Chapter 7. The Upper Mississippi River

Introduction

A Task 1 bank-erosion literature review by Maynord and Martin (1996) lists fourteen specific references for the Upper Mississippi River system. Eight of the references deal specifically with the impacts of traffic-generated waves on bank erosion for the Upper Mississippi River system, including the Illinois Waterway. The report by Maynord and Martin (1996), included as Appendix A, presents a brief summary for each reference (refer to Appendix A, pp.46-53). Therefore, no duplication is made in this report. Maynord and Martin (1996) also refers to three reports by Great River Environmental Action Teams (GREAT), GREAT-I (COE, St. Paul District), GREAT-II (COE, Rock Island District), and GREAT-III (COE, St. Louis District) (refer to Appendix A, pp.26-28). However, these studies were conducted to estimate overall bank-erosion characteristics for entire watersheds of these districts and no particular emphasis was placed on navigation-induced bank erosion.

Stage histograms and bank sections for the selected study sites for the Mississippi River are included in Appendix C. Records of dredging history and dredged material placement for the Mississippi River are included in Appendix D, and fleeting areas on the Mississippi River are listed in Appendix E. Appendix F shows sediment particle-size distributions obtained for all the soil samples collected in the study. Appendix G contains detailed river cross-section data, and a geomorphology study is described in Appendix H.

General Site Characteristics

A total of forty-three major study sites (Site 1 through Site 44 excluding Site 20), distributed through Minnesota, Wisconsin, Iowa, Illinois, and Missouri, was selected during the study period from 11 September 1995 to 17 October 1995, and forty-five additional sites were selected upstream and downstream of the major sites. Among the forty-three major sites, thirty-six sites were located in eighteen separate pools between Pool 2 and Pool 27, and seven sites were located in an open-water river section downstream from Lock & Dam No. 27. The locations of these major sites, including the site numbers (note that there is no Site 20), river miles (RM), and the right and left descending bank identifications, are shown in figure 7-1. Figure 7-1 also shows the locations of confluences of several major tributaries, such as the Chippewa River, the Wisconsin River, the Turkey River, the Rock River, the Iowa River, the Des Moines River, the Illinois River, and the Missouri River. The longitudinal location of each major site relative to the Locks and Dams and the major tributaries can easily be seen in this figure drawn at a linear longitudinal scale.

The average water-surface slope between Site 1 (RM 825.5) and Site 37 (RM 197.6) for the pool section during the study period was about $8.62x10^{-5}$ (5 inches/mile), and that of the open-water section between Site 38 (RM 172.1) and Site 44 (RM 25.8) was $1.08x10^{-4}$ (7 inches/mile). In addition to the forty-three major sites, fifty-four observation sites were selected during the field study. These observation sites were judged by the team members to be sufficiently significant to be noted in the study. Although some observation sites were investigated in detail, systematic data collection similar to that for the major sites was not done at the observation sites; therefore, they are not described in detail in this report. However, the original data sheets for the observation sites are on file at the COE-RID for review.

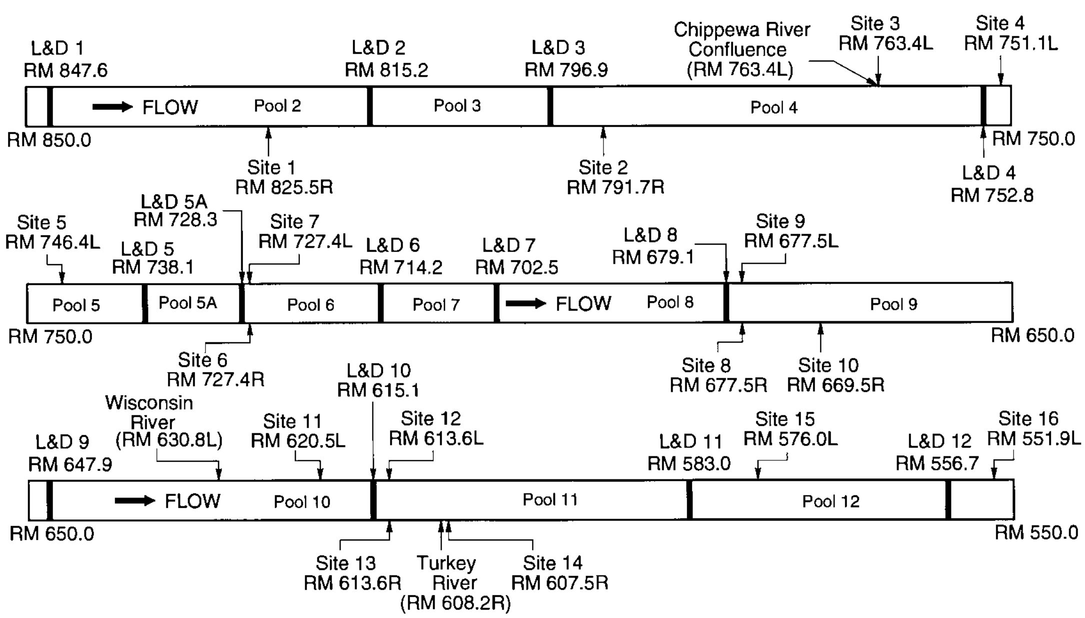


Figure 7-1a Site locations along the Mississippi River (RM 550-850)

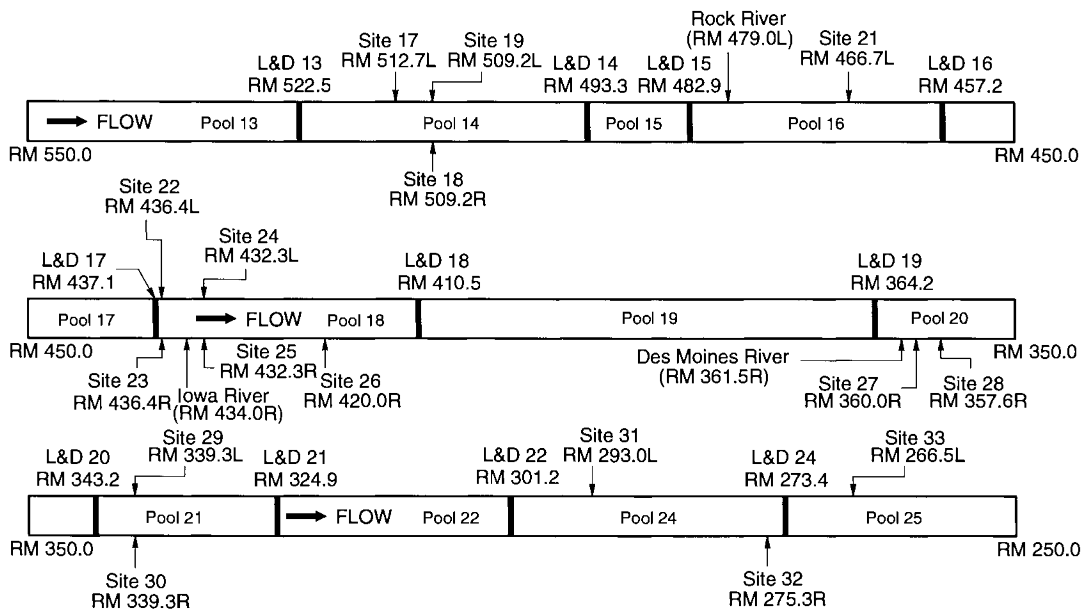


Figure 7-1b Site locations along the Mississippi River (RM 250-550)

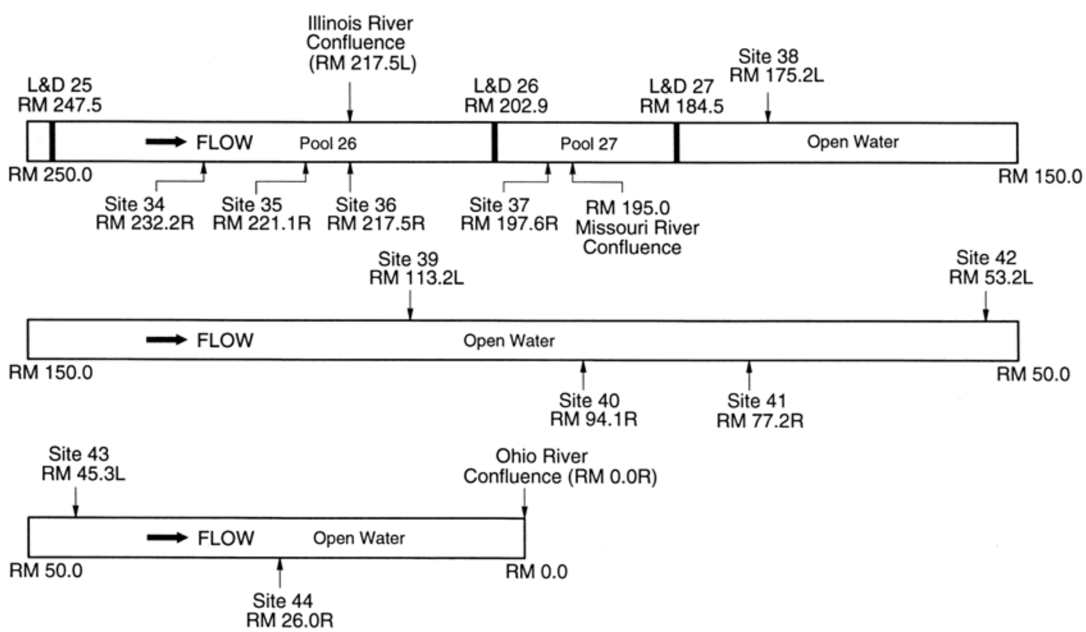


Figure 7-1c Site locations along the Mississippi River (RM 0-250)

As shown in table 7-1, twelve major sites were located on the outsides of bends, twelve on the insides of bends, sixteen in straight river reaches, and three sites in crossovers. Just over half of the major sites (twenty-four sites) were located close to thalweg sailing lines and the remainder (nineteen sites) were far from thalweg sailing lines. Among these forty-three major sites, twenty two were located on or near islands and six were located in barge fleeting areas.

Table 7-1 Geomorphic characteristics of the major sites along the UMR

Geomorphic Characteristics	Site Number
Outside Bend (12 sites)	1, 2, 4, 5, 6, 8, 10, 12, 24, 40, 41, 42
Inside Bend (12 site)	7, 9, 13, 14, 15, 16, 25, 31, 32, 37, 39, 44
Straight Reach (16 sites)	3, 17, 18, 19, 21, 22, 23, 26, 27, 29, 30, 34, 35, 36, 38, 43
Crossover Reach (3 sites)	11, 28, 33
Island Reach (22 sites)	5, 6, 7, 9, 11, 12, 13,15,16, 17, 18, 21, 23, 25, 26, 28, 29, 31, 33, 35, 39, 44

Site Selection and Data Collection Campaign

As mentioned in Section 2.c, an aerial reconnaissance survey, which generated oblique color video imagery and color still photographs, was conducted over the entire study reach. Survey information was used by the study team to pre-select potential field study bank-erosion sites which were visited by boat in the field. Not all of the potential sites were determined solely from aerial video and still photographs. The team also considered dredged material disposal sites or sites where bank erosion was not severe. Actual bank-erosion sites could only be selected during field site visits. Nonetheless, the aerial information was very useful for an overview and for listing potential sites.

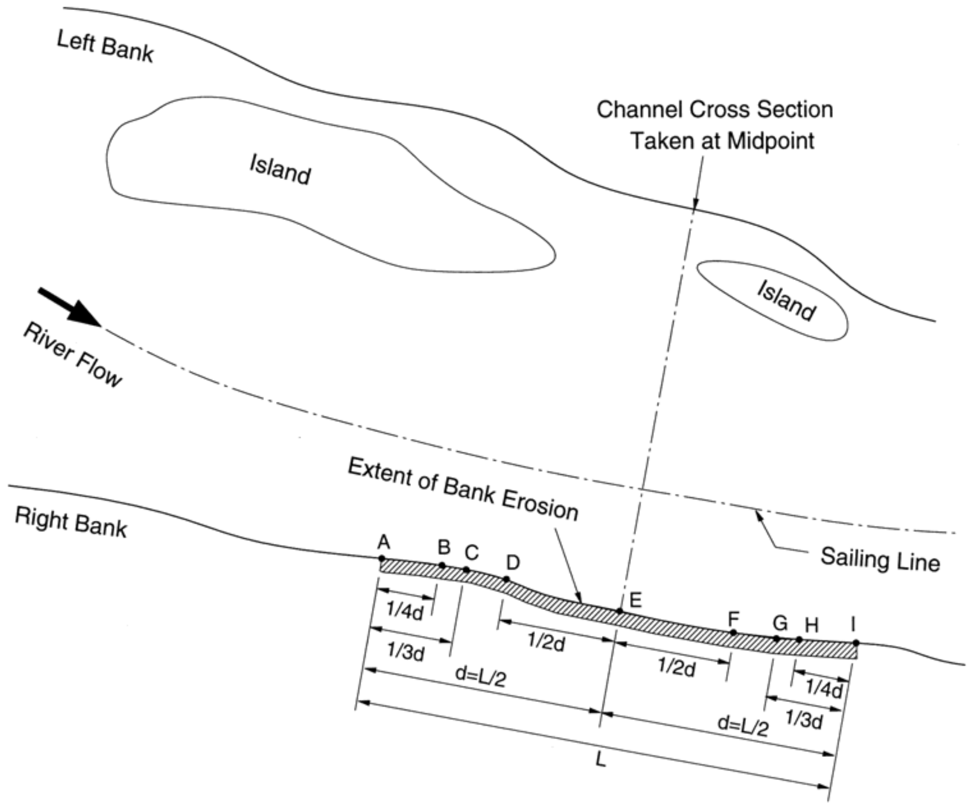
At each major site, a midpoint section (point E, as shown in figure 7-2) first was established at the approximate center of the extended bank-erosion reach, and upstream point (point D) and downstream points (point F) were established generally around the midpoints of both the upstream and downstream halves of the reach. Besides these three primary points (Upstream, Midpoint, and Downstream points), several additional points, such as points A through C and G through I, were established, particularly on island sites, in order to observe detailed longitudinal changes in bank sections along the islands.

At each midpoint section, a detailed bank section was taken first, extending generally from the top of the bank to subaqueous depths of up to 3 ft - 4 ft. A channel cross section, from one bank to the opposite bank, was taken at each midpoint section. Several surficial soil samples were collected at each distinct part of the bank section, such as the bench, berm, scarp, top of the bank, etc. These surficial soil samples were collected generally from soil layers no deeper than 12 in. Subaqueous soil core samples were collected at upstream, midpoint, and downstream sections at water depths of 1 ft and 2 ft, and occasionally at 3 ft or 4 ft depth. Photographic documentation at each midpoint section included typical site characteristics, upstream and downstream views of the erosion site, close-up views of bank soil samples, and locations where samples were collected, and other features, such as traffic-induced wave patterns, zebra-mussel habitats, etc. Field data which were collected at the auxiliary sections are summarized in figure 7-2. In addition to the data described above, a number of tube soil-core samples reflecting geomorphic features were collected at various eroded bank sites by Jeff Anderson, a geomorphologist, of Anderson Environmental Services.

Individual Site Characteristics

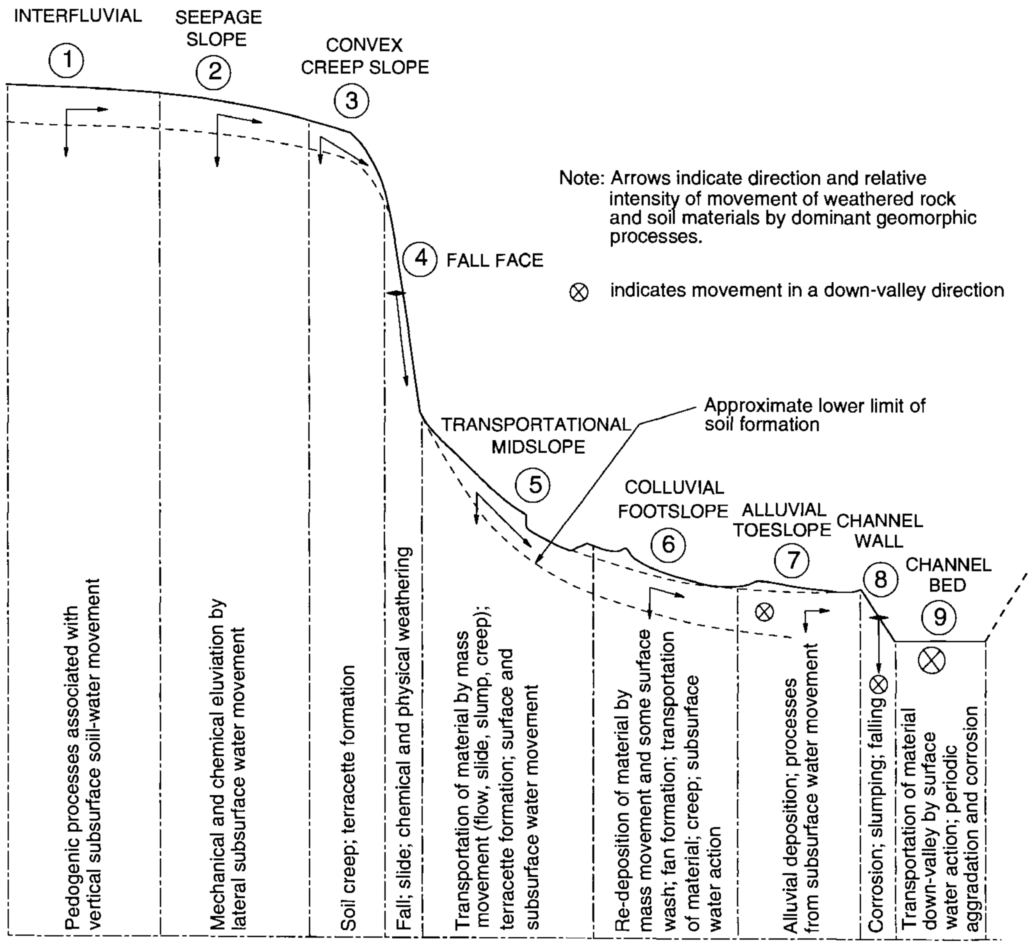
In order to display as much as possible of the information which was collected during the field investigation in one graph, the working team developed a method to incorporate all the principal information into one form, including the site location, date of work, channel cross section, measured bank sections, regression line of the bench section, bench slope, water-surface elevation on the date of survey, normal pool (NP – the lowest operating water level) elevation (for pool sections only), ordinary high water level (OHWL – the 25-percent occurrence water level) elevation (for pool sections only), geomorphic soil-core map, types of soil for individual surficial and subaqueous soil and sediment samples, and miscellaneous characteristics of the erosion site as observed during the field work.

Besides incorporating principal field information into one graph, an attempt to classify bank-erosion sites into six different types for the Mississippi River reach between RM 26.0 and RM 825.5 was made, as Dalrymple, et al. (1968) did for a hypothetical



Point	Location	Data Acquired	Comments
A	Upstream Limit	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.
B	Upstream 1/4 Point	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.
C	Upstream 1/3 Point	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.
D	**Upstream Point**	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.
E	**Midpoint**	• Bank Section • Subaqueous Core Samples (SCS) • Bank Soil Samples • Cross Section • Photos	SCS samples were taken generally at water depths of 1' and 2'.
F	**Downstream Point**	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.
G	Downstream 1/3 Point	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.
H	Downstream 1/4 Point	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.
I	Downstream Limit	• Bank Section • Subaqueous Core Samples (SCS) • Photos	SCS samples were taken generally at water depths of 1' and 2'.

Figure 7-2 A definition sketch showing bank-erosion field-study site locations



Re-drawn after Dalrymple et al., "A hypothetical nine-unit land surface model," Zeitschrift fur Geomorphologie, vol.12, 1968.

Figure 7-3 A hypothetical nine-unit land surface model proposed by Dalrymple et al. (1968)

nine-unit land surface model, which is shown in figure 7-3 for hillslope forms and their processes. Although it was extremely difficult to fit all the features of the Mississippi River sites into those nine categories, it was recognized during the field study that several features out of the nine units were easily identified at various sites. Six distinct bank-erosion site types were developed for the Mississippi River study reach, as sketched in figure 7-4. Synoptic bank-soil descriptions and erosion specifics for each type are given in table 7-2. These six types of eroded banks are all susceptible to specific features, such as "currents and waves," "river-stage variations," "overland drainage conditions," "internal and surficial seepage," and "wet-dry and freeze-thaw cycles." It should be noted that several types found in the UMR study sites appear identical to types described by Dalrymple, et al. (1968). For each site, erosion type was determined on the basis of the bank section and subaerial and subaqueous soil properties. Variations in the eroded-bank site types along the Mississippi River will be treated later in detail. Type A bank profile can be illustrated by a photo taken at Site 28 (RM357.6), a combination of Type A and Type B profiles by a photo taken at Site 44 (RM 26.0), Type C profile by a photo taken at Site 36 (RM 217.5), a combination of Type D and Type E profiles by a photo taken at Site 18 (RM 509.2), and Type F by a photo taken at Site 3 (RM 763.4), as shown in Photos 7-1, 7-2, 7-3, 7-4, and 7-5, respectively.

The work group also developed a schematic to illustrate the so-called rework-transport zone of the bank segment, as shown in figure 7-5. The process within this zone will be described when site-specific bank sections are presented.

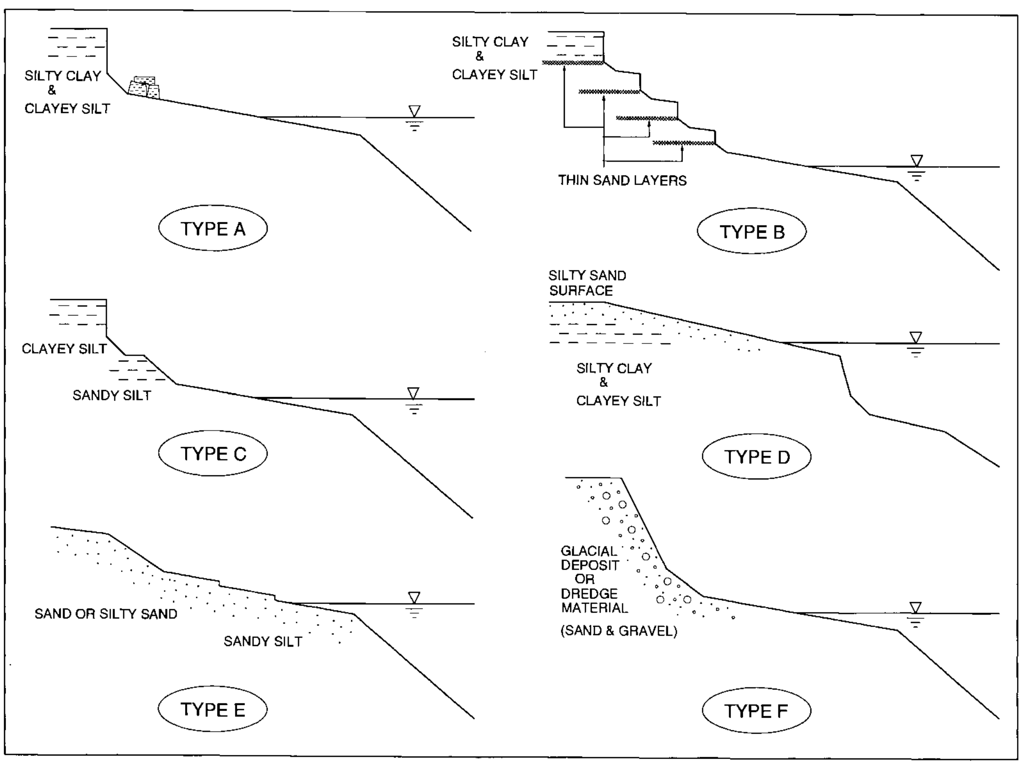


Figure 7-4 Classification of eroded-bank site types observed in the Mississippi River study reach

Table 7-2 Classification of eroded-bank site types which were observed during the field reconnaissance

Type	Principal Features
Type A	• Primarily silty clay and clayey silt • Similar to TYPE B but without sand layers • Nearly vertical scarp face • Internal and external cracks • Large scale block failures • Near-bank and underwater berms may form from fallen soil blocks • Piping features seen at scarp faces
Type B	• Multiple layers of silty clay and clayey silt deposit with thin layers of silty-sand and sandy-silt lenses • Scarp faces nearly vertical • Terracette formation at each sandy layer • Fallen blocks frequently found in terraces at different levels • Piping features seen at different scarp faces
Type C	• Upper layer of clayey silt and silty clay • Upper scarp face nearly vertical • Lower layer of sandy silt • Contains silty-sand and sandy-silt lenses • Berm structure with terracette formation • Piping features
Type D	• Clayey silt and silty clay covered by layers of silty sand or sand • Bank with modest slope • No significant subaerial scarps • Severe near-shore subaqueous bank erosion • Typically found in fleeting area and outside of bend close to thalweg sailing line
Type E	• Primarily sand or silty sand characterized by bank with modest slope • Typically seen along small islands or downstream tips of large islands • Multiple miniature scarp faces affected by river-stage variations
Type F	• Noncohesive glacial deposit or dredge disposal material composed primarily of sand and gravel • On placement bank slope nearly equal to angle of repose • Typical along the Upper Mississippi River above St. Louis and along the Illinois Waterway

Photo 7-1 Type A eroded-bank site (Site 28, RM 357.6)

Photo 7-2 Combination of Type A and Type B eroded-bank sites (Site 44, RM 26.0)

Photo 7-3 Type C eroded-bank site (Site 36, RM 217.5)

Photo 7-4 A combination of Type D and Type E eroded-bank sites (Site 18, RM 432.3)

Photo 7-5 Type F eroded-bank site (Site 3, RM 763.4)

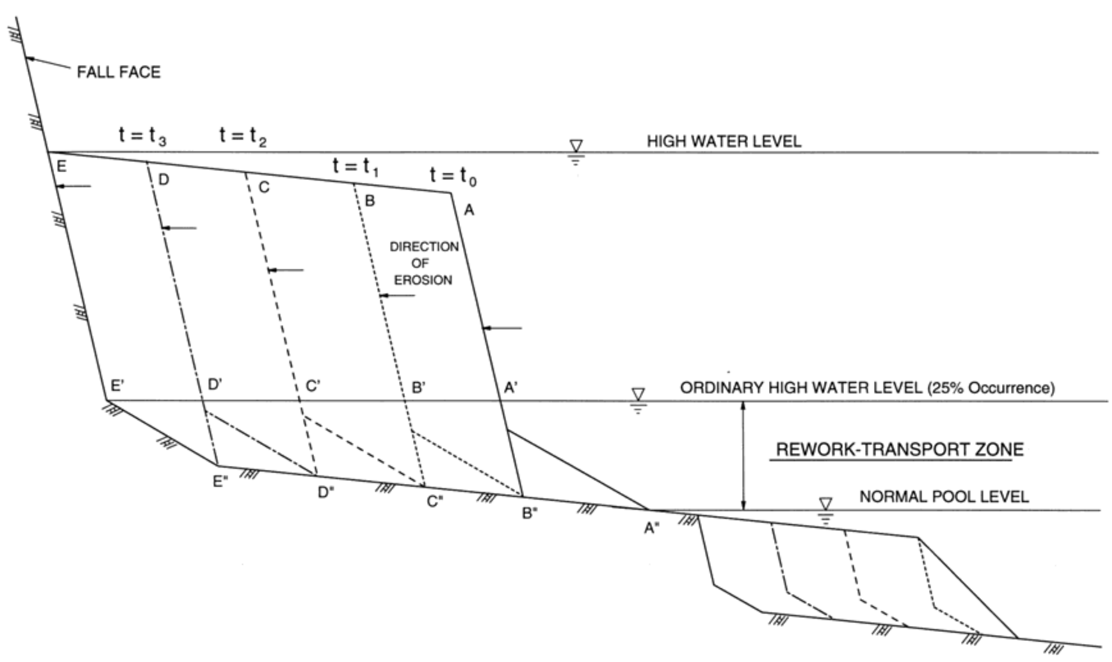


Figure 7-5 A schematic showing typical bank sections within the river rework-transport zones

Geological and Soils Investigation

Geological and soils investigations also were conducted at selected sites along the Mississippi River from St. Paul, Minnesota, to Cairo, Illinois. These investigations were conducted in order to provide the erosion study team a geological overview of the Mississippi River near-channel landscapes at erosion sites. Additional directives for the geological portion of the study included:

1. to evaluate the recent historical deposits;
2. to identify, if possible, the relative ages of the depositional units (landscape sediment assemblages-LSAs) below the historical deposit;
3. to identify buried soils (paleosols) of older Holocene age;
4. to describe the deposits according to the Unified Soil Classification System (USCS) and according to USDA soil taxonomy; and
5. to evaluate the relative impacts to cultural resources along this reach of the Mississippi River and, specifically, at the bank erosion sites.

Geologic studies of the Mississippi River have been more numerous since 1980 than in prior years; consequently, more is known about the evolution of the Upper Mississippi River Valley, particularly during the Holocene. Most of the Quaternary geologic work has been done in the Rock Island District COE jurisdiction. Bettis and Anderson (report in progress) are currently conducting an inventory of geologic work in the Upper Mississippi River Valley between St. Paul, Minnesota and Cairo, Illinois. The recent completion of Rock Island District work has resulted in the production of a set of landscape sediment assemblage (LSAs) maps on 7.5-minute topographic quadrangles (Bettis et al. 1996). The maps identify Wisconsinan and Holocene depositional units within the Mississippi River Valley walls from Pool 11 through Pool 24. The LSA information is available on the internet from the COE, Rock Island District and the reference section of this report contains additional citations of Mississippi River Valley work.

Paleozoic-aged sedimentary rock occurs along the margin of the Mississippi River Valley. Sedimentary rocks, including sandstone, siltstone, shale, limestone, and dolomite, are exposed along this portion of the Mississippi River Valley. Some of the carbonates are cherty. Generally, bedrock dips southwestward and downstream in the Mississippi River system.

The oldest Cambrian rocks occur along the valley wall in southeastern Minnesota. Younger Paleozoic rocks are exposed downstream in Illinois, Iowa, and Missouri. Generally, the sedimentary rocks in the valley are of the Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian Periods. The youngest rocks occur in the Mississippi Embayment area of extreme southeastern Missouri and include rocks from the Cretaceous and Tertiary Periods.

Willman and Frye (1970) indicate that major Mississippi River Valley erosion and drainage development occurred during the Pleistocene between Nebraskan and Kansan (pre-Illinoian) times. It appears that the Mississippi Valley was in its present position upstream from Clinton, Iowa, but was diverted by glaciation to the southeast passing north of Rock Island through the Meridosia Channel (Anderson 1968). Drainage continued to flow from the southeast through the Princeton Bedrock Valley, joining the Illinois River Valley near Hennepin, Illinois. Drainage continued southward through central Illinois, re-joining the contemporary Mississippi Valley near Grafton, Illinois.

Glacial advances during the early Pleistocene moved eastward out of Iowa, diverting flow to the east of the ancient Mississippi/Illinois River Valley. The pre-Illinoian glacial events were followed by Yarmouth Interglacial times which began about 500,000 years ago. During the relatively long interglacial period, the ancient Mississippi River drainage system re-occupied the Princeton Bedrock Valley and joined the Illinois River Valley from Hennepin, Illinois to Peoria and southward toward St. Louis.

Drainage patterns changed during Illinoian glaciation about 250,000 years ago. During the maximum Illinoian glacial advance, the Mississippi River drainage was diverted westward into Iowa, west of Davenport and Muscatine. Following Illinoian glaciation, the Mississippi River drainage reverted back through the Princeton Bedrock Valley and into the Illinois River Valley. By about 20,000 years ago, the impacts of Wisconsinan glaciation finally diverted the Mississippi River westward to its present course through the Port Byron and Andalusia Gorge south of Clinton, Iowa (Benn et al. 1988, 1989; Anderson 1968).

At the close of the late Wisconsinan, episodes of glacial lake discharges through the Mississippi River system occurred between about 12,000 and 9,500 yeas ago (Matsch 1983; Flock 1983). Episodes of major valley alluviation followed by degradation produced high outwash terraces primarily along the margins of the Mississippi River Valley, and up into the lower reaches of tributaries.

Since the last glacial discharges around 9,500 years ago, a period of valley incision followed by valley alluviation occurred in the Mississippi River Valley. The extent and magnitude of the early incision appears to have varied greatly throughout the river system. Meanwhile, hillslope valley margin deposits, sediment loadings from small tributaries and larger trunk streams produced Holocene fills in the valley beginning after 9,500 years ago. Tributary fan and hillslope sediment loadings have continued to the present. Major valley alluviation continued during the late Holocene, and the development of mid-channel islands began (Anderson et al. 1988, 1989; Benn et al. 1988, 1989, 1994; Bettis and Anderson 1990; Bettis et al. 1996).

Recent human activities have produced major impacts on the Mississippi River system. One of the most significant human impacts has been accelerated historical valley alluviation (Knox 1977, 1987; Magilligan 1985). The historical alluvial deposit is a result of Euro-American settlement and subsequent destructive land use. Removal of the original vegetation cover has exposed and mobilized the highly erodible native surface soils (Anderson 1991). Upland erosion has led to temporal sediment storage throughout the drainage hierarchy. However, historical erosion recently has caused valley incision and remobilized stored sediment in the upper tributary reaches.

Erosion occurring in the upper tributary reaches has accelerated main valley alluviation. The historical deposit occurs as a laminated silty to sandy deposit near the present Mississippi River channel. Away from the main channel, this alluviation is massive, thickly-bedded fine grained deposits.

In the Upper Mississippi River Valley and tributaries, thick historical deposits are found:

1. adjacent to the main channel;
2. along island margins and swales;

3. in backwater sloughs, abandoned channels, and flood chutes;
4. in lower reaches of tributary valleys particularly where they enter larger valleys; and
5. along valley margin footslopes (Anderson and Bettis 1989).

In the Rock Island District, the distribution of historical alluvium is influenced by the lock and dam system that has been in place since the late 1930s. Thick-bedded fine-grained deposits tend to accumulate in the lower pool reaches, while lesser amounts are found in the upper reaches of the pools.

This erosion study focused on locations where major erosion is active along the margins of the main channel. Because of the reconnaissance nature of the erosion study, geological observations were made at each erosion study site and considered in the context of earlier more detailed geological studies previously conducted by Jeff Anderson and his colleagues. Note that the sampling tube cores and observations are biased due to their location near the main Mississippi River channel where the major erosional impacts are found. Furthermore, some heavily impacted areas were sandy dredged-spoil material placement sites, particularly in the St. Paul District. As a result, cores and bank sections often revealed only historical deposits. Holocene-aged surfaces were not observed, but were expected to occur at least some distance away from the erosion site and below the historical deposits.

The Upper Mississippi River is an integrated system composed of specific reaches. Parameters, such as (1) valley width and gradient, (2) bedrock geology, (3) sediment loadings from within the reach and from major tributaries, and (4) late glacial impacts, have strongly influenced main valley evolution and the distribution and relative age of deposits. For example, within narrow valley reaches the Mississippi River generally reworks valley floors and confines older Holocene and late Wisconsinan deposits along the valley margins. These are net erosional or transportational reaches of the river. Where valley widening occurs, especially downstream from a narrow reach, multiple-aged Holocene and late Wisconsinan surfaces are observed across the valley. These portions of the valley are net storage reaches.

For the purposes of simplicity, the Mississippi River System from St. Paul to Cairo can be divided into a few major reach categories based on the predominant sediment type, or sediment loadings. More detailed work has defined four major reaches in the Rock Island District from Pool 11 through Pool 22 (Bettis and Anderson 1990). The upper reach from St. Paul to about the Wisconsin River confluence tends to be a reach dominated by coarse-grained bedload. Within this upper reach, the vast quantities of dredged spoil sand are found along the channel margins. Native soils often appear below the relatively thin cap of historical deposits. At some locations, multiple buried late Holocene-aged soils were found, as shown in Photo 7-6. Natural levee building has occurred along the main channel during the late Holocene with the deposition of thin A-C or A-Bw-C sequence paleosols.

The Mississippi River System from the Wisconsin River to about the Des Moines River confluence is a mixed-load reach. Most of the Holocene-aged surfaces are found beneath thicker deposits of historical silt and sand. The most significant erosion and a relatively thin surface deposit of historical alluvium can be found in the upper pool reaches just below the locks and dams, as shown in Photo 7-7. The upper portions of the pools often contain multiple buried soils and multiple-aged Holocene and late Wisconsinan surfaces. The lower pool reaches contain thicker fine-grained historical deposits, and most of the Holocene surfaces are either deeply buried or are inundated at normal pool elevations. Generally, only alluvial fans, colluvial slopes, and late Wisconsinan terraces can be found at these lower pool locations.

Below the confluence with the Des Moines River, the Mississippi River is more of a suspended-load system. Dominant sediment type is silt and very fine sand. Upper reaches of the pools contain Holocene-aged surfaces buried by increasing thicknesses of historical alluvium. More or less continuous constructed levees below the Des Moines River concentrate cut-and-fill activities near the channel margin. Most of these near-channel surfaces are historic in age; however, some older deeply buried Holocene surfaces are expected.

Below the confluences with the Illinois and Missouri Rivers, Holocene-aged surfaces along the channel margin all but disappear and are replaced by thick-bedded historical alluvium, as shown in Photo 7-8. With the exception of a few areas, a continuous levee occurs along the open river below St. Louis. Massive, thick-bedded historical silt and very fine sand are being reworked actively below St. Louis. Major floods, such as the Great Flood of '93, have produced extremely thick vertical accretion of sand deposits along the channel margin. Major channel margin scour of historical silt, with scarps of 20 ft to 30 ft, is common in this reach, as shown in Photos 7-9 and 7-10. However, where the main channel abuts the valley wall, levees are absent and truncation of small depositional fans and colluvial deposits occur. Generally, these valley-wall deposits are the only remaining Holocene and older aged surfaces being impacted by main channel erosion below St. Louis.

Photo 7-6 Buried native soil below historical alluvium observed at Site 4, RM 751.1 (the lighter colored upper unit is the historical deposit)

Photo 7-7 Severe bank erosion at barge mooring area observed at Site 15, RM 576.0

Photo 7-8 Thick historical alluvium overlying the native soil observed at Observation Site, RM 194.0 (the bottom of stadia rod indicates the native soil surface)

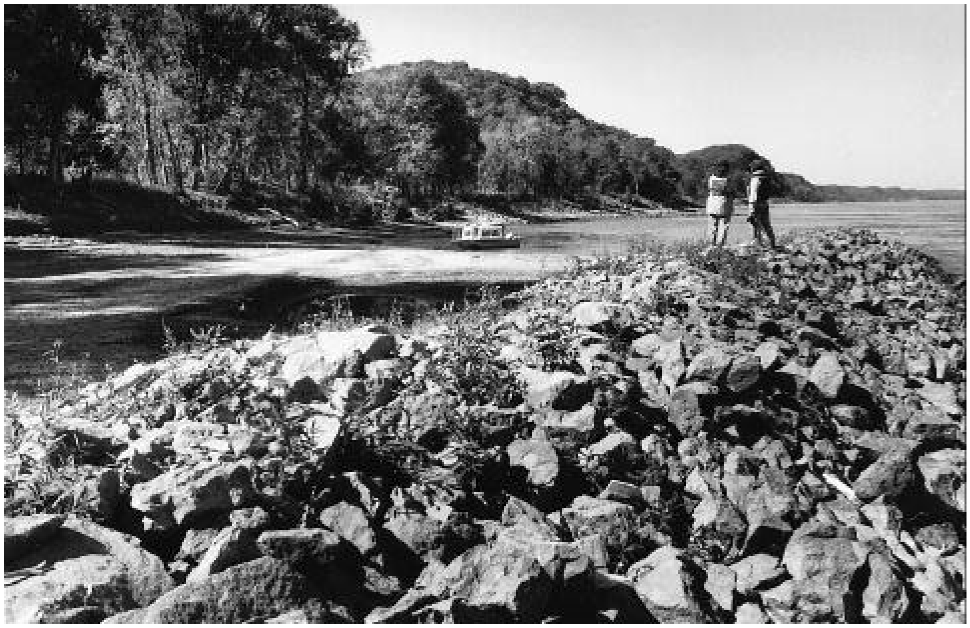


Photo 7-9 Observation Site, RM 134.1 -- looking north upstream -- (this photo shows study team members standing on CCC-placed riprap (ca. 1930s) About 150 ft of bank erosion has occurred westward to the left since riprap placement)

Photo 7-10 Bank face showing a profile composed entirely of recent historical alluvium at Site 39, RM 112.4

Field Methods

The field study required accessing the sites by boat. Bank exposure observations, and advancement of 1.25-in. ID sampling tube cores were conducted during the investigations. Subsurface investigations consisted of obtaining 70 sample tube cores at 61 locations. The detailed soil profile descriptions can be found in Appendix H.

Places chosen for coring were generally midpoints within the erosion study site. Cores were advanced to provide an overall picture of the thickness of historical alluvium and underlying native soils (if present). The soil descriptions included color, texture, structure, consistency, sorting, special features (roots, peds – individual aggregates of soil particles, voids, mottling, gleying, concretions – round or sub-rounded clasts of secondary minerals, organics, clay skins – clay coatings on soil peds or grains that result from pedogenic process), effervescence and/or pH, and horizon boundary. Colors of the deposits were determined with a Munsell color chart. Soil reaction was determined through application of a weak 14% hydrochloric acid solution, and soil field pH was determined through the use of a Hellige-Truog soil pH kit. Vegetation, depth to the water table, and total core depth were recorded at each location, as included in Appendix H. The profiles were described according to the Unified Soil Classification System (USCS) and according to USDA soil taxonomy. Horizon depths were listed in both feet and centimeters.

For each site, a summary description of the geological soil characteristics is included in the second paragraph. The following terms are used therein to describe the geological ages of the Mississippi River site soils:

- Late Wisconsinan 20,000 to 9,500 years old
- Early Holocene 9,500 to 7,500 years old
- Middle (mid) Holocene 7,500 to 5,000 years old
- Late Holocene 5,000 to present
  - Very Late Holocene Less than 1,000 years old
  - Historic Since ca. AD1830 (Euro-American Settlement)

General Site Characteristics

1. Site 1 at RM 825.5 RDB (Pool 2)

This right-bank site shown in figure 7-6 is located along the outer bank of a sharp river bend, and is very close to the thalweg sailing line. Side and upstream views of the site are shown in Photos 7-11 and 7-12, respectively. As can be seen in figure 7-7, the active steeply failing bank slope, approximately 90 ft high, consists primarily of glacial deposits.

Each site map similar to figure 7-6 was prepared by the COE-RID using the geographic information system (GIS)-based navigation-chart data superimposed by the global positioning system (GPS) data acquired during the field study. It should be noted that the land coverage shown in each site map is based on the COE's 1984 aerial survey and the water's edge is drawn for a river stage of 90% frequency occurrence. Each bold line shown over the river channel is drawn between the starting and ending points of the GPS data, indicating the location of the site and the orientation of the river cross section taken. Each bold broken line shown for some of the site location maps in this chapter is drawn over the eroded-bank reach determined by the GPS. No GPS data on the eroded-bank length were collected at Site 1; therefore, only a bold line was drawn in figure 7-6. Similarly, no eroded-bank length was determined at Sites 1, 7, 13, 21, 23, 25, 27, 30, 31, 36, 37, 39, 41, 42, 43, and 44; therefore, only the river cross-section lines are shown in their site maps.

All the bank sections and river cross sections shown in this chapter are drawn looking downstream, and there is no distortion in both horizontal and vertical scales. Although detailed river cross-section data are included in Appendix G, the available river cross section for each site was plotted together with the bank section for readers' convenience. Each subaerial and subaqueous soil types and soil-core map are shown in each bank-section plot at locations where the samples were taken. Detailed soil particle-size distributions are given in Appendix F. A bench slope was determined for each site in such a way that a straight-line bench was first sought by the naked eye in the bank-section plot around the water's edge and a linear regression line was then drawn on the bank section. The bench slope was then determined using a regression method. The bench slope thus determined is shown in each figure. Determination of the bench slope for each site was not straightforward; engineering judgments were required in some cases for selecting proper bank-section points to define the bench.

The surficial soil near the water's edge at this site is fine to coarse sands (FS and CS, see table 7-3 for soil-gradation scales), and the tube soil sample taken at the top of the bank was classified as poorly-graded gravelly sands (SP, see table 7-4 for definition). The bank soils also include very coarse sands, gravels, cobbles, and boulders. The bench slope was estimated to be 0.200, as shown in figure 7-7. A regression line, shown by a thick solid line in each bank-section plot and noted as Regression Line in the legend, shows the bench. The river cross section shown in this figure does not indicate a typical profile for the concave bank in which flow depth and velocity are much larger along the outer bank.

The site is located at the base of a Late Wisconsinan outwash terrace. A bouldery lag deposit has accumulated at base of the steep terrace scarp and mantles the channel margin.

Primary causes of bank retreat at this site study include gravitational fall of the loose material, flood erosion and oversteepening, and current and wave wash. The loose bank soils close to the sailing line are susceptible to impacts of high-stage flood flows and subsequent wave erosion. As can be seen in Photos 7-11 and 7-12, failed fine soil and recently deposited sediment had been washed out and only large gravel or boulder lag remain near the water's edge. This erosion site is classified as bank Type F (see figure 7-4). The principal information for this site and every other site is summarized in tables 7-5a, 7-5b, and 7-5c.

2. Site 2 at RM 791.7 RDB (Pool 4)

Three sections were established on the outside of a bend, as shown in figure 7-8. Photos 7-13 and 7-14 show upstream and downstream views of the site, respectively. Figures 7-9, 7-10, and 7-11 show the bank sections obtained at the upstream point, midpoint, and downstream point, respectively. As at Site 1, the river cross section at the upstream point did not exhibit a deep channel along the right bank. However, the midpoint river cross section shows a shape typical for a mildly curved channel. As can be seen in these three figures, the bank soils are predominantly sands varying from fine

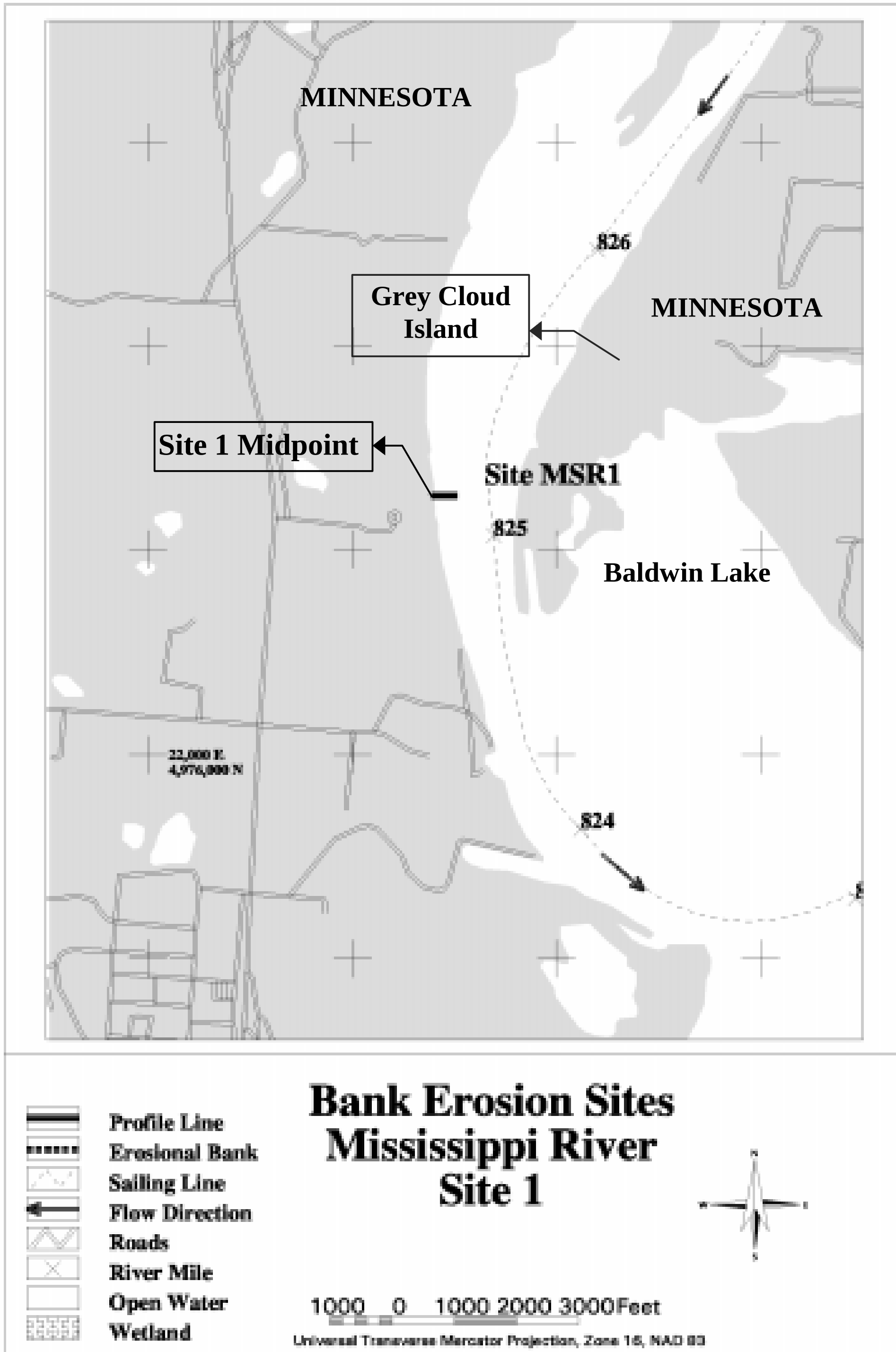


Figure 7-6 A map showing Mississippi River Site 1

Photo 7-11 A side view of Site 1 midpoint

Photo 7-12 An upstream view of Site 1 midpoint