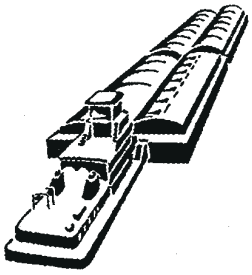
Interim Report For The Upper Mississippi River - Illinois Waterway System Navigation Study

Definitions, Boundary Delineations, Measurements of Attributes, and Analysis of the Hydraulic Classification of Aquatic Areas, Upper Mississippi River System



May 2000

US Army Corps of Engineers

Rock Island District
St. Louis District
St. Paul District

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

PRINTED ON RECYCLED PAPER

Upper Mississippi River - Illinois Waterway System Navigation Study

ENV Report 27
May 2000

Definitions, Boundary Delineations, Measurements of Attributes, and Analysis of the Hydraulic Classification of Aquatic Areas, Upper Mississippi River System

by Charles R. Nickles, Thomas J. Pokrefke, Jr.

Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Interim report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Engineer District, Rock Island
Rock Island, IL 61204-2004
U.S. Army Engineer District, St. Louis
St. Louis, MO 63103-2833
U.S. Army Engineer District, St. Paul
St. Paul, MN 55101-1638

Engineer Research and Development Center Cataloging-in-Publication Data

Contents

List of Figures

Preface

The work reported herein was conducted as part of the Upper Mississippi River – Illinois Waterway (UMR-IWW) System Navigation Study. The information generated for this interim effort will be considered as part of the plan formulation process for the System Navigation Study.

The UMR-IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts, Rock Island, St. Louis, and St. Paul, under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing and, in consideration of existing system lock constraints, will result in traffic delays which will continue to grow into the future. The system navigation study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic. The study will determine the location and appropriate sequencing of potential navigation improvements on the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report, including the decision documents for processing to Congress.

This study was conducted in the Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. CHL was formed in October 1996 with the merger of the ERDC Coastal Engineering Research Center (CERC) and the Hydraulics Laboratory (HL). The work was conducted during the period of September 1994 to March 1999 under the direction of Mr. F. A. Herrmann, Jr., Director, HL; and Dr. J. R. Houston, Director, CHL.

The hydraulic classification and analysis were performed by Messrs. C. R. Nickles and T. J. Pokrefke, Jr., under the supervision of Dr. W. H. McAnally, Chief, Estuaries and Hydrosciences Division, CHL. Dr. Rose M. Kress and Mr. S. Bourne, ERDC, Environmental Laboratory, Natural Resources Division, provided technical assistance relative to the database development, delineation, and application. Numerous staff members from the U.S. Army Engineer Districts, Rock Island, St. Louis, and St. Paul, and various state and Federal resource agencies also provided technical guidance in the development and analysis of the classification system. The report was written by Messrs. Nickles and Pokrefke, ERDC, CHL.

At the time of publication of this report, Dr. Lewis E. Link was Acting Director of ERDC, and COL Robin R. Cababa, EN, was Commander.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4046.873	square meters
cubic feet	0.02831	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles	1609.35	kilometers

1 Introduction

The U.S. Army Corps of Engineers (CE) was tasked to study and assess the impacts of potentially increased navigation traffic on the Upper Mississippi River System (UMRS). The UMRS includes the upper Mississippi River (UMR) from the confluence of the Ohio River (Mile 0) near Cairo, IL, to Lock and Dam No. 3 (Mile 797) and the entire Illinois Waterway (IWW) from its confluence with the Mississippi River to Lake Michigan (Figure 1). Pool 3 and above were not included in the UMRS because the potential for increased navigation traffic did not extend upstream of Dam No. 3. The study includes the development, integration, and application of hydrodynamic, hydrologic, sediment transport, and biological models to assess the impacts on the ecosystem. This modeling system will also aid in the design of required mitigation measures. The impacts include those potentially induced by new CE structures, rehabilitation, Operations and Maintenance (O&M) practices, etc. that might occur as a result of the increased navigation traffic over the next 50 years. Both long- and short-term effects are of concern for the habitat in the main channel and channel borders, around islands, in backwater areas, sloughs, erosion of islands and banks, secondary channels, and sedimentation caused by navigation.

There was a definite need to classify the hydraulic characteristics of aquatic areas in the UMRS for use in selecting representative study sites for various proposed studies and to provide a basis for extrapolating impacts obtained from detailed evaluations on specific reaches to the remainder of the UMRS. The hydraulic classification is a collapsed (simplified) extension of the aquatic habitat classification of the UMRS[1] that has been adopted for use in monitoring and research activities of the Long-Term Resource Monitoring Program (LTRMP). Hydraulic classification is the key to the overall UMRS and modeling efforts. This system model will integrate the results of the numerous modeling efforts to evaluate the incremental impacts on the UMRS ecosystem produced by increased navigation. Hydraulic classification of the aquatic areas is essential to the system model for habitat identification and mitigation.

It should be noted that the hydraulic classifications of aquatic areas presented in this report and used in this study are <u>not</u> equivalent to the aquatic classifications used by the various state resource agencies for fish and wildlife habitats. The various classifications used herein are similar but vary in definition to some of those used by the resource agencies. Fish and wildlife

[1] D. B. Wilcox. (1993). "An aquatic habitat classification system for the Upper Mississippi River," EMTC 93-T003 (including Appendix A), U.S. Fish and Wildlife Service Environmental Management Technical Center, Onalaska, WI.

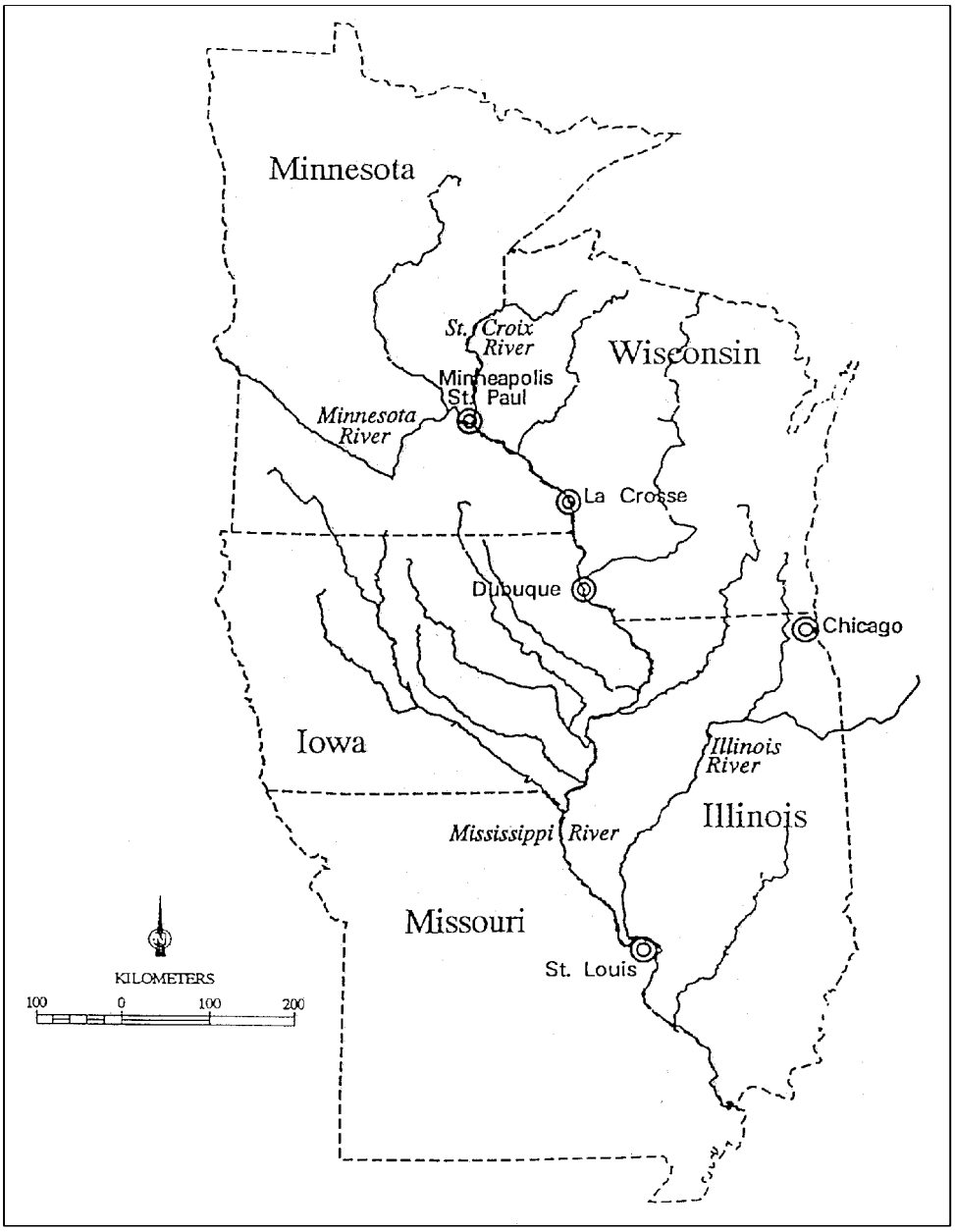


Figure 1. Upper Mississippi River System

habitat factors include velocity and depth parameters, whereas this hydraulic classification is based more on planform.

2 Hydraulic Classification

Description

The hydraulic classification of aquatic areas was divided into four main classes as follows:

a. Main channel.

b. Secondary channels.

c. Backwaters.

d. Tributary channels.

Each of these classes will be discussed in detail, to include description, attributes, and limits. The attributes have been used to categorize similar attributes together to allow for selection of similar reaches for extrapolating impacts obtained from the system model.

Definitions of Hydraulic Classes

Main channel

The main channel conveys the majority of the river discharge and includes the navigation channel and channel border areas (Figure 2). Limits of the main channel are the land-to-water interface at the apparent natural river bank line and straight lines across the secondary channels, mouths of tributaries, and along the top of inundated portions of the natural river bank lines. For the overall hydraulic classification, the main channel was divided into separate segments or reaches containing bends, river crossings, or straight reaches. Crossings are short, straight sections of the main channel between opposing bends where the thalweg of the river "crosses" from one side of the river to the other. Straights are straight sections of the main channel between nonopposing bends or long sections between opposing bends where a definite shifting of the thalweg from one side to the other can not be defined.

Navigation channel. The navigation channel on most of the UMRS is 91 m (300 ft) wide in straight reaches and 152 m (500 ft) wide in bends. Because of the difficulty in determining the points at which the channel width is reduced or expanded, the navigation channel limits were defined as 91 m (300 ft) wide and

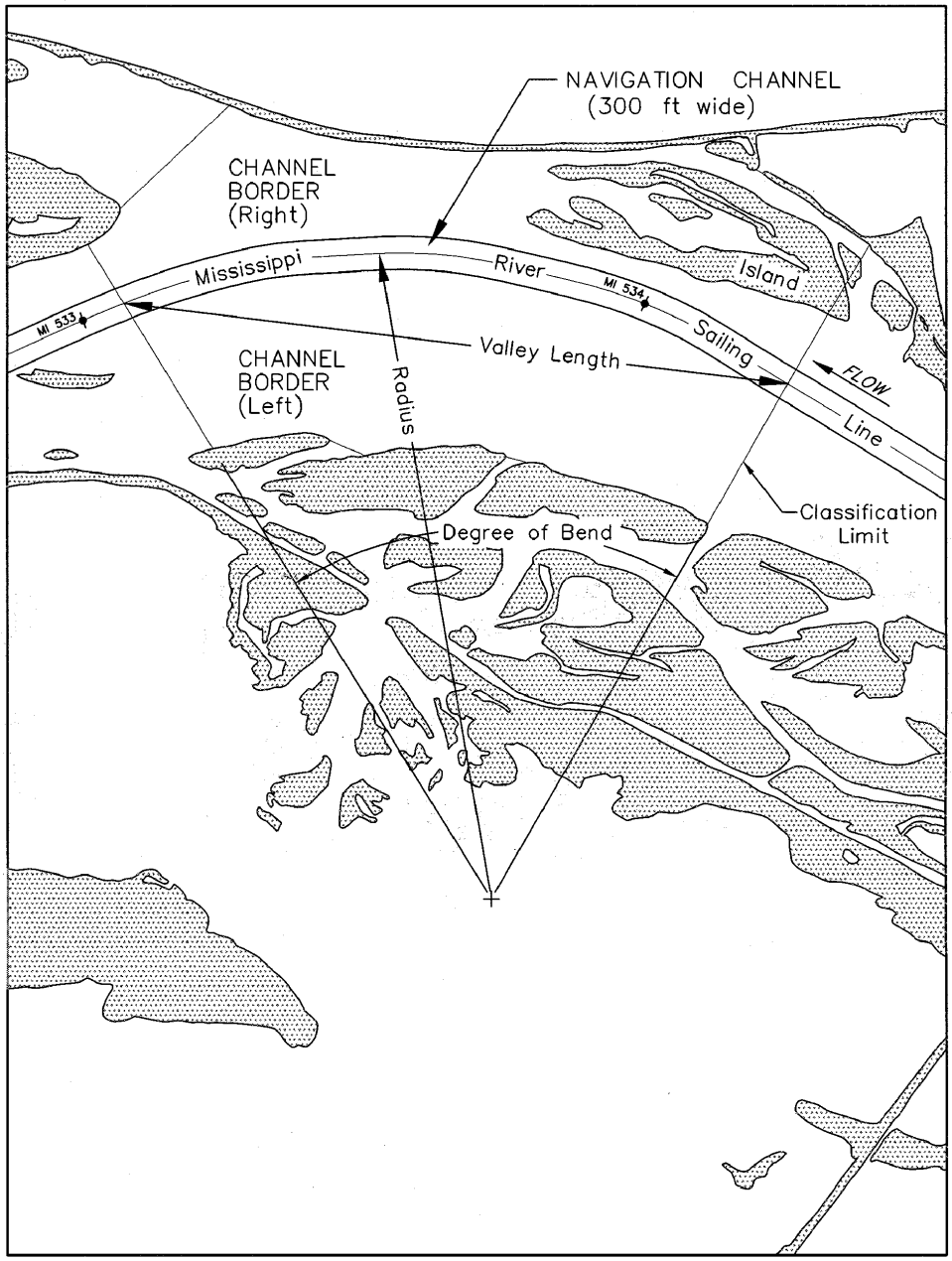


Figure 2. Main channel - bend

were centered on the sailing line. This creates a channel in some locations narrower than what would be available based on the water depth available, but it is consistent over the entire classification system. This is particularly true in the pooled areas immediately upstream of the locks and dams or where few islands exist; however, the same definition was used in those areas also. The various resource agencies involved with the UMRS were concerned with the use of a constant navigation channel width; however, that width was used strictly in delineation of the navigation channel limits and adjacent channel border areas.

Subsequent research took significant efforts to delineate the navigation channel width based on the bathymetry of the main channel.

Channel borders. The channel borders are the areas along and immediately adjacent to the navigation channel that separate the navigation channel from the other river valley attributes. Channel training structures: wing dams (both emergent and submerged), islands (sand bars), and bank revetments are features normally found in the channel border areas. For this classification, the upstream and downstream limits of the channel borders coincide with the upstream and downstream limits of its associated navigation channel segment. The channel border side limits in areas where wing dams are present are the navigation channel limits and the land-to-water interface on the landside of the wing dams. In areas where wing dams are not present, the channel border side limits are the navigation channel limits and the land-to-water interface at the bank line. The channel border limits in pooled areas are the navigation channel limit and the submerged prepool top bank as best can be defined.

Secondary channels

Secondary (or side) channels are channels connected directly to the river flow and adjacent to the main channel (Figure 3). The secondary channel length is approximately equal to the navigation channel length and has a definitive entrance and exit and no emergent closure structures. A secondary channel can contain submerged closure structures and, in some cases, is navigable. For this classification, the riverside limit of a secondary channel is the landside limit of the adjacent channel border area and the landside limit is the land-to-water interface along the channel limit farthest from the main channel. In pooled areas, secondary channels are not identified since those channels are submerged.

Backwaters

Backwaters are areas that are beyond the banks of the main channel or secondary channels. Backwaters can include floodplain terrestrial features and a variety of alluvial floodplain water bodies and connecting channels. For this classification, backwaters were divided into the following subclasses:

Contiguous Backwater
Contiguous-Single-Opening Backwater
Impounded Backwater
Isolated Backwater

Contiguous backwater. Contiguous backwaters are backwaters that are hydraulically connected by surface gravity flow to the main channel at normal pool water levels (Figure 4). For this classification, a contiguous backwater must have an inlet from the main channel into the backwater, an outlet from the backwater returning to the main channel, and at least one gravity flow channel through the backwater must exist. Contiguous backwaters could contain interconnecting channels between through channels, but such channels are not

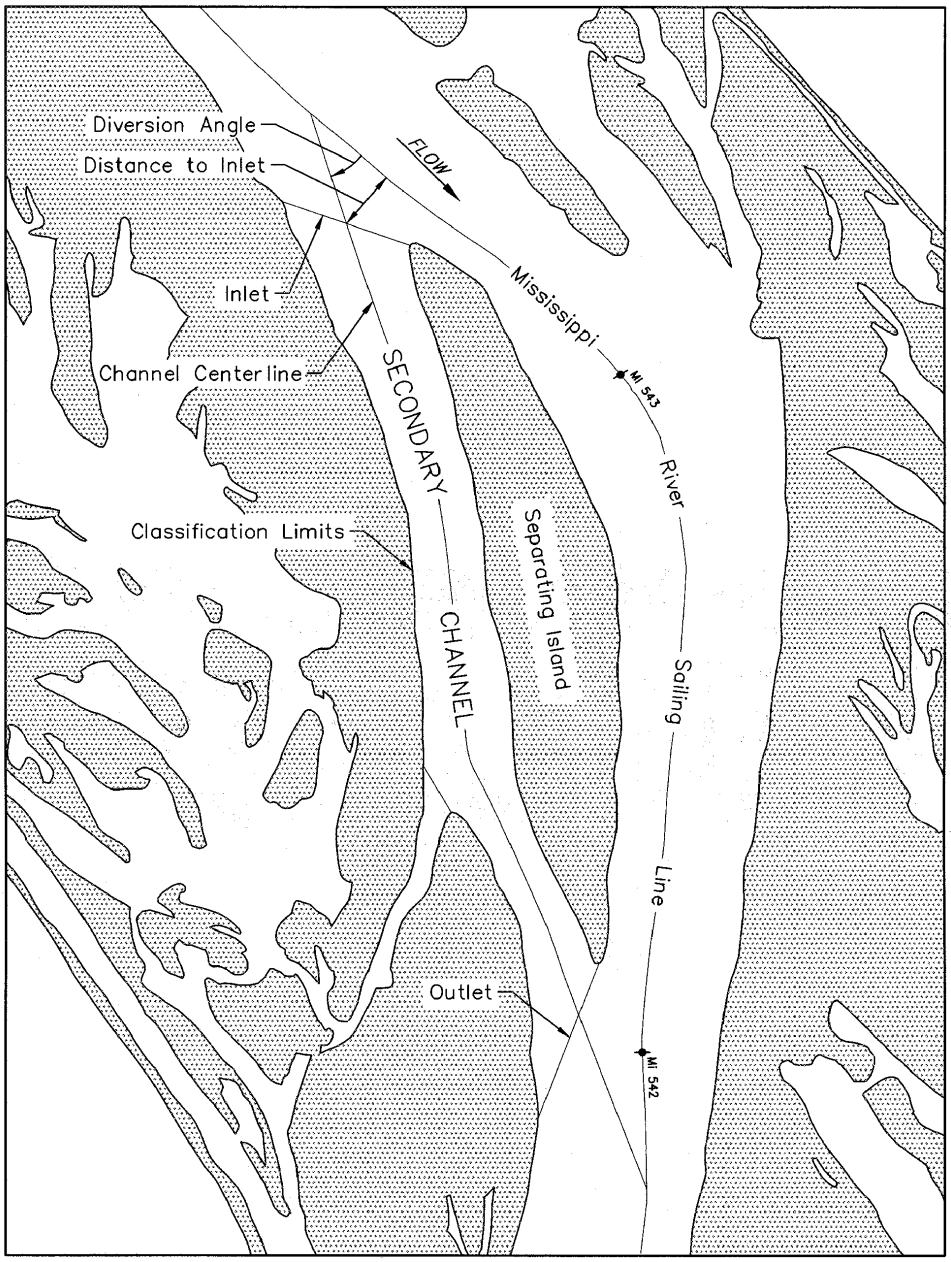


Figure 3. Secondary channel

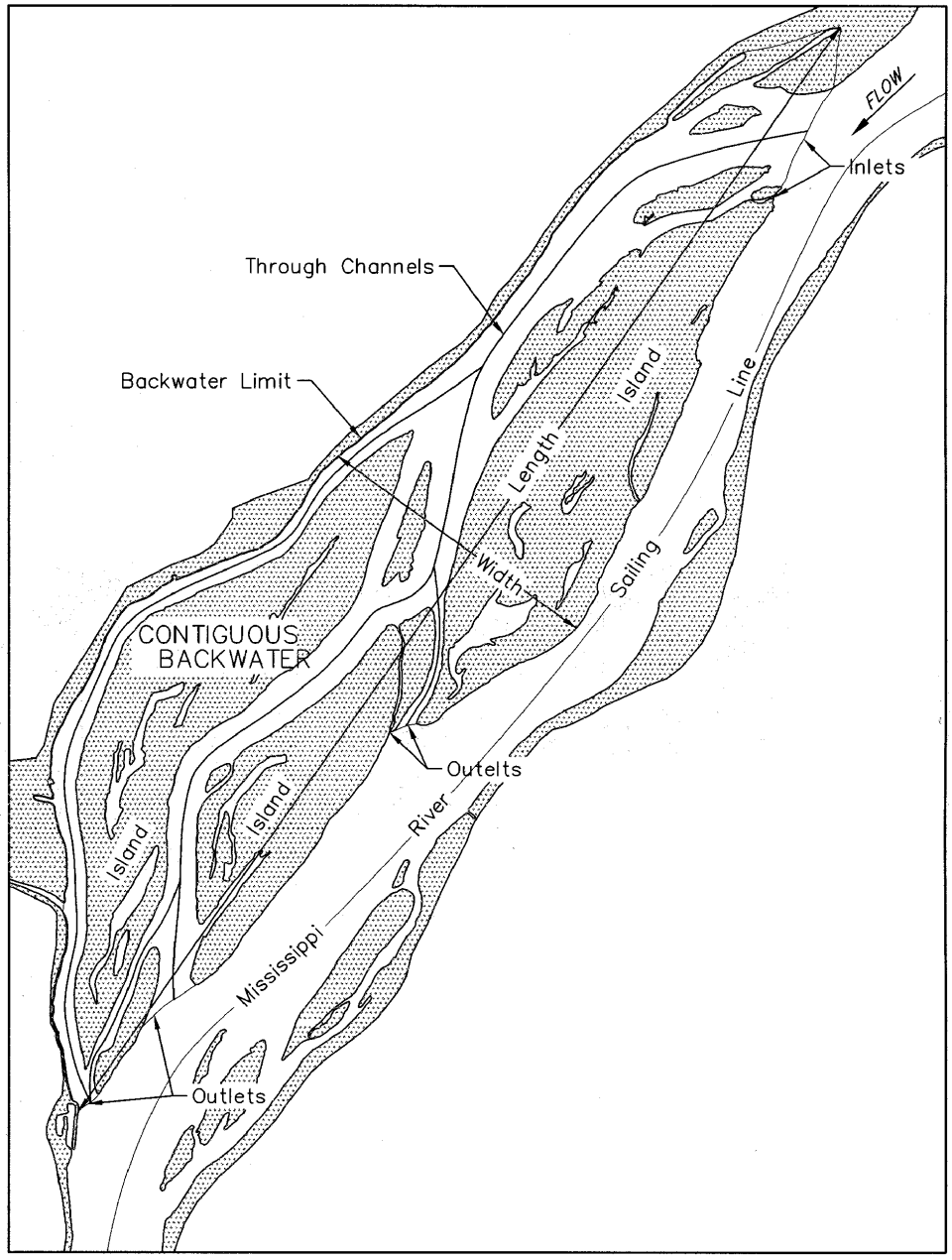


Figure 4. Contiguous backwater

necessary to class a backwater as contiguous. The riverside limit of a contiguous backwater is the landside limit of the main channel border or secondary channel. The landside limit is the land-to-water interface along the bank line or the landside pool limit.

Contiguous-Single-opening backwater. For this classification, a contiguous-single-opening backwater is a contiguous backwater that is connected to the main channel by only one surface gravity flow opening (Figure 5). This single opening is both an inlet and outlet depending on the river stage. The

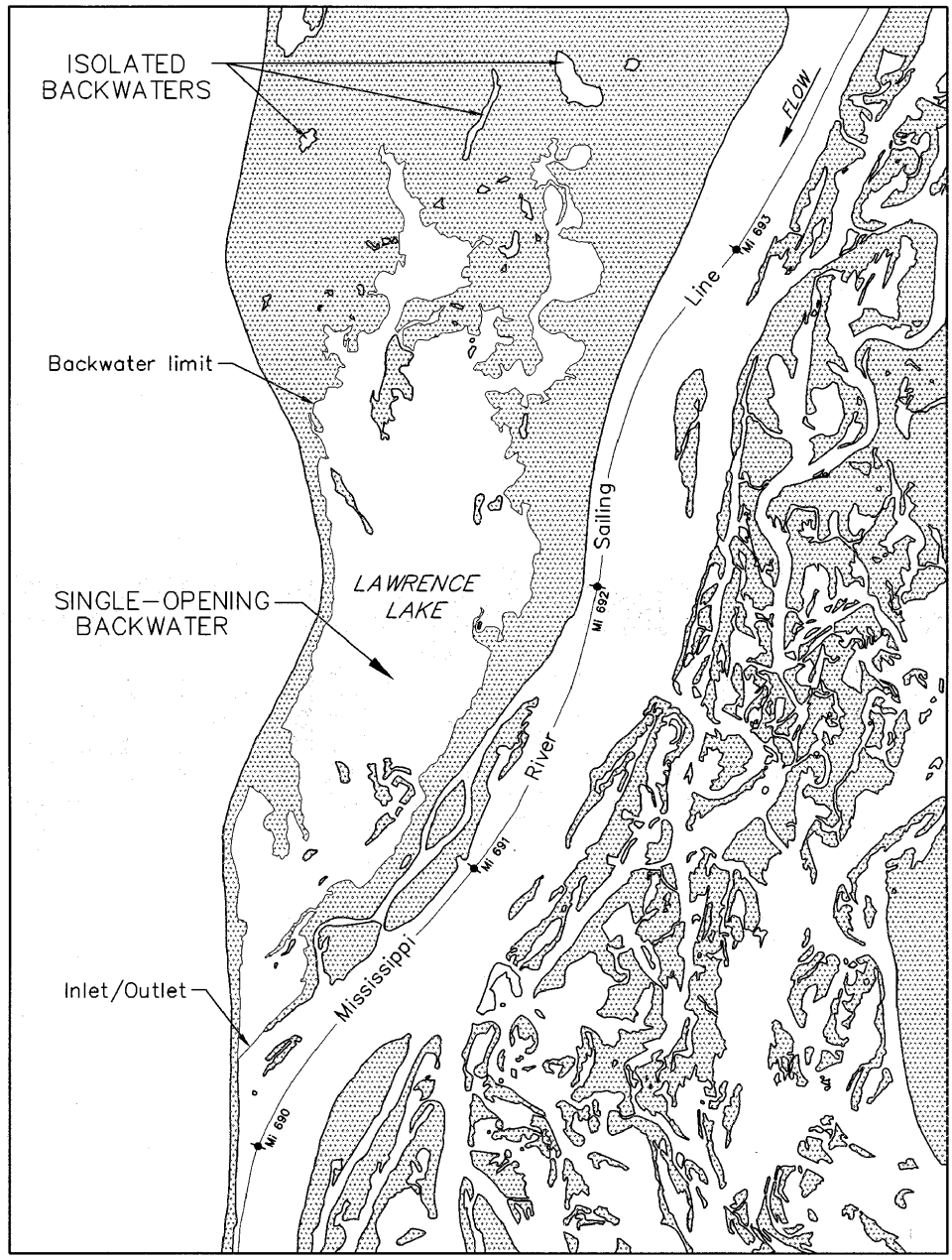


Figure 5. Contiguous-single-opening backwater and isolated backwater

riverside limit of a contiguous-single-opening backwater is the main channel border limit at the opening to the backwater. The outer or landside limit encompasses all areas hydraulically connected to the opening of the backwater. Harbors are single-opening backwaters, but for this classification were separately classed as harbors.

Impounded backwater. For this classification, an impounded backwater is the area immediately upstream of the locks and dams where most of the features are submerged (Figure 6). The riverside of an impounded backwater is the

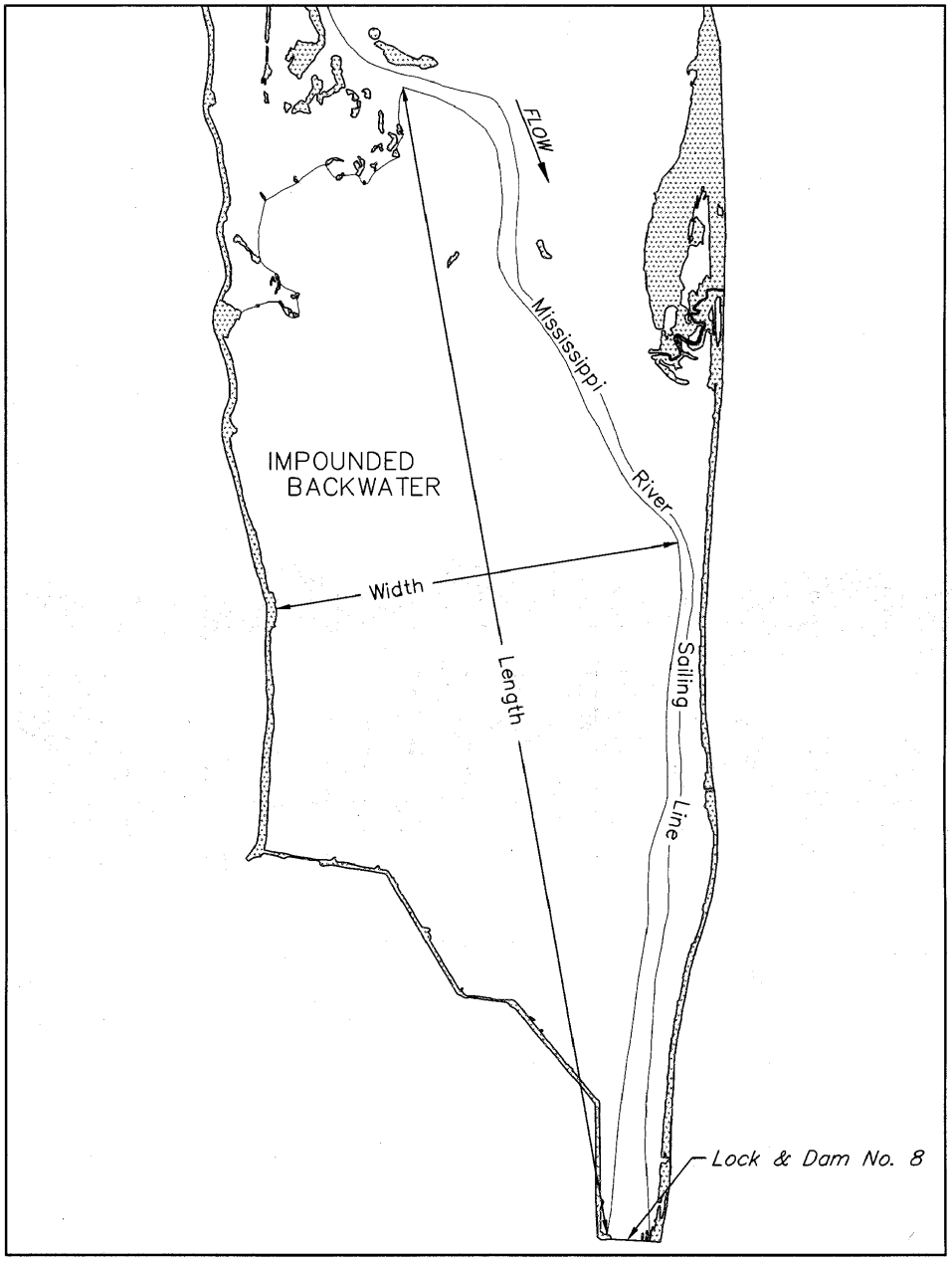


Figure 6. Impounded backwater

landside limit of the main channel border (prepool bank line), and the landside limit is the land-to-water interface at the outer limits of the pool.

Isolated backwater. For this classification, isolated backwaters are pools or lakes located on the overbanks that have no hydraulic connection by surface gravity flow at normal pool levels (Figure 5). Limits of isolated backwaters are their apparent shorelines.

Tributary channels

Tributary channels are channels of tributary streams and rivers. The landward limit is the line where the tributary crosses the study area boundary. The lateral limits are the apparent shorelines and any inundated natural bank lines of the tributary channel. The riverward limit is the line where the tributary channel crosses the limit of the main channel, secondary channel, or backwater. For this classification, tributary channels will be attributes of the hydraulic classification to which it connects.

3 Description of Spatial Data

The spatial data set consists of 30 ARC/INFO Geographic Information System (GIS) polygon coverage characterizing hydraulic environments of the UMR and the IWW. Each coverage in the data set includes data for a single navigation pool associated with each lock and dam on the UMR and IWW or sections of the Mississippi River from Mile 0 to Mile 203 (Lock and Dam No. 26). For this classification, the UMR pools, St. Anthony Falls, 1, 2, and 3, were not included. Pools 1, 2, and 3 were added near the end of the UMRS; however, data for these pools were very limited and provided a lower degree of definition relative to the other UMR pools.

ARC/INFO coverages of the land-water interface for UMRS were extracted from the existing aquatic habit areas database for Mississippi River navigation pools 4, 5, 5a, 6, 8, 9, 13, 19, 26, and an open river section from mile 31 to 74, and the La Grange pool on the IWW. The remaining Mississippi River pools and open river sections were extracted from land use/land cover data created from 1989 aerial photography. The land/water coverage for the pools on IWW, except La Grange, were extracted from the National Wetlands Inventory (NWI) database. ARC/INFO coverage of levees, some wingdam locations, and the sailing line location were obtained from either the U.S. Army Engineer District, St. Louis (SLD), U.S. Army Engineer District, Rock Island (RID), or U.S. Army Engineer District, St. Paul (SPD). Some wingdam locations and bank revetment locations were obtained from the "1989 Upper Mississippi River Navigation Charts."[1]

Bathymetric data sets were collected for each pool or river reach as part of this classification. Extensive bathymetry data were collected for the "trend pools" (pools 4, 8, 13, and 26 on the UMR and La Grange pool on the IWW) to be used in the models of representative study sites.

[1] "1989 Upper Mississippi River Navigation Charts" are prepared under the direction of the U.S. Army Engineer District, Rock Island, and may be obtained by contacting P.O. Box 2004, Rock Island, Illinois 61204-2004, or area code 309, 788-6361.

4 Measurements of Attributes

Attributes pertaining to a depth or cross-sectional area could only be obtained where sufficient bathymetric data were available. The most extensive bathymetry data were collected in the trend pools. Most measurements were recorded in both English and metric (SI) units. A table for converting non-SI units of measurement to SI units is presented on page vii.

Main Channel

Attributes for the Main Channel classification (Figure 2) were obtained or measured according to the following definitions and methods.

Navigation Channel (91 m (300 ft) centered on the sailing line).

Type of reach: Bend, crossing, or straight reach.
Location: Universal Transverse Mercator (UTM) coordinates and River Mile (RM), estimated to one-tenth mile, of upstream and downstream limits measured at sailing line.
Reach length: Length (meters and feet) measured along sailing line.
Valley length: Straight line length (meters and feet) from intersection of sailing line and upstream limit to intersection of sailing line and downstream limit.
Channel sinuosity: Reach length divided by valley length.
Width: Both the maximum and minimum width for navigation channel section is 91.4 m (300 ft).
Area: Planform area in acres (ARC/INFO feature area in square meters times 0.0002471 acres/square meter).
Radius of bend: For bend reaches, average radius (meters and feet) of sailing line.
Degree of bend: For bend reaches, angle in degrees from upstream limit to downstream limit.
Structures: Bridge crossings, control structures, etc.
Channel cross-sectional area: Obtained in square meters and square feet at each river mile and one-half river mile along sailing line.
Average channel depth: Computed (square meters and square feet) by dividing the cross-sectional area by width.

Channel Borders

Type of channel border: Dependent on associated navigation channel reach as a crossing, straight, outside of bend, or inside of bend.
Location: Associated with a specific navigation channel reach.
Minimum width: Minimum width (meters and feet) from navigation channel limit to outer or bank-side limit of channel border.
Maximum width: Maximum width (meters and feet) from the navigation channel limit to the outer or bank-side limit of the channel border.
Area: Planform area in acres (ARC/INFO feature area in square meters times 0.0002471 acres/square meter).
Cross-sectional area: Obtained in square meters and square feet at each river mile and one-half river mile along sailing line.
Average depth: Computed (meters and feet) by dividing cross-sectional area by average width.
Islands: Number of islands within limits of channel border.
Revetments: Number of revetments located within limits of channel border.
Wingdams: Number of wingdams located within limits of channel border.
Structures: Bridge crossings, control structures, etc.
Tributaries: Number of tributary channels that cross land side limit of channel border.
Position: Location right (west) or left (east) side, looking downstream, of river relative to associated navigation channel.

Secondary Channels

Attributes for the secondary channels classification (Figure 3) were obtained or measured according to the following definitions and methods.

Location: UTM coordinates and river mile, estimated to one-tenth mile, of upstream and downstream intersection of sailing line and secondary channel center line, along with the associated navigation channel reach.
Reach length: Length (meters and feet) measured along secondary channel center line from upstream to downstream intersection of sailing line and secondary channel center line.
Valley length: Straight line length (meters and feet) from upstream to downstream intersection of sailing line and secondary channel center line.
Channel sinuosity: Reach length divided by valley length.
Width: Selected by observation of maximum and minimum width (meters and feet) of main water channel of the secondary channel (defined by center line).
Surface area: Planform area of secondary channel in acres (ARC/INFO feature area in square meters times 0.0002471 acres/square meter).
Diversion angle: Angle in degrees measured clockwise from sailing line to center line of secondary channel at upstream intersection of sailing line and secondary channel center line.
Distance to inlet: Minimum distance (meters and feet) from sailing line to intersection of secondary channel limits and its center line at inlet to secondary channel.

Islands: Number of islands including the island or islands that separate secondary channel from main channel or any islands located within channel itself.
Revetments: Number of revetments located within limits of the secondary channel.
Wingdams: Number of wingdams, both submerged and emergent, located within the limits of the secondary channel.
Structures: Bridge crossings, control structures, etc.
Tributaries: Number of tributary channels that cross landside limit of secondary channel.
Position: Location right (west) or left (east) side, looking downstream, of the river relative to associated navigation channel.
Channel cross-sectional area: Cross-sectional area in square meters and square feet at the inlet, outlet, and controlling section (minimum cross-sectional area) within secondary channel.
Average depth: Computed average depth (meters and feet) at the inlet, outlet, and controlling section by dividing cross-sectional area at each location by its width.

Backwaters

Attributes for the backwater classification were obtained or measured according to the following definitions and methods. Some of the attributes listed below do not have a significance for all the types of backwaters delineated for this classification but were obtained or measured for each type of backwater where applicable, except for isolated backwaters. For this classification, no attributes other than the type of backwater were obtained or measured for isolated backwaters.

Type of backwater: Contiguous backwater (Figure 4), contiguous-single-opening backwater (Figure 5), harbor, impounded backwater (Figure 6), or isolated backwater (Figure 5).
Location: UTM coordinates and river mile of upstream and downstream limits of the backwater selected by observation.
Length: Straight line length (meters and feet) from upstream to downstream limit.
Width: By observation, maximum width (meters and feet) of backwater measured perpendicular to river channel.
Area: Total planform area of backwater in acres (ARC/INFO feature area in square meters times 0.0002471 acres/square/meter).
Area of water: Total area (square meters, square feet, and acres) in the backwater covered by water.
Area of land: Total area (square meters, square feet, and acres) in the backwater above water level.
Percent of water: Ratio of total water area to total backwater area (Area of water divided by area).
Number of inlets: By observation, number of inlets into the backwater (An inlet is defined as a water connection into the backwater that is orientated downstream from perpendicular to the river).

Number of outlets: By observation, number of outlets from the backwater (An outlet is defined as a water connection from the backwater that is orientated upstream from perpendicular to the river).
Number of through channels: By observation, number of channels within the backwater that are a direct water connection from an inlet to an outlet.
Number of islands: Number of islands contained within limits of the backwater.
Structures: Bridge crossings, control structures, etc.
Tributaries: Number of tributary channels that cross landside limit of the backwater.
Position: Location right (west) or left (east) side, looking downstream, of main river channel.
Backwater depth: Average or representative depth (meters and feet) of the backwater.
Cross-sectional area: Measured cross-sectional area (square meters and square feet) for each inlet, outlet, and specified transverse section across the backwater.
Average section depth: Average depth (meters and feet) for each inlet, outlet, and specified transverse section was obtained by dividing the cross-sectional area by the width of the section.

Tributary Channels

Attributes for the tributary channel classification were obtained or measured according to the following definitions and methods.

Name: Name of tributary if known.
Location: Classification feature to which tributary is attributed.
Area: Planform area of the tributary to study area boundary in acres (ARC/INFO feature area in square meters times 0.002471 acres/square meter).
Position: Location right (west) or left (east) side, looking downstream, of main river channel.
Width: Measurement of width (meters) at tributary mouth (where the tributary crosses the limit of its associated classification feature).
Cross-sectional area: Measurement of cross-sectional area (square meters and square feet) at tributary mouth.
Average Depth: Average depth (meters and feet) at tributary mouth computed by dividing the cross-sectional area by the width.

This classification was compiled for a specific CE activity. The point of contact to receive additional information or data for this classification is Mr. Kenneth A. Barr, CEMVR. Mr. Barr may be reached by mail at RID, Clock Tower Building, P.O. Box 2004, Rock Island, Illinois 61204-2004, by telephone at area code 309 794-5349, or by electronic mail at *Kenneth.A.Barr@mvr02.usace.army.mil* .

5 Analysis of Hydraulic Classification

Background

The hydraulic classification of aquatic areas in the UMR study areas was undertaken for use in selecting representative study sites for various proposed studies. These studies included the development, integration, and application of hydrodynamic, hydrologic, sediment transport, and biological models to assist in assessing the impacts of potentially increased navigation traffic on the UMR aquatic ecosystem. The hydraulic classification also provides a basis for extrapolating impacts predicted on a subset of reaches to the entire system.

The purpose of this portion of the report is to document the analysis of the hydraulic classification and linkages developed during that analysis. While the analysis is comprehensive in that it covers the pooled and open river portions of the Mississippi River from Pool 4 to Cairo, IL, and the Illinois Waterway, the analysis was based on mainly hydraulic considerations and not necessarily biological attributes.

Many, but not all, of the characteristics determined during the classification were used in this analysis. For backwaters, only like types were associated with others. For example, contiguous backwaters with one inlet and one outlet were linked together. Then the area of the backwater covered by water was the final linkage. The reasoning here was that a large contiguous backwater with a large combined land area would be similar to a smaller contiguous backwater containing little or no land area as long as the watered area was about the same. In the absence of specific backwater depths, this approach is reasonable for equating on a system-wide basis. A similar approach was taken on all backwaters. On secondary channels, the diversion angle was converted to a deflection angle. The difference here was that during the hydraulic classification all angles from the sailing line into the secondary channel were measured looking downstream and turning the angle clockwise. This resulted in all secondary channels to the right of the navigation channel generally having a diversion angle of less than 90 deg. Secondary channels to the left of the navigation generally had diversion angles between 270 and 360 deg. There were few differences in these secondary channels, other than being to the right or left of the navigation channel. Therefore, the deflection angle, measured to the right or left of the sailing line was computed and used in this analysis. That procedure

allows for linking secondary channels, regardless of their location relative to the navigation channel.

It should be noted that in the tables presented later in this analysis, the backwaters are arranged in increasing water area and the secondary channels are arranged in increasing deflection angle. Also, attributes which are in the long-term trend pools: Mississippi River Pools 4, 8, 13, and 26, the open river reach from RM 31 to 74, and the La Grange Pool on the Illinois Waterway have an asterisk attached to the location in the first column as a reference.

Other Pertinent Data

This analysis was based on data other than the hydraulic classification. During the UMR study, data such as river stages and discharges, suspended sediment measurements, bed material attributes, and similar data were collected or obtained and integrated into the UMR database. Such data were used to categorize and establish linkages for the analysis. While the use of such data not included within the hydraulic classification appears to be beyond the analysis of that classification, there is sufficient reason to do so to accomplish the final desired goal of linking various attributes within the classification.

Delineation of the Upper Mississippi River System

For this analysis, the UMR system was initially divided into three obvious segments: (a) the pooled portion of the Mississippi River from Pool 4 to Pool 27, (b) the open river portion from Pool 27 to the confluence of the Mississippi and Ohio Rivers at Cairo, IL (RM 0), and (c) the Illinois Waterway from Lockport through Alton Pools. The purpose of this separation was to associate similar existing hydraulic conditions to attributes determined within the hydraulic classification. Also, it was determined early in the UMR study that the pooled portion of the Mississippi River was significantly different from the open river portion and that the sediments on the Illinois Waterway were significantly different than on the Mississippi River pooled segment. Thus, the delineation of the system was carried forward into the analysis.

The analysis of the hydraulic classification will be presented in individual chapters covering the three segments described above. Additional delineations were developed on individual segments, which will be presented in the appropriate chapter.

Bed Material Analysis

While the hydraulic classification focused essentially on planform and various attributes in and adjacent to the main channel, the types of sediments in the navigation channel and channel border areas were also important. Since some of the major research for the UMR study effort was computation of

resuspension of bed sediments due to towboat traffic, the particular type of bed material adjacent to backwaters and secondary channels provide another linkage for similar hydraulic attributes within the system.

Resuspension of bed material is highly dependent on the size and degree of cohesiveness of the sediments. For the UMR study, samples were obtained normally at a spacing of 8-km (5-mile) intervals with nine samples or attempts at most sediment sampling sections. The first and ninth samples at each section were obtained on the river bank at an elevation about 0.5 m above the normal, flat pool; the fourth and sixth samples were obtained at a depth of about 1 m; the second and eighth samples were obtained at the water's edge; the third and seventh samples were midway (horizontally) between the 1-m site and the water's edge location; and the fifth sample was taken in the navigation channel at the section (Figure 7). The samples were classified visually and some through laboratory analysis to establish the required characteristics for the various computations during the study.

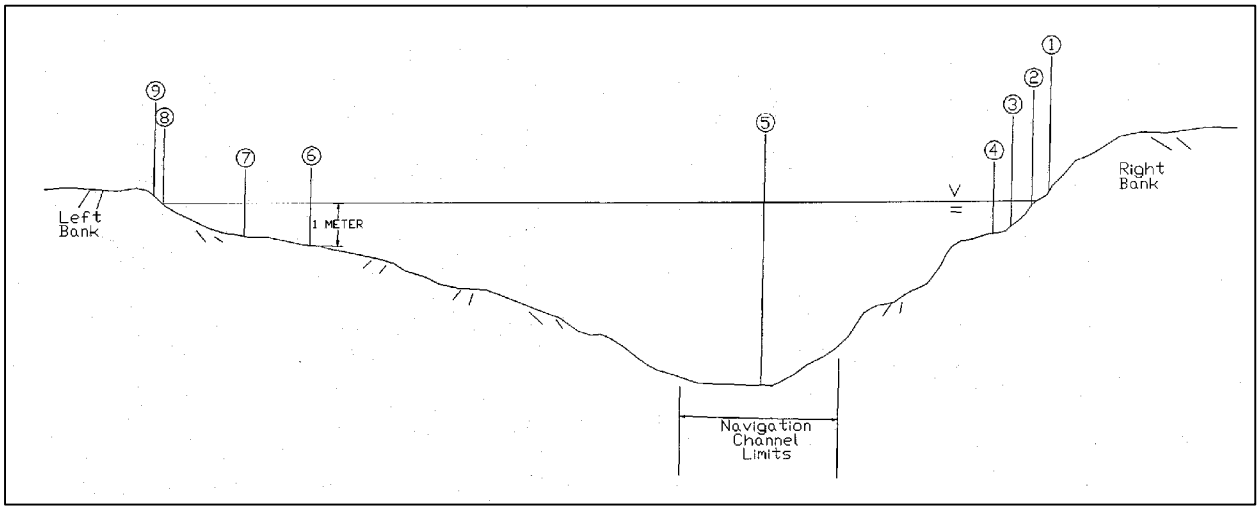


Figure 7. Bed material sample locations looking downstream

The bed material characteristics were tabulated and then categorized based on the cohesive properties of the sediments.[1] Two cohesive types, designated as Group 1 Cohesive and Group 2 Cohesive, were established along with a Noncohesive category. The Group 1 Cohesive sediments were based on the D_{70} # 4 microns or 0.004 mm. These samples would be completely cohesive in nature; however, no samples with such characteristics were obtained within the main channel on the Upper Mississippi River or Illinois Waterway. Samples classified as Group 2 Cohesive sediments have a D_{70} # 62 microns (0.062 mm) **or** a D_{16} # 4 microns. These samples include those with 70 percent of the sample finer than sand-size material or those with a meaningful (16 percent)

[1] T. M. Parchure, W. H. McAnally, and A. M. Teeter. "A wave-induced sediment resuspension near the shorelines of Upper Mississippi River" (Technical report in preparation), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

amount of clay in them. These criteria of D_{16} # 4 microns support the existence of clays in the sample and a cohesive nature of the sample, even though the D_{50} for those samples classifies them as medium or coarse silt. Noncohesive sediments were based on D_{70} > 62 microns and the D_{16} > 4 microns. These samples have no significant amounts of clay-size material, and while the parameter suggests that 70 percent of the samples are silts and clays, this classification, in fact, will be much coarser than that. Once the sample has less than 50 percent at the sand-silt break (62 microns) and a D_{16} above the clay range, the sample is classified as very fine sand or coarser and becomes noncohesive. Computations on the cohesive sediments also required further classification of such sediments. Therefore, Groups 1 and 2 in the cohesive category were classified using erodibility labels of soft, medium, and hard. The classification for these erodibility labels was based on the organic content and bulk density of the samples. It should be noted that the laboratory analysis of the samples established erodibility of soft and medium only with no samples determined to be hard. The following tabulation gives the various sediment classifications and their appropriate size characteristics used in this study.

Upper Mississippi River Sediments	
Sediment Classification	Sediment Size Characteristics
Group 1 Cohesive	$D_{70} \leq 0.004$ mm
Group 2 Cohesive	$D_{70} \leq 0.062$ mm ***or*** $D_{16} \leq 0.004$ mm
Noncohesive	$D_{70} > 0.062$ mm ***and*** $D_{16} > 0.004$ mm

The bed material samples were obtained on the Mississippi River from Pools 4 through 26. In this section of the river a total of 797 samples were obtained or attempted. Some of the sites were classified as “large rock” or “boulders” and no sample was actually obtained. Elimination of such sites reduced the sample number from 797 to 638. For this analysis, the samples taken 0.5 m above the normal, flat pool elevation (at the first and ninth sample locations) were also eliminated. This was based on the flows used for the various study efforts, and the highest flow was exceeded 5 percent of the time. In most instances, such a flow event would not be at the elevation where the sample on the shore had been obtained. Geomorphically, deposits above the normal pool will be laid down by higher flows and will consist of the finer materials making up the natural levees along the river. Elimination of the first and ninth locations reduced the number of samples from 638 to 485 samples. Of the 485 samples, 118 were classified as Group 2 cohesive sediments and 367 as noncohesive sediments. The 118 Group 2 cohesive sediments occurred along 670 km (416 miles) of channel border (left and right sides combined), with 589 km (366 miles) adjacent to backwaters or secondary channels.

In Mississippi River Pool 27 and the open river reach RM 1 to 202, no bed material samples were taken. Keown, Dardeau, and Causey[1] indicated that from St. Louis, MO, to Cairo, IL, the bed material varied somewhat over time and location. They found that the bed material in this section of the Mississippi River, based on the D_{50}, was generally fine sand or coarser. Therefore, for this analysis Pool 27 and the open river reach were assumed to have noncohesive bed material in the navigation and channel border areas. In the tables addressing the bed materials adjacent to backwaters and secondary channels, the words "Not Available" are inserted. The analysis is presented this way since the UMR study obtained no data for bed material in this specific reach of the Mississippi River. However, based on the Keown, Dardeau, and Causey[1] report, it can be assumed that the bed materials are noncohesive (sand) adjacent to those attributes.

Bed material samples were obtained on the Illinois Waterway in the Alton, La Grange, Peoria, Starved Rock, Marseilles, and Dresden Pools. No bed material samples were obtained in the Lockport and Brandon Road Pools; therefore, those two pools were not included in this analysis. In the Illinois Waterway pools where samples were taken or attempted, a total of 395 samples were presented. When the sites with "large rock" or "boulders" and no sample were eliminated, the sites reduced the sample number from 395 to 343. When the sites taken 0.5 m above the normal, flat pool elevations were eliminated, the number of samples went from 343 to 254. Of the 254 samples, 137 were classified as Group 2 cohesive sediments and 117 as noncohesive sediments. The 137 Group 2 cohesive sediments occurred along 599 km (372 miles) of channel border (left and right sides combined) with 202 miles adjacent to backwaters or secondary channels. On the Illinois Waterway, 32 km (20 miles) of the navigation channel in the Peoria Pool (RM 202.5 to 197.5 and RM 177.5 to 162.5), 8 km (5 miles) in the La Grange Pool (RM 152.5 to 147.5), and 16 km (10 miles) in the Alton Pool (RM 62.5 to 57.5 and RM 32.5 to 27.5) had Group 2 cohesive bed material present.

[1] Keown, Malcolm P., Dardeau, Elba A., Jr., and Causey, Etta M. (1981). "Characterization of the suspended-sediment regime and bed-material gradation of the Mississippi River Basin," Potamology Program (P-1), Report 1, Vol 1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

6 Mississippi River Pools 4 through 27

Initial Delineation

Initial inspection of the hydraulic classification resulted in an obvious observation. From Pool 4 through Pool 17, the backwater areas tended to have a braided channel configuration often with multiple inlets and outlets and through channels. From Pool 18 through Pool 27, the backwaters had significantly different shapes than the upstream pools with the backwater planform generally comprised of less channels in an island braided configuration. The reason for this change in planform was not apparent from the various hydraulic classification attributes. Other than the fact that the confluence of the Iowa and Mississippi Rivers was in Pool 18 and the confluence of the Des Moines and Mississippi Rivers was in Pool 20, there appeared to be no explanation for this change. From a geomorphic stand point, such a change in backwater planform could be related to change in river slope, discharge, bed material gradation, and/or sediment concentrations.

An analysis was performed using the Mississippi River stage and discharge and suspended sediment data relative to high flow conditions, i.e., flows exceeded 5 percent of the time. The 5-percent flow was chosen since it would tend to have the greatest energy of the three flows used for the study and would tend to move the most sediment. The approach taken was documentation of those various parameters by pool using data for Mississippi River Pools 5 through 22. The following tabulation was developed during that analysis.

Mississippi River Pool	Water Surface Slope ft/mile	Discharge cfs	Computed Suspended Sediment Concentration, mg/l
5	0.44	86,400	26
5A	0.41	82,800	25
6	0.49	84,700	27
7	0.45	81,600	29
8	0.38	89,700	35
9	0.24	98,700	44
10	0.21	115,000	66
11	0.30	115,000	100
12	0.25	116,000	107
13	0.28	116,000	110
14	0.34	118,000	115
15	0.45	118,000	116
16	0.30	135,000	137
17	0.29	136,000	141
18	0.41	161,000	176
19	0.21	172,000	198
20	0.41	195,000	230
21	0.31	197,000	232
22	0.44	200,000	235

Note: To obtain meters/kilometer, multiply feet/mile by 0.3048/1.609; to obtain cubic meters/second, multiply cubic feet by 0.02831.

Review of these data indicates that the river slope is relatively constant for Pools 8 through 17. The only exception is Pool 15, which is shorter (about 16 km (10 miles)) in length than the other pools in that segment, which range from about 32 to 55 km (20 to 34 miles) long. Pools 5 through 7 also have higher slopes, but those pools are relatively short also, ranging from about 16 to 23 km (10 to 14 miles) long. From Pools 18 through 22, the river slope is greater than from Pools 12 through 17. The only exception here is Pool 19. That particular pool is much longer (about 74 km (46 miles) long) compared to the other segment pools, which range from about 29 to 42 km (18 to 26 miles) long. Starting in Pool 18, the volume of water discharge measurably increases, which probably has an impact on the planform in that pool and extending downstream.

Therefore, it was decided that analysis and results based on the hydraulic classification would link Mississippi River Pools 4 through 17 and 18 through 27. That procedure was followed throughout the analysis of the Mississippi pools.

Pools 4 through 17

The analysis of the hydraulic classification of contiguous backwaters for Pools 4 through 17 is presented in Table 1. In this portion of the Mississippi River there was a total of 77 contiguous backwaters classified. There were 11 backwaters with one inlet and one outlet, 9 backwaters with multiple inlets and a single outlet, 7 backwaters with a single inlet and multiple outlets, and 50 backwaters with multiple inlets and outlets. Each type of contiguous backwater had a relatively wide variation in the attributes presented in Table 1. The following tabulation is a summary of the characteristics, particularly total area and the area in the backwater covered by water. The values presented in Table 1 and the other subsequent tables were obtained directly from the hydraulic classification with the areas, percentages, distances, and other attributes rounded to the nearest whole number.

Mississippi River Pools 4 through 17 (from Table 1)

Contiguous Backwater Type	Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
Single Inlet - Single Outlet	660	112 to 2,771	416	42 to 2,328
Multiple Inlets - Single Outlet	1,305	53 to 5,471	527	24 to 2,517
Single Inlet - Multiple Outlets	1,187	85 to 4,116	461	39 to 1,235
Multiple Inlets - Multiple Outlets	2,201	54 to 8,246	1,166	23 to 4,143

The actual analysis and linking of various hydraulic areas were based on the amount of area covered by water and the type of bed material adjacent to the particular feature being addressed. Contiguous backwaters were separated initially by the number of inlets and outlets - single inlets and outlets, multiple inlets and single outlet, single inlet and multiple outlets, and multiple inlets and outlets. In this way, backwaters having similar inlet and outlet conditions, water area, and adjacent bed material could be linked to each other and to long-term trend pool backwaters. The UMR study of long-term trend pools and reaches has the greatest amount of data available. From this study, extrapolation of similar hydraulic areas from those trend pools to nontrend pool areas allows for the most intensive investigations in areas where good bathymetry and biological data are available to areas where a reduced amount of data are available. It should be repeated that one main area of interest in the evaluation of the incremental impacts as a result of towboat traffic in the UMR study is resuspension of the bed materials. Therefore, the particular type of bed material adjacent to a hydraulic area is critical in the linkage of similar areas. For the

Mississippi River Pools 4 through 17, the linkages in the following tabulation were concluded from Table 1. They indicate that 33 contiguous backwaters have Group 2 cohesive bed material adjacent to them. Those backwaters would have the greatest possibility of having fines resuspended as a result of return currents or waves from towboat, and the possibility of that resuspended material to move into the backwater.

Mississippi River Pools 4 through 17 (from Table 1)			
Single Inlet and Single Outlet			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
1	3	7	11
Multiple Inlets and Single Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
1	2	6	9
Single Inlet and Multiple Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
None	2	5	7
Multiple Inlets and Multiple Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
2	22	26	50

Association of trend pool hydraulic areas to similar areas in nontrend pools was accomplished by linking the watered area and adjacent bed material type from the trend pools to the nontrend pools. Inspection of Table 1 shows that this procedure requires some modification. For instance, single-inlet and outlet backwaters had trend pool backwaters adjacent to noncohesive sediments (4-BW2* and 13-BW10*)[1] and Group 2 cohesive soft sediments (13-BW8*) but no backwaters adjacent to Group 2 cohesive medium sediments. In such cases, the linkage and association were based on similar inlet conditions, i.e., single-inlet and multiple-outlet conditions. This approach was taken based on the premise that the inlet conditions, which are adjacent to the documented bed material types, were the most critical, and outlet conditions or through channels within the backwaters would have less significant impact of the potential for delivery of resuspended sediments into backwaters.

[1] Asterisk after pool-backwater number indicates location in long-term trend pool.

Mississippi River Pools 4 through 17 (from Table 1)	
Single Inlet and Single Outlet with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW8**	None
Single Inlet and Single Outlet with Medium Cohesive Bed Material	
*13-BW6**	5-BW1, 14-BW6, 17-BW5
Single Inlet and Single Outlet with Noncohesive Bed Material	
*4-BW2**	16-BW3
*4-BW7**	12-BW2, 14-BW3, 11-BW5
*13-BW10**	None

The single inlet and outlet with medium cohesive bed material had no trend pool backwater. In fact, the only trend pool backwaters with medium cohesive bed material adjacent to them were multiple inlets and outlets. Backwater number 6 (BW6) in trend pool 13 was the only backwater in Pools 4 through 17 that had about the same size watered area and medium cohesive bed material adjacent to it; therefore, 13-BW6* was used as the reference trend pool backwater for linking to the single inlet and outlet backwaters adjacent to medium cohesive bed material.

Mississippi River Pools 4 through 17 (from Table 1)	
Multiple Inlets and Single Outlets with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW4**	None
Multiple Inlets and Single Outlets with Medium Cohesive Bed Material	
*13-BW6**	14-BW1
*8-BW2**	14-BW5
Multiple Inlets and Single Outlets with Noncohesive Bed Material	
*4-BW10**	14-BW2, 12-BW3, 11-BW4, 11-BW9
*13-BW7**	14-BW4
*4-BW9**	10-BW1

The multiple inlets and single outlet had only one trend pool backwater, and it was adjacent to a Group 2 cohesive soft bed material. Therefore, the Group 2 cohesive medium bed material and noncohesive reference trend pool backwaters for those adjacent bed materials were obtained from the multiple inlets and outlets for Pools 4 through 17. The referenced trend pool backwaters were once again based on the watered area of the backwater for the particular type of bed material being addressed.

Mississippi River Pools 4 through 17 (from Table 1)	
Single Inlet and Multiple Outlets with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
None	None
Single Inlet and Multiple Outlets with Medium Cohesive Bed Material	
*13-BW6**	12-BW9, 14-BW8
Single Inlet and Multiple Outlets with Noncohesive Bed Material	
*4-BW7**	10-BW2, 10-BW7, 12-BW5
*4-BW12**	5A-BW1

Single-inlet and multiple-outlet contiguous backwater had only one trend pool backwater (4-BW12*), and it was adjacent to noncohesive bed material and had a relatively large watered area. Therefore, the backwaters adjacent to medium cohesive bed materials were linked to a multiple inlets and outlets backwater (13-BW6*), and the other backwaters near noncohesive bed material were linked to a single-inlet and outlet trend pool backwater (4-BW7*).

Mississippi River Pools 4 through 17 (from Table 1)	
Multiple Inlets and Multiple Outlets with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW6**	None
*13-BW11**	None
Multiple Inlets and Multiple Outlets with Medium Cohesive Bed Material	
*13-BW6**	5-BW2, 17-BW2
*8-BW2**	17-BW6, 5-BW6, 14-BW7, 12-BW6, 10-BW10
*13-BW1**	None
*13-BW5**	17-BW3
*4-BW3**	12-BW8, 10-BW9, 5-BW4, 9-BW1, 16-BW4, 11-BW8
*8-BW3**	9-BW4, 9-BW5
Multiple Inlets and Multiple Outlets with Noncohesive Bed Material	
*4-BW10**	5-BW3, 10-BW3, 7-BW1, 6-BW4, 11-BW7, 12-BW1, 6-BW5, 9-BW2
*13-BW7**	11-BW6, 6-BW1, 10-BW5, 12-BW4, 10-BW6, 8-BW6, 10-BW8
*8-BW1**	17-BW1, 11-BW1, 6-BW2, 10-BW4, 7-BW2
*4-BW9**	5A-BW2, 5-BW5

Backwaters that had multiple inlets and outlets in Pools 4 through 17 were adjacent to all three identified bed materials. Therefore, the nontrend pool backwaters were linked directly to multiple inlets and outlets of similar size with corresponding identical type of bed material.

Single-channel contiguous backwaters were linked in a similar manner as the contiguous backwaters which had flow through them. The analysis of the hydraulic classification of single-channel contiguous backwaters for Pools 4 through 17 is presented in Table 2. In this portion of the Mississippi River there were a total of 20 single-channel contiguous backwaters classified. The attributes of these backwaters varied somewhat, but not to the extent that the flow-through backwaters did. Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water.

Mississippi River Pools 4 through 17 Single-Channel Contiguous Backwaters (from Table 2)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
208	8 to 653	146	5 to 633

The analysis and linking of various hydraulic areas were again based on the amount of area covered by water and the type of bed material adjacent to the particular feature addressed. For the Mississippi River Pools 4 through 17, the following linkages were concluded from Table 2. They indicate that 6 single-channel contiguous backwaters have Group 2 cohesive medium bed material adjacent to them and 13 have noncohesive bed material. One backwater, 4-BW11*, was actually created by a railroad embankment and not included in this breakdown.

Mississippi River Pools 4 through 17 Single-Channel Contiguous Backwaters (from Table 2)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
None	6	13	20

As accomplished previously, the association of trend pool hydraulic areas to similar areas in nontrend pools was accomplished by linking the watered area and adjacent bed material type from the trend pools to the nontrend pools. Based on Table 2, the following linkages were established for single-channel contiguous backwaters in Pools 4 through 17.

Mississippi River Pools 4 through 17 (from Table 2)	
Single-Channel Contiguous Backwater with Medium Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW9**	16-BW2, 12-BW7, 15-BW1, 17-BW4
*8-BW4**	None
Single-Channel Contiguous Backwater with Noncohesive Bed Material	
*4-BW6**	7-BW3, 11-BW2, 5A-BW3, 11-BW3, 4-BW5, 6-BW3
*4-BW1**	None
*4-BW8**	16-BW1, 5A-BW4
*4-BW4**	9-BW3

The single-channel contiguous backwaters delineated in the hydraulic classification in Pools 4 through 17 were adjacent to Group 2 medium cohesive and noncohesive bed material sediments only. There were sufficient trend pool backwaters with both types of bed material to provide good linkages to nontrend pool backwaters within this portion of the river.

As stated previously, the impounded contiguous backwaters are the pooled areas immediately upstream of some of the locks and dams. These backwaters are usually comprised of a large percentage of watered area compared to the

other types of contiguous backwaters. The analysis of the hydraulic classification of impounded contiguous backwaters for Pools 4 through 17 is presented in Table 3. In this portion of the Mississippi River there were 16 such backwaters. Following is a summary of the characteristics, particularly total area, percentage of the backwater covered by water, and the area in the backwater covered by water.

Mississippi River Pools 4 through 17 Impounded Contiguous Backwater (from Table 3)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
3,683	377 to 8,042	3,466	366 to 7,946

It should be noted that, at the time of this analysis, backwater 4-BW13* did not have all of its attributes included within the hydraulic classification. That particular backwater is listed in Table 3 with not available (N/A) entered in the Total and Water Area columns. As the hydraulic classification is updated, such data can and will be addressed. However, for this analysis, the absence of data from one particular backwater does not significantly reduce the meaningfulness of the attributes for the rest of the backwaters.

The impounded contiguous backwaters in the Mississippi River Pools 4 through 17 had eight backwaters adjacent to Group 2 cohesive medium bed material and eight adjacent to noncohesive bed materials. The following linkages were concluded from Table 3. No Group 2 soft cohesive bed material samples were obtained adjacent to these backwaters.

Mississippi River Pools 4 through 17 Impounded Contiguous Backwaters (from Table 3)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
None	8	8	16

Linkage of the trend and nontrend pool impounded backwaters provided the following:

Mississippi River Pools 4 through 17 (from Table 3)	
Impounded Contiguous Backwater with Medium Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW12**	16-BW6, 16-BW5, 10-BW11
*8-BW5**	9-BW7
*13-BW13**	9-BW6
Impounded Contiguous Backwater with Noncohesive Bed Material	
*8-BW7**	10-BW12, 6-BW6, 5A-BW5, 12-BW10, 11-BW10, 7-BW4

The impounded contiguous backwater linkages do not include backwater 4-BW13*. It should also be noted that only one trend pool backwater (8-BW7*) had noncohesive bed material adjacent to it, and that backwater was linked to the nontrend pool backwaters which include a wide range of watered areas for the reaches of Pools 4 through 17.

As stated previously, secondary channels were delineated by the deflection angle and then linked using the adjacent bed material. The secondary channels addressed in the hydraulic classification are presented in Table 4. For Mississippi River Pools 4 through 17, there were 30 secondary channels. Following is a summary of the characteristics, including channel length, minimum width, deflection angle, and distance to the secondary channel inlet.

Mississippi River Pools 4 through 17 Secondary Channels (from Table 4)							
Average Channel Length ft	Limits Channel Length ft	Average Minimum Width, ft	Limits Minimum Width, ft	Average Deflection Angle, deg	Limits Deflection Angle, deg	Average Distance to Inlet, ft	Limits Distance to Inlet, ft
9,179	3,474 to 22,449	406	123 to 763	39	2 to 84	881	263 to 1,734

It should be noted that, at the time of this analysis, secondary channels 8-SEC4*, 8-SEC5*, and 13-SEC8* did not have their attributes included within the hydraulic classification. Those channels are listed in Table 4 with N/A in the applicable columns. As the hydraulic classification is updated, such data can and will be addressed. However for this analysis, the absence of data on three secondary channels does not significantly reduce the meaningfulness of the attributes for the rest of the secondary channels.

The secondary channels in the Mississippi River Pools 4 through 17 had 1 channel adjacent to Group 2 soft cohesive bed material, 11 channels adjacent to Group 2 medium cohesive bed material, and 16 adjacent to noncohesive bed materials. The following linkages were concluded from Table 4.

Mississippi River Pools 4 through 17 Secondary Channels (from Table 4)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
1	11	16	28

Linkage of the trend and nontrend pool secondary channels provided the following tabulation:

Mississippi River Pools 4 through 17 (from Table 4)	
Secondary Channels with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-SEC5**	None
Secondary Channels with Medium Cohesive Bed Material	
*13-SEC2**	10-SEC2
*13-SEC7**	None
*8-SEC3**	12-SEC2
*8-SEC1**	9-SEC2, 14-SEC3
*13-SEC6**	12-SEC1, 14-SEC2
Secondary Channels with Noncohesive Bed Material	
*8-SEC2**	None
*13-SEC4**	7-SEC2, 11-SEC1, 14-SEC4, 7-SEC4, 10-SEC1, 15-SEC1
*13-SEC1**	9-SEC3, 14-SEC1, 5A-SEC1, 9-SEC1, 7-SEC3
*13-SEC3**	7-SEC1

The secondary channel linkages do not include 8-SEC4*, 8-SEC5*, and 13-SEC8* channels, since the various attributes were not available at this time. It should also be noted that channel 8-SEC2* had an unusually small deflection angle (2 deg), and that channel was not linked to any other secondary channels.

Pools 18 through 27

The analysis of the hydraulic classification of contiguous backwaters for Pools 18 through 27 are presented in Table 5. In this portion of the Mississippi River there were a total of 47 contiguous backwaters classified. There were 16 backwaters with one inlet and one outlet, 16 backwaters with multiple inlets and

a single outlet, 3 backwaters with a single inlet and multiple outlets, and 12 backwaters with multiple inlets and outlets. Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water. The values presented in Table 5 and the other subsequent tables were obtained directly from the hydraulic classification with the areas, percentages, distances, and other attributes rounded to the nearest whole number.

Mississippi River Pools 18 through 27 (from Table 5)

Contiguous Backwater Type	Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
Single Inlet - Single Outlet	285	8 to 1,342	101	2 to 631
Multiple Inlets - Single Outlet	740	125 to 2,128	311	50 to 979
Single Inlet - Multiple Outlets	1,305	336 to 2,574	538	262 to 849
Multiple Inlets - Multiple Outlets	2,859	369 to 7,218	1,030	114 to 3,753

As in the Pools 4 through 17 portion, the actual linking of various hydraulic areas was based on the amount of area covered by water and the type of bed material adjacent to the particular feature being addressed. The same procedure was followed for the Pools 18 through 27 portion as was previously applied. For the Mississippi River Pools 18 through 27, the following linkages were concluded from Table 5. They indicate that 23 contiguous backwaters have Group 2 cohesive bed material adjacent to them. Those backwaters would have the greatest possibility of having fines resuspended as a result of return currents or waves from towboats, and the possibility of that resuspended material to move into the backwater.

Mississippi River Pools 18 through 27 (from Table 5)			
Single Inlet and Single Outlet			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
1	8	7	16
Multiple Inlets and Single Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
0	6	10	16
Single Inlet and Multiple Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
0	1	2	3
Multiple Inlets and Multiple Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
0	7	5	12

As performed previously for Pools 4 through 17, association of trend pool hydraulic areas to similar areas in nontrend pools was accomplished by linking the watered area and adjacent bed material type from the trend pools to the nontrend pools. Inspection of Table 5 shows that this procedure requires some modification. For instance, the only soft cohesive bed material (in 19-BW4) was in a nontrend pool. In Pools 18 through 27, Pool 26 was the only trend pool and it had no soft cohesive bed material sediments for any inlet and outlet configuration. Therefore, in this case the linkage and association was based on similar inlet conditions in the portion of the Mississippi River in Pools 4 through 17.

Mississippi River Pools 18 through 27 (from Table 5)	
Single Inlet and Single Outlet with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW8**	19-BW4
Single Inlet and Single Outlet with Medium Cohesive Bed Material	
*26-BW7**	22-BW8, 24-BW4, 24-BW7, 24-BW5, 20-BW3, 19-BW8, 21-BW3
Single Inlet and Single Outlet with Noncohesive Bed Material	
*4-BW2**	21-BW1, 22-BW2, 20-BW1, 18-BW2, 22-BW5
*4-BW7**	20-BW5, 25-BW6

The single inlet and outlet with soft cohesive bed material had no trend pool backwater; therefore, that backwater was linked to backwater 13-BW8* in Table 1. Backwaters with Group 2 medium bed material were linked to the one trend pool backwater with single inlet and outlet in Pools 18 through 27. The backwaters with noncohesive bed material were linked to single-inlet and outlet backwaters in Pools 4 through 17 (Table 1) based on watered area.

Backwaters with multiple inlets and single outlets in Pools 18 through 27 were linked as presented here.

Mississippi River Pools 18 through 27 (from Table 5)	
Multiple Inlets and Single Outlets with Medium Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
None	None
Multiple Inlets and Single Outlets with Medium Cohesive Bed Material	
*13-BW6**	22-BW9, 18-BW4, 20-BW2, 24-BW1, 18-BW5
*8-BW2**	25-BW11
Multiple Inlets and Single Outlets with Noncohesive Bed Material	
*4-BW10**	25-BW2, 19-BW2
*26-BW2**	18-BW1
*26-BW11**	20-BW4, 25-BW5, 22-BW4, 25-BW3, 18-BW8

There were no areas with soft cohesive bed material in the Pool 18 and 27 reach. The multiple inlets and single outlet had only two trend pool backwaters, and they were adjacent to noncohesive bed material. Therefore, the Group 2 cohesive medium bed material were linked to Pools 4 through 17 trend pool backwaters with multiple inlets and outlets (Table 1). The smaller watered area backwaters with noncohesive bed material were linked to backwater 4-BW10* in the Pool 4 through 17 reach.

Mississippi River Pools 18 through 27 (from Table 5)	
Single Inlet and Multiple Outlets with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
None	None
Single Inlet and Multiple Outlets with Medium Cohesive Bed Material	
*13-BW6**	25-BW4, 25-BW8
Single Inlet and Multiple Outlets with Noncohesive Bed Material	
*4-BW12**	19-BW1

There were no areas with soft cohesive bed material in the reaches for Pools 18 and 27, and no trend pool, single-inlet and multiple-outlet contiguous backwaters which were adjacent to Group 2 medium cohesive or noncohesive bed material. Therefore, the backwaters with medium cohesive bed material were linked to backwater 13-BW6*, and the noncohesive bed material backwater was linked to backwater 4-BW12* in the reaches for Pools 4 through 17.

Mississippi River Pools 18 through 27 (from Table 5)	
Multiple Inlets and Multiple Outlets with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
None	None
Multiple Inlets and Multiple Outlets with Medium Cohesive Bed Material	
*26-BW1**	25-BW9, 20-BW6
*4-BW3**	25-BW7, 18-BW7, 21-BW2
*8-BW3**	19-BW9
Multiple Inlets and Multiple Outlets with Noncohesive Bed Material	
*4-BW10**	22-BW3, 18-BW6
*26-BW6**	25-BW1
*8-BW1**	24-BW3

There were no multiple-inlet and outlet backwaters with soft cohesive bed material in the reaches for Pools 18 and 27. Backwaters with medium cohesive bed material and watered areas less than 2,428 sq m (600 acres) were linked to the trend pool backwater 26-BW1*, while the remainder of such backwaters were linked to multiple-inlet and outlet backwaters in Pools 4 through 17. The

backwaters with noncohesive bed material were linked to trend pool backwater 26-BW6* or Pools 4 through 17 multiple-inlet and outlet trend pool backwaters of similar size relative to the watered area.

The analysis of the hydraulic classification of single-channel contiguous backwaters for Pools 18 through 27 is presented in Table 6. In this portion of the Mississippi River there were a total of 17 single-channel contiguous backwaters classified. Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water.

Mississippi River Pools 18 through 27 Single-Channel Contiguous Backwaters (from Table 6)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
180	11 to 701	96	10 to 338

For the Mississippi River Pools 18 through 27 the following linkages were concluded from Table 6. They indicate that seven single-channel contiguous backwaters have Group 2 cohesive medium bed material adjacent to them and eight have noncohesive bed material. Two backwaters, 27-BW3 and 27-BW2, did not have bed material sample data available; however, these backwaters are in the reach addressed by Keown, Dardeau, and Causey (1981)[1] which characterized the bed material sediments as sand. Therefore, for this analysis the bed material adjacent to those backwaters will be considered as being noncohesive.

Mississippi River Pools 18 through 27 Single-Channel Contiguous Backwaters (from Table 6)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
None	7	10	17

Based on Table 6, the following linkages were established for single-channel contiguous backwaters in Pools 18 through 27.

[1] Ibid.

Mississippi River Pools 18 through 27 (from Table 6)	
Single-Channel Contiguous Backwater with Medium Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*26-BW9**	22-BW7, 24-BW2
*26-BW10**	None
*26-BW8**	19-BW7, 25-BW10
Single-Channel Contiguous Backwater with Noncohesive Bed Material	
*26-BW12**	19-BW5, 27-BW3, 22-BW1, 22-BW6, 19-BW6, 21-BW4, 27-BW2, 19-BW3, 18-BW3

The single-channel contiguous backwaters delineated in the hydraulic classification in Pools 18 through 27 were adjacent to Group 2 medium cohesive and noncohesive bed material sediments only. The trend pool backwaters were well represented for medium cohesive bed material to provide good linkages to nontrend pool backwaters within this portion of the river; however, only one trend pool backwater, 26-BW12*, was adjacent to noncohesive bed material.

The impounded contiguous backwaters in the Pools 18 through 27 portion of the Mississippi River were very limited. In this portion of the Mississippi River there were only five such backwaters (see Table 7). Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water.

Mississippi River Pools 18 through 27 Impounded Contiguous Backwaters (from Table 7)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
1,306	684 to 1,923	1,163	684 to 1,728

It should be noted that, at the time of this analysis, backwater 27-BW1 did not have all of its attributes included within the hydraulic classification. That particular backwater is listed in Table 7 with not available (N/A) entered in the Total and Water Area columns. As the hydraulic classification is updated, these data can and will be addressed. For this analysis, the 27-BW1 was not included.

The impounded contiguous backwaters in the Mississippi River Pools 18 through 27 had four backwaters adjacent to Group 2 cohesive medium bed material and only 27-BW1 adjacent to noncohesive bed materials. The following linkages were concluded from Table 7. No Group 2 soft cohesive bed material samples were obtained adjacent to these backwaters, nor was the backwater with noncohesive bed materials included.

Mississippi River Pools 18 through 27 Impounded Contiguous Backwaters (from Table 7)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
None	4	Not included	5

There were no trend pool impounded backwaters to make linkage to non-trend pool impounded backwaters. Therefore, linkages for Pools 18 through 27 were based on the trend pools for Pools 4 through 17, with Group 2 medium cohesive bed materials present. For this analysis, the trend pool impounded backwater 13-BW12* was used for linkage. While this particular backwater is relatively large, watered area of 3,658 acres, compared to the Pool 18 through 27 impounded backwaters, it was felt that it provided the most reasonable linkage between a trend pool and the four nontrend pools in the reach of Pools 18 through 27.

Mississippi River Pools 18 through 27	
Impounded Contiguous Backwater with Medium Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW12**	25-BW12, 18-BW10, 24-BW6, 18-BW9

As stated previously, secondary channels were delineated by the deflection angle and then linked using the adjacent bed material. The secondary channels addressed in the hydraulic classification are presented in Table 8. For Mississippi River Pools 18 through 27 there were 18 secondary channels. Four of those secondary channels had not been completely delineated at the time of this analysis, and those channels have the attributes designated as N/A in Table 8. Following is a summary of the characteristics, including channel length, minimum width, deflection angle, and distance to the secondary channel inlet of the remaining 14 secondary channels in Pools 18 through 27.

Mississippi River Pools 18 through 27 Secondary Channels (from Table 8)							
Average Channel Length, ft	Limits Channel Length ft	Average Minimum Width, ft	Limits Minimum Width, ft	Average Deflection Angle, deg	Limits Deflection Angle, deg	Average Distance to Inlet, ft	Limits Distance to Inlet, ft
11,637	4,486 to 19,702	552	173 to 1,209	38	17 to 82	1,044	546 to 1,758

The secondary channels in the Mississippi River Pools 18 through 27 had 11 channels adjacent to Group 2 medium cohesive bed material, and 7 channels adjacent to noncohesive bed materials. The following linkages were concluded from Table 8.

Mississippi River Pools 18 through 27 Secondary Channels (from Table 8)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
0	11	7	18

Linkage of the trend and nontrend pool secondary channels provided the information in the table below. It should be noted that the four secondary channels not delineated in Table 8 were not linked to other channels at this time.

Mississippi River Pools 18 through 27 (from Table 8)	
Trend Pool Backwater	Nontrend Pool Backwater
Secondary Channels with Medium Cohesive Bed Material	
*26-SEC1**	19-SEC1, 22-SEC4, 24-SEC2, 22-SEC1, 25-SEC1, 22-SEC2, 22-SEC3
Secondary Channels with Noncohesive Bed Material	
*26-SEC2**	21-SEC1, 20-SEC1, 20-SEC2
*26-SEC3**	24-SEC1

Summary

Pools 4 through 17

The following is a summary of the analysis for Pools 4 through 17.

a. Eleven (11) contiguous backwaters have single inlet and outlet.

(1) Average total area is 660 acres.

(2) Total area ranges from 112 to 2,771 acres.

(3) Average area covered by water is 416 acres.

(4) Area covered by water ranges from 42 to 2,328 acres.

(5) One (1) backwater is adjacent to Group 2 soft cohesive bed material, three (3) are adjacent to Group 2 medium cohesive bed material, and seven (7) are adjacent to noncohesive bed material.

b. Nine (9) contiguous backwaters have multiple inlets and single outlet.

(1) Average total area is 1,305 acres.

(2) Total area ranges from 53 to 5,471 acres.

(3) Average area covered by water is 527 acres.

(4) Area covered by water ranges from 24 to 2,517 acres.

(5) One (1) backwater is adjacent to Group 2 soft cohesive bed material, two (2) are adjacent to Group 2 medium cohesive bed material, and six (6) are adjacent to noncohesive bed material.

c. Seven (7) contiguous backwaters have single inlet and multiple outlets.

(1) Average total area is 1,187 acres.

(2) Total area ranges from 85 to 4,116 acres.

(3) Average area covered by water is 461 acres.

(4) Area covered by water ranges from 39 to 1,235 acres.

(5) No backwater is adjacent to Group 2 soft cohesive bed material, two (2) are adjacent to Group 2 medium cohesive bed material, and five (5) are adjacent to noncohesive bed material.

d. Fifty (50) contiguous backwaters have multiple inlets and outlets.

(1) Average total area is 2,201 acres.

(2) Total area ranges from 54 to 8,246 acres.

(3) Average area covered by water is 1,166 acres.

(4) Area covered by water ranges from 23 to 4,143 acres.

(5) Two (2) backwaters are adjacent to Group 2 soft cohesive bed material, twenty-two (22) are adjacent to Group 2 medium cohesive bed material, and twenty-six (26) are adjacent to noncohesive bed material.

e. Twenty (20) single channel contiguous backwaters.

(1) Average total area is 208 acres.

(2) Total area ranges from 8 to 653 acres.

(3) Average area covered by water is 146 acres.

(4) Area covered by water ranges from 5 to 633 acres.

(5) No backwater is adjacent to Group 2 soft cohesive bed material, six (6) are adjacent to Group 2 medium cohesive bed material, and thirteen (13) are adjacent to noncohesive bed material.

(6) One (1) backwater was created by a railroad embankment and not included.

f. Sixteen (16) Impounded contiguous backwaters.

(1) Average total area is 3,683 acres.

(2) Total area ranges from 377 to 8,042 acres.

(3) Average area covered by water is 3,466 acres.

(4) Area covered by water ranges from 366 to 7,946 acres.

(5) No backwater is adjacent to Group 2 soft cohesive bed material, eight (8) are adjacent to Group 2 medium cohesive bed material, and eight (8) are adjacent to noncohesive bed material.

g. Twenty-eight (28) secondary channels.

(1) Average channel length is 9,179 ft.

(2) Range of channel length is 3,474 to 22,449 ft.

(3) Average minimum width is 406 ft.

(4) Range of minimum width is 123 to 763 ft.

(5) Average deflection angel is 39 deg.

(6) Range of deflection angle is 2 to 84 deg.

(7) Average distance from navigation channel to inlet is 881 ft.

(8) Range of distance to inlet is 263 to 1,734 ft.

(9) One (1) secondary channel is adjacent to Group 2 soft cohesive bed material, eleven (11) are adjacent to Group 2 medium cohesive bed material, and sixteen (16) are adjacent to noncohesive bed material.

h. No sediment samples comprised of Group 1 cohesive bed material were identified.

i. All sediment samples obtained in the navigation channel were noncohesive bed material.

j. Collectively, 211 miles of channel borders have Group 2 cohesive bed material.

k. Of 211 miles, 191 miles have backwaters or secondary channels adjacent to the channel border with Group 2 cohesive bed material.

l. Of seventy-seven (77) contiguous backwaters with at least one inlet and outlet,

(1) All or part of four (4) are adjacent to Group 2 soft cohesive bed material.

(2) All or part of twenty-nine (29) are adjacent to Group 2 medium cohesive bed material.

(3) All or part of forty-four (44) are adjacent to noncohesive bed material.

m. Of twenty (20) single-channel contiguous backwaters,

(1) All or part of six (6) are adjacent to Group 2 medium cohesive bed material.

(2) All or part of fourteen (14) are adjacent to noncohesive bed material.

n. Of sixteen (16) impounded contiguous backwaters,

(1) All or part of eight (8) are adjacent to Group 2 medium cohesive bed material.

(2) All or part of eight (8) are adjacent to noncohesive bed material.

o. Of thirty-one (31) secondary channels,

(1) All or part of one (1) is adjacent to Group 2 soft cohesive bed material.

(2) All or part of eleven (11) are adjacent to Group 2 medium cohesive bed material.

(3) All or part of sixteen (16) are adjacent to noncohesive bed material.

(4) All or part of three (3) have not been completely delineated in the hydraulic classification.

Pools 18 through 27

The following is a summary of the analysis for Pools 18 through 27.

a. Sixteen (16) contiguous backwaters have single inlet and outlet.

(1) Average total area is 285 acres.

(2) Total area ranges from 8 to 1,342 acres.

(3) Average area covered by water is 101 acres.

(4) Area covered by water ranges from 2 to 631 acres.

(5) One (1) backwater is adjacent to Group 2 soft cohesive bed material, eight (8) are adjacent to Group 2 medium cohesive bed material, and seven (7) are adjacent to noncohesive bed material.

b. Sixteen (16) contiguous backwaters have multiple inlets and single outlet.

(1) Average total area is 740 acres.

(2) Total area ranges from 125 to 2,128 acres.

(3) Average area covered by water is 311 acres.

(4) Area covered by water ranges from 50 to 979 acres.

(5) No backwaters are adjacent to Group 2 soft cohesive bed material, six (6) are adjacent to Group 2 medium cohesive bed material, and ten (10) are adjacent to noncohesive bed material.

c. Three (3) contiguous backwaters have single inlet and multiple outlets.

(1) Average total area is 1,305 acres.

(2) Total area ranges from 336 to 2,574 acres.

(3) Average area covered by water is 538 acres.

(4) Area covered by water ranges from 262 to 849 acres.

(5) No backwater is adjacent to Group 2 soft cohesive bed material, one (1) is adjacent to Group 2 medium cohesive bed material, and two (2) are adjacent to noncohesive bed material.

d. Twelve (12) contiguous backwaters have multiple inlets and outlets.

(1) Average total area is 2,859 acres.

(2) Total area ranges from 369 to 7,218 acres.

(3) Average area covered by water is 1,030 acres.

(4) Area covered by water ranges from 114 to 3,753 acres.

(5) No backwaters are adjacent to Group 2 soft cohesive bed material, seven (7) are adjacent to Group 2 medium cohesive bed material, and five (5) are adjacent to noncohesive bed material.

e. Seventeen (17) single-channel contiguous backwaters.

(1) Average total area is 180 acres.

(2) Total area ranges from 11 to 701 acres.

(3) Average area covered by water is 96 acres.

(4) Area covered by water ranges from 10 to 338 acres.

(5) No backwater is adjacent to Group 2 soft cohesive bed material, seven (7) are adjacent to Group 2 medium cohesive bed material, and ten (10) are adjacent to noncohesive bed material.

f. Five (5) impounded contiguous backwaters.

(1) Average total area is 1,306 acres.

(2) Total area ranges from 684 to 1,923 acres.

(3) Average area covered by water is 1,163 acres.

(4) Area covered by water ranges from 684 to 1,728 acres.

(5) No backwater is adjacent to Group 2 soft cohesive bed material, four (4) are adjacent to Group 2 medium cohesive bed material, and one (1) is adjacent to noncohesive bed material, but was not included in this analysis.

g. Eighteen (18) secondary channels.

(1) Average channel length is 11,637 ft.

(2) Range of channel length is 4,486 to 19,702 ft.

(3) Average minimum width is 552 ft.

(4) Range of minimum width is 173 to 1,209 ft.

(5) Average deflection angel is 38 deg.

(6) Range of deflection angle is 17 to 82 deg.

(7) Average distance from navigation channel to inlet is 1,044 ft.

(8) Range of distance to inlet is 546 to 1,758 ft.

(9) No secondary channel is adjacent to Group 2 soft cohesive bed material, eleven (11) are adjacent to Group 2 medium cohesive bed material, and seven (7) are adjacent to noncohesive bed material.

h. No sediment samples comprised of Group 1 cohesive bed material were identified.

i. All sediment samples obtained in the navigation channel were noncohesive bed material.

j. Collectively, 205 miles of channel borders have Group 2 cohesive bed material.

k. Of 205 miles, 175 miles have backwaters or secondary channels adjacent to the channel border with Group 2 cohesive bed material.

l. Of forty-seven (47) contiguous backwaters with at least one inlet and outlet,

(1) All or part of one (1) is adjacent to Group 2 soft cohesive bed material.

(2) All or part of twenty-two (22) are adjacent to Group 2 medium cohesive bed material.

(3) All or part of twenty-four (24) are adjacent to noncohesive bed material.

m. Of seventeen (17) single-channel contiguous backwaters,

(1) All or part of seven (7) are adjacent to Group 2 medium cohesive bed material.

(2) All or part of ten (10) are adjacent to noncohesive bed material.

n. Of five (5) impounded contiguous backwaters,

(1) All or part of four (4) are adjacent to Group 2 medium cohesive bed material.

(2) All or part of one (1) is adjacent to noncohesive bed material.

o. Of eighteen (18) secondary channels,

(1) All or part of ten (10) are adjacent to Group 2 medium cohesive bed material.

(2) All or part of eight (8) are adjacent to noncohesive bed material.

7 Mississippi River Open River Reach

Introduction

The open river reach of the Mississippi River encompasses the portion of the river from Cairo, IL, upstream to Dam No. 27, which is just upstream of St. Louis, MO. For the UMR study, this reach is divided into five segments covering RM 1 to 31, 31 to 74, 74 to 106, 106 to 140, and 140 to 172. The "trend pool" segment of the open river reach is the segment between RM 31 and 74. While this segment is not a pool in the sense that no dam exists to create a pool as is the case starting at Dam No. 27, such designation has been applied to that reach prior to the UMR study and that designation has been maintained for the hydraulic classification and analysis.

In Tables 9 through 11, the specific river segment is presented in a form different from the previous chapter. For example, the river segment from RM 74 to RM 106 is identified by "74.106" in those tables. The remainder of the title is then associated with the specific backwater or secondary channel in the hydraulic classification. Since no dams exist in the open river reach, no impounded backwaters exist and such backwaters are not included in the hydraulic classification.

In the open river reach, all backwaters with at least one inlet and outlet were analyzed together. This differs from the previous method in Pools 4 through 17 and 18 through 27 where combination single or multiple inlets and single or multiple outlets were considered separately. The combined method was used in the open river reach since there were only 13 contiguous backwaters with separate inlets and outlets, and only one "trend pool" reach existed to provide linkages.

Relative to bed material, it should be noted, as discussed in Chapter 1, that no bed material samples were obtained in the open river reach for the UMR study. Therefore, the bed material, as indicated by Keown, Dardeau, and Causey[1] was assumed to have noncohesive bed material in the navigation and channel border areas. Therefore, in Tables 9 through 11 the words "Not Available" are inserted to indicate that for the UMR study no specific bed material data were obtained in

[1] Ibid.

the open river reach, and it can be assumed that the bed materials are noncohesive (sand) adjacent to those attributes.

Open River Reach

The analysis of the hydraulic classification of contiguous backwaters for the open river reach is presented in Table 9. In this portion of the Mississippi River there were a total of 13 contiguous backwaters classified having separate inlet(s) and outlet(s). Compared to the pooled portion of the Mississippi River presented in Chapter 2, these backwaters are relatively small in total and water covered areas. Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water. The values presented in Table 9 and the other subsequent tables were obtained directly from the hydraulic classification.

Mississippi River Open River Reach Contiguous Backwaters with at least One Inlet and One Outlet (from Table 9)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
206	30 to 579	32	10 to 268

Compared to the contiguous backwaters in the Pools 4 through 17 and Pools 18 through 27, the open river reach contiguous backwaters with at least one inlet and one outlet are significantly smaller. This condition is probably due to the fact that the majority of the open river backwaters are remnants of old channels or channel border areas. In the open river reach, the overall channel width is smaller than the varying width in the pooled reaches, and the river training structures (dikes) in the open river reach promote deposition of bed material within the dike fields.

Mississippi River Open River Reach Contiguous Backwaters with at least One Inlet and One Outlet (from Table 9)	
Trend Pool Backwater	Nontrend Pool Backwater
*31.74-BW5**	None
*31.74-BW4**	1.31-BW4, 140.172-BW2, 140.172-BW1, 1.31-BW6, 106.140-BW6, 74.106-BW4, 75.106-BW3, 1.31-BW1, 106.140-BW3, 106.140-BW2, 106.140-BW1

All of the backwaters in “nontrend pool” reaches were linked to one backwater, 31.74-BW4* in the open river reach. This linkage is reasonable, and the only situation that may be a significant extrapolation of that linkage is for backwaters 106.140-BW2 and BW1. Those two particular backwaters were significantly larger than the “trend pool” backwater to which it was linked. Such linkage is reasonable however, due to the relative size of all of the contiguous backwaters in the open river reach.

The analysis of the hydraulic classification of single channel contiguous backwaters for the open river reach is presented in Table 10. In this portion of the Mississippi River there were a total of 16 single-channel contiguous backwaters classified. Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water.

Mississippi River Open River Reach Single-Channel Contiguous Backwaters (from Table 10)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
163	15 to 1,141	82	12 to 227

In this case, the open river single-channel contiguous backwaters are smaller in total and water areas than similar type backwaters in Pools 4 through 17 (Table 2), but the open river backwaters are similar in size to similar backwaters in Pools 18 through 27 (Table 6).

The following linkages were established between "trend pool" backwaters and "nontrend pool" single-channel contiguous backwaters in the open river reach:

Mississippi River Pools Open River Reach Single-Channel Contiguous Backwater (from Table 10)	
Trend Pool Backwater	Nontrend Pool Backwater
*31.74-BW2**	74.106-BW1, 1.31-BW7, 1.31-BW9, 140.172-BW4, 74.106-BW5, 1.31-BW2, 1.31-BW5, 140.172-BW3, 1.31-BW8, 106.140-BW5
*31.74-BW1**	None
*31.74-BW3**	106.140-BW4

As was the case with contiguous backwaters with at least one inlet and outlet, the majority of the single-channel contiguous backwaters in the open river reach were linked to one particular backwater, in this case 31.74-BW2*. The larger "trend pool" backwaters were well represented in this case, while the smaller backwaters were not present in the "trend pool" reach.

The analysis of the hydraulic classification of secondary channels for the open river reach is presented in Table 11. In this portion of the Mississippi River, three secondary channels were classified. Following is a summary (from Table 11) of the characteristics of the secondary channels in the open river reach:

Mississippi River Open River Reach Secondary Channels (from Table 11)							
Average Channel Length, ft	Limits Channel Length, ft	Average Minimum Width, ft	Limits Minimum Width, ft	Average Deflection Angle, deg	Limits Deflection Angle, deg	Average Distance to Inlet, ft	Limits Distance to Inlet, ft
12,997	10,542 to 16,945	635	130 to 1,165	51	35 to 77	1,114	828 to 1,509

The secondary channels in the open river reach are longer than those in Mississippi River Pools 4 through 17 (Table 4) and Pools 18 through 27 (Table 8). Also, the average minimum channel width was larger in the open river reach than in Pools 4 through 27. The larger secondary channel in the open river reach are probably a function of the greater discharges throughout the flow range due to tributary flow from the Missouri River and other rivers.

Mississippi River Open River Reach Secondary Channels (from Table 11)	
Trend Pool Backwater	Nontrend Pool Backwater
*26-SEC2**	74.106-SEC1, 1.31-SEC1
*26-SEC3**	1.31-SEC2

Of the three secondary channels classified in the open river reach, not one was in the "trend pool." Therefore, the linkage to trend pool secondary channels was based on similar secondary channels in Pool 26. That pool was chosen since it is the trend pool nearest to the open river reach and the fact that operationally Pool 26 is operated as a hinged pool which should produce conditions closest to open river conditions. While this situation is not ideal, it appeared to be the only reasonable approach for this analysis.

Summary

The following is a summary of the analysis for the open river reach.

a. All segments of the reach have noncohesive (sand) bed material in the channel borders and navigation channel.

b. Thirteen (13) contiguous backwaters with at least one inlet and one outlet.

(1) Average total area is 206 acres.

(2) Total area ranges from 30 to 579 acres.

(3) Average area covered by water is 32 acres.

(4) Area covered by water ranges from 10 to 268 acres.

c. Sixteen (16) single-channel contiguous backwaters.

(1) Average total area is 163 acres.

(2) Total area ranges from 15 to 1,141 acres.

(3) Average area covered by water is 82 acres.

(4) Area covered by water ranges from 12 to 227 acres.

d. Three (3) secondary channels.

(1) Average channel length is 12,997 ft.

(2) Range of channel length is 10,542 to 16,945 ft.

(3) Average minimum width is 635 ft.

(4) Range of minimum width is 130 to 1,165 ft.

(5) Average deflection angel is 51 deg.

(6) Range of deflection angle is 35 to 77 deg.

(7) Average distance from navigation channel to inlet is 1,114 ft.

(8) Range of distance to inlet is 828 to 1,509 ft.

e. All sediments in the navigation channel and channel borders were noncohesive.

8 Illinois Waterway

Introduction

The analysis of the backwaters and secondary channels on the Illinois Waterway was accomplished in the identical manner as was used on the pooled portion of the Mississippi River. It should be noted that the two most upstream pools on the Illinois Waterway, Brandon Road and Lockport Pools, were not included in the hydraulic classification due to limited data. Therefore, those pools are not included in this analysis. The Illinois Waterway pools included in the hydraulic classification are Alton, La Grange, Peoria, Starved Rock, Marseilles, and Dresden Pools. Of these pools, the La Grange Pool is the trend pool on the Illinois Waterway and will be the reference pool for this analysis.

In the following tables presented for the Illinois Waterway, the pool name related to a specific backwater or secondary channel was abbreviated. In column one of each table, “ALT” stands for Alton Pool, “LAG” stands for La Grange Pool, “PEOR” stands for Peoria Pool, “SR” stands for Starved Rock Pool, “MAR” indicates Marseilles Pool, and “DRES” is used for Dresden Pool.

Illinois Waterway

The analysis of the hydraulic classification of contiguous backwaters for the Illinois Waterway is presented in Table 12. In this portion of the waterway included in the classification there were a total of 22 contiguous backwaters classified. There were 12 backwaters with one inlet and one outlet, 1 backwater with multiple inlets and a single outlet, 7 backwaters with a single inlet and multiple outlets, and 2 backwaters with multiple inlets and outlets. The single-inlet and single-outlet and single-inlet and multiple-outlet backwater groups had a relatively wide variation in the attributes (Table 12). The following tabulation is a summary of the characteristics, particularly total area and the area in the backwater covered by water.

Illinois Waterway (from Table 12)				
Contiguous Backwater Type	Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
Single Inlet - Single Outlet	851	29 to 6,055	750	18 to 5,873
Multiple Inlets - Single Outlet	131	131	1,159	1,159
Single Inlet - Multiple Outlets	2,953	84 to 11,095	1,159	71 to 2,762
Multiple Inlets - Multiple Outlets	914	353 to 1,476	322	311 to 334

As was the case on the Mississippi River, no Group 1 cohesive bed material was identified in the sampling. In the Illinois Waterway, the bed material present in the channel border areas particularly is important because of the relative size of the navigation channel and the total river width. Unlike the majority of the conditions on the Mississippi River, the navigation channel on the Illinois Waterway occupies a significantly large portion of the entire river channel in most reaches. Therefore, the type and distribution of the bed materials are of major significance on the Illinois Waterway.

Illinois Waterway (from Table 12)			
Single Inlet and Single Outlet			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
0	8	4	12
Multiple Inlets and Single Outlet			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
0	0	1	1
Single Inlet and Multiple Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
0	6	1	7
Multiple Inlets and Multiple Outlets			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
1	1	0	2

Association of trend pool hydraulic areas to similar areas in nontrend pools was accomplished by linking the watered area and adjacent bed material type from the trend pools to the nontrend pools. Inspection of Table 12 shows that this procedure required some modification, which was the case on the Mississippi River. For instance, no trend pool backwaters have noncohesive bed

material adjacent to them, but some nontrend pool backwaters do have noncohesive material adjacent to them. Additionally, there is only one backwater PEOR-BW15 adjacent to Group 2 soft cohesive bed material and no such backwater in the La Grange (trend) Pool. In fact, the only two backwaters of any type (Table 13) with soft, cohesive bed materials adjacent to them are in the Peoria Pool with no similar trend pool to provide a linkage. For this analysis, the backwaters with a combination of inlets and outlets in Table 12 which were adjacent to noncohesive bed material were linked, depending on size, to either backwater *LAG-BW2** or *LAG-BW3** from Table 13. The backwaters with Group 2 soft, cohesive bed material will be linked to similar type backwaters in Mississippi River Pools 4 through 17 (Table 1).

Illinois Waterway	
Trend Pool Backwater	Nontrend Pool Backwater
Single Inlet and Single Outlet with Medium Cohesive Bed Material	
*LAG-BW6**	ALT-BW3, MAR-BW3, PEOR-BW20
*LAG-BW5**	PEOR-BW18, PEOR-BW13, PEOR-BW14
*LAG-BW4**	PEOR-BW10
Single Inlet and Single Outlet with Noncohesive Bed Material	
*LAG-BW2**	DRES-BW1, DRES-BW2, PEOR-BW22, DRES-BW4
Multiple Inlets and Single Outlet with Noncohesive Bed Material	
*LAG-BW7**	PEOR-BW1
Single Inlet and Multiple Outlets with Medium Cohesive Bed Material	
*LAG-BW5**	SR-BW2, SR-BW3, PEOR-BW17
*LAG-BW4**	ALT-BW5
Single Inlet and Multiple Outlets with Noncohesive Bed Material	
*LAG-BW2**	SR-BW1
Multiple Inlets and Multiple Outlets with Soft Cohesive Bed Material	
*13-BW4**	PEOR-BW15
Multiple Inlets and Multiple Outlets with Medium Cohesive Bed Material	
*LAG-BW5**	ALT-BW2

The backwater in Peoria Pool with soft, cohesive bed material was linked to Mississippi River Pool 13 backwater BW4* based on the sizes of the watered area of both backwaters. While linking an Illinois Waterway backwater to a Mississippi River backwater may not be exactly desirable, such linkage was justified by the need to associate channel border areas with similar bed material.

Since the potential impacts of the tows to be analyzed will be focused on the hydraulics associated with the movement of the tow, using a Mississippi River backwater to link to an Illinois Waterway backwater is appropriate.

Single-channel contiguous backwaters were linked in a similar manner as the contiguous backwaters which have flow through them. The analysis of the hydraulic classification of single-channel contiguous backwaters for the Illinois Waterway is presented in Table 13. In this portion of the waterway, 24 single-channel contiguous backwaters were classified. Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water.

Illinois Waterway Single-Channel Contiguous Backwaters (from Table 13)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
479	17 to 3,490	425	15 to 3,420

The analysis and linking of various hydraulic areas was again based on the amount of area covered by water and the type of bed material adjacent to the particular feature being addressed. For the Illinois Waterway, the following linkages were concluded from Table 13. The classification indicated that one single-channel contiguous backwater has Group 2 cohesive soft bed material, 15 single-channel contiguous backwaters have Group 2 cohesive medium bed material adjacent to them, and 8 have noncohesive bed material.

Illinois Waterway Single-Channel Contiguous Backwaters (from Table 13)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
1	15	8	24

As accomplished previously, the association of trend pool hydraulic areas to similar areas in nontrend pools was accomplished by linking the watered area and adjacent bed material type from the trend pools to the nontrend pools. Inspection of Table 13 shows that this procedure requires some modification. Specifically, Peoria Pool backwater BW8, which has soft, cohesive bed material adjacent to it, has no trend pool on the Illinois Waterway to provide a linkage. Therefore, once again the linkage was made to a Mississippi River pool covering Pools 4 through 17 in Table 1. The Mississippi River single-channel contiguous backwaters presented in Table 2 was not used since there were no such backwaters with soft, cohesive bed material.

Illinois Waterway	
Single-Channel Contiguous Backwater with Soft Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW4**	PEOR-BW8
Single-Channel Contiguous Backwater with Medium Cohesive Bed Material	
*LAG-BW7**	PEOR-BW19, PEOR-BW3, PEOR-BW5
*LAG-BW8**	PEOR-BW12, ALT-BW6, PEOR-BW2, MAR-BW2, PEOR-BW9, PEOR-BW16, PEOR-BW6
*LAG-BW1**	ALT-BW4, ALT-BW1
Single-Channel Contiguous Backwater with Noncohesive Bed Material	
*LAG-BW2**	PEOR-BW7, PEOR-BW4, MAR-BW1, MAR-BW4
*LAG-BW3**	DRES-BW3, PEOR-BW11

The Illinois Waterway had only two impounded contiguous backwaters based on the hydraulic classification, and neither of those backwaters are in the La Grange (trend) Pool. The analysis of the hydraulic classification of impounded contiguous backwaters for the Illinois Waterway is presented in Table 14. Following is a summary of the characteristics, particularly total area and the area in the backwater covered by water.

Illinois Waterway Impounded Contiguous Backwaters (from Table 14)			
Average Total Area, acres	Limits Total Area acres	Average Water Area, acres	Limits Water Area acres
2,264	816 to 3,712	2,130	808 to 3,452

The impounded contiguous backwaters in the Illinois Waterway has both backwaters adjacent to Group 2 cohesive medium bed material. The following linkages were concluded from Table 14.

Illinois Waterway Impounded Contiguous Backwaters (from Table 14)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
None	2	None	2

Linkage of the trend and nontrend pool impounded backwaters provided the following tabulation.

Illinois Waterway	
Impounded Contiguous Backwater with Medium Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-BW4**	SR-BW4
*13-BW8**	PEOR-BW21

The Illinois Waterway impounded contiguous backwaters were linked to Mississippi River Pools 4 through 17 backwaters with at least one inlet and one outlet (Table 1). There were no impounded contiguous backwaters in that portion of the Mississippi River with Group 2 soft, cohesive bed material adjacent to them. Therefore, it was appropriate to establish the linkage between the Illinois Waterway with those Mississippi River Pools 4 through 17 backwaters.

As stated previously, secondary channels were delineated by the deflection angle and then linked using the adjacent bed material. The secondary channels addressed in the hydraulic classification are presented in Table 15. For the Illinois Waterway, there were 14 secondary channels. Following is a summary of the characteristics, including channel length, minimum width, deflection angle, and distance to the secondary channel inlet.

Illinois Waterway Secondary Channels (from Table 15)							
Average Channel Length, ft	Limits Channel Length ft	Average Minimum Width, ft	Limits Minimum Width, ft	Average Deflection Angle deg	Limits Deflection Angle deg	Average Distance to Inlet, ft	Limits Distance to Inlet, ft
6,432	2,654 to 10,779	204	74 to 380	40	19 to 64	413	230 to 582

It should be noted that at the time of this analysis, secondary channels SR-SEC1 and SR-SEC2 did not have their attributes included within the hydraulic classification. Those channels are listed on Table 15 with "N/A" (not available) entered in the various columns. As the hydraulic classification is updated, these data can and will be addressed. However, for this analysis the absence of data on two secondary channels does not significantly reduce the meaningfulness of the attributes for the rest of the secondary channels.

Of the 14 secondary channels on the Illinois Waterway, no channels were adjacent to Group 2 soft cohesive bed material, 8 channels were adjacent to Group 2 medium cohesive bed material, and 6 channels were adjacent to noncohesive bed materials. The following linkages were concluded from Table 15.

Illinois Waterway Secondary Channels (from Table 15)			
Cohesive-Soft	Cohesive-Med	Noncohesive	Total
None	8	6	14

A review of Table 15 indicates that the only La Grange (trend) Pool secondary channel is LAG-SEC1* which is adjacent to noncohesive bed material. There are no trend pool secondary channels adjacent to Group 2 soft or medium cohesive bed material. Therefore, for the Illinois Waterway secondary channels adjacent to Group 2 medium cohesive bed material were linked to Mississippi River Pools 4 through 17 secondary channels adjacent to that type of material. Specifically secondary channel 13-SEC2* was used as the linkage (Table 4).

Illinois Waterway	
Secondary Channels with Medium Cohesive Bed Material	
Trend Pool Backwater	Nontrend Pool Backwater
*13-SEC2**	ALT-SEC7, ALT-SEC2, PEOR-SEC2, ALT-SEC1, ALT-SEC2, ALT-SEC3, ALT-SEC8
Secondary Channels with Noncohesive Bed Material	
*LAG-SEC1**	MAR-SEC1, PEOR-SEC1, ALT-SEC4, ALT-SEC5

The secondary channel linkages do not include SR-SEC1 and SR-SEC2 channels, since the various attributes were not available at this time.

Navigation Channel Sediments

In all of the pooled and open river reaches of the Mississippi River, the samples of the bed material in the navigation channel were classified as non-cohesive (sand mainly) bed material. Some of the Illinois Waterway samples were somewhat different from those observed from the Mississippi River in that cohesive bed material was also collected from the navigation channel. Identification of the portions of the Illinois Waterway with cohesive bed material in the navigation channel is important for separate studies to be conducted later in the UMR study.

In the following tabulation, the portions of the various reaches in the Alton, La Grange, and Peoria Pools with cohesive bed material are identified. The pool name, river miles extrapolated from the bed material sampling range, and the bed material identified in the navigation channel are presented.

Illinois Waterway		
Navigation Channel Bed Material		
Pool	River Miles	Bed Material
Alton	27.5 to 32.5	Cohesive-Medium
Alton	57.5 to 62.5	Cohesive-Medium
La Grange	147.5 to 152.5	Cohesive-Medium
Peoria	162.5 to 167.5	Cohesive-Soft
Peoria	167.5 TO 172.5	Cohesive-Soft
Peoria	172.5 TO 177.5	Cohesive-Soft
Peoria	197.5 to 202.5	Cohesive-Medium

Therefore, there are a total of 35 miles on the Illinois Waterway that have Group 2 cohesive, either medium or soft, bed material in the navigation channel. Of those 35 miles, there is a 5-mile-long reach within the La Grange Pool, which is a study trend pool. This means that computations made in the navigation channel on that reach of the La Grange Pool can be extrapolated to similar reaches in the Alton and Peoria Pools. However, some consideration must be made within the Peoria Pool because of the existence of soft cohesive bed material and the fact that the navigation channel between RM 162.5 and 177.5 are within the impounded backwater portion of the pool (PEOR-BW21). This particular reach is significantly different from the La Grange Pool reach with cohesive bed material in the navigation channel and should be taken into consideration when making that extrapolation.

Summary

The following is a summary of the analysis for the Illinois Waterway:

a. Twelve (12) contiguous backwaters have single inlet and outlet.

(1) Average total area is 851 acres.

(2) Total area ranges from 29 to 6,055 acres.

(3) Average area covered by water is 750 acres.

(4) Area covered by water ranges from 18 to 5,873 acres.

(5) No backwaters are adjacent to Group 2 soft cohesive bed material, eight (8) are adjacent to Group 2 medium cohesive bed material, and four (4) are adjacent to noncohesive bed material.

b. One (1) contiguous backwater has multiple inlets and single outlet.

(1) Average total area is 131 acres.

(2) Average area covered by water is 527 acres.

(3) Backwater is adjacent to noncohesive bed material.

c. Seven (7) contiguous backwaters have single inlet and multiple outlets.

(1) Average total area is 2,953 acres.

(2) Total area ranges from 84 to 11,095 acres.

(3) Average area covered by water is 1,159 acres.

(4) Area covered by water ranges from 71 to 2,762 acres.

(5) No backwaters are adjacent to Group 2 soft cohesive bed material, six (6) are adjacent to Group 2 medium cohesive bed material, and one (1) is adjacent to noncohesive bed material.

d. Two (2) contiguous backwaters have multiple inlets and outlets.

(1) Average total area is 914 acres.

(2) Total area ranges from 353 to 1,476 acres.

(3) Average area covered by water is 322 acres.

(4) Area covered by water ranges from 311 to 334 acres.

(5) One (1) backwater is adjacent to Group 2 soft cohesive bed material, one (1) is adjacent to Group 2 medium cohesive bed material, and none are adjacent to noncohesive bed material.

e. Twenty-four (24) single-channel contiguous backwaters.

(1) Average total area is 479 acres.

(2) Total area ranges from 17 to 3,490 acres.

(3) Average area covered by water is 425 acres.

(4) Area covered by water ranges from 15 to 3,420 acres.

(5) One (1) backwater is adjacent to Group 2 soft cohesive bed material, fifteen (15) are adjacent to Group 2 medium cohesive bed material, and eight (8) are adjacent to noncohesive bed material.

f. Two (2) impounded contiguous backwaters.

(1) Average total area is 2,264 acres.

(2) Total area ranges from 816 to 3,712 acres.

(3) Average area covered by water is 2,130 acres.

(4) Area covered by water ranges from 808 to 3,452 acres.

(5) No backwater is adjacent to Group 2 soft cohesive bed material, two (2) are adjacent to Group 2 medium cohesive bed material, and none are adjacent to noncohesive bed material.

g. Fourteen (14) secondary channels.

(1) Average channel length is 6,432 ft.

(2) Range of channel length is 2,654 to 10,779 ft.

(3) Average minimum width is 204 ft.

(4) Range of minimum width is 74 to 380 ft.

(5) Average deflection angel is 40 deg.

(6) Range of deflection angle is 19 to 64 deg.

(7) Average distance from navigation channel to inlet is 413 ft.

(8) Range of distance to inlet is 230 to 582 ft.

(9) No secondary channel is adjacent to Group 2 soft cohesive bed material, eight (8) are adjacent to Group 2 medium cohesive bed material, and six (6) are adjacent to noncohesive bed material.

h. No sediment samples comprised of Group 1 cohesive bed material were identified.

i. The navigation channel sediment samples were noncohesive bed material except for 10 miles in the Alton Pool, 5 miles in the La Grange Pool, and 20 miles in the Peoria Pool.

(1) In the Alton Pool, RM 27.5 to 32.5 and 57.5 to 62.5, samples were medium cohesive bed material.

(2) In the La Grange Pool, RM 147.5 to 152.5, samples were medium cohesive bed material.

(3) In the Peoria Pool, RM 162.5 to 177.5, samples were soft cohesive bed material, and in RM 197.5 to 202.5, the samples were medium cohesive bed material.

j. Collectively, 312.5 miles of channel borders have Group 2 cohesive bed material.

k. Of the 312.5 miles, 167.5 miles have backwaters or secondary channels adjacent to the channel border with Group 2 cohesive bed material.

l. Of twenty-two (22) contiguous backwaters with at least one inlet and outlet,

(1) All or part of one (1) is adjacent to Group 2 soft cohesive bed material.

(2) All or part of fifteen (15) are adjacent to Group 2 medium cohesive bed material.

(3) All or part of six (6) are adjacent to noncohesive bed material.

m. Of twenty-four (24) single-channel contiguous backwaters,

(1) All or part of one (1) is adjacent to Group 2 soft cohesive bed material.

(2) All or part of fifteen (15) are adjacent to Group 2 medium cohesive bed material.

(3) All or part of eight (8) are adjacent to noncohesive bed material.

n. Of two (2) impounded contiguous backwaters, part or all of both are adjacent to Group 2 medium cohesive bed material.

o. Of fourteen (14) secondary channels,

(1) None are adjacent to Group 2 soft cohesive bed material.

(2) All or part of eight (8) are adjacent to Group 2 medium cohesive bed material.

(3) All or part of six (6) are adjacent to noncohesive bed material.

9 General Comments

The analysis of the hydraulic classification should be considered as one method for linking the various types of backwaters and secondary channels in the UMR study of trend pools where significant data exist to similar attributes in nontrend pools or river reaches where much less data are present. There are probably almost infinite ways to establish those linkages, and in fact, the methodology presented in this analysis was developed over several months and numerous reviews of the hydraulic classification and associated maps. What became evident in working through the hydraulic classification was that if one tries to provide linkages using numerous characteristics, a new classification tended to be developed. Therefore in this analysis, the linkage was based on a minimum number of characteristics or measured quantities within the hydraulic classification. Thus, the approach taken was that general characteristics and separation of attributes, such as contiguous backwaters with single inlets and outlets, was sufficient for delineation and linkage to other backwaters.

Probably one of the less attractive results using the presented analysis is the lack of trend pool data for certain attributes to provide linkages to nontrend pools. That situation was not too critical in the Mississippi River Pools 4 through 17 where three trend pools, Pools 4, 8, and 13, exist. In most cases there were adequate linkages within the hydraulic classification. In the Mississippi River Pools 18 through 27, there was only one trend pool, Pool 26, to provide linkages. While this was somewhat limiting, generally adequate linkages could be established in the nontrend pools in this portion of the Mississippi River. In the Open River portion reach with one trend "pool" in RM 31 through 74, the lack of at least one example of all of the hydraulic classification attributes in the trend "pool" reach limited linkages. However, the Illinois Waterway was the most difficult to make all of the appropriate linkages. Here the La Grange Pool did not have certain hydraulic classification attributes, such as impounded contiguous backwaters, to provide linkage to similar attributes in nontrend pools on the Illinois Waterway. In this analysis, the linkage was made to Mississippi River Pools 4 through 17 trend pools to provide at least some association. While this may not be ideal, it does provide some association to areas which have sufficient hydraulic computations to use in linking overall effects together.

Other Considerations

As this analysis progressed, it became apparent that specific hydraulic classified areas could be set aside for separate consideration when establishing

linkages. For example, the single-channel contiguous backwater 4-BW11* (Table 2) was created by a railroad embankment and hydraulically, this backwater probably reacts differently than a naturally created, similarly sized backwater. For this reason that particular backwater was not included in this analysis. Backwaters which include the confluence of tributaries such as backwaters 4-BW7* at the confluence with the Chippewa River; 10-BW7 at the confluence with the Wisconsin River; 12-BW7 at the confluence with the Galena River; 14-BW8 at the confluence with the Wapsipinican River; and numerous similar situations are potentially influenced significantly by those tributaries and the sediment from them. Such data are not readily available to apply to such specific sites; however, it may be reasonable to evaluate the impacts of navigation on such areas differently than strictly linking them to trend pools.

Size of Backwaters

The size of backwaters appears to be another hydraulic classification attribute that could be used to delineate or separate various areas. For instance, a review of Tables 1, 2, 5, and 6 indicates that several backwaters have watered areas of less than 20 acres. The 20-acre area is not the critical value. It was selected rather arbitrarily, the point being that these relatively small backwaters, when compared to the rest of the classified areas, may react significantly differently during a tow passage. Additionally, based on resource issues, such backwaters may be more or less sensitive to the potential dynamics of a tow passage. Therefore, this analysis could have separated these “small” backwaters into groups outside of the overall groups.

There are other situations throughout the hydraulic classification that could have been used to single out groups. Downstream of many of the dams and rather remote to the navigation channel some backwaters exist that, because of the operation of the dam, are not impacted by navigation at all. There are other backwaters that are associated with other structures, such as bridges or navigation features (ports and harbors), that may react differently than other backwaters in the same group. Many of the backwaters which were classified are more than 5 miles long. Again, the length of 5 miles is arbitrary, but the point is that such “long” backwaters may react differently than shorter backwaters.

The considerations presented above were not used in this analysis. The reason for that is fairly simple - as more and more specific situations are considered, the number of separate classified areas increases. The desired goal of this analysis was to reduce the number of computations required and then provide the linkages to nontrend pools. The specific or special circumstances of particular backwaters or secondary channels could be taken into consideration at the time that the linkages are applied. Then, any special consideration or critical areas can be considered on their own merits and requirements.

Table 1
Mississippi River Pools 4 through 17, Backwaters

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
Single Inlet and Single Outlet				
5-BW1	114	3	42	Cohesive-Med
14-BW6	176	28	49	Cohesive-Med
4-BW2*	249	2	67	Noncohesive
16-BW3	141	51	72	Noncohesive
17-BW5	112	72	81	Cohesive-Med
4-BW7*	697	14	98	Noncohesive
12-BW2	416	40	166	Noncohesive
14-BW3	302	7	217	Noncohesive
11-BW5	714	38	271	Noncohesive
13-BW10*	1,563	76	1,188	Noncohesive
13-BW8*	2,771	84	2,328	Cohesive-Soft
Average	660	38	416	
Multiple Inlets and Single Outlet				
14-BW2	53	45	24	Noncohesive
12-BW3	110	37	41	Noncohesive
14-BW1	234	37	87	Cohesive-Med
11-BW4	407	41	167	Noncohesive
11-BW9	226	91	206	Noncohesive
14-BW5	613	47	288	Cohesive-Med
14-BW4	2,293	23	527	Noncohesive
13-BW4*	2,338	38	888	Cohesive-Soft
10-BW1	5,471	46	2,517	Noncohesive
Average	1,305	45	527	
Single Inlet and Multiple Outlets				
10-BW2	85	46	39	Noncohesive
12-BW9	312	59	184	Cohesive-Med

Table 1 (Continued)

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
Single Inlet and Multiple Outlets (Continued)				
10-BW7	734	31	228	Noncohesive
14-BW8	523	55	288	Cohesive-Med
12-BW5	934	42	392	Noncohesive
4-BW12*	1,602	53	859	Noncohesive
5A-BW1	4,116	30	1,235	Noncohesive
Average	1,187	45	461	
Multiple Inlets and Multiple Outlets				
5-BW3	54	43	23	Noncohesive
10-BW3	55	52	29	Noncohesive
5-BW2	154	42	65	Cohesive-Med
13-BW6*	198	42	83	Cohesive-Med
7-BW1	167	58	97	Noncohesive
4-BW10*	245	42	103	Noncohesive
6-BW4	192	77	148	Noncohesive
11-BW7	312	52	162	Noncohesive
12-BW1	269	63	169	Noncohesive
17-BW2	339	53	180	Cohesive-Med
6-BW5	271	79	214	Noncohesive
9-BW2	459	49	225	Noncohesive
11-BW6	707	41	290	Noncohesive
17-BW6	774	42	325	Cohesive-Med
5-BW6	667	50	334	Cohesive-Med
6-BW1	854	42	359	Noncohesive
14-BW7	664	55	365	Cohesive-Med
13-BW7*	923	43	397	Noncohesive
10-BW5	919	46	423	Noncohesive
12-BW6	1,218	37	451	Cohesive-Med

Table 1 (Continued)

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
Multiple Inlets and Multiple Outlets				
12-BW4	908	60	545	Noncohesive
10-BW10	727	77	560	Cohesive-Med
8-BW2*	1,391	44	612	Cohesive-Med
10-BW6	1,381	50	691	Noncohesive
8-BW6	842	86	721	Noncohesive
10-BW8	1,760	42	739	Noncohesive
13-BW1*	2,900	27	783	Cohesive-Med
8-BW1*	1,718	46	790	Noncohesive
13-BW5*	1,807	44	795	Cohesive-Med
17-BW3	2,020	42	848	Cohesive-Med
17-BW1	1,944	46	894	Noncohesive
13-BW6*	2,570	36	934	Cohesive-Soft
11-BW1	2,661	39	1,038	Noncohesive
13-BW11*	1,510	74	1,117	Cohesive-Soft
12-BW8	2,281	55	1,255	Cohesive-Med
4-BW3*	3,155	43	1,345	Cohesive-Med
6-BW2	2,678	64	1,714	Noncohesive
10-BW4	3,979	47	1,870	Noncohesive
7-BW2	4,817	41	1,975	Noncohesive
10-BW9	3,006	69	2,074	Cohesive-Med
5A-BW2	4,639	45	2,088	Noncohesive
5-BW4	3,494	73	2,558	Cohesive-Med
4-BW9*	5,159	52	2,683	Noncohesive
9-BW1	8,246	35	2,886	Cohesive-Med
16-BW4	5,252	55	2,889	Cohesive-Med
11-BW8	4,767	75	3,575	Cohesive-Med
5-BW5	4,596	82	3,754	Noncohesive

Table 1 (Concluded)

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
Multiple Inlets and Multiple Outlets (Continued)				
8-BW3*	7,485	53	3,967	Cohesive-Med
9-BW4	6,726	60	4,036	Cohesive-Med
9-BW5	6,184	67	4,143	Cohesive-Med
Average	2,201	53	1,166	

Note: Asterisk after pool-backwater number indicates located in long-term trend pool. Med and Soft in Adjacent Bed Sediment column indicates erodibility label based on bed sediment characteristics.

Table 2
Mississippi River Pools 4 through 17, Single-Channel Contiguous Backwater

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
7-BW3	8	68	5	Noncohesive
11-BW2	24	73	18	Noncohesive
5A-BW3	39	62	24	Noncohesive
11-BW3	34	84	29	Noncohesive
4-BW5	111	28	31	Noncohesive
6-BW3	65	62	40	Noncohesive
16-BW2	44	92	40	Cohesive-Med
12-BW7	48	88	42	Cohesive-Med
4-BW6*	195	36	70	Noncohesive
4-BW1*	134	62	83	Noncohesive
13-BW9*	127	100	127	Cohesive-Med
15-BW1	166	85	141	Cohesive-Med
16-BW1	153	92	141	Noncohesive
5A-BW4	243	59	143	Noncohesive
4-BW8*	287	50	144	Noncohesive
4-BW4*	597	30	179	Noncohesive
4-BW11*	311	71	221	Railroad
17-BW4	349	67	234	Cohesive-Med
9-BW3	572	64	366	Noncohesive
8-BW4*	653	97	633	Cohesive-Med
Average	208	69	136	

Table 3
Mississippi River Pools 4 through 17, Impounded Contiguous Backwaters

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
4-BW13*	N/A	99	N/A	Noncohesive
10-BW12	377	97	366	Noncohesive
6-BW6	532	86	458	Noncohesive
5A-BW5	831	96	798	Noncohesive
16-BW6	1,550	71	1,101	Cohesive-Med
16-BW5	1,398	81	1,132	Cohesive-Med
10-BW11	1,684	90	1,516	Cohesive-Med
12-BW10	2,933	86	2,522	Noncohesive
13-BW12*	3,658	100	3,658	Cohesive-Med
8-BW5*	4,052	99	4,011	Cohesive-Med
9-BW7	4,657	98	4,564	Cohesive-Med
13-BW13*	6,022	86	5,179	Cohesive-Med
11-BW10	5,645	99	5,589	Noncohesive
8-BW7*	5,839	100	5,839	Noncohesive
7-BW4	8,042	91	7,318	Noncohesive
9-BW6	8,026	99	7,946	Cohesive-Med
Average	3,683	92	3,466	

Table 4
Mississippi River Pools 4 through 17, Secondary Channels

Pool-Channel	Length, ft	Minimum Width, ft	Deflection Angle deg	Distance To Inlet ft	Adjacent Bed Sediment
8-SEC4*	N/A	N/A	N/A	N/A	Left Side
8-SEC5*	N/A	N/A	N/A	N/A	Right Side
12-SEC8*	N/A	N/A	N/A	N/A	Right Side
8-SEC6*	N/A	N/A	N/A	N/A	Right Side
8-SEC2*	3,474	296	2	727	Noncohesive
7-SEC2	7,551	519	17	383	Noncohesive
10-SEC2	13,611	641	18	710	Cohesive-Med
11-SEC1	4,315	308	20	696	Noncohesive
14-SEC4	17,299	401	20	617	Noncohesive
13-SEC5*	6,055	477	26	292	Cohesive-Soft
7-SEC4	13,116	698	29	627	Noncohesive
10-SEC1	10,577	302	31	1,082	Noncohesive
13-SEC2*	5,558	386	31	263	Cohesive-Med
13-SEC4*	3,802	211	32	1,555	Noncohesive
13-SEC7*	4,922	123	32	1,276	Cohesive-Med
15-SEC1	14,217	185	35	1,286	Noncohesive
8-SEC3*	3,837	296	38	1,009	Cohesive-Med
12-SEC2	18,572	581	40	1,396	Cohesive-Med
13-SEC1*	6,851	763	41	1,289	Noncohesive
9-SEC3	6,874	241	42	474	Noncohesive
8-SEC1*	9,630	282	43	620	Cohesive-Med
9-SEC2	6,591	296	44	1,031	Cohesive-Med
14-SEC1	9,110	629	47	770	Noncohesive
14-SEC3	13,357	420	49	1,103	Cohesive-Med
5A-SEC1	7,428	747	50	551	Noncohesive
9-SEC1	9,630	581	50	704	Noncohesive
7-SEC3	7,462	575	51	562	Noncohesive
12-SEC1	22,449	279	51	877	Cohesive-Med
14-SEC2	15,142	306	52	671	Cohesive-Med
13-SEC6*	5,974	182	55	1,584	Cohesive-Med
13-SEC3*	4,412	292	60	1,734	Noncohesive
7-SEC1	5,198	351	84	779	Noncohesive
Average	9,179	406	39	881	

Table 5
Mississippi River Pools 18 through 27, Backwaters

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
Single Inlet and Single Outlet				
21-BW1	15	16	2	Noncohesive
22-BW2	15	23	2	Noncohesive
20-BW1	8	78	6	Noncohesive
22-BW8	16	61	10	Cohesive-Med
24-BW4	48	69	33	Cohesive-Med
18-BW2	57	59	34	Noncohesive
26-BW7*	169	21	35	Cohesive-Med
22-BW5	152	25	38	Noncohesive
24-BW7	81	91	74	Cohesive-Med
24-BW5	308	26	80	Cohesive-Med
20-BW3	431	25	108	Cohesive-Med
20-BW5	451	26	117	Noncohesive
25-BW6	273	44	120	Noncohesive
19-BW8	400	31	124	Cohesive-Med
19-BW4	792	26	206	Cohesive-Soft
21-BW3	1,342	47	631	Cohesive-Med
Average	285	42	101	
Multiple Inlets and Single Outlet				
22-BW9	125	40	50	Cohesive-Med
18-BW4	213	28	60	Cohesive-Med
25-BW2	144	42	60	Noncohesive
19-BW2	174	45	78	Noncohesive
20-BW2	333	29	97	Cohesive-Med
18-BW1	367	42	154	Noncohesive
26-BW2*	380	41	156	Noncohesive
24-BW1	244	66	161	Cohesive-Med
20-BW4	743	42	312	Noncohesive

(Continued)

Table 5 (Concluded)

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
Multiple Inlets and Single Outlet (Continued)				
18-BW5	1,023	31	317	Cohesive-Med
26-BW11*	1,023	33	338	Noncohesive
25-BW5	841	41	345	Noncohesive
22-BW4	870	42	365	Noncohesive
25-BW3	1,686	31	523	Noncohesive
18-BW8	2,128	46	979	Noncohesive
25-BW11	1,554	63	979	Cohesive-Med
Average	740	41	311	
Single Inlet and Multiple Outlets				
25-BW4	336	78	262	Noncohesive
25-BW8	1,004	50	502	Noncohesive
19-BW1	2,574	33	849	Cohesive-Med
Average	1,305	54	538	
Multiple Inlets and Multiple Outlets				
22-BW3	369	31	114	Noncohesive
18-BW6	422	43	181	Noncohesive
26-BW1*	2,513	15	377	Cohesive-Med
25-BW9	791	56	443	Cohesive-Med
20-BW6	883	63	556	Cohesive-Med
26-BW6*	2,237	31	693	Noncohesive
25-BW1	2,535	31	786	Noncohesive
25-BW7	3,752	33	1,238	Cohesive-Med
24-BW3	2,993	44	1,317	Noncohesive
18-BW7	3,596	38	1,366	Cohesive-Med
21-BW2	7,003	22	1,541	Cohesive-Med
19-BW9	7,218	52	3,753	Cohesive-Med
Average	2,859	38	1,030	

Table 6
Mississippi River Pools 18 through 27, Single-Channel Contiguous Backwater

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
19-BW5	13	80	10	Noncohesive
27-BW3	11	94	10	Not Available
22-BW1	14	87	12	Noncohesive
22-BW7	18	79	14	Cohesive-Med
24-BW2	28	85	24	Cohesive-Med
22-BW6	33	79	26	Noncohesive
19-BW6	38	86	33	Noncohesive
21-BW4	75	70	53	Noncohesive
26-BW9*	191	38	73	Cohesive-Med
26-BW10*	279	30	84	Cohesive-Med
27-BW2	107	92	98	Not Available
26-BW8*	178	56	100	Cohesive-Med
19-BW3	244	49	120	Noncohesive
19-BW7	422	36	152	Cohesive-Med
26-BW12*	314	72	226	Noncohesive
25-BW10	701	38	266	Cohesive-Med
18-BW3	389	87	338	Noncohesive
Average	180	68	96	

Table 7
Mississippi River Pools 18 Through 27, Impounded Contiguous Backwaters

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
27-BW1	N/A	100	N/A	Not Available
25-BW12	684	100	684	Cohesive-Med
18-BW10	738	95	701	Cohesive-Med
24-BW6	1,923	80	1,538	Cohesive-Med
18-BW9	1,878	92	1,728	Cohesive-Med
Average	1,306	92	1,163	

Table 8
Mississippi River Pools 18 through 27, Secondary Channels

Pool-Channel	Length, ft	Minimum Width, ft	Deflection Angle deg	Distance To Inlet ft	Adjacent Bed Sediment
21-SEC2	N/A	N/A	N/A	N/A	Noncohesive
26-SEC7*	N/A	N/A	N/A	N/A	Cohesive-Med
26-SEC8*	N/A	N/A	N/A	N/A	Cohesive-Med
26-SEC9*	N/A	N/A	N/A	N/A	Cohesive-Med
21-SEC1	12,885	459	17	546	Noncohesive
19-SEC1	13,538	452	25	590	Cohesive-Med
20-SEC1	10,413	337	28	732	Noncohesive
22-SEC4	6,556	611	30	1,323	Cohesive-Med
26-SEC1*	4,486	357	30	814	Cohesive-Med
24-SEC2	10,483	409	35	882	Cohesive-Med
26-SEC2*	12,212	1,168	35	1,766	Noncohesive
20-SEC2	15,120	674	36	773	Noncohesive
22-SEC1	10,835	563	40	1,180	Cohesive-Med
25-SEC1	12,306	1,209	40	1,758	Cohesive-Med
22-SEC2	10,542	254	45	1,282	Cohesive-Med
26-SEC3*	18,249	456	45	744	Noncohesive
22-SEC3	5,593	173	48	1,595	Cohesive-Med
24-SEC1	19,702	600	82	633	Noncohesive
Average	11,637	552	38	1,044	

Table 9
Mississippi River Open River Reach, Contiguous Backwaters

Reach-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
31.74-BW5*	30	34	10	Not Available
1.31-BW4	49	26	13	Not Available
31.74-BW4*	84	16	13	Not Available
140.172-BW2	102	29	30	Not Available
140.172-BW1	114	34	39	Not Available
1.31-BW6	142	31	44	Not Available
106.140-BW6	415	11	44	Not Available
74.106-BW4	148	33	49	Not Available
74.106-BW3	111	52	57	Not Available
1.31-BW1	224	37	84	Not Available
106.140-BW3	245	37	91	Not Available
106.140-BW2	433	29	124	Not Available
106.140-BW1	579	46	268	Not Available
Average	206	32	67	

Table 10
Mississippi River Open River Reach, Single-Channel Contiguous Backwaters

Reach-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
74.106-BW1	15	79	12	Not Available
1.31-BW7	15	88	13	Not Available
1.31-BW9	30	95	29	Not Available
140.172-BW4	43	95	41	Not Available
74.106-BW5	48	92	44	Not Available
1.31-BW2	48	95	46	Not Available
1.31-BW5	66	84	56	Not Available
140.172.BW3	63	94	60	Not Available
1.31-BW8	95	90	85	Not Available
106.140-BW5	91	96	87	Not Available
31.74-BW2*	171	55	94	Not Available
1.31-BW3	98	97	95	Not Available
74.106-BW2	108	93	100	Not Available
31.74-BW1*	1,141	15	172	Not Available
31.74-BW3*	291	68	199	Not Available
106.140-BW4	289	78	227	Not Available
Average	163	82	85	

Table 11
Mississippi River Open River Reach, Secondary Channels

Reach-Channel	Length, ft	Minimum Width, ft	Deflection Angle deg	Distance To Inlet ft	Adjacent Bed Sediment
74.106-SEC1	10,542	1,165	35	1,509	Not Available
1.31-SEC1	11,503	130	40	828	Not Available
1.31-SEC2	16,945	610	77	1,006	Not Available
Average	12,997	635	51	1,114	

Table 12
Illinois Waterway, Backwaters

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
Single Inlet and Single Outlet				
LAG-BW6*	90	17	15	Cohesive-Med
ALT-BW3	337	5	17	Cohesive-Med
DRES-BW1	39	59	23	Noncohesive
MAR-BW3	29	84	24	Cohesive-Med
PEOR-BW20	47	65	31	Cohesive-Med
DRES-BW2	136	49	67	Noncohesive
PEOR-BW22	198	38	75	Noncohesive
DRES-BW4	134	59	79	Noncohesive
PEOR-BW18	555	94	522	Cohesive-Med
PEOR-BW13	1,067	96	1,024	Cohesive-Med
PEOR-BW14	1,522	82	1,248	Cohesive-Med
PEOR-BW10	6,055	97	5,873	Cohesive-Med
Average	851	62	750	
Multiple Inlets and Single Outlet				
PEOR-BW1	131	50	66	Noncohesive
Single Inlet and Multiple Outlets				
SR-BW2	172	41	71	Cohesive-Med
SR-BW3	84	87	73	Cohesive-Med
SR-BW1	202	60	121	Noncohesive
LAG-BW5*	3,366	30	1,010	Cohesive-Med
PEOR-BW17	2,495	79	1,971	Cohesive-Med
LAG-BW4*	11,095	19	2,108	Cohesive-Med
ALT-BW5	3,255	85	2,762	Cohesive-Med
Average	2,953	57	1,159	
Multiple Inlets and Multiple Outlets				
PEOR-BW15	353	88	311	Cohesive-Soft
ALT-BW2	1,476	23	334	Cohesive-Med
Average	914	56	322	

Table 13
Illinois Waterway, Single-Channel Contiguous Backwater

Pool-Backwater	Total Area, acres	Percent Water	Water Area, Acres	Adjacent Bed Sediment
PEOR-BW19	17	91	15	Cohesive-Med
PEOR-BW7	28	91	25	Noncohesive
PEOR-BW4	29	89	26	Noncohesive
PEOR-BW3	33	83	27	Cohesive-Med
MAR-BW1	53	80	42	Noncohesive
MAR-BW4	71	73	52	Noncohesive
PEOR-BW5	60	89	53	Cohesive-Med
LAG-BW7*	86	81	70	Cohesive-Med
PEOR-BW12	81	92	75	Cohesive-Med
PEOR-BW8	166	86	143	Cohesive-Soft
LAG-BW2*	200	85	170	Noncohesive
LAG-BW8*	362	50	181	Cohesive-Med
ALT-BW6	226	90	204	Cohesive-Med
DRES-BW3	284	96	273	Noncohesive
PEOR-BW2	297	96	285	Cohesive-Med
MAR-BW2	322	90	290	Cohesive-Med
PEOR-BW9	352	93	327	Cohesive-Med
LAG-BW3*	458	87	398	Noncohesive
PEOR-BW16	558	98	547	Cohesive-Med
PEOR-BW6	591	95	561	Cohesive-Med
PEOR-BW11	658	97	638	Noncohesive
ALT-BW4	1,045	77	801	Cohesive-Med
ALT-BW1	2,032	77	1,571	Cohesive-Med
LAG-BW1*	3,490	98	3,420	Cohesive-Med
Average	479	87	425	

Table 14
Illinois Waterway, Impounded Contiguous Backwaters

Pool-Backwater	Total Area, acres	Percent Water	Water Area, acres	Adjacent Bed Sediment
SR-BW4	816	99	808	Cohesive-Med
PEOR-BW21	3,712	93	3,452	Cohesive-Med
Average	2,264	96	2,130	

Table 15
Illinois Waterway, Secondary Channels

Pool-Channel	Length, ft	Minimum Width, ft	Deflection Angle deg	Distance To Inlet ft	Adjacent Bed Sediment
ALT-SEC7	10,779	334	19	582	Cohesive-Med
MAR-SEC1	5,962	120	22	230	Noncohesive
ALT-SEC6	4,757	289	30	463	Cohesive-Med
PEOR-SEC2	7,449	380	30	394	Cohesive-Med
ALT-SEC1	6,445	92	33	413	Cohesive-Med
PEOR-SEC1	3,013	208	40	411	Noncohesive
ALT-SEC2	10,217	117	45	547	Cohesive-Med
ALT-SEC3	7,980	106	49	482	Cohesive-Med
ALT-SEC8	8,564	281	50	339	Cohesive-Med
LAG-SEC1*	5,313	367	50	230	Noncohesive
ALT-SEC4	4,047	81	53	427	Noncohesive
ALT-SEC5	2,654	74	64	437	Noncohesive
SR-SEC1	N/A	N/A	N/A	N/A	Noncohesive
SR-SEC2	N/A	N/A	N/A	N/A	Cohesive-Med
Average	6,432	204	40	413	

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 2000	Interim report

4. TITLE AND SUBTITLE
Definitions, Boundary Delineations, Measurements of Attributes, and Analysis of the Hydraulic Classification of Aquatic Areas, Upper Mississippi River System

5. FUNDING NUMBERS

6. AUTHOR(S)
Charles R. Nickles, Thomas J. Pokrefke, Jr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center
Coastal and Hydraulics Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
See reverse.

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ENV Report 27

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

The work reported herein was conducted as part of the Upper Mississippi River - Illinois Waterway (UMR-ILWW) System Navigation Study. The information generated for this interim effort will be considered as part of the plan formulation process for the System Navigation Study.

The UMR-IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts, Rock Island, St. Louis, and St. Paul, under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing and, in consideration of existing system lock constraints, will result in traffic delays which will continue to grow into the future. The system navigation study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic. The study will determine the location and appropriate sequencing of potential navigation improvements on the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report, including the decision documents for processing to Congress.

The U.S. Army Corps of Engineers (CE) was tasked to study and assess the impacts of potentially increased navigation traffic on the Upper Mississippi River System. The Upper Mississippi River System (UMRS) includes the upper

(Continued)

14. SUBJECT TERMS	15. NUMBER OF PAGES
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

9. (Concluded).

U.S. Army Engineer District, Rock Island, Clock Tower Building, P.O. Box 2004, Rock Island, IL 61204-2004;
U.S. Army Engineer District, St. Louis, 1222 Spruce Street, St. Louis, MO 63103-2833;
U.S. Army Engineer District, St. Paul, Army Corps of Engineers Centre, 190 5th Street East, St. Paul, MN 55101-1638

13. (Concluded).

Mississippi River (UMR) from the confluence of the Ohio River (Mile 0) near Cairo, IL, to Lock and Dam No. 3 (Mile 797) and the entire IWW from its confluence with Mississippi River to Lake Michigan. Pool 3 and above were not included in the UMRS because the potential for increased navigation traffic did not extend upstream of Dam No. 3. The study includes the development, integration, and application of hydrodynamic, hydrologic, sediment transport, and biological models to assess the impacts on the ecosystem. This modeling system will also aid in the design of required mitigation measures. The impacts include those potentially induced by new CE structures, rehabilitation, Operation and Maintenance practices, etc., that might occur due to the increased navigation traffic over the next 50 years. Both long- and short-term effects are of concern for the habitat in the main channel and channel borders, around islands, in backwater areas, sloughs, erosion of islands and banks, secondary channels, and sedimentation caused by navigation.

The analysis of the hydraulic classification should be considered as one method for linking the various types of backwaters and secondary channels in the UMR study trend pools where significant data exist to similar attributes in nontrend pools or river reaches where much less data are present. There are probably almost infinite ways to establish those linkages, and in fact, the methodology presented in this analysis was developed over several months and numerous reviews of the hydraulic classification and associated maps. What became evident in working through the hydraulic classification was that if one tries to provide linkages using numerous characteristics, a new classification tended to be developed. Therefore in this analysis, the linkage was based on a minimum number of characterictics or measured quantities within the hydraulic classification. Thus, the approach taken was that general characteristics and separation of attributes, such as contiguous backwaters with single inlets and outlets, was sufficient for delineation and linkage to other backwaters.