					
5.3			SL					
5.4			L	**Channel**				
5.5								
5.6								

	MOV-MH-014		MOV-MH-015		MOV-MH-016		MOV-MH-017	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	OF	SiC	LR	LS		LS	
0.2	SiC		L		LS		LS	
0.3	SiC		L		L		C	
0.4	SiC		SiC		C		LS	
0.5	SiC		SiC		SiC		C	
0.6	SiC		C		L		C	
0.7	SiC		SiC		L		SiC	
0.8	L		SL		L		L	
0.9	L		LS	CB	L		L	
1	SiC		LS		L		L	
1.1	SiC		LS		LS		L	
1.2	SiC		LS		L		L	
1.3	SiL		LS		L		LS	
1.4	L		LS		LS		LS	
1.5	LS	Bar Sands	LS		LS		LS	
1.6	LS		LS		LS		LS	
1.7	LS		LS		LS		LS	
1.8	L		S		LS		LS	
1.9	SL		S		LS		L	
2	S		S	**Channel**	LS		LS	
2.1	S				S		L	
2.2	LS				S		L	
2.3	S				LS		L	
2.4	LS				LS		L	
2.5	S	**Bar**			LS		L	

	MOV-MH-014		MOV-MH-015		MOV-MH-016		MOV-MH-017	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6					LS		LS	
2.7					LS		SiC	
2.8					LS		L	
2.9					LS		LS	
3					LS		LS	
3.1					LS		LS	
3.2					LS		LS	
3.3					LS		LS	
3.4					LS		LS	
3.5					LS		LS	
3.6					LS		LS	
3.7					S		LS	
3.8					S		LS	
3.9					S		LS	
4					S	**Splay**	LS	**Splay**
4.1								
4.2								
4.3								
4.4								
4.5								
4.6								
4.7								
4.8								
4.9								
5								

	MOV-MH-018		MOV-MH-019		MOV-MH-020		MOV-MH-021	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		SiC		C		SL	
0.2	SiC		SiL		SiC		L	
0.3	SiC		SiL		SiC		L	
0.4	SiC	LR	SiC	JRD	SiC	LR	L	ACF
0.5	SiC		SiC		SiC		SL	
0.6	L		SiC		SiC		LS	
0.7	SiC		SiC		SiC		LS	
0.8	SiC		SiL		SiC		C	
0.9	SiL		SiL		SiC		C	
1	SiC		L		L		SiL	
1.1	C		L		L		SiC	
1.2	SiC		L		L		L	
1.3	SiC		L		L		SiC	
1.4	C		L		SiC		L	
1.5	SiC		SiL		SiC		LS	
1.6	SiC		L		LS		LS	
1.7	SiC		L		LS		L	
1.8	SiL		L		LS		C	
1.9	SiC		C		LS		LS	
2	SiC		C		L		LS	
2.1	SiC		C		LS		LS	
2.2	C		SiC		SiC		LS	
2.3	C		C	Floodplain	SiC		LS	
2.4	SiL		C		SiC		LS	
2.5	SL	ACF	C		LS		LS	

	MOV-MH-018		MOV-MH-019		MOV-MH-020		MOV-MH-021	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SL	ACF	C	Floodplain	C	LR	LS	ACF
2.7	SL		C		SiC		SiC	
2.8	L		C		SiC		SiC	
2.9	L		C		SiC		SiC	
3	L		C		C		S	CB
3.1	L		C		C		S	
3.2	SL		C		C		S	
3.3	LS	CB	C		C		S	
3.4	LS		C		C		LS	
3.5	LS		C		C		LS	
3.6	S		C		C		L	
3.7	S		C		C		LS	
3.8	S		C		C		LS	
3.9	S		C		C		LS	
4	S	**Channel**	C		L		LS	
4.1			C		L		LS	
4.2			C		LS	CB	LS	
4.3			SiC		LS		LS	
4.4			SiC		S		LS	
4.5			SiC		S		LS	
4.6			SiC		S		LS	
4.7			SiC		S		LS	
4.8			L		S		LS	
4.9			L		S		LS	
5			L		S	**Channel**	LS	**Channel**

	MOV-MH-018		MOV-MH-019		MOV-MH-020		MOV-MH-021	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			L	Floodplain				
5.2			L					
5.3			L					
5.4			L					
5.5			L					
5.6			L					
5.7			M/T	vcS				
5.8			M/T					
5.9			M/T	**Floodplain**				
6								
6.1								
6.2								
6.3								
6.4								
6.5								
6.6								
6.7								
6.8								
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-MH-022		MOV-MH-023		MOV-MH-024		MOV-MH-025	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SL	LR	SiL	OF	SL	ACF	SiC	
0.2	SL		SiL		SL		SiC	
0.3	SL		SiC		SL		SiC	
0.4	SiC		SiL		SL		SiC	
0.5	SiC		L		SL		SiL	
0.6	SiL		SiL		SL		SiL	
0.7	SiC		L		SL		SiL	
0.8	SiC		SiL		SL		SiL	
0.9	SiL		SiC		SL		SiC	
1	SiC		SL		SL		L	
1.1	C		SiC		SL		SiC	
1.2	L		SiC		SL		SiC	
1.3	L		L		L		SiL	
1.4	L		SiC		L		SiL	
1.5	L		SiL		SL		SiL	
1.6	L		L		L		SL	
1.7	L		L		L		SL	
1.8	SiL		L		SiC		L	
1.9	LS	CB	SL	Bar sands	L		L	
2	LS		LS		SiC		SL	
2.1	SL		LS		SiC		L	
2.2	L		LS		SiL		L	
2.3	S		S		SL		L	
2.4	S		S		SL		L	
2.5	S		S		SL		SL	

	MOV-MH-022		MOV-MH-023		MOV-MH-024		MOV-MH-025	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	S	CB	S	**Scroll Bar**	SL	ACF	SiC	
2.7	S				SL		SiL	
2.8	S				SL		SiC	
2.9	S				L		SiC	
3	S				SL		SiC	
3.1	S				SL		SiL	
3.2	S	**Channel**			SL		SiL	
3.3					L		SiL	
3.4					S		SiL	
3.5					S		SiL	
3.6					S		SiL	
3.7					SiC		SiC	
3.8					SiC		SiC	
3.9					L		SiC	
4					L		SiC	
4.1					L		SiC	
4.2					S		L	
4.3					S		SiL	
4.4					S		L	
4.5					S		L	
4.6					S		SL	
4.7					SiL		SL	
4.8					SL		SL	
4.9					LS		SL	
5					SL		SL	

	MOV-MH-022		MOV-MH-023		MOV-MH-024		MOV-MH-025	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1					L	LR	LS	
5.2					L		LS	
5.3					L		LS	
5.4					L		LS	
5.5					SL	CB	SiC	
5.6					LS		SiC	
5.7					S		SiC	
5.8					S		SiL	
5.9					S		SiC	
6					S	**Channel**	SiC	
6.1							C	
6.2							L	
6.3							SL	
6.4							SL	
6.5							SL	
6.6							SiC	
6.7							SiC	
6.8							SiC	
6.9							SiC	
7							C	**Floodplain**
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-MH-026		MOV-MH-027		MOV-GN-001		MOV-GN-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	L	OF	C	OF	C	OF
0.2	SiC		L		C		C	
0.3	SiL		L		C		C	
0.4	SiL		L		SiC		C	
0.5	SiL		L		C		C	
0.6	SiL		L		C		C	
0.7	SL		L		SiC		C	
0.8	SL		L		C		C	
0.9	L		L		C		C	
1	SL		L		C		C	
1.1	L		L		C		C	
1.2	L		L		SiC		C	
1.3	L		L		SiC		C	
1.4	L		L		SiC		C	
1.5	SiC		SiC		SiC		C	
1.6	LS	CB	SiC		C		C	
1.7	LS		SiC		C		C	
1.8	LS		SL	Bar sands	C		C	
1.9	LS		SL		C		C	
2	S		SL		C		C	
2.1	S		SL		C			
2.2	S		L		C		C	
2.3	S		L		C		C	
2.4	S		L		C		C	
2.5	S		SL		C		C	

	MOV-MH-026		MOV-MH-027		MOV-GN-001		MOV-GN-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	S	CB	SL	Bar sands	SiL		C	
2.7	S		SL		C		C	
2.8	S		SL		C		C	
2.9	S		SL		C		C	
3	S	**Channel**	SL	**James Bar**	C		C	
3.1					C		C	
3.2					C		C	
3.3					C		C	
3.4					C		C	
3.5					C		SiC	
3.6					C		SiC	
3.7					C		SiC	
3.8					C		SiC	
3.9					C		C	
4					C		C	
4.1					C		C	
4.2					C		C	
4.3					C		C	
4.4					C		SiL	
4.5					C		SiL	
4.6					C		L	
4.7					C		L	
4.8					C		L	
4.9					C		SiL	
5					C		L	

	MOV-MH-026		MOV-MH-027		MOV-GN-001		MOV-GN-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1					C		L	
5.2					C		L	
5.3					C		L	
5.4					SiC		SiL	
5.5					SiC		SiC	
5.6					SiC		SiC	
5.7					SiC		SiC	
5.8					SiC		SiC	
5.9					SiC		L	
6					SiC		SiC	
6.1					SL		SiC	
6.2					L		SiC	
6.3					L		C	
6.4					L		C	
6.5					L		C	
6.6					SiC		C	
6.7					SiC		C	
6.8					SiC		C	
6.9					SiC		C	
7					LS		SiC	
7.1					Si		C	
7.2					Si		C	
7.3					SiC		S	
7.4					SiC		S	
7.5					SiC		S	

	MOV-MH-026		**MOV-MH-027**		**MOV-GN-001**		**MOV-GN-002**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6					L		S	
7.7					SiL		S	
7.8					C		S	**Floodplain**
7.9					SiC			
8					SL			
8.1					SiC			
8.2					SiC			
8.3					SiC			
8.4					SL			
8.5					SL			
8.6					L	**Floodplain**		
8.7								

	MOV-GN-003		MOV-GN-004		MOV-GN-005		MOV-GN-006	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C		C		C		C	
0.2	C		C		C		C	
0.3	C		C		C		C	
0.4	C		C		SiC		SiC	
0.5	C		C		C		C	
0.6	C		C		C		C	
0.7	C		SiC		SiC		C	
0.8	C		SiC		C		SiC	
0.9	C		C		C		SiC	
1	C		C		C		SiC	
1.1	C		SiC		C		C	
1.2	C		C		C		SiC	
1.3	C		C		C		C	
1.4	SiC		SiC		C		C	
1.5	C		SiC		C		C	
1.6	C		SiC		C		C	
1.7	SiC		SiC		SiC		C	
1.8	SiC		SiC		SiC		C	
1.9	SiC		SiC		SiC		L	
2	C		SiC		SiC		C	
2.1	C		SiC		SiC		C	
2.2	C		SiC		SiC		C	
2.3	C		SiC		SiL		C	
2.4	C		SiL		SiC		C	
2.5	C		SL		SiL		C	

	MOV-GN-003		MOV-GN-004		MOV-GN-005		MOV-GN-006	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	C		SL		SiL		C	
2.7	C		SL		SiL		C	
2.8	C				SiL		C	
2.9	C		/		SiC		SiC	
3	C		/		SiC		SiC	
3.1	C		S		C		SiC	
3.2	SiC		S		SiC		SiC	
3.3	SiC		S		SiC		SiC	
3.4	SiC		S		SiC		SiC	
3.5	SiC		LS		SiC		SiL	
3.6	SiC		S		SiC		SiC	
3.7	SiC		S		C		SiL	
3.8	SiC		S		SiC		SiL	
3.9	SiC		S		SiC		SiL	
4	SiC		S		SiC		SiL	
4.1	SiC		S		L		SiL	
4.2	SiC		S		L		SiL	
4.3	SL		S		SL		SiC	
4.4	SiC		S		SiC		SiC	
4.5	SiC		S		SiC		SiC	
4.6	SiC		S	**Floodplain**	SiC		SiC	
4.7	SiC				SiL		SiC	
4.8	SiC				L		SiL	
4.9	SiC				SL		SiL	
5	L				L		L	

	MOV-GN-003		MOV-GN-004		MOV-GN-005		MOV-GN-006	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	SiL				SiC		SiL	
5.2	SiC				SiC		SiL	
5.3	C				SiC		SiL	
5.4	SiL				SiC		C	
5.5	SiL				SiC		C	
5.6	SiC				C		C	
5.7	SiC				C		C	
5.8	SiL				C		C	
5.9	SiL				C		C	
6	SiL				SiC		C	
6.1	SL				SiC		C	
6.2	/				SiC		C	
6.3	/				LS		C	
6.4	SiC				S		C	
6.5	SiC				S		C	
6.6	SiC				SL		C	
6.7	SiC				S		C	
6.8	SiC				S		C	
6.9	SL				S		C	
7	LS				S		C	**Floodplain**
7.1	LS				S			
7.2	SiC				S			
7.3	SiC				S			
7.4	C				S			
7.5	C				S			

	MOV-GN-003		MOV-GN-004		MOV-GN-005		MOV-GN-006	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6	C				S	**Floodplain**		
7.7	SiC							
7.8	C							
7.9	C							
8	C							
8.1	C							
8.2	C	**Floodplain**						
8.3								
8.4								

	MOV-GN-007		MOV-GN-008		MOV-GN-009		MOV-GN-010	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C		C		C		C	
0.2	SiC		C		C		C	
0.3	SiL		LS		LFS		SiC	
0.4	LS		LS		LFS		SiC	
0.5	LS		SL		LFS		SiC	
0.6	SiL		C		LFS		C	
0.7	C		SiC		C		C	
0.8	C		C		C		SiC	
0.9	C		SiC		C		C	
1	C		SiC		C		SiC	
1.1	C		SiC		C		Si	
1.2	C		SiC		C		SiC	
1.3	SiC		SiC		C		C	
1.4	SiC		SiC		C		C	
1.5	C		C		C		SiC	
1.6	C		C		C		SiC	
1.7	C		C		C		SiC	
1.8	C		C		C		C	
1.9	C		C		C		C	
2	C		C		C		C	
2.1	C		C		SiC		C	
2.2	C		C		L		C	
2.3	C		SiC		SiC		C	
2.4	C		SiC		C		C	
2.5	C		SiC		C		C	

	MOV-GN-007		MOV-GN-008		MOV-GN-009		MOV-GN-010	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC		C		C		C	
2.7	SiC		SiC		C		C	
2.8	C		C		C		C	
2.9	C		SiC		C		C	
3	C		C		C		C	
3.1	SiC		SiC		C		C	
3.2	C		C		SiC		C	
3.3	C		SiC		SiC		C	
3.4	SiC		SiC		SiC		C	
3.5	C		C		C		C	
3.6	C		C		C		C	
3.7	C		C		SiC		C	
3.8	C		SiC		SiC		C	
3.9	C		SiC		SiC		C	
4	SiC		SiC		C		C	
4.1	L		SiL		C		C	
4.2	L		SiL		L		C	
4.3	SiL		SiL		L		SiC	
4.4	SiC		LS		L		SiC	
4.5	SiC		C		L		C	
4.6	SiL		SiC		L		SiC	
4.7	SiC		SiC		L		SiL	
4.8	C		C		L		L	
4.9	C		C		L		SiC	
5	SiC		SiC		L		C	

	MOV-GN-007		MOV-GN-008		MOV-GN-009		MOV-GN-010	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	L		L		L		SiC	
5.2	SiL		SiC		L		SiC	
5.3	SiC		L		SiC		SiC	
5.4	C		SiC		L		SiC	
5.5	L		SiC		SiC		L	
5.6	L		SiC		C		L	
5.7	SiL		SiC		L		SL	
5.8	SiL		SiC		SiC		SL	
5.9	SiL		L		SiC		C	
6	SiL		L		C		L	
6.1	SiL		L		C		Si	
6.2	SiL		L		L		Si	
6.3	SiL		L		C		SiC	
6.4	SiL		L		C		SiC	
6.5	SiL		L		SiC		C	
6.6	SiL		L		SiC		C	
6.7	SiL		L		SiC		SiC	
6.8	SiC		L		SiC		C	
6.9	SiC		L		SiC		C	
7	SiC		SiL		SiC		C	
7.1	SiC		SiL		SiC		SiC	
7.2	C		SiL		C		C	
7.3	SiC		SL		SiC		C	
7.4	SiC		SL		SiC		C	
7.5	C		L		SiC		SiC	

	MOV-GN-007		MOV-GN-008		MOV-GN-009		MOV-GN-010	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6	C		L		SiL		SiC	
7.7	C		SL		SiL		SiC	
7.8	C		SL		L		S	
7.9	C		S		L		S	
8	C		S		L		S	
8.1	C		S		L		S	
8.2	C		S		L		S	
8.3	C		S		L		S	
8.4	C		S	**Floodplain**	SL		S	
8.5	C				SL		S	
8.6	C	**Floodplain**			S		S	**Floodplain**
8.7					SL			
8.8					S			
8.9					S			
9					S	**Floodplain**		
9.1								
9.2								
9.3								
9.4								
9.5								
9.6								
9.7								
9.8								
9.9								
10								

	MOV-GN-011		MOV-GN-012		MOV-GN-013		MOV-GN-014	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C		C		SiC		C	
0.2	C		C		SiC		C	
0.3	C		C		C		C	
0.4	SiC		C		C		C	
0.5	SiC		C		C		C	
0.6	SiC		C		C		C	
0.7	SiC		C		C		C	
0.8	C		C		C		L	
0.9	C		C		C		C	
1	L		C		C		L	
1.1	SiC		C		C		L	
1.2	C		C		C		L	
1.3	SiC		C		C		SC	
1.4	C		SiC		C		C	
1.5	C		SiC		C		C	
1.6	C		C		C		C	
1.7	C		C		C		C	
1.8	C		SiC		C		SiC	
1.9	C		SiC		C		SiC	
2	SiC		SiC		C		SiC	
2.1	SiC		SiL		C		C	
2.2	SiC		SiL		SiC		SiC	
2.3	SiC		L		SiC		SiC	
2.4	SiC		SiL		L		SiC	
2.5	SiC		SiL		L		SiC	

	MOV-GN-011		MOV-GN-012		MOV-GN-013		MOV-GN-014	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC		L		L		SiL	
2.7	SiC		SiC		L		SiL	
2.8	SiC		L		L		SiL	
2.9	SiC		SiC		L		C	
3	SiC		C		L		C	
3.1	SiC		C		L		C	
3.2	SiL		L		L		SiL	
3.3	L		L		L		SiL	
3.4	SiL		L		L		SiC	
3.5	L		L		SiC		C	
3.6	L		SiC		SiC		SiL	
3.7	L		L		L		SiL	
3.8	SL		L		L		Si	
3.9	SL		L		L		SiL	
4	L		L		L		SiL	
4.1	SL		L		SiL		SL	
4.2	SiL		L		SiL		Si	
4.3	L		L		SiL		SL	
4.4	L		SiL		SiL		SL	
4.5	Si		SiL		SiL		SL	
4.6	SiL		SiC		L		C	
4.7	SiL		Si		L		SiC	
4.8	SiC		Si		L		L	
4.9	SiC		SiC		L		SL	
5	SiC		SiC		L		SiC	

	MOV-GN-011		MOV-GN-012		MOV-GN-013		MOV-GN-014	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	SiC		SiC		L		SiC	
5.2	SiC		SiC		L		SiC	
5.3	SiC		SiC		L		SiC	
5.4	SiC		SiC		L		SiC	
5.5	SiC		SiC		SiL		C	
5.6	C		SiC		SiL		C	
5.7	C		SiC		SiL		SiC	
5.8	C		C		SiL		SiC	
5.9	C		SiC		SiL		SC	
6	C		SiC		L		SC	
6.1	C		SiC		SiL		S	
6.2	C		SiC		SiL		S	
6.3	C		C		SiL		S	
6.4	C		C		L		S	
6.5	C		C		C		S	
6.6	C		C		C		S	
6.7	C		SiC		C		S	**Floodplain**
6.8	C		SiC		C			
6.9	C		C		C			
7	C		C		C			
7.1	S		C		C			
7.2	S		C		C	**Floodplain**		
7.3	C		S					
7.4	C		S					
7.5	S		S					

	MOV-GN-011		MOV-GN-012		MOV-GN-013		MOV-GN-014	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6	S		S					
7.7	S		S	**Floodplain**				
7.8	S							
7.9	S							
8	S							
8.1	S							
8.2	S							
8.3	S							
8.4	S							
8.5	S							
8.6	S	**Floodplain**						
8.7								

	MOV-GN-015		MOV-GN-016		MOV-GN-020		MOV-GN-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C		C		C		C	
0.2	C		C		C		C	
0.3	C		C		SiC		C	
0.4	C		C		C		SiC	
0.5	C		C		C		SiC	
0.6	C		C		C		Si	
0.7	C		C		SiC		Si	
0.8	C		SiC		SiC		Si	
0.9	C		SiC		C		Si	
1	SiC		SiC		SiC		SiC	
1.1	C		SiC		C		SiC	
1.2	SiC		C		C		SiC	
1.3	C		C		C		SiC	
1.4	SiC		SiC		C		SiC	
1.5	C		C		SiC		SiC	
1.6	SiC		SiC		SiC		SiC	
1.7	SiC		SiC		SiC		SiC	
1.8	C		SiC		C		SiC	
1.9	SiC		C		C		SiC	**Floodplain**
2	SiC		C		C			
2.1	SiC		SiC		C			
2.2	SiC		C		C			
2.3	SiC		C		SiC			
2.4	L		SiC		SiC			
2.5	cS		SiC		SiC			

	MOV-GN-015		MOV-GN-016		MOV-GN-020		MOV-GN-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	S		SiC		SiC			
2.7	S		SiC		SiC			
2.8	Si		SiC		C			
2.9	S		SiC		C			
3	S		SiC		SiC			
3.1	S		Si		SiC			
3.2	S		SiC		SiC			
3.3	Si		SiC		SiC			
3.4	Si		SiC		C			
3.5	Si		SiC		C			
3.6	Si		SiC		C			
3.7	Si		SiC		C			
3.8	Si		SiC		SiC			
3.9	Si		C		SiC			
4	Si		C		SiC			
4.1	Si		SiC		SiC			
4.2	Si		SiC		SiL			
4.3	C		SiC		SiC			
4.4	C		SiC		SiC			
4.5	C		SiC		SiC			
4.6	C		L		SiC			
4.7	Si		L		SiC			
4.8	C		L		L			
4.9	C		SL		L			
5	C	**Floodplain**	SL		L			

	MOV-GN-015		MOV-GN-016		MOV-GN-020		MOV-GN-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			C		S			
5.2			C		S			
5.3			SiC		S			
5.4			L		S			
5.5			L		S			
5.6			Si		S			
5.7			Si		S			
5.8			SiC		S			
5.9			SiC		S			
6			L		S	**Floodplain**		
6.1			SiC					
6.2			SiC					
6.3			SiC					
6.4			SiC					
6.5			SiC					
6.6			SiC					
6.7			SiC					
6.8			C					
6.9			C					
7			C					
7.1			Si					
7.2			C					
7.3			C					
7.4			C					
7.5			C					

	MOV-GN-015		MOV-GN-016		MOV-GN-020		MOV-GN-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6			C					
7.7			C					
7.8			S	**Floodplain**				
7.9								
8								
8.1								
8.2								
8.3								
8.4								

	MOV-GN-023		MOV-GN-024		MOV-MK-001		MOV-MK-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		SiC		L		C	
0.2	SiC		SiC		C		SL	
0.3	SiC		SiC		C		SiL	
0.4	SiC		SiC		C	LR	SiL	
0.5	SiC		SiC		C		LS	
0.6	SiC		SiC		C		LS	
0.7	Si		SiC		C		LS	
0.8	SiC		SiC		C		LS	
0.9	SiC		SiC		C		LS	
1	SiC	**Floodplain**	SiC	**Floodplain**	C		LS	
1.1					SiC		LS	
1.2					SiC		LS	
1.3					SiC		L	
1.4					C		SiL	
1.5					SiC		C	
1.6					C		C	
1.7					C		SiC	
1.8					C		SiC	
1.9					C		SiC	
2					SiC		SiC	
2.1					C		C	
2.2					C		C	
2.3					C		C	
2.4					C		C	
2.5					C		C	

	MOV-GN-023		MOV-GN-024		MOV-MK-001		MOV-MK-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6					C		L	
2.7					C	LR	L	
2.8					C		LS	
2.9					C		LS	
3					C		LS	
3.1					C		LS	
3.2					C		LS	
3.3					C		fS	
3.4					C		fS	
3.5					C		LS	
3.6					C		LS	
3.7					VFS		LS	
3.8					VFS	CB	LS	
3.9					VFS		LS	
4					VFS		LS	
4.1					VFS		LS	
4.2					VFS		LS	
4.3					VFS		LS	
4.4					VFS		LS	
4.5					VFS		LS	**Splay**
4.6					VFS			
4.7					VFS			
4.8					VFS	**Channel**		
4.9								
5								

	MOV-MK-003		MOV-MK-004		MOV-MK-005		MOV-MK-006	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C	SC	C		SiC		C	OF
0.2	C		C		C		C	
0.3	C		C		C		C	
0.4	C		C		C		C	
0.5	C		C		C		C	
0.6	C		Si		SiC		C	
0.7	C		Si		SiL		C	
0.8	C		SiL		SiL		C	
0.9	C		L		SiL		C	
1	C		LS		L		SiC	
1.1	C		LS		L		C	
1.2	C		LS		L		C	
1.3	C		LS		SiC		C	
1.4	C		L		L		C	
1.5	C		LS		SL		C	
1.6	L		LS		LS		C	
1.7	SL		LS		L		C	
1.8	C		LS		L		SiC	
1.9	C		C		SiL		SiC	
2	C		C		SiL		SiC	
2.1	C		S		L		SiL	
2.2	C		S		L		L	
2.3	SiC		S		L		C	
2.4	SiC		S		L		SiL	
2.5	C		S		L		C	

	MOV-MK-003		MOV-MK-004		MOV-MK-005		MOV-MK-006	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	C		S		fSL		L	OF
2.7	C	SC	S		LfS		C	
2.8	C		S		LfS		C	
2.9	C		S		LfS		C	
3	C		S		LfS		L	
3.1	C		S		LfS		SL	
3.2	L		LS		LfS		SL	Bar sands
3.3	C		S		SiL		SL	
3.4	SiL		S		LfS		SL	
3.5	fS		S		LfS		LS	
3.6	fS	Bar sands	S	**Splay**	LfS		LS	
3.7	fS				fS		LS	
3.8	fS				fS		S	
3.9	fS				fS		S	
4	fS				fS	**Splay**	S	
4.1	fS						SL	
4.2	fS						SiC	
4.3	fS						SiC	OF
4.4	fS	**Bar**					SiC	
4.5							LS	
4.6							LS	
4.7							LS	
4.8							SiC	
4.9							SiC	
5							LS	

	MOV-MK-003		MOV-MK-004		MOV-MK-005		MOV-MK-006	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1							C	OF
5.2							LS	Bar sands
5.3							LS	
5.4							LS	
5.5							LS	
5.6							LS	
5.7							LS	
5.8							LS	**Bar**

	MOV-MK-008		MOV-MK-009		MOV-MK-010		MOV-MK-011	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C	LR	C	OF	C	OF	SiC	LR
0.2	C		SiC		C		SiC	
0.3	C		SiC		C		SiL	
0.4	C		SiC		C		SiL	
0.5	SiC		SL		C		C	
0.6	Sic		SL		C		SiL	
0.7	fS		SL		C		C	
0.8	C		LS		SiC		SiC	
0.9	C		SL		SiC		SiC	
1	C		SiL		SiL		SiC	
1.1	SiC		S	Bar sands	SiL		SiL	
1.2	C		S		SiL		SiL	
1.3	SiC		S		SiL		SiL	
1.4	C		LS		L		C	
1.5	C		S		SL		C	
1.6	SiC		LS		SL		C	
1.7	SiC		LS		SiC		C	
1.8	C		LS		SL	Bar sands	C	
1.9	SiC		S		SL		C	
2	C		LS		LS		C	
2.1	C		LS		LS		C	
2.2	SiC		LS		LS		C	
2.3	SiC		LS		LS		SiC	
2.4	C		S		L		SiC	
2.5	SiC		S		SL		SiC	

	MOV-MK-008		MOV-MK-009		MOV-MK-010		MOV-MK-011	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	C	LR	S	Bar sands	L	Bar sands	SiC	LR
2.7	C		S		SL		L	
2.8	C		S		SiL		L	
2.9	SiC		S		SL		L	
3	SiC		S	**Bar**	S		LfS	ACF
3.1	SiC				LS		LfS	
3.2	C				S		fS	
3.3	C				S		L	
3.4	SiL				S		L	
3.5	C				S		L	
3.6	SiC				S		LS	
3.7	SiC				S		LS	
3.8	SiL				S		LS	
3.9	SiL				S		LS	
4	SiL				S	**Bar**	LS	
4.1	SiL						L	LR
4.2	S	CB					L	
4.3	S						L	
4.4	S						L	
4.5	S						L	
4.6	S						L	
4.7	S						L	
4.8	S						L	
4.9	S						L	
5	S						L	

	MOV-MK-008		MOV-MK-009		MOV-MK-010		MOV-MK-011	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	S	CB					L	LR
5.2	S						L	
5.3	S	**Channel**					L	
5.4							L	
5.5							SiL	
5.6							SiL	
5.7							SiL	
5.8							SiL	
5.9							L	
6							SiL	
6.1							SiL	
6.2							SiL	
6.3							SiL	
6.4							L	
6.5							L	
6.6							L	
6.7							SL	**Channel**
6.8								
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-MK-012		MOV-MK-013		MOV-MK-014		MOV-MK-015	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C	OF	L		C	LR	C	LR
0.2	C		SC		C		Si	
0.3	C		C		C		Si	
0.4	C		C		C		SL	ACF
0.5	C		C		C		SiL	
0.6	C		SiL		C		S	
0.7	C		L		C		S	
0.8	C		L		C		LS	
0.9	C		SiC		C		LS	
1	C		SiC		C		L	
1.1	C		fS		C		L	
1.2	LS		fS		C		L	
1.3	L		fS		C		L	
1.4	SiL		fS		C		SiC	
1.5	L		fS		C		L	
1.6	SiC		fS		SiL		S	CB
1.7	LS	Bar sands	fS		SiL		LS	
1.8	LS		fS		SiL		LS	
1.9	LS		fS		SiC		SL	
2	LS		fS		L		SL	
2.1	LS		LfS		L		LS	
2.2	LS		L		L		LS	
2.3	LS		L		L		C	
2.4	LS		LfS		L		LS	
2.5	LS		fS		L		LS	

	MOV-MK-012		MOV-MK-013		MOV-MK-014		MOV-MK-015	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	LS		fS		SiL	LR	S	
2.7	LS		fS		SiL		LS	CB
2.8	SiC		fS		L		LS	
2.9	SiC	Bar sands	fS		L		LS	
3	S		fS	**Splay**	fS		S	
3.1	LS				LfS		S	
3.2	LS				LfS		S	
3.3	LS				LfS	CB	S	
3.4	LS				SL		S	
3.5	SiC				LfS		S	
3.6	LS				LS		S	
3.7	LS				LS		S	
3.8	LS				LS		S	
3.9	S				LS		S	
4	S				S		S	**Channel**
4.1	S				S			
4.2	S				S			
4.3	S				S			
4.4	S				S			
4.5	SL				S			
4.6	SL				S			
4.7	L				S			
4.8	S				S			
4.9	S				S			
5	SL				S			

	MOV-MK-012		MOV-MK-013		MOV-MK-014		MOV-MK-015	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	LS	Bar sands			S	CB		
5.2	LS				S			
5.3	L				S			
5.4	L				S	**Channel**		
5.5	S							
5.6	S	**Bar**						

	MOV-MK-016		**MOV-MK-017**		**MOV-MK/GN-017**		**MOV-MK-018**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	OF	fS	ACF	C	LR	fS	Bar sands
0.2	C		fS		C		fS	
0.3	C		fS		C		fS	
0.4	C		fS		C		fS	
0.5	C		fS		SiC		fS	
0.6	C		fS		C		fS	
0.7	C		SiC		C		fS	
0.8	L		SiL		C		fS	
0.9	SiC		LfS		C		fS	
1	C		fS		C		fS	
1.1	LfS	Bar sands	LfS		C		fS	
1.2	LfS		LfS		C		fS	
1.3	L		LfS		C		fS	
1.4	LfS		L		C		fS	
1.5	LfS		SiC		C		fS	
1.6	SL		SiC		C		fS	
1.7	LfS		fS	CB	C		fS	
1.8	fS		fS		C		fS	
1.9	fS		fS		C		fS	
2	fS		fS		C		fS	**Bar**
2.1	LfS		fS		C			
2.2	LfS		fS		C			
2.3	LfS		fS		C			
2.4	S		fS		C			
2.5	S		fS		C			

	MOV-MK-016		MOV-MK-017		MOV-MK/GN-017		MOV-MK-018	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	S	Bar sands	fS	CB	C	LR		
2.7	S		fS		SiC			
2.8	S		fS		SiC			
2.9	S		fS		SiC			
3	S		fS	**Channel**	SiC			
3.1	S				C			
3.2	S				C			
3.3	S				SiC			
3.4	S	**Bar**			SiC			
3.5					SiC			
3.6					C			
3.7					SiC			
3.8					C			
3.9					SiC			
4					SiC			
4.1					SiC			
4.2					C			
4.3					C			
4.4					C			
4.5					C			
4.6					SiC			
4.7					SiC			
4.8					SiC			
4.9					SiL			
5					L			

	MOV-MK-016		MOV-MK-017		MOV-MK/GN-017		MOV-MK-018	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1					L	LR		
5.2					L			
5.3					SiC			
5.4					L			
5.5					SiC			
5.6					SiC			
5.7					SiC			
5.8					C			
5.9					C			
6					C			
6.1					C			
6.2					C			
6.3					C			
6.4					C			
6.5					C			
6.6					C			
6.7					C			
6.8					C			
6.9					S	CB		
7					S			
7.1					S			
7.2					S			
7.3					S			
7.4					S			
7.5					S			

	MOV-MK-016		**MOV-MK-017**		**MOV-MK/GN-017**		**MOV-MK-018**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6					S	**Channel**		
7.7								
7.8								
7.9								
8								
8.1								
8.2								
8.3								
8.4								

	MOV-MK/GN-018		MOV-MK-019		MOV-MK/GN/019		MOV-MK-020	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C	LR	C	LR	C		C	OF
0.2	C		C		C		C	
0.3	C		C		SiC		S	
0.4	C		C		C		C	
0.5	C		C		C		L	
0.6	C		SiC		C		SiL	
0.7	C		C		C		S	
0.8	C		C		C		S	
0.9	C		C		C		SiC	
1	C		C		C		SiC	
1.1	C		C		C		S	Bar sands
1.2	C		C		C		S	
1.3	C		C		C		S	
1.4	C		C		C		LS	
1.5	C		C		SiC		LS	
1.6	SiC		C		C		LS	
1.7	SiC		C		C		LS	
1.8	SiC		C		C		LS	
1.9	SiC		SiC		C		LS	
2	SiC		C		C		L	
2.1	SiC		SiC		C		LS	
2.2	SiC		LS		C		S	
2.3	SiC		S		C		S	
2.4	SiC		C		SiC		LS	
2.5	SiC		C		SiC		LS	

	MOV-MK/GN-018		MOV-MK-019		MOV-MK/GN/019		MOV-MK-020	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC		S		C		LS	
2.7	L		S	CB	SiC		S	Bar sands
2.8	SL		S		SiC		S	
2.9	L	LR	S		SiC		S	
3	SiC		LS		SiC		S	**Bar**
3.1	SiC		S		SiC			
3.2	SiC		S		SiC			
3.3	SiC		LS		SiC			
3.4	SiL		S		SiC			
3.5	SiC		S		SiC			
3.6	SiC		S	**Channel**	SiC			
3.7	L				SiC			
3.8	L				SiC			
3.9	SiC				SiC			
4	SiC				SiC			
4.1	SiC				C			
4.2	C				SiC			
4.3	C				SiC			
4.4	SiC				SiC			
4.5	L				SiC			
4.6	L				SiC			
4.7	SL				SiL			
4.8	SiC				L			
4.9	L				L			
5	SiC				L			

	MOV-MK/GN-018		MOV-MK-019		MOV-MK/GN/019		MOV-MK-020	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	SiL	LR			SiL			
5.2	L				SiC			
5.3	SL	CB			SiC			
5.4	SL				SiC			
5.5	S				SiC			
5.6	S				SiC			
5.7	S				SiC			
5.8	S				SiL			
5.9	S				L			
6	S				C			
6.1	S				C			
6.2	S				C			
6.3	S				C			
6.4	S	**Channel**			C			
6.5					C			
6.6					C			
6.7					C			
6.8					C			
6.9					C			
7					C			
7.1					C			
7.2					C	**Floodplain**		
7.3								
7.4								
7.5								

	MOV-MK-021		MOV-MK/GN/021		MOV-MK-022		MOV-MK-023	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	fS		C		C	OF	C	OF
0.2	fS		C		C		SiC	
0.3	SiC		C		C		SiC	
0.4	SiC		C		C		SiC	
0.5	fS		C		SiC		SiL	
0.6	L		L		SiC		LS	
0.7	L		L		SL		L	
0.8	L		C		LS	Bar sands	L	
0.9	SiL		C		LS		LS	Bar sands
1	SiL		C		LS		LS	
1.1	LfS		C		LS		S	
1.2	SiL		C		SiC		S	
1.3	SL		C		LS		S	
1.4	SiL		C		S		S	
1.5	SiL		C		LS		S	
1.6	fS		C		LS		LS	
1.7	fS		C		LS		S	
1.8	fS		C		LS		S	
1.9	fS		C		LS		S	
2	fS		C		LS		S	
2.1	S		C		LS		S	
2.2	S		C		LS		S	
2.3	S		C		LS		S	
2.4	S		C		LS		S	
2.5	S		C		fS		S	

	MOV-MK-021		MOV-MK/GN/021		MOV-MK-022		MOV-MK-023	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	S		C		LS	Bar sands	S	Bar sands
2.7	S		C		S		S	
2.8	S	**Splay**	C		S		S	
2.9			C		S		S	
3			C		S	**Bar**	S	**Bar**
3.1			C					
3.2			SiC					
3.3			SiC					
3.4			SiC					
3.5			SiC					
3.6			SiC					
3.7			SiC					
3.8			SiC					
3.9			SiC					
4			SiC					
4.1			SiC					
4.2			SiC					
4.3			SiC					
4.4			SiC					
4.5			SiC					
4.6			SiC					
4.7			SiC					
4.8			SiC					
4.9			SiC					
5			SiC					

	MOV-MK-021		MOV-MK/GN/021		MOV-MK-022		MOV-MK-023	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			SiC					
5.2			SiC					
5.3			SiL					
5.4			SiL					
5.5			SiL					
5.6			SiL					
5.7			SiL					
5.8			SiL					
5.9			SiL					
6			SL					
6.1			L					
6.2			L					
6.3			L					
6.4			SiC					
6.5			C					
6.6			C					
6.7			C					
6.8			C					
6.9			C					
7			C					
7.1			C					
7.2			C					
7.3			C					
7.4			C					
7.5			C					

	MOV-MK-021		MOV-MK/GN/021		MOV-MK-022		MOV-MK-023	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6			C	**Floodplain**				
7.7								
7.8								
7.9								
8								
8.1								
8.2								
8.3								
8.4								

	MOV-MK-024		MOV-MK-025		MOV-MK-026		MOV-MK-027	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	C		C	OF	C	LR	C	LR
0.2	C		C		C		C	
0.3	SiC		C		C		C	
0.4	SiC		C		C		C	
0.5	SiC		SiC		C		C	
0.6	fS		SiC		C		C	
0.7	fS		fS	Bar sands	C		C	
0.8	fS		fS		C		C	
0.9	SiC		fS		C		C	
1	SiC		fS		C		C	
1.1	SiC		fS		C		C	
1.2	SiC		fS		C		C	
1.3	fS		fS		C		C	
1.4	C		fS		C		C	
1.5	C		fS		C		C	
1.6	C		LfS		C		C	
1.7	SiC		LfS		C		C	
1.8	SiC		fS		C		C	
1.9	LS		fS		C		C	
2	LS		S		C		C	
2.1	C		fS		C		C	
2.2	C		fS		C		C	
2.3	C		fS		C		C	
2.4	C		fS		C		SiC	
2.5	SiC		fS		C		L	

	MOV-MK-024		MOV-MK-025		MOV-MK-026		MOV-MK-027	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	C		fS	Bar sands	C		LfS	
2.7	C		fS	**Bar**	C		LfS	
2.8	C				C	LR	LfS	Bar sands
2.9	C				C		fS	
3	C				C		fS	
3.1	C	**Splay**			C		fS	
3.2					C		fS	
3.3					C		fS	
3.4					C		fS	
3.5					C		fS	
3.6					C		fS	
3.7					C		fS	
3.8					C		fS	
3.9					C		fS	
4					C		fS	
4.1					L		fS	
4.2					S		fS	
4.3					S	CB	fS	
4.4					S		fS	**Bar**
4.5					S			
4.6					S			
4.7					S			
4.8					S			
4.9					S			
5					S			

	MOV-MK-024		MOV-MK-025		MOV-MK-026		MOV-MK-027	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1					S	CB		
5.2					S			
5.3					S	**Channel**		
5.4								
5.5								
5.6								

	MOV-MK-028		MOV-MK-029		MOV-MK-030		MOV-MK-031	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		C		C	LR	C	
0.2	C		C		C		S	
0.3	C		C		C		S	
0.4	C	LR	SiC		C		S	
0.5	C		SiC		SiC		S	
0.6	C		SiC		LS	ACF	S	
0.7	C		SiC		LS		S	
0.8	C		C		LS		LS	
0.9	SiL		C		LS		fLS	
1	L		C		SiC		SL	
1.1	SiC		SiC		SiC	LR	SL	
1.2	C		SiC		SiC		LS	
1.3	C		SiC		SiC		SL	
1.4	C		SiL		SiC		L	
1.5	C		SL		C		L	
1.6	C		SL		C		SL	
1.7	C		C		C		SL	
1.8	C		SiC		SiC		S	
1.9	C		C		C		LS	
2	C		C		LS	ACF	SiC	
2.1	C		C		C	LR	SiC	
2.2	L		C		C		SiC	
2.3	C		C		C		SiC	
2.4	C		SiC		C		SiC	
2.5	L		SiC		C		SiC	

	MOV-MK-028		MOV-MK-029		MOV-MK-030		MOV-MK-031	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	L		C		C		C	
2.7	L		SiC		SiC		C	**Splay**
2.8	L	LR	SiC		C	LR		
2.9	L		SiC		C			
3	L		SiC		C			
3.1	L		SiC		C			
3.2	SL		SiC		C			
3.3	SL		SiC		C			
3.4	L		SL		C			
3.5	L		SL		SiC			
3.6	L		L		C			
3.7	C		SL		C			
3.8	SiL		SL		C			
3.9	SiL		LS		C			
4	SiC		S		C			
4.1	SL		S		C			
4.2	SL		S		C			
4.3	LS		S		SiC			
4.4	S		S		SiC			
4.5	S	CB	SL		S			
4.6	S		S		S	CB		
4.7	S		S	**Splay**	S			
4.8	S				S			
4.9	S				S			
5	S				S			

	MOV-MK-028		MOV-MK-029		MOV-MK-030		MOV-MK-031	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	S	CB			S	CB		
5.2	S				S			
5.3	S				S			
5.4	S				S			
5.5	S	**Channel**			S			
5.6					S	**Channel**		

	MOV-MK-032		MOV-MK-033		MOV-MK-034		MOV-GV-001	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SC		C		C		SiL	
0.2	fS		C		LS		SiL	
0.3	fS		C		LS		SiL	
0.4	fS		S	OF	LS		SiL	
0.5	fS		S		LS		SiL	
0.6	fS		C		LS		SiL	
0.7	fS		C		LS		SiL	
0.8	fS		C		LS		SiC	
0.9	fS		C		LS		SiC	
1	fS		C		LS		SiC	
1.1	fS		C		S		SiC	
1.2	fS		fS		S		SiC	
1.3	LfS		SL		C		SiC	
1.4	fS		SiC		C		SiC	
1.5	fS		C		C		SiL	
1.6	LfS		C		C		L	
1.7	SL		SiC		C		SL	
1.8	SL		SiC		C		SL	
1.9	L		SiC		C		SiL	
2	L		SiL		C		SiL	
2.1	L		SiL		C		SiL	
2.2	fS		SiC		C		SiL	
2.3	fS		SiC		SiC		SiL	
2.4	fS		SiL		C		L	
2.5	fS		SL		SiC		SiL	

	MOV-MK-032		MOV-MK-033		MOV-MK-034		MOV-GV-001	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	fS		LS		SiC		SiL	
2.7	SiC		LS		SiC		SiC	
2.8	SiC		LS		C		SiC	
2.9	LfS		LS	Bar sands	C		SiL	
3	LfS		LS		SiC		SiL	
3.1	LfS		LS		C		SiL	
3.2	LfS		LS		C		SiL	
3.3	L		LS		C		SiL	
3.4	L		LS		C		SiL	
3.5	LfS		LS		C		L	
3.6	fS		S		C		SL	
3.7	fS		LS		SiC		LS	
3.8	fS		LS		C		LS	
3.9	fS		LS		C		LS	
4	fS		LS		L		SL	
4.1	fS		S		L		SL	
4.2	fS		LS		SiC		SL	
4.3	fS		LS		SiC		SL	
4.4	fS		LS		C		SL	**Floodplain**
4.5	fS		LS		SiC			
4.6	fS	**Slay**	SL		SiC			
4.7			SL		C			
4.8			LS		S			
4.9			LS		S			
5			LS		S			

	MOV-MK-032		**MOV-MK-033**		**MOV-MK-034**		**MOV-GV-001**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			LS	Bar sands	S			
5.2			LS		S			
5.3			LS		S			
5.4			LS	**Bar**	S			
5.5					S			
5.6					S	**Splay**		

	MOV-GV-002		MOV-GV-003		MOV-GV-004		MOV-GV-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	C	LR	SiC	LR	SiC	LR
0.2	SiC		C		SiC		SiC	
0.3	SiC		C		SiC		SiC	
0.4	SiC		SiC		SiC		SiC	
0.5	SiC		SiC		SiC		SiC	
0.6	SiC		SiC		SiC		SiC	
0.7	SiC		SiC		SiL		SiC	
0.8	SiC		SiC		SiL		SiC	
0.9	SiC		SiC		SiL		SiC	
1	SiC		C		SiL		SiC	
1.1	SiC		C		SiL		SiC	
1.2	SiC		C		SiL		SiC	
1.3	SiC		C		SiL		SiC	
1.4	SiL		C		SiC		SiL	
1.5	SiL		C		SiC		SiL	
1.6	SiL		C		SiC		SiL	
1.7	SiC		C		SiC		SiL	
1.8	SiC		C		SiC		SiC	
1.9	C		C		SiC		SiC	
2	SiC		C		SiC		SiL	
2.1	SiL		C		SiC		SiL	
2.2	L		C		SiL		SiL	
2.3	SL	ACF	C		SiL		SiL	
2.4	SL		C		SiL		SiL	
2.5	SL		C		SiL		SiL	

	MOV-GV-002		MOV-GV-003		MOV-GV-004		MOV-GV-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	L	ACF	SiC	LR	SiL	LR	SiL	OF
2.7	L		SiC		SiL		SiL	
2.8	SL	CB	SiC		SiL		vfSL	Bar sands
2.9	SL		SiC		SiC		vfSL	
3	SL		SiC		SiL		vfSL	
3.1	SL		C		SiC		vfSL	
3.2	LS		C		SiL		vfSL	
3.3	LS		C		vfSL	ACF	vfSL	
3.4	LS		C		vfSL		vfSL	
3.5	fLS		C		vfSL		vfSL	
3.6	fLS		C		vfSL		vfSL	
3.7	fLS		C		vfSL		vfSL	
3.8	fLS		C		vfSL		vfSL	
3.9	fS		C		vfSL		vfSL	
4	fS		C		vfSL		vfSL	
4.1	fS		C		SiL	LR	vfLS	
4.2	fLS		C		SiC		vfLS	
4.3	fS		C		SiC		vfLS	
4.4	fS		C		SiC		vfLS	
4.5	fS		C		SiC		LmS	
4.6	fS	**Channel**	C		SiC		LmS	
4.7			C		SiC		mS	
4.8			C		SiC		mS	
4.9			C		SiC		vmS	
5			C		SiC		vmS	

	MOV-GV-002		MOV-GV-003		MOV-GV-004		MOV-GV-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			C		SiC	LR	vmS	
5.2			C		SiC		vmS	
5.3			C		SiC		vmS	
5.4			C	LR	SiL		vmS	Bar sands
5.5			C		SiC		vmS	
5.6			C		vfSL		vmS	
5.7			C		S		vmS	
5.8			C		S	CB	vmS	
5.9			C		S		vmS	
6			C		S		vmS	
6.1			SiL		S		vmS	
6.2			SiL		S		vmS	
6.3			SiL		S		vmS	
6.4			C		S		vmS	
6.5			C		S		vmS	
6.6			C		S		vmS	
6.7			C		S		vmS	
6.8			C		S		vmS	
6.9			C		S		vmS	
7			C		S		vmS	
7.1			C		S		vmS	
7.2			C		S		vmS	
7.3			C		S	**Channel**	vmS	
7.4			C				vmS	
7.5			C				vmS	

	MOV-GV-002		MOV-GV-003		MOV-GV-004		MOV-GV-005	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6			C	LR			vmS	Bar sands
7.7			C				vmS	
7.8			C				vmS	
7.9			C				vmS	**Bar**
8			C					
8.1			C					
8.2			C					
8.3			C					
8.4			C					
8.5			C					
8.6			C					
8.7			C					
8.8			C	**Channel**				
8.9								
9								
9.1								
9.2								
9.3								
9.4								
9.5								
9.6								
9.7								
9.8								
9.9								
10								

	MOV-GV-006		MOV-GV-007		MOV-GV-008		MOV-GV-009	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL		SiL		SiL		SiL	LR
0.2	SiL		SiL		SiL		SiC	
0.3	SiL		SiL		SiL		SiC	
0.4	SiC		SiL		SiC		SiL	
0.5	SiC		SiL		SiC		vfSL	ACF
0.6	LfS		SiL		SiC		vfSL	
0.7	LfS		SiL		SiC		vfSL	
0.8	LfS		SiL		SiC		SiL	LR
0.9	LfS		SiL		SiC		SiC	
1	LfS		SiL		SiC		SiC	
1.1	LfS		SiL		SiC		C	
1.2	SiC		L		SiC		SiC	
1.3	SiL		L		SiC		SiC	
1.4	SiL		L		SiC		LfS	CB
1.5	SiL		SiL		SiC		LfS	
1.6	SiC		SiL		SiC		fS	
1.7	SiC		SiL		SiC		fS	
1.8	SiC		SiL		SiC		fS	
1.9	SiC		SiL		SiL		fS	
2	SiC		SiL		SiL		fS	
2.1	SiC		SiL		SiL		fS	
2.2	SiC		SiC		SiC		fS	
2.3	SiC		SiC		SiC		fS	
2.4	SiC		SiC		SiC		fS	
2.5	SiL		SiC		SiC		fS	

	MOV-GV-006		MOV-GV-007		MOV-GV-008		MOV-GV-009	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	LfS		SiC		SiC		fS	
2.7	SL		SiC		SiC		fS	
2.8	SL		SiC		SiC		fS	
2.9	SL		SiC		SiC		fS	
3	SL		SiC		SiC		fS	
3.1	SL		SiC		SiC		fS	
3.2	SL		SiC		SiC		fS	
3.3	SL		SiC		SiC		SiC	CB
3.4	SiL		SiC		SiC		SiC	
3.5	SiL		SiC		SiC		SiL	
3.6	SL		SiC		SiC		fS	
3.7	SL		SiC		SiC		fS	
3.8	SL		SiC		SiC		fS	
3.9	SiL		SiC		SiC		fS	
4	SiL		SiC		SiC		fS	**Channel**
4.1	SL		SiL		SiC			
4.2	SL		SiL		SiC			
4.3	LS		SiL		SiC			
4.4	LS		SiL		SiC			
4.5	LS		SiL		SiC			
4.6	LS		SiL		SiC			
4.7	LS		SiL		SiC			
4.8	LS		SiL		SiC			
4.9	LS		L		SiC			
5	LS		SL		SiC			

	MOV-GV-006		MOV-GV-007		MOV-GV-008		MOV-GV-009	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	SL		SL		SiL			
5.2	SL		SL		SiL			
5.3	SiL		SL		SiL			
5.4	SiL		SL		SiL			
5.5	SiL		SL		SiL			
5.6	SiL		SL		SiL			
5.7	SiL		SL		SiL			
5.8	LS		SL		SiL			
5.9	LS		SL		SiL			
6	LS		SL		SiL			
6.1	SL		SL		SiL			
6.2	SL		SL		SiL			
6.3	SL		SL		SiL			
6.4	SL		SL		SiL			
6.5	LS		SL		SiL			
6.6	LS		SL		SiL			
6.7	SL	**Floodplain**	SL		SiL			
6.8			SL		SiL			
6.9			SL		SL			
7			SL	**Floodplain**	SL			
7.1					SL			
7.2					SL			
7.3					SL			
7.4					SL			
7.5					SL			

	MOV-GV-006		MOV-GV-007		MOV-GV-008		MOV-GV-009	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6					SL			
7.7					SL			
7.8					SL			
7.9					SL			
8					SL			
8.1					LS			
8.2					SL			
8.3					SL			
8.4					SL			
8.5					SL	**Floodplain**		
8.6								
8.7								

	MOV-GV-009X		MOV-GV-010		MOV-GV-011		MOV-GV-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	SiL	OF	SiC	JRD	SiL	JRD
0.2	SiC		SiL		SiC		SiL	
0.3	SiC		vfSL	Bar sands	SiC		SiL	
0.4	SiC		vfSL		SiC		SiL	
0.5	SiC		vfSL		SiC		SiL	
0.6	SiC		vfSL		SiC		SiL	
0.7	SiC		fS		SiC		SiC	
0.8	SiC		fS		SiC		SiL	
0.9	SiC		fS		SiC		SiL	
1	SiC		fS		SiC		SiC	
1.1	SiC		fS		SiC		SiC	
1.2	SiC		fS		SiC		SiC	
1.3	SiC		fS		SiC		SiC	
1.4	SiC		fS		SiL		SiL	
1.5	SiC		fS		SiC		SiL	
1.6	SiC		fS		SiC		SiC	
1.7	SiC		fS		SiC		SiC	
1.8	SiC		fS		SiC		SiL	
1.9	SiC		mfS		SiC		SiL	
2	SiC	**Channel**	mfS		SiC		SiL	
2.1			mfS		SiC		SiC	
2.2			mfS		SiC		SiC	
2.3			vfS		SiC		SiC	
2.4			vfS		SiC		SiC	
2.5			vfS		SiC		SiC	

	MOV-GV-009X		MOV-GV-010		MOV-GV-011		MOV-GV-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6			mS	Bar Sands	SiC	JRD	SiC	JRD
2.7			mS		SiL		SiL	
2.8			mS		vfSL	CB	SiC	
2.9			mS		vfSL		vfSL	
3			mS	**Bar**	vfSL		SiL	
3.1					SiL		SiL	
3.2					vfSL		vfSL	Bar sands
3.3					fS		SiL	
3.4					fS		vfSL	
3.5					mS		vfSL	
3.6					mS		LvfS	
3.7					cS		LvfS	
3.8					cS		vfSL	
3.9					cS		mS	
4					cS		mS	
4.1					cS		mS	
4.2					cS		mS	
4.3					cS		mS	
4.4					cS		mS	
4.5					cS		mS	
4.6					cS		mS	
4.7					cS		mS	
4.8					cS		C	
4.9					cS		mLS	
5					cS		C	

	MOV-GV-009X		MOV-GV-010		MOV-GV-011		MOV-GV-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1					cS		C	
5.2					cS		mLS	
5.3					cS		C	Bar sands
5.4					cS	CB	C	
5.5					cS		mS	
5.6					cS		mS	
5.7					cS		mS	
5.8					cS		mS	
5.9					cS		mS	
6					cS		mS	
6.1					cS		mS	
6.2					cS		mS	
6.3					cS		mS	
6.4					cS		mS	
6.5					cS		mS	
6.6					cS		mS	
6.7					cS		mS	
6.8					cS		mS	
6.9					cS		mS	
7					cS		mS	
7.1					cS		mS	**Bar**
7.2					cS			
7.3					cS			
7.4					cS			
7.5					cS			

	MOV-GV-009X		MOV-GV-010		MOV-GV-011		MOV-GV-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6					cS	**Channel**		
7.7								
7.8								
7.9								
8								
8.1								

	MOV-GV-013		MOV-GV-014		MOV-GV-015		MOV-GV-016	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	LR	SiC	OF	SiC	LR	SiL	OF
0.2	SiL		SiC		SiC		SiL	
0.3	SiL		SiC		SiC		SiL	
0.4	SiC		SiC		SiC		SiL	
0.5	SiC		SiC		SiC		SiL	
0.6	SiC		SiC		SiC		SiC	
0.7	SiC		SiC		SiC		SiL	
0.8	SiC		SiL		SiC		SiL	
0.9	SiC		SiL		SiC		SiL	
1	SiC		SiL		SiC		SiL	
1.1	SiC		SiL		SiC		SiL	
1.2	SiC		SiL		SiC		SiL	
1.3	SiC		SiL		SiC		L	
1.4	SiC		SiL		SiC		LvfS	
1.5	SiC		SiC		SL		LvfS	
1.6	SiC		SiC		SL		LvfS	
1.7	SiC		SiL		SL		LvfS	
1.8	SiC		SiL		SL		L	
1.9	SiL		SiL		SL		L	
2	SiL		SiL		SL		L	
2.1	SiC		SL	Bar sands	L		L	
2.2	SiC		SL		L		SiL	
2.3	SiC		SL		SiL		SL	
2.4	SiC		SL		L		fS	Bar sands
2.5	SiC		LS		SL		fS	

	MOV-GV-013		MOV-GV-014		MOV-GV-015		MOV-GV-016	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	C	LR	LS	Bar sands	SL	CB	fS	Bar sands
2.7	C		LS		LS		mfS	
2.8	C		LS		LS		mfS	
2.9	SiC		LS		LS		mfS	
3	C		LS		LS		mfS	
3.1	C		LS		LS		mfS	
3.2	C		LS		LS		mfS	
3.3	C		LS		LS		mfS	
3.4	C		LS		LS		mfS	
3.5	SiC		LS		LS		mfS	
3.6	SiL		LS		LS		mfS	
3.7	SiC		LS		LS		LmS	
3.8	SiL		LS		LS		LmS	
3.9	vfSL		LS		LS		LmS	
4	C		LS		LS		LmS	
4.1	fLS		LS		LS		LmS	
4.2	SiL		LS		LS		LmS	
4.3	C		LS		LS		LmS	
4.4	fS	CB	LS		LS		LmS	
4.5	fS		LS		LS		LmS	
4.6	fS		LS		LS		LmS	**Bar**
4.7	fS		LS		LS			
4.8	fS		LS		LS			
4.9	fS		LS		LS	**Channel**		
5	fS		LS					

	MOV-GV-013		MOV-GV-014		MOV-GV-015		MOV-GV-016	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	fS	CB	LS	Bar sands				
5.2	fS		LS					
5.3	fS		LS	**Bar**				
5.4	fS							
5.5	fS	**Channel**						
5.6								

	MOV-GV-017		MOV-GV-018		MOV-GV-019		MOV-GV-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		SiC		SL		SiC	
0.2	SiC		SiL		SL		SiC	
0.3	SiC		SiL		SL		SiC	
0.4	SiC	LR	SiC	LR	SL	Bar sands	SiC	
0.5	SiC		SiC		LS		SiC	
0.6	SiC		SiC		LS		SiC	
0.7	SiC		SiC		fS		SiC	
0.8	SiC		SiC		fS		SiC	
0.9	SiC		SiC		fS		SiC	
1	SiC		SiC		fS		C	
1.1	C		SiC		fS		C	
1.2	C		SiC		fS		C	
1.3	SiC		SiC		fS		C	
1.4	SiC		SiC		fS		C	
1.5	SiC		SiC		fS		SiC	
1.6	SiC		SiC		fS		SiC	
1.7	SiC		SiC		fS		SiC	
1.8	C		SiC		fS		SiC	
1.9	C		SiC		fS		SiC	
2	C		SiC		fS		SiC	
2.1	C		SiC		fS		SiC	
2.2	SiC		SiC		C	Terrace	L	
2.3	C		SiC		C		SiC	
2.4	C		SiC		C		SiC	
2.5	C		SiC		C		SiC	

	MOV-GV-017		MOV-GV-018		MOV-GV-019		MOV-GV-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	C		C		C		SiC	
2.7	C		C		C		SiC	
2.8	C		C		C	Terrace	SiC	
2.9	C	LR	C	LR	C		C	
3	C		C		C		C	
3.1	C		C		C		C	
3.2	C		C		C		C	
3.3	SiC		C		C		C	
3.4	SiC		C		C		SiL	
3.5	SiC		C		C		SiL	
3.6	C		C		C		C	
3.7	C		C		C		SiC	
3.8	C		C		C		SiL	
3.9	C		C		C		SiL	
4	SiC		C		C	**Bar**	SiC	
4.1	C		C				SiC	
4.2	C		C				SiC	
4.3	C		C				SiL	
4.4	C		C				SiL	
4.5	C		SiC				SiL	
4.6	C		SiC				SiL	
4.7	C		SiC				SiL	
4.8	C		SiC				SiC	
4.9	C		C				SiC	
5	C		SiC				SiC	

	MOV-GV-017		MOV-GV-018		MOV-GV-019		MOV-GV-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	C	LR	SiC	LR			SiC	
5.2	C		SiC				SiC	
5.3	C		SiC				cS	
5.4	C		SiC				cS	
5.5	C		SiC				mix	
5.6	C		SiC				mix	
5.7	C		SiC				cS	
5.8	C		SiC				cS	
5.9	C		SiC				LS	
6	C		SiC				LS	
6.1	vfSL	CB	SiC				SiL	
6.2	vfSL		SiC				SiC	
6.3	vfSL		SiC				SiC	
6.4	vfSL	**Channel**	SiC				SiC	
6.5			SiC				cS	
6.6			C				cS	
6.7			C				cS	
6.8			C				cS	
6.9			C				cS	
7			C				cS	
7.1			C				cS	
7.2			C				cS	
7.3			C				cS	
7.4			C				cS	
7.5			C				cS	

	MOV-GV-017		MOV-GV-018		MOV-GV-019		MOV-GV-022	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6			C				cS	
7.7			C	LR			cS	**Floodplain**
7.8			C					
7.9			C					
8			C					
8.1			C					
8.2			C					
8.3			C					
8.4			C					
8.5			C					
8.6			C					
8.7			C					
8.8			C	**Channel**				
8.9								
9								
9.1								
9.2								
9.3								
9.4								
9.5								
9.6								
9.7								
9.8								
9.9								
10								

	MOV-GV-023		MOV-GV-024		MOV-GV-025		MOV-GV-026	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	LR	SiL	LR	SiC		SiC	
0.2	SiL		SiL		SiC		SiC	
0.3	SiC		SiL		SiC		SiC	
0.4	SiC		SiC		SiC		SiL	
0.5	SiC		SiC		SiC		SiL	
0.6	SiC		SiC		SiC		SiL	
0.7	SiC		SiC		SiL		SiL	
0.8	SiC		SiC		SiC		SiL	
0.9	SiC		SiC		SiC		SiL	
1	SiC		SiC		SiC		SiL	
1.1	SiC		SiC		SiC		vfSL	
1.2	SiC		SiC		SiC		SiL	
1.3	SiC		SiL		SiC		SiL	
1.4	SiC		SiL		SiC		SiL	
1.5	SiC		SiL		SiC		L	
1.6	SiC		SiL		SiC		L	
1.7	SiC		fSL		SiC		L	
1.8	SiC		SiL		C		SiL	
1.9	SiC		SiC		C		LS	
2	SiL		SiC		C		SiL	
2.1	L		SiC		C		SiL	
2.2	L		SiC		C		L	
2.3	L		SiC		C		SiL	
2.4	LfS	ACF	L		C		SiC	
2.5	LfS		L		SiC		SiC	

	MOV-GV-023		MOV-GV-024		MOV-GV-025		MOV-GV-026	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC	ACF	SiC	LR	SiC		SiC	
2.7	LmS	CB	SiC		C		SiC	
2.8	mS		SiC		C		SiC	
2.9	mS		SiC		C		SiC	
3	mS		SiC		C		SiC	
3.1	mS		LS	CB	C		C	
3.2	mS		mS		SiC		C	
3.3	mS		mS		SiC		C	
3.4	mS		mS		SiC		C	
3.5	mS		mS		SiL		SL	
3.6	mS		mS		L		C	
3.7	mS		mS		SiC		C	
3.8	mS		mS		SiC		C	
3.9	mS		mS		SiC		SiC	
4	mS		mS		SiC		SiC	
4.1	mS		mS		C		C	
4.2	mS		mS		C		C	
4.3	mS		mS		SiC		C	
4.4	mS		mS		SiL		C	
4.5	mS	**Channel**	mS		L		C	
4.6			mS		SiC		SiC	
4.7			mS		SiC		SiC	
4.8			mS		SiC		SiC	
4.9			mS		LS		SiC	
5			mS		SL		SiC	

	MOV-GV-023		**MOV-GV-024**		**MOV-GV-025**		**MOV-GV-026**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			mS	CB	SiL		SiC	
5.2			mS		C		SiC	
5.3			mS	**Channel**	SiC		SiC	
5.4					SiC		C	
5.5					SiC		SiC	
5.6					C		C	
5.7					SiC		C	
5.8					SiC		C	
5.9					LfS		SiC	
6					fSL		C	
6.1					L		C	
6.2					SiC		C	
6.3					fSL		SiC	
6.4					C		SiC	
6.5					fSL		SiC	
6.6					fSL		SiC	
6.7					SiL		SiC	
6.8					SiC		SiC	
6.9					SiL		SiC	
7					fSL		SiC	
7.1					SiC		SL	
7.2					SiC		fLS	
7.3					SiC		fLS	
7.4					SiC		fLS	
7.5					SiC		fS	

	MOV-GV-023		MOV-GV-024		MOV-GV-025		MOV-GV-026	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6					SiC		fS	
7.7					SiC		fS	
7.8					SiC		fS	
7.9					SiC		fS	
8					SiC		fS	
8.1					C		S	
8.2					C		S	
8.3					C		S	
8.4					C		S	
8.5					C		S	
8.6					SiC		S	**Floodplain**
8.7					SiC			
8.8					SiC			
8.9					SiC			
9					SiC			
9.1					mS			
9.2					mS	**Floodplain**		
9.3								
9.4								
9.5								
9.6								
9.7								
9.8								
9.9								
10								

	MOV-GV-027		MOV-GV-028		MOV-GV-029		MOV-GV-030	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	OF	SiC	OF	SiC	OF	SiC	OF
0.2	SiC		SiC		SiC		SiC	
0.3	SiC		SiC		SiC		SiC	
0.4	SiC		SiC		SiL		SiC	
0.5	SiC		SiL		SiL		SiL	
0.6	SiC		SiC		SiC		SiL	
0.7	SiL		SiC		SiL		SiL	
0.8	SiL		SiC		SiL		SiL	
0.9	L		SiL		SiL		SiL	
1	L		SiL		SiC		SiC	
1.1	L		L		SiC		SiC	
1.2	SiL		vfSL	Bar Sands	SiL		SiC	
1.3	SiC		vfLS		L		SiC	
1.4	SiC		vfLS		L		SiC	
1.5	SiL		vfLS		L		C	
1.6	SiL		vfLS		L		SiL	
1.7	L		vfLS		SiL		SiL	
1.8	SiC		SiL	OF	SiC		SiL	
1.9	SiC		L		SiL		L	
2	SiC		SiL		SiC		fSL	Bar sands
2.1	L		SiL		SiC		vfS	
2.2	L		SiC		SiC		mS	
2.3	SiC		SiL		SiC		mS	
2.4	SiC		L		SiC		mS	
2.5	SiL		vfSL	Bar sands	LS	Bar sands	mS	

	MOV-GV-027		MOV-GV-028		MOV-GV-029		MOV-GV-030	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiL	OF	vfLS	Bar sands	S	Bar sands	mS	Bar sands
2.7	vfSL		S		S		mS	
2.8	vfSL		S		S		mS	
2.9	vfSL		S		LS		mS	
3	vfSL		S		S		mS	
3.1	L		S		S		mS	
3.2	L		S		S		mS	
3.3	SiC		vfSL		LS		mS	
3.4	vfSL	Bar sands	vfSL		S		mS	
3.5	vfSL		vfSL		S		mS	
3.6	vfSL		vfSL		S		mS	**Bar**
3.7	S		vfSL		S			
3.8	S		vfSL		mS			
3.9	S		vfSL		mS			
4	S		vfSL		mS			
4.1	S		vfSL		mS			
4.2	S		vfSL		mS			
4.3	S		vfLS		mS			
4.4	S		vfLS		mS			
4.5	S		vfLS		mS			
4.6	S		fS		mS			
4.7	S		S		mS	**Bar**		
4.8	S		S					
4.9	S		S					
5	S		LS					

	MOV-GV-027		MOV-GV-028		MOV-GV-029		MOV-GV-030	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	S	Bar sands	LS	Bar sands				
5.2	S		LS					
5.3	S		S					
5.4	S		S					
5.5	S		S					
5.6	S	**Bar**	S					
5.7			S					
5.8			S					
5.9			S					
6			S	**Bar**				
6.1								
6.2								
6.3								
6.4								
6.5								
6.6								
6.7								
6.8								
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-GV-031		MOV-GV-032		MOV-GV-033		MOV-GV-034	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	OF	SiL		SiL	OF	SiC	OF
0.2	SiL		SL		SiL		SiC	
0.3	SiL		SL		SiL		SiC	
0.4	SiL		S		SiL		SiC	
0.5	SiL		S		SiL		SiC	
0.6	SiC		G	Pleistocene	SiL		SiC	
0.7	SiC		G		SiL		SiL	
0.8	SiL		G		SiL		SiC	
0.9	SiL		G		SiL		SiC	
1	SiC		G	**Floodplain**	SiL		L	
1.1	SiL				SiL		L	
1.2	SiL				SiL		vfSL	Bar sands
1.3	SiL				SiL		fS	
1.4	SiL				SiL		L	OF
1.5	SiL				SiC		fS	Bar sands
1.6	SiC				SiC		fS	
1.7	SiC				SiC		LfS	
1.8	SiC				SiL		LfS	
1.9	SiC				LS		fS	
2	SiL				G	Pleistocene	S	
2.1	SiL				G		S	
2.2	SiL				G		S	
2.3	SiL				G		mS	
2.4	SiL				G		mS	
2.5	SiL				G	**Floodplain**	LvfS	

	MOV-GV-031		MOV-GV-032		MOV-GV-033		MOV-GV-034	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiL	OF					LvfS	Bar sands
2.7	SiL						LvfS	
2.8	SL						vfSL	
2.9	LmS						vfSL	
3	LmS						vfLS	
3.1	mS						vfS	
3.2	G	Pleistocene					LvfS	
3.3	G						vfS	
3.4	G						LvfS	
3.5	G	**Floodplain**					vfSL	
3.6							vfSL	
3.7							SiL	OF
3.8							SiC	
3.9							SiL	
4							vfSL	Bar sands
4.1							vfSL	
4.2							vfSL	
4.3							SiL	OF
4.4							SiL	
4.5							SiL	
4.6							mS	Bar sands
4.7							mS	
4.8							mS	
4.9							mS	
5							mS	

	MOV-GV-031		MOV-GV-032		MOV-GV-033		MOV-GV-034	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1							mS	Bar sands
5.2							mS	
5.3							mS	
5.4							mS	
5.5							S	
5.6							S	
5.7							S	
5.8							mS	
5.9							mS	
6							mS	
6.1							mS	
6.2							mS	
6.3							mS	
6.4							cS	
6.5							cS	
6.6							cS	
6.7							cS	**Bar**
6.8								
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-GV-035		MOV-GV-036		MOV-GV-037		MOV-GV-038	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		SiL	OF	SiC		SiL	
0.2	SiC		SiL		SiC		SiL	
0.3	SiC		SiL		SiC		SiL	
0.4	SiC		SiL		SiC		SiL	
0.5	SiC		SiL		SiC		SiL	
0.6	SiC		SiL		SiC		SiL	
0.7	SiC		SiC		SiC		SiL	
0.8	SiC		SiC		SiC		SiL	
0.9	SiC		SiC		SiL		SiL	
1	SiC		SiC		SiL		SiL	
1.1	SiL		SiC		SiL		SiL	
1.2	SiC		SiL		SiL		SiL	
1.3	SiC		L		SiC		SiL	
1.4	SiC		L		SiL		SiL	
1.5	SiC		SiL		SiL		SiL	
1.6	SiC		SiL		SiL		S	
1.7	SiC		L		SiL		S	
1.8	SiC		SiL		SiL		S	
1.9	SiC		SiL		SiL		S	
2	SiC		L		SiL		S	
2.1	SiC		L		SiL		cS	
2.2	SiC		SiL		SiC		cS	
2.3	SiC		SiL		SiC		cS	**Floodplain**
2.4	SiC		Sic		L			
2.5	SiC		L		L			

	MOV-GV-035		MOV-GV-036		MOV-GV-037		MOV-GV-038	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiL		L	OF	SiL			
2.7	SiC		SiL		SiC			
2.8	SiC		vfSL		SiC			
2.9	SiC		vfSL		SiL			
3	SiC		vfSL		SiL			
3.1	SiC		vfSL	Bar Sands	SiL			
3.2	SiC		fSL		SiL			
3.3	LS		fSL		SiL			
3.4	SiC		fSL		SiL			
3.5	SiC		vfSL		SiL			
3.6	SiC		vfSL		SiC			
3.7	SiC		vfSL		Sic			
3.8	SiC		vfSL		LfS			
3.9	SiC		fSL		LfS			
4	SiC		fSL		LfS			
4.1	SiC		fSL		fS			
4.2	SiC		fSL		fS			
4.3	SiC		fSL		fS			
4.4	SiC		fSL		S			
4.5	SiC		LfS		S			
4.6	SiC		LfS		S			
4.7	SiC		LfS		SiL			
4.8	SiC		LfS		L			
4.9	LvcS		LfS		L			
5	LvcS	**Floodplain**	LfS		L			

	MOV-GV-035		MOV-GV-036		MOV-GV-037		MOV-GV-038	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			LfS	Bar sands	LS			
5.2			LfS		S			
5.3			mS		C			
5.4			mS		C			
5.5			mS		SiC			
5.6			mS		SiC			
5.7			fS		S			
5.8			fS		S			
5.9			fS		C			
6			fS		C			
6.1			mS		C			
6.2			mS		C			
6.3			mS		C			
6.4			mS	**Bar**	C	**Floodplain**		
6.5								
6.6								
6.7								
6.8								
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-GV-039		MOV-GV-040		MOV-GV-041		MOV-GV-042	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		SiC		SiC		SiC	
0.2	SiC		SiC		SiC		SiC	
0.3	SiC		SiC		SiC		SiC	
0.4	SiC		SiC	LR	SiC		SiL	OF
0.5	SiC		SiC		SiC		SiL	
0.6	SiC		SiC		SiC		SIl	
0.7	SiC		SiC		SiC		SiC	
0.8	SiC		SiC		SiC		SiC	
0.9	SiC		SiC		C		L	
1	SiC		SiC		C		SiC	
1.1	SiC		SiC		C		SiC	
1.2	SiC		C		C		SiC	
1.3	SiC		SiC		SiL		SiC	
1.4	SiC		SiC		SiL		SiC	
1.5	SiC		SiC		C		SiC	
1.6	SiC		SiC		SiC		SiC	
1.7	SiC		SiC		SiL		SiC	
1.8	SiC		C		SiL		SiL	
1.9	SiL		C		SiC		SiL	
2	SiL		SiC		C		L	
2.1	SiL		SiC		SiL		SiL	
2.2	L		C		L		SiL	
2.3	SiC		C		SiC		L	
2.4	SiC		C		SiC		L	
2.5	SiC		C		SiC		SL	

	MOV-GV-039		MOV-GV-040		MOV-GV-041		MOV-GV-042	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC		C		SiC		SL	OF
2.7	SiC		C		SiC		SiL	
2.8	SiC		C		SiC		SiC	
2.9	SiC		C	LR	SiC		SiC	
3	SiL		C		SiC		SiL	
3.1	SiC		C		SiL		SL	Bar sands
3.2	SiC		C		SiC		SL	
3.3	SiC		C		SiC		SL	
3.4	SiC		C		SiL		SL	
3.5	SiC		C		vfSL		SL	
3.6	SiC		C		vfSL		SL	
3.7	SiC		C		vfSL		S	
3.8	SiC		C		L		S	
3.9	SiC		C		SiL		S	
4	SiC		C		C		S	
4.1	SiC		C		SiC		C	
4.2	SiC		C		SiC		SiC	OF
4.3	SiC		C		SiL		SiL	
4.4	LcS		C		SiL		SiC	
4.5	LcS		C		C		S	Bar sands
4.6	SiC	**Floodplain**	C		SiC		S	
4.7			SiL		SiC		S	
4.8			SiL		C		S	
4.9			C		SiC		S	**bar**
5			C		SiC			

	MOV-GV-039		MOV-GV-040		MOV-GV-041		MOV-GV-042	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			C		SiL			
5.2			C		SiL			
5.3			C	LR	vfSL			
5.4			C		vfSL			
5.5			C		SiL			
5.6			C		SiL			
5.7			C		C			
5.8			C		SiL			
5.9			C		SiC			
6			C		SiL			
6.1			C		C			
6.2			C		C			
6.3			C		C			
6.4			C		SiL			
6.5			C		SiL			
6.6			LvfS	ACF	SiC			
6.7			C		SiC			
6.8			C	LR	SiC			
6.9			C		SiC			
7			C		SiC			
7.1			C		fSL			
7.2			C		SiL			
7.3			C		SiL			
7.4			C		SII	**Floodplain**		
7.5			C					

	MOV-GV-039		MOV-GV-040		MOV-GV-041		MOV-GV-042	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6			C	LR				
7.7			vfS	ACF				
7.8			vfS					
7.9			vfS					
8			vfS					
8.1			SiL	LR				
8.2			SiL					
8.3			SiL					
8.4			SiL					
8.5			SiL					
8.6			vfSL	CB				
8.7			vfSL					
8.8			vfSL					
8.9			vfSL					
9			vfSL					
9.1			vfSL	**Channel**				
9.2								
9.3								
9.4								
9.5								
9.6								
9.7								
9.8								
9.9								
10								

	MOV-GV-043		MOV-GV-044		MOV-GV-045		MOV-GV-046	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	SiC	LR	SiC	OF	L	LR
0.2	SiC		SiC		SiC		L	
0.3	SiL		SiC		SiC		L	
0.4	SiC		SiC		SiC		L	
0.5	SiC		SiC		SiC		vfSL	ACF
0.6	SiL		SiC		SiC		LvfS	
0.7	SL	ACF	SiC		SiC		LvfS	
0.8	SL		SiC		SiC		LvfS	
0.9	SL		SiC		SiC		SiC	LR
1	SL		SiC		SiC		SiC	
1.1	SL		SiC		SiL		SiC	
1.2	SL		SiC		LS	Bar sands	vfSL	ACF
1.3	LS		SiC		S		vfSL	
1.4	LS		SiC		S		vfSL	
1.5	SL		SiC		S		vfSL	
1.6	SL		SiC		S		vfSL	
1.7	S		SiC		S		LvfS	
1.8	LS		SiC		S		LvfS	
1.9	SL		SiC		S		vfSL	
2	L	LR	SiC		S		vfSL	
2.1	SiL		SiC		S		SiC	LR
2.2	SiC		SiC		S		vfSL	ACF
2.3	SiC		SiC		S		vfSL	
2.4	L		C		S		SiL	LR
2.5	SiC		SiC		S	**Bar**	SiL	

	MOV-GV-043		MOV-GV-044		MOV-GV-045		MOV-GV-046	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC	LR	C	LR			L	LR
2.7	SiL		C				L	
2.8	SiL		SiC				SiC	
2.9	S	ACF	SiL				SiL	
3	S		SiL				SiL	
3.1	SiC	LR	L				SiL	
3.2	SiL		L				SiL	
3.3	SiC		L				SiL	
3.4	mS	ACF	L				SiL	
3.5	SiL	LR	SiL				SiC	
3.6	SiL		SiL				vfSL	ACF
3.7	SiC		SiL				mS	
3.8	SiC		SiL				mS	
3.9	mS	CB	L				mS	
4	mS		SiL				mS	
4.1	SiL		SiL				C	LR
4.2	mS		vfSL				C	
4.3	mS		SiL				C	
4.4	mS		vfSL	CB			C	
4.5	mS		u				C	
4.6	mS		LfS				C	
4.7	mS		LfS				SiC	
4.8	mS		LfS				C	
4.9	mS		LfS				C	
5	mS	**Channel**	LfS				mS	CB

	MOV-GV-043		MOV-GV-044		MOV-GV-045		MOV-GV-046	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			LfS	CB			mS	**Channel**
5.2			LfS					
5.3			LfS					
5.4			LfS					
5.5			LfS					
5.6			LfS					
5.7			LfS					
5.8			LfS					
5.9			fSL					
6			fSL					
6.1			fLS					
6.2			fLS					
6.3			fLS					
6.4			fSL					
6.5			vfSL	**Channel**				
6.6								
6.7								
6.8								
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-SH-001		MOV-SH-002		MOV-SH-003		MOV-SH-004	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	SL	LR	SiC	LR	SiC	LR
0.2	SiC		L		SiL		SiC	
0.3	SiC		SiL		SiL		SiL	
0.4	SiC		SiL		SiL		SiL	
0.5	SiC		SiL		SiC		SiC	
0.6	SiC		L		SiC		SiC	
0.7	SiL		SL	ACF	SiC		SiC	
0.8	SiL		SL		SiC		SiC	
0.9	SiC		SL		SiC		SiC	
1	SiC		SiL		SiC		SiC	
1.1	SiC		SL		SiC		SiL	
1.2	SiC		SL		SiL		SiL	
1.3	SiC		L	LR	SiL		SiL	
1.4	SiC		SiL		L		SiL	
1.5	SiL		SiL		SL	ACF	SiL	
1.6	SiL		SiC		SL		SiL	
1.7	SiC		SiL		SL		SiL	
1.8	SiC		SiL		SL		SiL	
1.9	SiC		SiC		SL		SiL	
2	SiC		SiC		SL		SiL	
2.1	SiC		SiC		SL		SiL	
2.2	SiC		SiC		SL		SiL	
2.3	SiC		SiC		SL		SiL	
2.4	SiC		SiC		SL		SiL	
2.5	SiC		SiC		SL		L	

	MOV-SH-001		MOV-SH-002		MOV-SH-003		MOV-SH-004	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC	LR	SiC	LR	LS	CB	SL	ACF
2.7	SiC		SiC		LS		L	
2.8	SiC		SiL		LS		SL	
2.9	SiC		SL	ACF	LS		SL	
3	SiC		SL		LS		SL	
3.1	SiC		SL		LS		SL	
3.2	SiC		LS		LS		SL	
3.3	SiC		LS		LS		SL	
3.4	SiC		LS		LS		SL	
3.5	SiC		LS		LS		SL	
3.6	SL	ACF	LS		LS		LS	CB
3.7	SL		fS	CB	LS		LS	
3.8	SL		fS		LS		S	
3.9	SL		fS		LS		S	
4	SiC	LR	fS		LS		S	
4.1	SiC		fS		LS		S	
4.2	SiL		fS		LS		S	
4.3	SL	CB	S		LS		S	
4.4	fS		S		LS		LS	
4.5	fS		S		LS		S	
4.6	fS		S		S	**Channel**	S	
4.7	fS		S				S	
4.8	fS		S				S	
4.9	fS		S				S	
5	fS		S				S	

	MOV-SH-001		MOV-SH-002		MOV-SH-003		MOV-SH-004	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	fS	CB	S	CB			S	CB
5.2	fS		S				S	
5.3	fS		S				S	
5.4	fS		S				LS	
5.5	fS		S	**Channel**			LS	**Channel**
5.6	vfS							
5.7	vfS							
5.8	vfS							
5.9	vfS	**Channel**						
6								
6.1								
6.2								
6.3								
6.4								
6.5								
6.6								
6.7								
6.8								
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-SH-005		MOV-SH-006		MOV-SH-007		MOV-SH-008	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	OF	SiL	OF	SiC	LR	SiL	LR
0.2	SiL		SiC		SiC		SiC	
0.3	SiL		SiC		SiC		SiC	
0.4	SiL		SiC		SiC		SiC	
0.5	SiL		SiC		SiC		SiC	
0.6	SiL		SiL		SiC		SiC	
0.7	SiL		SiL		SiC		SiC	
0.8	SiC		SiL		SiC		SiC	
0.9	L		SL		C		SiC	
1	L		SL		C		SiC	
1.1	vfSL	Bar sands	SL		SiC		SiC	
1.2	LS		SL		SiC		SiC	
1.3	LS		LS		SiC		SiC	
1.4	LS		L		C		SiL	
1.5	LS		L		SiC		SiL	
1.6	LS		LS	Bar sands	SiC		L	
1.7	fS		fS		SiC		L	
1.8	fS		fS		SiC		L	
1.9	fS		fS		SiC		L	
2	fS		fS		SiC		SiL	
2.1	vfS		fS		SiC		SiC	
2.2	vfS		fS		SiC		SiC	
2.3	fS		fS		SiC		SiL	
2.4	fS		fS		SiC		L	
2.5	vfS		fS		C		SL	ACF

	MOV-SH-005		MOV-SH-006		MOV-SH-007		MOV-SH-008	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	fS	Bar sands	fS	Bar sands	C	LR	SiL	LR
2.7	fS		fS		C		SiL	
2.8	vfS		fS		C		SiC	
2.9	fS		fS		C		SL	ACF
3	fS		fS		C		SL	
3.1	fS		fS		C		SL	
3.2	fS		fS		C		SL	
3.3	fS		fS		C		LS	
3.4	fS		fS		SiL		LS	
3.5	fS		fS		SiL		LS	
3.6	fS		fS		SiL		fS	CB
3.7	SiC		fS		fSL	ACF	fS	
3.8	SL		fS		LS		fS	
3.9	LS		fS		LS		fS	
4	LS		fS		LS		S	
4.1	LS		fS		SiL	LR	S	
4.2	fS		fS		SiC		S	
4.3	fS		fS		SiC		S	
4.4	fS		fS		C		S	
4.5	fS		fS		C		S	
4.6	fS		fS	**Bar**	C		S	
4.7	fS				C		S	
4.8	fS				C		S	
4.9	fS				C		S	
5	fS				mS	CB	S	

	MOV-SH-005		MOV-SH-006		MOV-SH-007		MOV-SH-008	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	fS				mS		S	
5.2	fS	Bar sands			mS		S	CB
5.3	fS				cS	CB	S	
5.4	fS				cS		S	
5.5	fS				cS		S	
5.6	vfS				cS		S	
5.7	vfS				cS		S	
5.8	vfS				cS		S	
5.9	vfS				cS		S	
6	fS				cS		S	
6.1	vfS				cS		S	
6.2	vfS	**Bar**			cS		S	
6.3					cS		S	
6.4					cS		S	
6.5					cS		S	**Channel**
6.6					cS			
6.7					cS			
6.8					cS	**Channel**		
6.9								
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-SH-009		MOV-SH-010		MOV-SH-011		MOV-SH-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	OF	SiL	OF	SiC	LR	SiL	LR
0.2	SiC		SiL		SiC		SiL	
0.3	SiC		SiL		SiC		SiL	
0.4	SiC		SiL		SiC		SiL	
0.5	SiC		L		SiL		SiL	
0.6	SiC		LS		L		SiL	
0.7	SiC		LS		SiL		SiL	
0.8	SiC		vfS	Bar sands	SiC		SiL	
0.9	SiC		vfS		SiC		SiL	
1	SiC		vfS		SiC		SiC	
1.1	SiC		vfS		SiL		SiL	
1.2	SiC		vfS		SiC		SiL	
1.3	C		vfS		SiC		SiL	
1.4	C		vfS		SiC		SiL	
1.5	SiC		vfS		SiC		SiL	
1.6	SiL		vfS		SiL		SiL	
1.7	LS		vfS		L		SiL	
1.8	LS		vfS		SL	ACF	SiC	
1.9	LS		vfS		SL		SiC	
2	L		vfS		SL		L	
2.1	SiL		vfS		SiL	LR	vfSL	ACF
2.2	SiL		vfS		SiC		vfSL	
2.3	SiL		vfS		SiC		vfSL	
2.4	SiL		vfS		SiC		vfSL	
2.5	SiL		vfS		SiC		vfSL	

	MOV-SH-009		MOV-SH-010		MOV-SH-011		MOV-SH-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	L	OF	vfS	Bar sands	SiC	LR	vfSL	ACF
2.7	SiL		vfS		SiC		vfSL	
2.8	SiL		vfS		SiC		vfSL	
2.9	SiL		vfS		SiC		vfSL	
3	SiL		vfS		C		vfSL	
3.1	L		vfS		SiC		SiC	LR
3.2	SiL		vfS		SiC		L	
3.3	SiL		vfS		vfS	ACF	SiC	
3.4	SiL		vfS		SiL	LR	C	
3.5	SiL		vfS		SiC		C	
3.6	SiL		vfS		SiC		C	
3.7	SiL		vfS		SiC		C	
3.8	SiL		vfS		SiC		C	
3.9	SiL		vfS		C		C	
4	SiL		vfS		C		C	
4.1	SiL		vfS		C		SiC	
4.2	SiL		vfS		C		SiL	
4.3	SiL		vfS		C		SiL	
4.4	vfSL	Bar sands	vfS	**Bar**	SiC		SiL	
4.5	vfSL				SiC		SiL	
4.6	vfSL				SiC		SiL	
4.7	vfSL				SiC		vfSL	CB
4.8	vfSL				SiC		vfSL	
4.9	vfSL				SiC		vfSL	
5	vfSL				L		vfSL	

	MOV-SH-009		MOV-SH-010		MOV-SH-011		MOV-SH-012	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	LvfS	Bar sands			SL	ACF	vfLS	CB
5.2	LvfS				SL		vfLS	
5.3	LvfS				SiL	LR	vfLS	
5.4	vfSL				SiL		vfLS	
5.5	vfSL				SiL		vfLS	
5.6	vfSL				SL	ACF	vfS	
5.7	LvfS				SL		fS	
5.8	LvfS				S	CB	fS	
5.9	LvfS				S		fS	
6	LvfS				mS		fS	
6.1	LvfS				mS		fS	
6.2	LvfS				mS		fS	
6.3	LvfS	**Bar**			cS		fS	
6.4					cS		fS	
6.5					cS		fS	
6.6					cS		fS	
6.7					cS		fS	
6.8					cS		fS	
6.9					cS		fS	
7					cS		fS	
7.1					cS		fS	
7.2					cS		fS	
7.3					cS		fS	
7.4					cS		fS	
7.5					cS		fS	

	MOV-SH-009		**MOV-SH-010**		**MOV-SH-011**		**MOV-SH-012**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6					cS	CB	fS	CB
7.7					cS		fS	**Channel**
7.8					cS			
7.9					cS	**Channel**		
8								
8.1								
8.2								
8.3								
8.4								

	MOV-SH-013		MOV-SH-014		MOV-SH-015		MOV-SH-016	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	LR	SiC	LR	SiL	OF	SiL	LR
0.2	SiL		SiC		SiL		SiL	
0.3	SiL		SiC		SiL		SiL	
0.4	SiL		SiC		SiL		SiL	
0.5	SiL		SiL		vfS	Bar sands	SiL	
0.6	L		SiL		vfS		SiL	
0.7	SiL		SiL		vfS		SiL	
0.8	SiC		SiL		vfS		SiL	
0.9	SiC		SiL		fS		SiL	
1	SiC		LS	ACF	fS		SiL	
1.1	SiC		L	LR	fS		SiL	
1.2	SiC		SiL		fS		SiC	
1.3	SiC		SiL		fS		SiC	
1.4	SiL		SiL		fS		SiL	
1.5	SiC		SiL		fS		SiC	
1.6	SiC		SiL		fS		SiL	
1.7	SiC		SiL		vfS		SiC	
1.8	SiC		SiL		vfS		C	
1.9	SiL		SiL		vfS		SiC	
2	SiL		L		vfS		SiC	
2.1	L		LfS	ACF	vfS		SiC	
2.2	SiL		LfS		vfS		SiL	
2.3	L		fS		vfS		SiL	
2.4	L		fS		vfS		SiC	
2.5	L		fS		vfS		SiC	

	MOV-SH-013		MOV-SH-014		MOV-SH-015		MOV-SH-016	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	L	LR	fS	ACF	vfS	Bar sands	SiC	LR
2.7	SiL		fS		vfS		SL	
2.8	SiC		LfS		vfS		SiC	
2.9	SiC		LfS		vfS		SiL	
3	SiC		fS		vfS		SiL	
3.1	SiC		fS		vfS		SiL	
3.2	SiC		LfS		vfS		SiL	
3.3	SiC		SL		vfS	**Bar**	SiL	
3.4	SiC		SL				SiC	
3.5	SiC		fS				SiC	
3.6	LS	ACF	fS				SiL	
3.7	LS		fS				SiC	
3.8	LS		fS				SiL	
3.9	LS		fS				SiL	
4	LS		mS				SiL	
4.1	LvfS		C	LR			SiC	
4.2	LvfS		C				SiC	
4.3	LvfS		SiL				SiL	
4.4	LvfS		SiL				SiL	
4.5	LvfS		C				SiL	
4.6	vfS		C				SiL	
4.7	vfS		SiC				vfSL	
4.8	vfS		C				vfSL	
4.9	vfS		C	**Channel**			SiL	
5	vfS						SiL	

	MOV-SH-013		MOV-SH-014		MOV-SH-015		MOV-SH-016	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	vfS	ACF					C	LR
5.2	vfS						C	
5.3	L						C	
5.4	LS						C	
5.5	LS						SiC	
5.6	fS						SiC	**Channel**
5.7	fS							
5.8	LS							
5.9	LS							
6	vfS	CB						
6.1	vfS							
6.2	vfS							
6.3	vfS							
6.4	vfS							
6.5	vfS							
6.6	vfS							
6.7	vfS							
6.8	vfS							
6.9	vfS							
7	vfS							
7.1	vfS							
7.2	vfS	**Channel**						
7.3								
7.4								
7.5								

	MOV-SH-017		MOV-SH-018		MOV-SH-019		MOV-SH-020	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	SiC	OF	SiL	OF	SiL	
0.2	SiC		SiC		SiL		SiL	
0.3	SiC		SiC		SiL		SiL	
0.4	SiC		SiC		SiL		SiL	
0.5	SiL		SiC		SiL		L	
0.6	SiL		SiC		SiL		vfSL	
0.7	L		SiC		SiC		L	
0.8	SiL		SiC		SiL		L	
0.9	SiL		SiC		SiL		L	
1	SiL		SiC		L		SiL	
1.1	SiL		SiC		SiL		SiL	
1.2	SiL		SiL		SiL		SiL	
1.3	SiL		SiC		SiL		SiL	
1.4	SiL		SiC		L		SiL	
1.5	SiL		SiL		SiL		SiL	
1.6	L		SiC		L		fS	
1.7	L		L		LvfS	Bar sands	fLS	
1.8	L		SiL		LvfS		fLS	
1.9	SiC		fSL		LvfS		fSL	
2	SiC		L		SiC		fSL	
2.1	fS	CB	L		LvfS		SiL	
2.2	fS		L		vfS		SiL	
2.3	fS		vfSL	Bar sands	vfS		SiL	
2.4	fS		vfSL		fS		SiC	
2.5	fS		vfSL		fS		C	

	MOV-SH-017		MOV-SH-018		MOV-SH-019		MOV-SH-020	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	fS	CB	vfSL	OF	fS	Bar sands	SiC	
2.7	fS		SiL		fS		C	
2.8	fS		vfS		fS		C	
2.9	fS		SiL		fS		C	
3	mS		SiC		fS		C	
3.1	mS		vfSL	Bar sands	fS		C	
3.2	mS		vfSL		fS		SiC	
3.3	mS		vfSL		fS		SiC	
3.4	mS		fSL		fS		SiC	
3.5	SiL		vmS		fS		SiC	
3.6	SiL		vmS		vfS		SiC	
3.7	SiL		vmS		vfS		SiC	
3.8	mS	Bar sands	vmS		vfS		SiC	
3.9	mS		vmS		vfS		SiC	
4	mS		cS		vfS		SiL	
4.1	mS		cS		vfS		C	
4.2	mS		cS		mS		C	
4.3	mS		cS		mS	**Bar**	C	
4.4	mS		cS				C	
4.5	mS		cS				C	
4.6	mS		cS				C	
4.7	mS		cS				C	
4.8	mS		cS				C	
4.9	mS		cS				SiC	
5	mS		cS				fSL	

	MOV-SH-017		MOV-SH-018		MOV-SH-019		MOV-SH-020	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	vmS	Bar sands	cS	**Bar**			SiL	
5.2	vmS						vfSL	
5.3	vmS						vfSL	
5.4	vmS						SiL	
5.5	vmS						vfSL	
5.6	vmS						vfSL	
5.7	vmS	**James channel**					vfS	
5.8							vfS	
5.9							vfS	
6							vfS	
6.1							vfS	
6.2							vfS	
6.3							vfS	
6.4							vfS	
6.5							vfS	
6.6							vfS	
6.7							vfS	
6.8							vfS	
6.9							vfS	**Splay**
7								
7.1								
7.2								
7.3								
7.4								
7.5								

	MOV-SH-021		MOV-SH-022		MOV-SH-023		MOV-SH-024	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	SiC	OF	SiC	OF	SiL	OF
0.2	SiC		SiC		SiC		SiL	
0.3	SiC		SiC		SiC		SiL	
0.4	SiC		SiC		SiC		SiL	
0.5	SiC		SiC		SiC		SiC	
0.6	vfSL	ACF	SiC		SiC		SiC	
0.7	vfSL		vfSiL		SiC		SiC	
0.8	vfSL		SiL		SiC		SiC	
0.9	vfSL		SiL		SiC		SiL	
1	SiC	LR	SiL		SiC		SiL	
1.1	SiC		SiC		SiC		SiL	
1.2	SiC		SiL		SiC		SiL	
1.3	vfSL	ACF	vfS	Bar sands	SiC		SiL	
1.4	SiC	LR	vfS		L		SiL	
1.5	SiC		vfS		SiL		SiL	
1.6	SiC		vfS		L		SiL	
1.7	SiC		vfS		SiC		SiL	
1.8	SiC		vfS		SiL		SiL	
1.9	SiC		fS		SiL		fSL	Bar sands
2	SiC		fS		SiL		fS	
2.1	SiC		fS		vfSL	Bar sands	fS	
2.2	SiC		fS		vfSL		fS	
2.3	SiC		fS		vfSL		fS	
2.4	SiC		fS		vfSL		S	
2.5	SiC		LfS		vfSL		S	

	MOV-SH-021		MOV-SH-022		MOV-SH-023		MOV-SH-024	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC	LR	mS	Bar sands	vfSL	Bar sands	S	Bar sands
2.7	SiC		mS		fS		S	
2.8	SiC		mS		fS		S	
2.9	SiC		L		fS		S	
3	LfS	CB	mS		fS		S	
3.1	LfS		mS		fS		S	
3.2	LS		mS	**Bar**	fS		S	
3.3	LS				fS		S	
3.4	LS				S		S	
3.5	LS				S		S	**Bar**
3.6	LS				S			
3.7	LS				S			
3.8	LfS				S			
3.9	LfS				S			
4	LfS				S	**Bar**		
4.1	LfS							
4.2	LfS							
4.3	LfS							
4.4	LS							
4.5	LS							
4.6	S							
4.7	S							
4.8	S							
4.9	S							
5	S							

	MOV-SH-021		MOV-SH-022		MOV-SH-023		MOV-SH-024	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	LS	CB						
5.2	LS							
5.3	S							
5.4	S							
5.5	S							
5.6	S							
5.7	S	**Channel**						

	MOV-SH-025		MOV-SH-026		MOV-SH-027		MOV-SH-028	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	LR	SiL	OF	SiL	JRD	SiL	LR
0.2	SiL		SiL		SiL		SiL	
0.3	L		SiL		SiL		SiL	
0.4	SiL		L		SiL		SiL	
0.5	SiC		LvfS		SiL		SiL	
0.6	C		LvfS		SiL		SiL	
0.7	C		LvfS		SiL		SiL	
0.8	C		SiL		L		SiL	
0.9	LS	ACF	SiC		SiL		vfSL	ACF
1	C	LR	SiC		SiL		SiC	LR
1.1	C		SiL		SiL		SiC	
1.2	C		SiL		SiL		SiC	
1.3	C		SiL		SiL		SiL	
1.4	C		SiL		SiL		SiC	
1.5	SiC		SiL		SiL		SiC	
1.6	C		LS	Bar sands	SiL		SiL	
1.7	SiC		LS		SL		fSL	ACF
1.8	SiC		LS		L		fSL	
1.9	SiC		LS		L		fSL	
2	C		LS		SiL		fSL	
2.1	C		LS		SiL		SiC	LR
2.2	C		LS		SiL		SiC	
2.3	C		LS		SiL		SiC	
2.4	C		L		SiL		SiC	
2.5	C		L		SiC		SiC	

	MOV-SH-025		MOV-SH-026		MOV-SH-027		MOV-SH-028	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	C	LR	SL	Splay?	SiC	JRD	SiL	LR
2.7	C		L		SiC		SiL	
2.8	C		SL		SiC		SiL	
2.9	C		LS		SiL		SiL	
3	C		LS		SiC		SiL	
3.1	C		SL		SiC		SL	ACF
3.2	C		LS		SiC		SL	
3.3	C		LS		SiC		SiC	LR
3.4	C		SL		SiC		SiC	
3.5	S	CB	LS		C		SiC	
3.6	S		LS		C		C	
3.7	S		LS		C		C	
3.8	S		S	Bar sands	C		C	
3.9	S		mS		SiC		C	
4	S		mS		SL	Bar sands	C	
4.1	S		mS		fSL		SiL	
4.2	S	**Channel**	mS		LS		SiL	
4.3			mS		LS		SiC	
4.4			mS		SL		C	
4.5			mS		fSL		C	
4.6			mS		fSL		C	
4.7			mS		fSL		SiC	
4.8			mS		fSL		SiC	
4.9			mS		fSL		SiC	
5			mS		fLS		SiL	

	MOV-SH-025		MOV-SH-026		MOV-SH-027		MOV-SH-028	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1			mS	Bar sands	fLS	Bar sands	L	LR
5.2			mS		fLS		SiL	
5.3			mS		mS		L	
5.4			mS		mS		SiC	
5.5			mS		mS		SiL	
5.6			mS		mS		SiL	
5.7			mS	**Bar**	mS		SiL	
5.8					mS		SL/LS	ACF
5.9					mS		LS	
6					mS		LS	
6.1					mS		LS	
6.2					mS		LS	
6.3					cS		mS	CB
6.4					cS		mS	
6.5					cS		cS	
6.6					cS		cS	
6.7					cS		cS	
6.8					cS		cS	
6.9					cS		cS	
7					cS		cS	
7.1					cS		cS	
7.2					cS		cS	
7.3					cS		cS	
7.4					cS		cS	
7.5					cS		cS	

	MOV-SH-025		**MOV-SH-026**		**MOV-SH-027**		**MOV-SH-028**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6					cS	Bar sands	cS	CB
7.7					cS		cS	
7.8					cS		cS	
7.9					cS		cS	
8					cS		cS	
8.1					cS		cS	
8.2					cS	**Bar**	fS	
8.3							fS	
8.4							fS	
8.5							fS	
8.6							fS	**Channel**
8.7								

	MOV-SH-029		MOV-SH-030		MOV-SH-031		MOV-SH-032	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	LR	SiC	LR	L	LR	SiC	Splay?
0.2	SiL		SiC		L		SiC	
0.3	SiL		SiL		L		SiC	
0.4	SiL		SiL		L		SiC	
0.5	LfS	ACF	SiL		L		SiC	
0.6	LfS		SiL		L		SiC	
0.7	LfS		SiL		L		SiC	
0.8	LfS		SiC		L		SiL	
0.9	LfS		SiL		SiL		SiL	
1	SiC	CF	SiL		L		SiC	
1.1	LfS	ACF	C		L		SiL	
1.2	SiC	LR	SiL		L		SiL	
1.3	SiC		SiL		L		SiL	
1.4	SiC		SiC		L		SiL	
1.5	SiC		SiC		L		L	
1.6	SiC		C		SiL		SiC	
1.7	SiC		C		vfSL	ACF	SiC	
1.8	SiL		SiC		vfSL		SiL	
1.9	SiC		SiC		vfSL		SiL	
2	C		SiL		vfSL		SiC	
2.1	fSL	ACF	SiC		L		SiC	
2.2	fSL		SiC		vfSL		SiC	
2.3	SiL	LR	SiL		SiL	LR	SiC	
2.4	SiC		fSL	CB	SiL		SiC	
2.5	SiC		LfS		SiL		SiC	

	MOV-SH-029		MOV-SH-030		MOV-SH-031		MOV-SH-032	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiC	LR	LfS	CB	SiC	LR	SiL	Splay?
2.7	SiC		LfS		SiC		SiC	
2.8	SiC		LfS		SiC		SiC	
2.9	SiC		LfS		SiC		SiC	
3	C		LfS		SiC		SiL	
3.1	C		LfS		SiC		SiC	
3.2	fSL	ACF	vfS		SL		SiC	
3.3	C	LR	vfS		SiC		vfSL	Bar sands
3.4	LfS		vfS		SiL		fSL	
3.5	SiL		vfS		SiC		fSL	
3.6	C		vfS		SiC		fSL	
3.7	S		mS		SiC		LfS	
3.8	C		mS		SiC		vfS	
3.9	LvfS		mS		SiC		vfS	
4	C		mS	**Channel**	SiL		mS	
4.1	SiC				fSL		mS	
4.2	C				SiL		mS	
4.3	C				SiC		mS	
4.4	C				C		mS	
4.5	SiC				C		vmS	
4.6	SiC				C		cS	
4.7	SiC				C		cS	
4.8	SiL				C		cS	
4.9	SiC				C		cS	
5	vfSL	ACF			SiL		cS	

	MOV-SH-029		**MOV-SH-030**		**MOV-SH-031**		**MOV-SH-032**	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	vfSL	ACF			SiL	LR	cS	Bar sands
5.2	vfSL				SiL		cS	
5.3	SiL	LR			mS	CB	cS	
5.4	SiL				mS		cS	
5.5	SiC				mS		cS	
5.6	SiC				mS		cS	**Bar**
5.7	SiL				mS			
5.8	L				mS			
5.9	L				cS			
6	SiC				cS			
6.1	LS	CB			cS			
6.2	LS				cS			
6.3	LS				cS			
6.4	S				cS			
6.5	S				cS			
6.6	S				cS	**Channel**		
6.7	S							
6.8	S							
6.9	S							
7	S							
7.1	S							
7.2	S							
7.3	S							
7.4	S							
7.5	S							

	MOV-SH-029		MOV-SH-030		MOV-SH-031		MOV-SH-032	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6	S	CB						
7.7	S	**Channel**						
7.8								
7.9								
8								

	MOV-SH-033		MOV-SH-034		MOV-SH-035		MOV-SH-036	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL	LR	SiC	OF	SiL	LR	SiC	LR
0.2	SiL		SiC		SiL		SiC	
0.3	SiL		SiC		SiC		SiL	
0.4	SiL		SiC		SiL		SiC	
0.5	SiL		SiC		SiC		SiC	
0.6	SiL		SiC		SiL		SiC	
0.7	SiL		SiC		SiL		SiC	
0.8	SiL		SiL		SiL		SiC	
0.9	SiL		SiC		SiC		SiC	
1	SiL		SiC		SiC		SiC	
1.1	SiL		SiC		SiL		SiC	
1.2	SiC		SiC		SiL		C	
1.3	SiL		SiC		SiL		C	
1.4	L		SiL		SiC		SiC	
1.5	L		SiL		SiC		SiC	
1.6	LS		SiC		SiC		SiC	
1.7	SiL		SiC		SiC		SiC	
1.8	SiL		SiC		SiC		SiC	
1.9	SiC		SiC		SiC		SiC	
2	SiC		SiC		SiC		C	
2.1	SiL		SL		SiC		C	
2.2	fSL	ACF	LS	Bar sands	SiC		C	
2.3	fSL		LS		SiC		C	
2.4	fSL		LS		SiC		C	
2.5	fSL		LS		SiC		C	

	MOV-SH-033		MOV-SH-034		MOV-SH-035		MOV-SH-036	
Depth meters	Facies	Interpretation	Facies	Interpretation	**Depth meters**	Facies	Interpretation	Facies
2.6	fSL	ACF	LS	Bar sands	SiC	LR	C	LR
2.7	SiC	LR	S		C		C	
2.8	SiC		S		SiC		C	
2.9	SiC		LS		SiC		SiL	
3	SiL		LS		C		SiC	
3.1	SiL		LS		C		C	
3.2	SiL		LS		fSL		C	
3.3	SiL		SL		C		C	
3.4	L		mS		SiL		C	
3.5	L		mS		LfS	ACF	C	
3.6	L		mS		vfS		C	
3.7	LfS		mS		vfS		C	
3.8	fSL		mS		LfS		C	
3.9	SiC		mS		SiL	LR	C	
4	fSL		cS		SiC		C	
4.1	S	ACF	cS		SiC		C	
4.2	S		cS		SiC		C	
4.3	S		cS		C		C	
4.4	SiL	LR	cS		SiC		C	
4.5	SiL		cS		SiC		C	
4.6	C		cS		SiC		C	
4.7	C		cS		SiL		C	
4.8	C		cS	**Bar**	SiC		C	
4.9	C				LS	ACF	C	
5	C				LS		C	

	MOV-SH-033		MOV-SH-034		MOV-SH-035		MOV-SH-036	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	C	LR			LS	ACF	SiC	LR
5.2	C				mS	CB	C	
5.3	C				mS		C	
5.4	C				mS		C	
5.5	C				mS		C	
5.6	C				mS		C	
5.7	C				mS		C	
5.8	C				mS		C	
5.9	C				mS		C	
6	C				mS		C	
6.1	C				cS		C	
6.2	L				cS		C	
6.3	SiC				cS		C	
6.4	SiC				cS		C	
6.5	C				cS		cS	CB
6.6	C				cS		cS	
6.7	C				cS	**Channel**	cS	
6.8	C						cS	
6.9	SiL						cS	
7	C						cS	
7.1	C						cS	
7.2	C						cS	
7.3	C						cS	
7.4	C						cS	
7.5	C						cS	

	MOV-SH-033		MOV-SH-034		MOV-SH-035		MOV-SH-036	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6	C						cS	**Channel**
7.7	C							
7.8	C	LR						
7.9	C							
8	C							
8.1	C							
8.2	C							
8.3	C							
8.4	C							
8.5	C							
8.6	SiC							
8.7	C							
8.8	SiL							
8.9	SiC							
9	SiC							
9.1	fSL							
9.2	C							
9.3	LfS	CB						
9.4	LfS	**Channel**						
9.5								
9.6								
9.7								
9.8								
9.9								
10								

	MOV-SH-037		MOV-SH-038		MOV-SH-039		MOV-SH-040	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC	LR	SiL	LR	SiC	LR	SiL	OF
0.2	SiC		SiL		SiC		SiL	
0.3	SiC		SiL		SiC		SiL	
0.4	SiC		SiL		SiL		SiL	
0.5	SiC		SiL		SiL		SiC	
0.6	SiC		SiL		SiC		SiC	
0.7	SiC		SiL		SiC		SiL	
0.8	SiC		SiL		SiL		SiL	
0.9	SiC		SiL		SiL		SiC	
1	SiC		SiL		SiL		SiL	
1.1	SiL		SiL		SiL		SiC	
1.2	SiC		SiL		SiL		SiC	
1.3	SiC		SiL		SiC		SiC	
1.4	SiL		SiC		SiC		SiC	
1.5	SiL		SiL		SiL		SiC	
1.6	L		SiL		L		SL	Bar sands
1.7	L		SiL		L		SL	
1.8	L		vfSL	ACF	vfSL		LS	
1.9	L		vfSL		L		S	
2	L		vfSL		LvfS	ACF	S	
2.1	SiL		SiL	LR	LvfS		S	
2.2	L		SiC		LvfS		S	
2.3	SiL		SiC		vfS		S	
2.4	SiL		SiC		vfS		S	
2.5	SiL		SiL		vfS		S	

	MOV-SH-037		MOV-SH-038		MOV-SH-039		MOV-SH-040	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	SiL	LR	SiL	LR	fS	ACF	mS	Bar sands
2.7	SiC		SiL		fS		mS	
2.8	SiL		L		fS		vmS	
2.9	SiL		L		fS		vmS	
3	SiC		L		fS		vmS	**Bar**
3.1	SiC		SiL		LfS			
3.2	SiC		L		L			
3.3	SiC		SiL		L			
3.4	SiC		SiL		LS			
3.5	SiC		SiL		LS			
3.6	SiL		SiL		S	CB		
3.7	SiL		SiC		S			
3.8	SiL		C		vfS			
3.9	SiL		C		vfS			
4	SiC		C		vfS			
4.1	SiC		C		mS			
4.2	SiL		C		mS			
4.3	SiL		C		mS	**Channel**		
4.4	SiL		C					
4.5	vfSL	ACF	C					
4.6	vfSL		C					
4.7	vfSL		C					
4.8	vfSL		C					
4.9	vfSL		C					
5	SiC	LR	C					

	MOV-SH-037		MOV-SH-038		MOV-SH-039		MOV-SH-040	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	SiC	LR	C	LR				
5.2	C		C					
5.3	C		S					
5.4	C		LS					
5.5	SiC		SiL					
5.6	SiC		SiL					
5.7	vfSL	ACF	vfS	CB				
5.8	vfSL		vfS					
5.9	vfSL		vfS					
6	C	LR	vfS					
6.1	C		vfS					
6.2	SiC		vfS					
6.3	C		vfS					
6.4	C		vfS					
6.5	SiC		vfS					
6.6	SiC		vfS					
6.7	SiL		vfS					
6.8	vfLS	**Channel**	vfS					
6.9			vfS					
7			vfS					
7.1			vfS					
7.2			vfS					
7.3			vfS					
7.4			vfS					
7.5			vfS					

	MOV-SH-037		MOV-SH-038		MOV-SH-039		MOV-SH-040	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6			vfS	CB				
7.7			vfS	**Channel**				
7.8								
7.9								
8								
8.1								
8.2								
8.3								
8.4								

	MOV-SH-041		MOV-SH-042		Borehole I.D		Borehole I.D	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		SiC					
0.2	SiC		SiL					
0.3	SiC		SiL					
0.4	SiC	Splay?	SiC	LR				
0.5	SiC		SiL					
0.6	SiC		SiC					
0.7	SiC		SiC					
0.8	SiL		SiC					
0.9	SiC		SiC					
1	SiC		SiC					
1.1	SiC		SiC					
1.2	SiC		SiC					
1.3	SiL		SiC					
1.4	SiL		SiC					
1.5	SL		SiC					
1.6	SL		SiC					
1.7	SL		SiC					
1.8	SL		SiC					
1.9	SiC		SiC					
2	LS		SiL					
2.1	vfLS		SiL					
2.2	vfLS		SiL					
2.3	vfLS		SiL					
2.4	LS		C					
2.5	LfS		C					

	MOV-SH-041		MOV-SH-042		Borehole I.D		Borehole I.D	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.6	LfS		C					
2.7	LfS		C					
2.8	LfS	Splay?	C					
2.9	fSL		C	LR				
3	L		C					
3.1	L		C					
3.2	SiL		C					
3.3	SiL		C					
3.4	SiL		SiC					
3.5	SiL		C					
3.6	C		C					
3.7	C		C					
3.8	SiC		C					
3.9	SiL		C					
4	S		C					
4.1	LS		SiL					
4.2	LS	Bar sands	C					
4.3	LS		C					
4.4	LS		C					
4.5	S		LS					
4.6	S		C					
4.7	vfS		SiC					
4.8	vfS		SiC					
4.9	mS		SiC					
5	mS		SiC					

	MOV-SH-041		MOV-SH-042		Borehole I.D		Borehole I.D	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5.1	mS		SiC					
5.2	mS	Bar sands	SiL					
5.3	mS		SiL					
5.4	mS		SiL	LR				
5.5	mS		SiL					
5.6	mS		SiL					
5.7	mS		SiL					
5.8	mS		SiL					
5.9	mS		SiL					
6	mS	**Bar**	SiC					
6.1			SiL					
6.2			SiC					
6.3			SiL					
6.4			vfSL					
6.5			SiL					
6.6			SiC					
6.7			SiC					
6.8			SiC					
6.9			SiC					
7			SiL					
7.1			SiC					
7.2			vfSL					
7.3			C					
7.4			C					
7.5			cS	ACF				

	MOV-SH-041		MOV-SH-042		Borehole I.D		Borehole I.D	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
7.6			cS	ACF				
7.7			cS					
7.8			cS					
7.9			C					
8			S					
8.1			cS					
8.2			SiL					
8.3			SiL					
8.4			SiL					
8.5			S	CB				
8.6			S					
8.7			S					
8.8			S	**Channel**				
8.9								
9								
9.1								
9.2								
9.3								
9.4								
9.5								
9.6								
9.7								
9.8								
9.9								
10								

APPENDIX C

OSL DATES

Missouri River

UNL #	Field #	Burial Depth (m)	H_2O (%)[a]	K_2O (%)	U (ppm)	Th (ppm)	Cosmic (Gy)	Dose Rate (Gy/ka)	D_e (Gy)	No. of Aliquots	Age (ka)
UNL2203	MOV-MH-023 3.6-3.9m	3.8	21.0	1.82	1.26	3.89	0.13	1.77±0.08	4.78±0.09	38	2.70±0.16
UNL2204	MOV-MK-045 4.7-4.5m	4.6	28.5	2.01	1.90	6.30	0.12	2.00±0.11	5.13±0.09	37	2.56±0.17
UNL2205	MOV-MK-044 4.2-4.5m	4.4	23.8	2.03	1.72	5.02	0.12	2.00±0.10	7.87±0.13	37	3.94±0.24
UNL2206	MOV-MK-043 6.7-6.9m	6.8	18.8	1.86	1.21	3.35	0.09	1.76±0.08	4.57±0.07	38	2.59±0.15
UNL2207	MOV-SH-001 4.5-4.7m	4.6	26.4	1.98	1.54	5.40	0.12	1.91±0.10	2.79±0.07	43	1.46±0.10
UNL2208	MOV-MH-022 3.25-3.6m	3.4	21.1	1.77	1.05	4.04	0.14	1.71±0.08	3.10±0.07	34	1.82±0.11
UNL2209	MOV-MK-042 3.0-3.2m	3.1	5.6	1.74	1.13	3.26	0.15	1.96±0.07	6.28±0.11	34	3.21±0.16
UNL2210	MOV-SH-002 4.1-4.3m	4.2	23.5	1.90	1.96	6.20	0.13	2.03±0.10	3.08±0.02[b]	64	1.51±0.09[b]
UNL2211	MOV-MH-002 2.2-2.4m	2.3	5.2	1.69	0.89	2.49	0.13	1.81±0.07	1.15±0.09[b]	65	0.63±0.06[b]
UNL2212	MOV-BV-30 3.6-3.8m	3.7	8.1	1.92	1.58	4.97	0.14	2.24±0.08	0.92±0.05[b]	84	0.41±0.03[b]

[a] In-situ Moisture Content
[b]Minimum Age Model (Galbraith et al. 1999)
Error on De is 1 standard error
Error on age includes random and systematic errors calculated in quadrature

2008 field season OSL data

Quadrangle abbreviations as follows:

MH: Mission Hill

MK: Meckling

SH: St. Helena

Missouri R., Nebraska

UNL #	Field #	Burial Depth (m)	H_2O (%)*	K_2O (%)	±	U (ppm)	±	Th (ppm)	±	Cosmic (Gy)	Dose Rate (Gy/ka)	D_e (Gy)	No. of Aliquots	Age (ka)	Model
UNL2490	MOV-AL-12	1.6-1.9	17.1	2.18	0.06	3.51	0.14	8.10	0.33	0.17	2.82±0.12	2.84±0.25	34	1.01±0.10	CAM
												1.94±0.07	34	0.69±0.04	**MAM**
UNL2491	MOV-SL-45	2.25-2.45	21.9	1.90	0.05	1.66	0.09	4.26	0.24	0.16	1.93±0.09	14.05±0.47	31	7.29±0.48	CAM
UNL2492	MOV-SL-47	1.5-1.65	21.5	2.14	0.06	1.62	0.09	4.67	0.26	0.18	2.12±0.10	13.90±0.27	32	6.56±0.39	CAM
UNL2493	MOV-ONA-33	3.2-3.35	34.2	2.15	0.06	3.37	0.14	7.57	0.32	0.14	2.32±0.14	10.86±0.47	29	4.68±0.37	CAM
UNL2494	MOV-OSW-5	1.1-1.4	24.9	1.74	0.05	1.41	0.08	3.46	0.20	0.19	1.70±0.09	2.65±0.14	35	1.56±0.12	CAM
UNL2495	MOV-OSW-12	0.9-1.2	5.9	1.61	0.05	4.03	0.15	13.99	0.39	0.19	3.26±0.11	1.91±0.15	43	0.59±0.05	CAM
												1.21±0.03	43	0.37±0.02	**MAM**
UNL2496	MOU-LSY-50	4.0-4.25	25.8	1.89	0.05	2.25	0.10	6.09	0.25	0.13	2.03±0.10	24.92±0.27	44	12.2±0.7	CAM
UNL2497	MOV-OSW-58	0.7-1.0	16.5	2.13	0.06	3.69	0.14	4.69	0.26	0.20	2.66±0.11	1.80±0.15	37	0.68±0.06	CAM
												0.86±0.10	37	0.32±0.04	**MAM**
UNL2498	SSC-138	2.4-2.65	7.7	1.73	0.05	1.46	0.14	7.43	0.33	0.16	2.26±0.08	1.52±0.19	37	0.67±0.09	CAM
												0.85±0.07	37	0.38±0.04	**MAM**
UNL2499	MOV-AL-39	2.6-2.8	8.8	2.21	0.06	3.10	0.13	4.44	0.25	0.15	2.75±0.10	4.90±0.24	27	1.78±0.12	CAM
UNL2500	SSC-137	1.4-1.6	4.6	1.95	0.03	3.08	0.20	4.84	0.30	0.18	2.73±0.09	1.46±0.12	47	0.46±0.06	CAM
												0.80±0.09	47	0.29±0.04	**MAM**
UNL2501	MOV-SL-3	2.8-3.0	20.0	1.82	0.05	3.17	0.13	4.52	0.25	0.15	2.21±0.10	14.56±0.50	41	6.59±0.42	CAM

* In-situ Moisture Content
Error on De is 1 standard error
Error on age includes random and systematic errors calculated in quadrature

2009 field season OSL data

Quadrangle abbreviations as follows:

AL= Albaton

SL= Sloan

ONA= Onawa

OSW= Onawa SW

LSY= Salix (typo, abbrv. should be SLX)

SSC= South Sioux City.

MOU= is a typo, should be MOV

	MOV-MK-001		MOV-MK-041		MOV-MK-042		MOV-MK-043	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiL		SiC		SiL		L	
0.2	SiL		SiC		SiL		L	
0.3	SiL		SiC		SiL		L	
0.4	LS		SiC		SiL		SiC	
0.5	LS		SiC		L		L	
0.6	LS		SiC		L		L	
0.7	LS		SiC		L		SiL	
0.8	LS		SiC		L		SiC	
0.9	LS		SiC		L		L	
1	LS		SiC		L		SL	
1.1	LS		L		SL		L	
1.2	LS		SiL		SL		L	
1.3	LS		SiC		SL		L	
1.4	L		L		LS		SiC	
1.5	LS		SiC		LS		SiC	
1.6	LS		SiC		LS		L	
1.7	LS		SiC		LS		L	
1.8	LS		SiL		LS		SL	
1.9	LS		SiL		LS		SL	
2	LS		SiC		L		SL	
2.1	LS		SiL		L		LS	
2.2	S		SiC		S		LS	
2.3	S		SiC		SL		LS	
2.4	S		SiC		SL		LS	

	MOV-MK-001		MOV-MK-041		MOV-MK-042		MOV-MK-043	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.5	S		SiL		LS		LS	
2.6	S		L		S		L	
2.7	S		C		S		L	
2.8	S		C		S		L	
2.9	S		C		S		L	
3	S		SiC		S		L	
3.1			C				L	
3.2			SiC				SiC	
3.3			SiC				L	
3.4			SiC				L	
3.5			SiC				SiC	
3.6			SiC				SiC	
3.7			SiC				SiC	
3.8			SiC				L	
3.9			SiC				L	
4			SiC				SL	
4.1			SL				L	
4.2			SL				L	
4.3			S				L	
4.4			LS				L	
4.5			LS				L	
4.6			S				SiC	
4.7			S				SiC	
4.8			S				SiL	
4.9			L				L	

	MOV-MK-001		MOV-MK-041		MOV-MK-042		MOV-MK-043	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5			SL				SL	
5.1			SL				SL	
5.2			SiC				L	
5.3			LS				L	
5.4			LS				L	
5.5			LS				C	
5.6			LS				C	
5.7							C	
5.8							C	
5.9							C	
6							S	
6.1							S	
6.2							S	
6.3							S	
6.4							S	
6.5							S	
6.6							S	
6.7							S	
6.8							S	
6.9							S	
7								
7.1								
7.2								
7.3								
7.4								

	MOV-MK-044		MOV-MK-045		MOV-SH-001		MOV-SH-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
0.1	SiC		C		SiC		SiC	
0.2	SiC		SiC		SiC		SiL	
0.3	SiC		SiC		SiC		SiL	
0.4	SiL		SiL		SiL		SiL	
0.5	SiL		SiL		SiL		L	
0.6	SiL		SiL		L		L	
0.7	SiC		L		L		L	
0.8	SiL		L		L		L	
0.9	SiL		L		LS		L	
1	SiC		L		L		L	
1.1	C		L		L		L	
1.2	SiC		SiC		L		L	
1.3	SiL		L		L		L	
1.4	SL		L		LS		LS	
1.5	SiC		L		SL		SL	
1.6	SiC		L		SL		SL	
1.7	SiC		L		LS		SL	
1.8	SiC		SiC		LS		C	
1.9	SiC		SiC		LS		L	
2	SiC		SiC		LS		L	
2.1	SiC		SiC		LS		L	
2.2	SiL		C		LS		L	
2.3	SiL		C		SL		L	
2.4	SiC		C		LS		L	

	MOV-MK-044		MOV-MK-045		MOV-SH-001		MOV-SH-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
2.5	SiC		C		L		L	
2.6	SiC		SiC		LS		L	
2.7	SiC		SiC		L		L	
2.8	SiL		SiC		L		L	
2.9	SiL		LS		L		L	
3	L		LS		L		SiC	
3.1	L		LS		L		SL	
3.2	L		LS		L		SL	
3.3	L		LS		L		S	
3.4	LS		LS		L		S	
3.5	SL		LS		L		S	
3.6	LS		S		L		SL	
3.7	LS		S		L		LS	
3.8	LS				L		SL	
3.9	LS				LS		SiC	
4	LS				LS		LS	
4.1					L		LS	
4.2					L		LS	
4.3					S		LS	
4.4					S		LS	
4.5					S		LS	
4.6					S		L	
4.7							LS	
4.8							SL	
4.9							SiC	

	MOV-MK-044		MOV-MK-045		MOV-SH-001		MOV-SH-002	
Depth meters	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation	Facies	Interpretation
5							L	
5.1							SL	
5.2							LS	
5.3							LS	
5.4								
5.5								
5.6								

REFERENCES

Alexandrowicz, Neal, Jordan Garrett, April D. Moreno, Dustin E. Ward, and John Holbrook, 2007, **Gayville Quadrangle map**.

Andrews, J.T., 1987, **The late Wisconsin glaciation and deglaciation of the Laurentide ice sheet**, in Ruddiman, W.F., ed., North America and adjacent oceans during the last deglaciation: The geology of North America: Boulder Colorado, Geological Society of America, v. K-3, p. 13-37.

Baumhoff, Richard G. 1951, **The Dammed Missouri Valley: One Sixth of Our Nation**, Knopf, New York.

Benson, RD, 1983, **Preliminary Assessment of Hydrologic Characteristics of the James River in South Dakota**, USGS Water-Resources Investigations Report 83-4077, 115 p, 37 Fig., 25 Tab.

Berry Jr., Charles R and Bradley Young, 2004, **Fishes of the Missouri National Recreational River, South Dakota and Nebraska**, Great Plains Research, 14, pgs. 89-114.

Blevins, Dale W., 2007, **The Response of Suspended Sediment, Turbidity, and Velocity to Historical Alterations of the Missouri River**, U.S. Geologic Survey, circular 1301, http://pubs.usgs.gov/circ/2006/1301/pdf/circ_1301.pdf

Bluemle, J.P., 1972, **Pleistocene Drainage Development in North Dakota**: Geological Society of America Bulletin, v. 83, p. 2189-2193, doi: 10.1130/0016-7606(1972)83[2189:PDDIND]2.0.CO;2.

Bøtter-Jensen, L., McKeever, S.W.S., and Wintle, A.G., 2003, Optically stimulated luminescence dosimetry Amsterdam, Elsevier.

Bown, T.M, and M.J. Kraus, 1987. Integration of channel and floodplain suites, I. Developmental sequence and lateral relations of alluvial paleosols. Journal of Sedimentary Petrology, v. 57, p. 587-601.

Bridge, J.L., 2003, Rivers and floodplains: forms, processes, and sedimentary record Malden, MA, Blackwell Pub.

Bugliosi, Edward F., 1986. **Water resources of Yankton County, South Dakota, U.S. Geological Survey**, Water-Resource Investigations Report 84-4241.

Calvert, Graham S., John M. Holbrook, Ronald J. Goble, Steven Emenhiser, Jill C. Meyers, Tim Freed, Matt Wessale, Aaron, Soultaire, Josh Arten, Amy Radakovich, Katherine Miller, Sara Figuerosa, 2009. **Evidence for Preservation of Pleistocene Outwash within the Missouri River Valley Fill**. Missouri River National Resources Conference & BiOP Forum.

Carlson, A.E., Jenson, J.W., and Clark, P.U., 2007, **Modeling the subglacial hydrology of the James Lobe of the Laurentide ice sheet**: Quaternary Science Reviews, v. 26, p. 1384-1397, doi: 10.1016/j.quascirev.2007.02.002.

Chittenden, H.M, 1903. **History of Early Steamboat Navigation on the Missouri River**, Francis P. Harper, New York (1903).

Clark, P.U., 1992, **Surface form of the southern Laurentide ice sheet and its implications to ice-sheet dynamics**: Geological Society of America Bulletin, v. 104, p. 595-605, doi: 10.1130/0016-7606(1992)104<0595:SFOTSL>2.3.CO;2.

Elliot, Caroline M. and Robert B. Jacobson, 2006. **Geomorphic classification and assessment of channel dynamics in the Missouri National Recreational River, South Dakota and Nebraska**. Scientific Investigations Report 2006-5313

Ensz, Edgar H., 1979. **Soil survey of Yankton County, South Dakota**. United States Department of Agriculture Soil Conservation Service. South Dakota Online Soil Survey Manuscripts. http://soils.usda.gov/

Ferrell, John R. 1993. **Big Dam Era: a legislative and institutional history of the Pick-Sloan Missouri basin program**. Missouri River Division, U.S. Army Corps of Engineers, Omaha, Nebraska.

Flint, R.F., 1971, **Glacial and Quaternary Geology**: New York, London, Sydney, Toronto, John Wiley and Sons, Inc.,.

Flint, R.F., 1955, **Pleistocene geology of eastern South Dakota**: U.S. Geological Survey Professional Paper 262, 173p.

Flint, R.F., 1947, **Glacial Geology and the Pleistocene Epoch**: New York, John Wiley and Sons, Inc., p. 589.

Flint, R.F., 1949**, Chronology of the Pleistocene epoch**: Florida Scientist, v. 8, p. 1-34.

Garrett, Jordan, Neal Alexandrowicz, April D. Moreno, Dustin E. Ward, and John Holbrook, 2007. **St. Helena Quadrangle map**.

Gilbertson, J.P., ed., 1989, **Quaternary geology of northeastern South Dakota**: South Dakota Geological Survey Guidebook 3, 57p.

Gotze , J, M. Plotze and D. Habermann, 2001. **Origin, spectral characteristics and practical applications of the cathodoluminescence (CL) of quartz- a review**. Mineralogy and Petrology, v. 71, n. 3-4, p. 225-250.

Grimley, D.A., 2000, **Glacial and non-glacial sediment contributions to Wisconsin Episodes loess in the central United States**: GSA Bulletin, v. 112, p. 1475-1495, doi: 10.1130/0016-7606(2000)112<1475:GANSCT>2.0.CO;2.

Heine, R., and Lant, C., 2009, **Spatial and Temporal Patterns of Stream Channel Incision in the Loess Region of the Missouri River**, Annals of the Association of American Geographers, v. 99, p. 231 - 253, doi: 10.1080/00045600802685903.

Holbrook, John, Robert W. Scott and Francisca E. Oboh-Ikuenobe, 2006**. Base-Level buffers and buttresses: a model for upstream versus downstream control on fluvial geometry and architecture within sequences**. Journal of Sedimentary Research, v. 76, no. 1, p.162-174, DOI: 10.2110/jsr.2005.10.

Horowitz, A.J., 2003. **An evaluation of sediment rating curves for estimating suspended sediment concentrations for subsequent flux calculations**: Hydrological Processes, v. 17, p. 3387-3409.

Jacobson, Robert B., Dale W. Blevins, Chance J.Bitner, 2009, **Sediment regime constraints on river restoration- An example from the Lower Missouri River**. The Geological Society of America Special Paper 451.

Jacobson, Robert B. and David L. Galat. 2006, **Flow and form in rehabilitation of large-river ecosystems: An example from the Lower Missouri River**. Geomorphology, v. 77, i 3-4, p. 249-269.

James River Comprehensive Report: Garrison Diversion Unit, 1989, Department of the Interior Bureau of Reclamation Missouri-Souris Project Office Bismarck, North Dakota.

Johnson, Gary D., and Kelli A. McCormick, 2005, **Geology of Yankton County, South Dakota**, U.S. Geological Survey, Bulletin 34.

Keown, M.P., Dardeau, E.A. Jr., and Causey, E.M., Etta M., 1986, **Historic trends in the sediment flow regime of the Mississippi River:** Water Resources Research, v. 22, no. 11, 1555-1564.

Kraus, Mary J. 1999. Paleosols in clastic sedimentary rocks: their geologic applications. Earth-Science Reviews. v. 47, i. 1-2, p. 41-70.

Lawson, Michael L., 1982, **Dammed Indians: The Pick-Sloan Plan and the Missouri River Sioux, 1944-1980**: University of Oklahoma Press

Lewis, M., and William Clark, 1965**, History of the Expedition under the command of Lewis & Clark**: New York, Dover Publications Inc., Edited by Elliot Coues.

Lian , O.B., 2007. Luminescence Dating, in: Encyclopedia of Quaternary Science. Elsevier. 3576 p.

Library of Congress Geography & Map division, Call Number G4126.S12 1814 .L4

Lundstrom, S., COWMAN, T., HOLBROOK, J.M., PACES, J.B., HANSON, P., SWEENEY, M.R., JACOBSON, R.B., HEISE, B., and ABRAHAM, J.D., 2009, **Geologic mapping and research along the Missouri National Recreational River, Nebraska and South Dakota: Integration of results and significance to hydrologic and ecologic issues.** Geological Society of America Abstracts with Programs, v. 41, p. 149.

Mack, Greg H., W. Calvin James, and H. Curtis Monger. 1993. Classification of paleosols. Geological Society of America Bulletin. v. 105, i. 2, p. 129-136.

Miall, A.D., 1996, **The Geology of Fluvial Deposits: Sedimentary Facies, Basin Analysis, and Petroleum Geology**: Springer-Verlag, Berlin, 582 p.

Mickelson, D.M., and Lee Clayton, D.S. Fullerton, and H.W. Borns, Jr., 1983, **The Late Wisconsin Glacial Record of the Laurentide Ice sheet in the United States**. in H.E. Wright, Jr. and Stephen C. Porter, ed., Late-Quaternary Environments of the United States: Minneapolis, University of Minnesota Press, p. 3-37.

Missouri River Commission, 1890's map

Missouri River Environment Assessment Program: http://infolink.cr.usgs.gov/Science/MoREAP/MoREAP.pdf

Missouri River Recovery Program fact sheet, 2007: http://www.mostreamteam.org/Documents/Research/BigRiver/MissouriRiverSediment.pdf

Moody, John A., Robert H. Meade, and David R. Jones, 2003. **Lewis and Clark's observations and measurements of geomorphology and hydrology, and changes with time.** U.S. Department of the Interior, U.S. Geological Survey circular 1246.

Moreno, April D., Dustin E. Ward, Neal Alexandrowicz, Jordan Garrett, and John Holbrook, 2007. **Meckling Quadrangle map**.

Moreno, April D., Eli Erickson, and John Holbrook, 2008. **Mission Hill Quadrangle map**.

Moreno, April D., Eli Erickson, and John Holbrook, 2008. **Menominee Quadrangle map**.

Muhs, D., E. Arthur Bettis III, 2000, **Geochemical Variations in Peoria Loess of Western Iowa Indicate Paleowinds of Midcontinental North America during Last Glaciation,** Quaternary Research, v. 53, p. 49 - 61, doi: 10.1006/qres.1999.2090.

Murray, A.S. and A.G. Wintle, 2000**, Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol**. Radiation Measurements, v. 32, I. 1, p. 57-73.

North American Commission on Stratigraphic Nomenclature, (NACSN), 1983, North American stratigraphic code: American Association of Petroleum Geologists Bulletin, v.67, p.841-875.

Patterson, C.J., 1997a, **Contributions to the Quaternary geology of southwestern Minnesota**: Minnesota Geological Survey Report of Investigations 47, 78p.

Rahn, PH, 1981, **Remote Sensing of Bank Erosion Along the Missouri River, South Dakota, Satellite Hydrology**. Proceedings of the Fifth Annual William T. Pecora Memorial Symposium on Remote Sensing, Sioux Falls, South Dakota June 10-15, 1979. p. 697-700, 3fig, 3ref.

Reuss, Martin, 1982. **The Pick-Sloan Plan. In Builders and fighters: U.S. Army Engineers in World War II**., Barry W. Fowle, editor. U.S. Army Corps of Engineers. Office of History. EP 870-1-42.

Schoeneberger, P.J., Wysocki, D.A., Benham, E.C., and Broderson, W.D. 1998. **Field book for describing and sampling soils**. Natural Resources Conservation Service, USDA, National Soil Survey Center, Lincoln, NE.

Simpson, H.E., 1960, **Geology of the Yankton area South Dakota and Nebraska**: Geological survey professional paper 328: Washington, United States printing office.

U.S. Army Corps of Engineers, 2004c, Summary Missouri River Final Environmental Impact Statement — Master Water Control Manual Review and Update: Portland, Ore., U.S. Army Corps of Engineers, Northwestern Division, 28p.

U.S Bureau of Reclamation Dept. of Interior, U.S. Government Printing Office 1945, 0-629774

Wallinga, Jakob, 2002. **Optically stimulated luminescence dating of fluvial deposits: a review**. Boreas, v. 31, issue 4, pgs. 303-322.

Ward, Dustin E., April D. Moreno, Neal Alexandrowicz, Jordan Garrett, and John Holbrook, 2007. **Gayville NE Quadrangle map**.

Wentworth, C.K., 1922. A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, p. 377-392

Williams, Garnett P., 1986. **River meanders and channel size**. Journal of Hydrology, v. 88, i 1-2, pgs. 147-164.

Additional Reading

A.G. Leonard, 1972, **Pleistocene drainage changes in western North Dakota**: Bulletin of the Geological Society of America, v. 27, p. 295-304.

Holbrook, J., Kliem, G., Nzewunwah, C., Jobe, Z., and Goble, R., 2006, **Surficial Alluvim and topography of the Overton bottoms north unit, Big Muddy National Fish and Wildlife Refuge in the Missouri River Valley and its potential influence on environmental management: Science to Support Adaptive Habitat Management:** Overton Bottoms North Unit, Big Muddy National Fish and Wildlife Refuge, Missouri, p. 19-19-25.

Horberg, C.L., and Anderson. Richard Charles, 1956, **Bedrock topography and Pleistocene glacial lobes in central United States**: Journal of Geology, v. 64, p. 101-116.

Moreno, A.D., 2009**, Leading the James: the Morphological changes of the Missouri River and the subservient James**: Geological Society of America Abstracts with Programs, v. 41, p. 31.

Moreno-ward, A.D., Erickson, E.N., and Holbrook, J., 2010, **Geomorphological interactions of the James River and Missouri River during a portion of the Holocene.** Geological Society of America Abstracts with Programs, v. 42, p. 39.

STANLEY, K.O., and WAYNE, W.J., 1972, **Epeirogenic and Climatic Controls of Early Pleistocene Fluvial Sediment Dispersal in Nebraska**: The Geological Society of America Bulletin, v. 83, p. 3675-3690, doi: 10.1130/0016-7606(1972)83[3675:EACCOE]2.0.CO;2.

Ward, Dustin E., April D. Moreno, Neal Alexandrowicz, Jordan Garrett, and John Holbrook, 2008**, Counter-Intuitive Braid Deposits in from Active Channel Belt**,; #90078, AAPG poster session v. 2010, .

Wright, H.F., and Porter, S.R.,1984.**Late-Quaternary environments of the United States.** University of Minnesota press. ISBN 0-582-30124-6.

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April hopes to share this passion of rivers with others by pursuing a career in academia.