FEASIBILITY INVESTIGATION

HYDROGEOMORPHIC MODELING AND ANALYSES

UPPER MISSISSIPPI RIVER SYSTEM FLOODPLAIN

Report Prepared For:

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Photo credits

Cover photo - "The Mississippi" by Jean Baptiste Louis Franquelin (ca. 1682). Notation says this may be the very first map of the Mississippi River. Library of Congress. Louisiana: European Explorations and the Louisiana Purchase. <http://memory.loc.gov/ammem/collections/maps/lapurchase/index.html>

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National Park Service <nps.gov>

U. S. Army Corps of Engineers <www.mvp.usace.army.mil>

University of Missouri. Lewis and Clark Expedition, University of Missouri Geography website, <http://lewisclark.geog.missouri.edu>

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EXECUTIVE SUMMARY

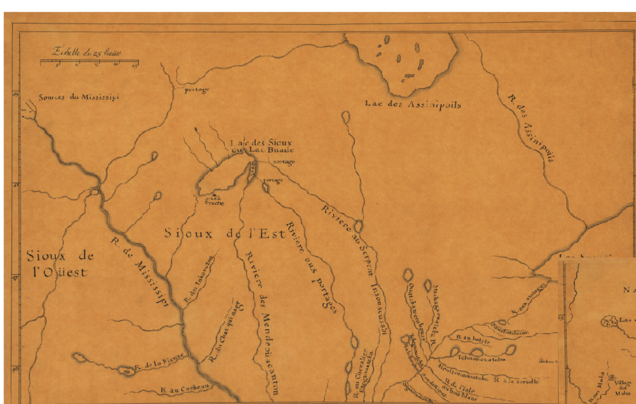
This report assesses the feasibility of conducting a Hydrogeomorphic Method (HGM) evaluation of ecosystem restoration and management options for the Upper Mississippi River System (UMRS). Objectives of the report are to: 1) identify the availability of historic data for use in developing HGM matrix models for the historic UMRS ecosystem, 2) identify the availability of current data for understanding changes to the UMRS ecosystem from historic condition, 3) identify current technology and expertise needed to develop HGM models and maps, and 4) assess the feasibility of developing HGM evaluations for the entire UMRS.

The HGM process of evaluating ecosystem restoration and management options relies heavily on eight types of data, most of which requires geospatial digital information usable in an ArcGIS/ArcMAP format. These data include historic and current information about: 1) soils, 2) geomorphology, 3) topography/elevation, 4) hydrology/flood frequency, 5) aerial photographs and cartography maps, 6) land cover and vegetation communities, 7) presence and distribution of key plant and animal species, and 8) physical anthropogenic features. A questionnaire asking about availability of these HGM data was sent to key staff of the U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service, and other resource agencies and groups within the St. Paul, Rock Island, and St. Louis Districts of the USACE. In addition to the questionnaire, many other individuals familiar with GIS databases and historical biological information were contacted and a thorough review of published literature also was conducted.

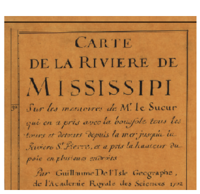
The discovery and understanding of the geospatial and biological data from this feasibility study indicates that most of the data needed to conduct an HGM evaluation for the UMRS are available. Fortunately, all of the basic data for soils, geomorphology, topography, and hydrology are available for the broad river regions of the UMRS and further, historic information on vegetation/ecological communities are present, at least to

some extent. Some data are more detailed and extensive (e.g., soils) than others (e.g., topographic surveys at < 5-foot contours) and some limitations occur. Also, data are most complete for the Mississippi and Illinois River floodplain regions and less available for the navigable tributary reaches of the Kaskaskia, Black, St. Croix, and Minnesota rivers.

This report concludes that an HGM evaluation for the UMRS is possible with existing geospatial and ecological data sets. This conclusion depends on refinement, spatial reference conversion, collation, and geo-referencing of certain GIS data sets. The HGM evaluation should be divided into project work plans and time schedules by UMRS ecoregions, not by political or physical boundaries. These ecoregion evaluations then should be compiled by major river area within an entire UMRS systemic framework to form comprehensive evaluation and understanding of ecosystem conservation needs and strategy under the Navigation and Environmental Sustainability Program (NESP) Forest Management Project. A complete HGM evaluation for the UMRS probably can be done in 3-5 years, given certain caveats. Currently, an HGM evaluation for the southern UMRS (Mississippi River floodplain from Cairo, IL to the confluence of the Missouri and Mississippi rivers) is being conducted. This evaluation will be completed in FY08 and will be a foundation to continue comprehensive HGM evaluations from the south to the north along the Mississippi River and then expansion to the Illinois River and major navigable tributaries.



Guillaume, 1702



St. Anthony Falls, MN. NPS photo

Figure 1. Location of rivers and navigation pools in the Upper Mississippi River System.

INTRODUCTION

The Upper Mississippi River System (UMRS) includes floodplain lands (area between river bluffs) and waters along the Upper Mississippi River, the Illinois River, and navigable portions of the Minnesota, St. Croix, Black, and Kaskaskia rivers in the states of Missouri, Illinois, Iowa, Wisconsin, and Minnesota (Fig. 1). The UMRS contains five distinct regions that contain about 2.8 million acres (Table 1) and is an internationally important ecosystem and waterborne transportation corridor. The UMRS also contains the largest continuous system of open water, wetlands, and floodplain habitats in North America. The ecological communities in the UMRS are highly productive and diverse and provide critical ecosystem functions and values including groundwater recharge, surface water storage, flood control, climate control, biogeochemical cycling and storage including carbon sequestration, filtration of chemicals and contaminants, high primary and secondary production, erosion control, denitrification, habitat for unique species, sustaining biodiversity, timber production, medicinal and cultural resources, recreation, and education/research. Several million U.S. citizens use and rely on these UMRS functions and values each year.

The Mississippi River (and its tributaries) is one of the world's most important and intensively regulated river systems. Most UMRS rivers and associated floodplains have been extensively modified for commercial navigation, agriculture, and other human developments. Ecological degradations to UMRS ecosystems have been caused by alterations to natural hydrology, increased sedimentation and dissolved solids in waters and wetlands, land clearing for agriculture and human developments, and changes in local and regional topography. Perhaps the most dramatic change to the region occurred after construction of Locks and Dams on the Mississippi River from Alton, IL to St. Paul, MN and on the Illinois River from Alton to Starved Rock, IL (Table 1). After Locks and Dams were built, water levels generally were raised and stabilized in these rivers and more frequent and prolonged flooding ultimately killed less water tolerant trees in floodplains and enlarged bottomland lakes.

The cumulative environmental changes to the UMRS have greatly altered type, distribution, and area of vegetation communities from Presettlement to current times. Generally, bottomland prairie and bottomland hardwood forests have been greatly destroyed, river connectivity to floodplains has

Table 1. Location and area of Mississippi (UMR) and Illinois (IWW) River regions within the Upper Mississippi River System.

Region	Location	Acres
UMR Upper Impounded	Pool 1 - St. Paul, MN through Pool 13 - Fulton, IL	507,004
UMR Lower Impounded	Pool 14 - LeClair, IA through Pool 26 - Alton, IL	976,395
UMR Un-Impounded	Hartford, IL through Cairo, IL	673,053
IWW Upper	Lockport, IL through Starved Rock, IL	62,823
IWW Lower	Pool 26 - Grafton, IL through Peoria, IL	549,354

been eliminated or reduced, remnant native habitat patches are highly fragmented, and plant and animal species composition have shifted and communities now include many non-native species. For example, UMRS forests immediately adjacent to the Mississippi and Illinois rivers have changed from a heterogeneous mix of many hardwood species that were distributed along geomorphic, soil, and topographic gradients to more monotypic stands dominated by early successional "riverfront" species such as silver maple, black willow, cottonwood, and sycamore. Further, many riverfront forest stands are even-aged (often relatively mature) with little understory and limited seedling regeneration.

Active restoration, management, and enhancement programs are needed to protect and sustain UMRS native ecosystems, especially bottomland forest types. The Navigation and Environmental Sustainability Program (NESP) Forest Management Project is a Special Initiative Measure of the Ecosystem Restoration feature of NESP and it seeks to develop and implement a "Systemic Forest Management Plan" for the UMRS. The NESP seeks long-term sustainability of the ecological integrity of the UMRS with goals to provide diverse ecological communities for fish and wildlife, especially during flood events; reduce soil erosion and sediment loads in rivers and wetlands; improve water quality; ensure sustainability and diversity (species composition, distribution, size and age classes, and regeneration) of floodplain forests; and improve recreational and scenic landscapes.

The purpose of the NESP Systemic Forest Management Plan is to provide a long-term plan of action that will ensure that the UMRS ecosystem restores and sustains critical ecosystem functions and values through the management and restoration of floodplain forests, grasslands, and associated wetlands to a desired future condition. The desired future condition is intended to be some semblance of native Presettlement species composition, distribution, size, disturbance processes, and regeneration. The NESP Systemic Forest Management Plan seeks to use a three-stage process, referred to as the Hydrogeomorphic Method (HGM) to identify ecosystem restoration and management options in the UMRS. This HGM evaluation process recently has been used to successfully identify and plan restoration and management options in several large river floodplain ecosystems (e.g., Heitmeyer and Fredrickson 2005, Heitmeyer et al. 2006, Heitmeyer and Westphall 2007) and is applicable to the UMRS. A major benefit of HGM evaluations is the ability to determine what a sustainable "desired future condition" can be in large river floodplains. HGM evaluations are based on: 1) information on geomorphology, soils, topography, and hydrology to determine type, distribution, and sustaining ecological processes of Presettlement communities; 2) a desire to emulate natural water regimes and natural vegetation comminutes where possible; 3) an understanding of local and regional land use changes; 4) incorporation of state-of-the-art scientific knowledge of wetland/floodplain ecological processes and key plant and animal species; and 5) recognition of the desire for multiple uses.

The three-stages of HGM are as follows:

First, the historic condition and ecological processes of an area and its surrounding landscapes are determined from a variety of historical and current information such as geological, hydrological, and botanical maps and data. General Land Office (GLO) maps and notes are especially useful to understand historic vegetation composition and distribution. A key element of HGM is developing a "matrix" of understanding of which plant communities historically occurred in different geomorphological, soil, topographic, and flood-frequency settings. For example, in the Mississippi-Missouri River Confluence Area, wet bottomland prairie that was dominated by prairie cordgrass historically occurred at elevations greater than 417 feet, on relict alluvial floodplain terrace surfaces, on Beaucoup silt loam soils, and between the two- and five-year flood frequency zones (Heitmeyer and Westphall 2007). Contemporary areas that offer these conditions, especially surface, soil, and flood frequency attributes now offer the best potential sites for restoring wet bottomland prairie communities.

Second, alterations in hydrological condition, topography, vegetation community structure and distribution, and resource availability to key fish and wildlife species are determined by comparing historic vs. current landscapes. This analyses essentially is a realistic honest assessment of current condition and the types and magnitudes of changes, including assessment of which communities are most resilient to changes and which change types are the most/least reversible.

Third, options and approaches are identified to restore specific habitats and ecological conditions. The foundation of ecological history coupled with assessment of current conditions helps to determine which system processes (e.g. periodic dormant season flooding) and habitats (e.g. forest composition) can be restored or enhanced, and where this is possible, if it is at all. Obviously, some landscape changes are more permanent and less reversible (e.g., mainstem levees on the Mississippi and Illinois rivers) than others (e.g., clearing of bottomland forest). Through development of the HGM "matrix," conservation planners can identify: 1) which, and where, habitat types have been lost or altered the most and establish some sense of priority for restoration efforts; 2) where opportunities exist to restore habitats in appropriate geomorphic, soil, hydrological, topographic settings including both public and private lands; 3) how restoration can replace lost functions and values including system connectivity; and 4) what management types and intensity will be needed to sustain restored communities.

Given the tremendous potential, proven success, and immediate application of results from the HGM process, the UMRS Forest Management Project seeks to determine the feasibility of using an HGM approach for the entire UMRS as part of NESP. Currently HGM is being used to develop ecosystem restoration options for the Middle Mississippi River region from St. Louis, MO to the confluence with the Ohio River at Cairo, IL. NESP planners are interested in learning if adequate data are available to conduct a similar evaluation for the remainder of the UMRS. A system/regional-scale HGM approach is considered to be a critical initial screening and scenario-testing tool within an integrated decision support system, and is expected to assist in UMRS prioritization of restoration planning and decision making for the NESP Forest Management Project.

Objectives of this feasibility report are to:

1. Identify the availability of historic data for use in developing HGM matrix models for the historic UMRS ecosystem.

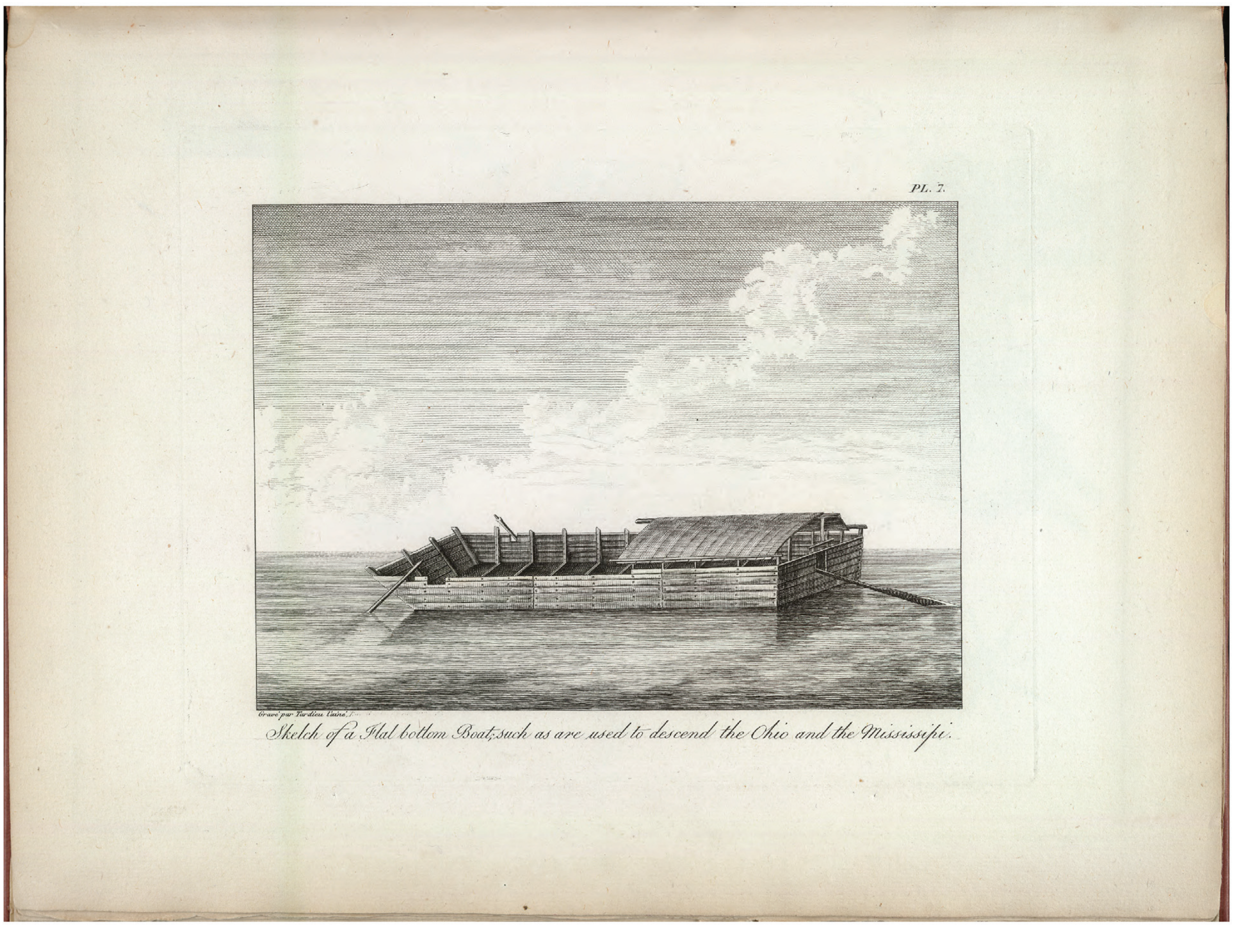
2. Identify the availability of current data for understanding changes to the UMRS ecosystem from historic condition.

3. Identify current technology and expertise needed to develop HGM models and maps.

4. Evaluate and assess the feasibility of developing HGM assessments for the entire UMRS.

This report will recommend an approach to using the HGM evaluation process to evaluate restoration and management options for the UMRS and identify constraints and assumptions that are inherent in HGM models and analyses as they may be used in the UMRS.

Panoramic photograph, St. Paul, MN. c1916


PL. 7.
Gravé par Tardieu l'ainé.
Sketch of a Flat bottom Boat; such as are used to descend the Ohio and the Mississipi.

AVAILABILITY OF HGM "DATA"

The HGM process of evaluating ecosystem restoration and management options relies heavily on eight types of data/information, most of which requires geospatial digital information usable in an ArcGIS/ArcMAP format. These data include historic and current information about: 1) soils, 2) geomorphology, 3) topography/elevation, 4) hydrology/flood frequency, 5) aerial photographs and cartography maps, 6) land cover and vegetation communities, 7) presence and distribution of key plant and animal species, especially those of concern, and 8) physical anthropogenic features.

A major part of assessing the feasibility of conducting an HGM evaluation for the UMRS is determining the availability and form of these eight data sets. A questionnaire asking about availability of HGM data (Appendix A) was prepared and sent to key contact staff of the U.S. Army Corps of Engineers (USACE), U. S. Fish and Wildlife Service (USFWS), and other resource agencies/groups within the USACE St. Paul, Rock Island, and St. Louis Districts. In addition to the questionnaire, many other individuals familiar with GIS data bases and historical biological information from the USACE, USFWS, state resource agencies, universities, non-governmental organizations, and natural history groups were contacted about data availability. Also, numerous reference articles, books, reports, etc. were obtained and checked for literature cited and information sources. A summary of data availability in the three USACE Districts (St. Paul, Rock Island, St. Louis) of the UMRS is provided below.

Soils

Digital soils data and maps are readily available for all areas of the UMRS (Table 2). Most importantly, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) now has developed a U.S. General Soil Map (STATSGO) and Soil Survey Geographic data

Table 2. Availability of historic and current soils data for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
Soils	Some hard copy county maps - old & new	Some hard copy county maps - old & new	Some hard copy county maps - old & new
	STATSGO data	STATSGO data	STATSGO data
	Digital SSURGO by county	Digital SSURGO by county	Digital SSURGO by county
	Alluvial soils data digitized from old maps	Soil boring data for several projects	
	Boring log data 1999, 2000, 2005	Navigation study boring data	
	Hard copies of older soils maps for counties in Pools 24-27 and Kaskaskia Lock	Grain size analyses for dredge cuts	

base (SSURGO) for the entire U.S. including all of the UMRS. STATSGO is a contemporary soil map of general soil association units developed by the National Cooperative Soil Survey and supersedes the State Soil Geographic Dataset that was published in 1994. It is a broad based inventory of soils and non-soil areas that occur in a repeatable pattern on the landscape and is cartographically shown at various scales. The data set was assembled from data on geology, topography, vegetation, and climate along with Land Remote Sensing Satellite (LANDSAT) images. This data set is geo-referenced vector digital data and tabular digital data. All soils data were collected in 1- by 2-degree topographic quadrangle units and merged into a "seamless" national data set. This seamlessness is important to merge information across county lines and to address inconsistencies related to mapping soils across physical boundaries (such as county lines), among different surveyors, and over different time periods. The soil map units are linked to attributes in the tabular data, which give the proportionate extent of the component soils and their properties.

SSURGO is the soil mapping database with map scales ranging from 1:12,000 to 1:63,360. SSURGO is the most detailed level of soil mapping ever conducted by NRCS and is based on digitizing duplicates of original soil maps and refining older maps with recent ground surveys. SSURGO is available for all counties in the UMRS. Digitizing soil boundaries was done by line segment (vector) format in accordance with NRCS standards and data are distributed as a complete coverage for a soil survey area. The attribute database gives the proportionate extent of the component soils and their properties for each map unit. Information that can be queried from the database are available water capacity; soil reaction; electrical conductivity; flooding frequency; building site development and engineering uses; and potential for cropland, woodland, rangeland, and pasture establishment. A convenient website to obtain soil survey information is www.websoilsurvey.nrcs.usda.gov.

In addition to SSURGO and STATSGO, other soils information exists for many areas within the UMRS (Table 2). Hard copies of older soil survey maps and reports are available for most counties in the UMRS. Dates of older soil surveys vary depending on when each county was first surveyed and how many times revised surveys and new reports were completed. These older surveys have been integrated into SSURGO. As independent reports, they are useful to HGM evaluations because they often have ecological descriptions of UMRS floodplain areas that existed at the time of the original surveys and help understanding of topographic and vegetation community distribution and subsequent changes that have occurred in the last century.

Some soil boring data also are available for specific locations along the Mississippi and Illinois rivers where specific engineering projects have occurred. These data are not stored in a central database, but are available within project files and can be retrieved if this information is needed for a specific location or area. Soil core data also are available for 950 locations associated with the USACE Navigation Study from St. Paul to St. Louis. Grain size analyses for dredge cuts and stockpile sites are in Excel files by river mile and year for Mississippi River areas within the Rock Island District.

Geomorphology

Several sources of information are available on the geology and geomorphology of the UMRS (Table 3). Landform sediment assemblage (LSA) maps for the Mississippi River floodplain area in the USACE St. Louis District and in the Illinois and Des Plaines River Valleys (Hajic 2000). Rock Island District (Bettis et al 1996) and St. Paul District (Madigan and Schirmer 1998) now are available in digital form. These LSA unit maps are interpreted from geomorphic maps constructed on U.S. Geological Survey (USGS) 7.5' topographic maps and available subsurface information. Data maps are geo-referenced and digitized using ArcInfo GIS platforms. LSA units are defined, described, and summarized related to distribution along river floodplain valleys, relationships to other LSAs, sedimentology, stratigraphy, and depositional environments. They also attempt to determine relative and absolute ages of surfaces. LSA maps are based on substantial geologic literature and maps of the UMRS and construct a framework of late Wisconsin and Holocene landscape evolution. Soil boring records listed in the previous soils section provide useful stratigraphic information. For example, in the Illinois River Valley, the depth of contact between subsurface sand and overlying fine-textured alluvial silts, and whether the sand is oxidized or not, can be very different depending on the LSA. Understanding geomorphic stratigraphy is important to determine soil restrictive layers, surface and groundwater flow, root-zone penetration areas and depths, and availability of nutrients. These features affect which plant communities can survive on a site and are important considerations for devel-

Table 3. Availability of geomorphology data for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
Geomorphology	Surface geology maps	Surface geology maps	Surface geology maps
	Land Sediment Assemblage maps	Land Sediment Assemblage maps	Land Sediment Assemblage maps
	Hard copy and digital - Saucier & Woerner		Land form maps Mississippi River RM 855-614
	Channel change geomorphology - Brauer et al.		Subsurface stratigraphy maps

opment plans if projects intend to remove or alter surface soils for levees, ditches, etc.

The Quaternary geology of the Mississippi River floodplain from St. Louis to Cape Girardeau, MO also has been mapped for approximately ten topographic quadrangles (Woerner et al. 2003). This mapping: 1) determined the areal distribution and physical characteristics of the various alluvial deposits, 2) reconstructed the general geology of the area, 3) conducted subsurface stratigraphic correlation of various geologic environments of deposition, and 4) determined the depth and general nature of Paleozoic deposits beneath the Holocene alluvium to the extent possible. The “Woerner” report for this region is a continuation of previous studies (Saucier 1994) within the Lower Mississippi Valley and the Deltaic Plain that was sponsored by the USACE Research and Development Center (ERDC) in the 1980s and 1990s. The “Saucier” surface and stratigraphy maps are available for the Mississippi River floodplain south of Cape Girardeau and provide a complete mapping of geomorphology in the lower UMRS to Cairo, IL. Both the “Woerner” and “Saucier” maps present data at a standard 1:62,400-scale topographic map supplemented with the surface geology and one or more detailed geologic cross sections. These geologic maps and cross sections are presented as scanned digital images in a JPEG format. The “Saucier” maps are geo-referenced and recently, the “Woerner” maps were geo-referenced as part of the Middle Mississippi Partnership HGM ecosystem evaluation project.

The USACE also has conducted geomorphological studies of channel changes of the Mississippi River in some regions (e.g., Brauer et al. 2005). These studies qualitatively and quantitatively chronologize the historic planform changes of the river and adjacent floodplain areas. These channel change maps are based on many historic maps, surveys and journals dating back to the eighteenth century. They include early 1800s Government Land Office (GLO) surveys (Government Land Office 1806-1850), 1866 Mississippi River maps produced by the USACE under the direction of Bvt. Major General G.K. Warren (Warren 1869), the 1881 Mississippi River Commission (MRC) surveys (Mississippi River Commission 1881), and aerial photographs from 1928-2003. Other old maps originate from river charts prepared by Victor Collet in 1796 (Collot 1826).

Many geological articles, reports, and maps exist for UMRS regions including detailed stratigraphy maps for some areas (e.g., Willman et al. 1975). All states in the UMRS have extensive published accounts of geology (e.g., Unklesbay and Vineyard 1992) including readily available digital surface geology maps (e.g., www.geo.umn.edu/mgs, www.igsb.uiowa.edu, www.uwex.edu/wgnhs, www.usgs.gov). Also, many specific geological and archaeological studies have been conducted at many UMRS locations including USACE project sites (e.g., Munson 1966, Smith and Smith 1984).

Topography/Elevation

Data on topography and elevations of UMRS floodplains are variable in extent and scale (Table 4). Digital and hard copy 7.5 minute USGS quadrangle maps at a 5-foot contour scale are available for all of the UMRS and are stored in UTM coordinates. These maps are 1:24,000 digital raster graphic (DRG) maps mostly from the late 1990s. Data are available through ArcSDE and as TIFF and SID files. Older hard copy USGS quadrangle maps also are

Table 4. Availability of historic and current topography/elevation data for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
Topography/ Elevation	Digital & hard copy USGS quads - late 1990's	Digital & hard copy USGS quads - late 1990's	Digital & hard copy USGS quads - late 1990's
	1881 Mississippi River Commission Maps	1881 Mississippi River Commission Maps	1881 Mississippi River Commission Maps
	1866 Warren maps	1866 Warren maps	1866 Warren maps
	1928-1929 Acquisition Maps	1928-1929 Acquisition Maps	1928-1929 Acquisition Maps
	USGS 30m DEMs	USGS 30m DEMs	USGS 30m DEMs
	1993 Landsat - NED dataset	1993 Landsat - NED dataset	1993 Landsat - NED dataset
	SAST Flowage survey map	SAST Flowage survey map	SAST Flowage survey map
	Mississippi River DEM/DTM project, Earthdata	Mississippi River DEM/DTM project, Earthdata	Mississippi River DEM/DTM project, Earthdata
	1 & 5' bathymetry for several sites on the Illinois River	1' bathymetry 1890 & 1930	
	Special project maps: Shanks Wilkinson Island Cuivre West Port Dardenne Alton to Gale Chain of Rocks	Sediment Range profiles 1930s-1970s 1998 Mississippi River & 2004 Illinois River digital terrain maps	Special project maps
	Site-specific LIDAR	Pool 8 to 24 LIDAR supplement to Iowa State data	Pool 8 to 24 LIDAR supplement to Iowa State data
	1902-1904 Woermann maps - Illinois River		LIDAR Lake Odessa Pools 17 & 18
			LIDAR lower Pool 4 & Pool 5 and Emiquon West

available for most of the UMRS but dates of maps vary widely (e.g., early 1930s to late 1950s) among areas. Older topographic maps at a 5-foot contour scale include those produced by the MRC in 1881 for the Mississippi River, Mississippi River Board maps prepared in 1908, and USACE "acquisition" maps prepared by Brown in the 1930s (most of the Upper Mississippi River floodplain areas). These older maps now are available in hard copy and in TIFF format generated by scanning original maps. The "Brown" maps are geo-referenced for Mississippi River miles 604-815. The MRC and Brown maps currently are being digitized to determine the best data for future reference to historic flood regimes.

Topographic maps at a < 5-foot contour scale exist for many areas in the UMRS, but they are not complete coverage maps. Most topographic maps of < 5-foot contours were generated by special project needs. The oldest topographic maps, prepared at a 1-foot contour interval, were conducted by Woermann (1902-1904) for the Illinois and Des Plaines rivers. These "Woermann" maps identify topographic contours and also show general habitat communities (i.e., forest, prairie, open water) and other physical features. The "Woermann" maps are available in hard copy and digital, georeferenced forms. In the 1930s, a series of 2- foot contour maps were produced for most of the UMRS by the USACE prior to land acquisition for development and operation of Locks and Dams. These "acquisition" maps are available in hard copy and scanned versions. Some acquisition (plane table) maps from the late 1930s to mid 1940s also exist in 1-foot contours; these are hard copy and some scanned versions. None are completely available in digital or geo-referenced form.

Following the 1993 flood, the White House established the Scientific Assessment and Strategy Team (SAST) to provide scientific data and advice for flood recovery and river basin management in the Upper Mississippi River Basin. The SAST, USACE, and private industry cooperated to collect high-resolution elevation data and to produce high accuracy digital elevation models (DEM) along parts of the floodplains of the Upper Mississippi, Lower Missouri, and Illinois rivers. These DEMs were developed from aerial photography up to 1996 and are available in ArcGIS and CAD digital files. Data are from mass points and break lines and were intended to create 4-foot contours and assist development of flowage survey maps. A digital terrain map (DTM) was refined for most of the Illinois River in 2004 by the Rock Island District of the USACE. A recent Mississippi River DEM/DTM project is seeking to refine the DEMs to a small vertical resolution (in some cases to 1/10 foot for elevated roads, levees, railroads, and major topographic changes).

Light Detection and Ranging (LIDAR) elevation maps, usually <2-foot contour resolution, are available for some special project sites and areas in the UMRS. In the St. Paul District, LIDAR is available for most of Pools 4 and 5. In the Rock Island District, the state of Iowa has completed some LIDAR mapping of the Mississippi River floodplain south to Keokuk, IA in cooperative funding with the USACE. Specific LIDAR information is available at the Lake Odessa HREP project area in Pools 17 and 18, for much of Pool 18 associated with a 2-foot drawdown planned for summer 2007, at the Long Island Division of the Great River NWR, and at the Emiquon West site within the Emiquon NWR. The USACE recently contracted LIDAR mapping of bluff to bluff elevations (for a 2-foot contour map) for Pools 8 to 24 in FY08 to supplement LIDAR acquisition by the state of Iowa for the Iowa side of these pools.

In the St. Louis District, stereoscopic photogrammetry has been used to map elevations for the Ted Shanks Conservation Area south of Hannibal, MO and at Wilkinson Island. Other specific elevation maps at a 1-foot contour interval exist for EMP projects at Cuiver Island, West Port and Dardenne, and along the Mississippi River from Alton to Gale, IL and in the Chain of Rocks area.

Other sporadic elevation data exist for certain areas of the UMRS including sediment range profiles, river bathymetry, and ground elevation GPS maps. Sediment range profiles in the Rock Island District date from the 1930s to the 1970s and were permanently marked sediment profiles established approximately every river mile. Data include elevation, distance along transect, and topographic features every 50 to 100 feet in Pools 10-24. Comprehensive 5-foot and 1-foot bathymetry data from 1890 and the 1930s also are present for many areas from Pools 1-26 and on the Illinois River. A few sites with bathymetry data are digitized and all maps are scanned and geo-referenced. Ground elevation GPS data have been generated from many sources including NRCS Wetland Reserve Program (WRP) lands, state and federal resource agency acquisitions and ownerships, private hunting clubs, and non-governmental conservation organization projects in UMRS floodplains. The availability of these ground data is variable, however, and is in various GIS formats.

Hydrology and Flood Frequency

Much basic data exist on the hydrological patterns of the UMRS, its rivers, and surface water fluctuations in floodplains. Data include historic and contemporary information on timing, depth, duration, and frequency of river flows and overbank flooding for the navigable portions of the Mississippi, Illinois, Minnesota, St. Croix, Black, and Kaskaskia rivers (Table 5). Geographically, GIS shape files and maps exist for the 11-digit watersheds of all ecological drainage units and SAST data and maps are available to delineate the 100- and 500-year floodplains of each river area. Further, the SAST data and maps couple elevation with river flow and discharge data to identify current flood frequency zones at a 1-, 2-, 5, 10-, 25- 50-, and 100-year flood intervals. These data are available for the entire Mississippi River floodplain from St. Paul to Cairo (www.mvr02.usace.army.mil/flow_freq/flow_freq.cfm). The USACE has tabular and shape file data on cross section vector line data with frequency stage data accompanying it for elevations in the 2-, 5-,10-, 25-, 50-, 100-, and 500-year floodplains. The USACE supported a "Cumulative Effects Study" (WEST

Table 5. Availability of historic and current hydrology and flood frequency data for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
Hydrology and Flood frequency	SAST data and Flow Frequency Maps	SAST data and Flow Frequency Maps	SAST data and Flow Frequency Maps
	River gauge data	River gauge data	River gauge data
	Maps of 11-digit watersheds & ecological drainage units	Maps of 11-digit watersheds & ecological drainage units	Maps of 11-digit watersheds & ecological drainage units
	2000 Cumulative Effects Study	2000 Cumulative Effects Study	2000 Cumulative Effects Study
	Groundwater well & peziometer - various	Groundwater well & peziometer - some limited sites	Groundwater well & peziometer - some limited sites
	Pre-post dam hydrologic analyses	Pre-post dam hydrologic analyses	Pre-post dam hydrologic analyses
		1903 Bathymetric data	

Consultants, Inc. 2000) that investigated Mississippi River navigation including planar changes in land form, profile changes, flood storage, and includes both recent and older historic maps and photography. Additionally, a metadata inventory of hydrographic survey and cross-section data for the Upper Mississippi River and Illinois Waterway was conducted by Soileau (2002).

River gauge data are available at many stations on UMRS rivers and most stations have relatively uninterrupted data back to the late 1800s. Some stations (e.g., Grafton, IL) have data to the late 1870s while others (e.g., Thebes Gap) have continuous data only to the early 1900s. Gauge data are available in graphic and tabular form and most information is readily available from USGS and USACE websites (e.g., www.mvr02.usace.army.mil/watercontrol/new/layout.cfm). Several studies have analyzed Mississippi and Illinois river flow dynamics pre- and post-Lock and Dam periods (e.g., Theiling 1996, Demissie 1998) and describe dynamics of flow amplitudes both seasonally and long-term. Other specific studies have evaluated site-specific changes and flooding characteristics of floodplain habitat types (e.g., Heitmeyer and Westphall 2007).

Many studies have investigated sediments and dissolved solids in UMRS waters including tributaries to larger rivers and in floodplain wetlands and lakes (e.g., Cahill and Steele 1986, Demissie et al. 1992). These data and historic bathymetric data from rivers and bottomland lakes provide assessment of changes in water storage capacity and flooding inundation in many UMRS areas. Other studies, most recently the USGS Long Term Resource Monitoring program (LTRM) have documented changes in limnological characteristics of the river waters.

Information on groundwater levels and subsurface water interactions between UMRS rivers and their floodplains is less available than for surface waters. Groundwater wells and peziometer stations are present in some UMRS floodplain locations in each of the St. Paul, Rock Island, and St. Louis Districts. The availability and accessibility of this groundwater data are variable and occur in CAD files, hard copy files, Excel spreadsheets, and engineering design data sheets from the 1950s.

Aerial Photographs and Older Cartography Maps

An excellent time-series of aerial photographs exist for most of the UMRS regions (Table 6). The oldest complete aerial photographs for the Mississippi River are digital (TIFF) photographs from 1928 and 1929. These photographs were obtained prior to the period of major acquisition of lands along the Mississippi River by the USACE in preparation for construction of Locks and Dams and upstream reservoirs. In 1930 aerial photographs were taken covering most of the floodplain of the

Mississippi River and are known as the "Brown" survey photos. These photographs now are digital files scanned at 300 dpi resolution and they have been geo-referenced. Older aerial photographs also are available from this period on the Illinois River and are in digital form. Some similar photographs also are available for areas of the Kaskaskia, Black, St. Croix, and Minnesota rivers near their confluences with the Mississippi. In specific pools (e.g., Pools 8, 15, and 21) old aerial photographs have been organized as georeferenced mosaics from 1930, 1937, 1947, 1954, and 1961.

A variety of aerial photographs exist for the UMRS from the 1940s to the present. Most older photography has been digitally scanned and exist as analog aerial photos. Analog stereo photo paired

Table 6. Availability of historic and current aerial photographs and cartography maps for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
Aerial photographs and older cartography	Older photographs, pre-navigation project periods	Older photographs, pre-navigation project periods	Older photographs, pre-navigation project periods
	1928-1929 Acquisition Photographs	1928-1929 Acquisition Photographs	1928-1929 Acquisition Photographs
	1890 Landcover maps	1890 Landcover maps	1890 Landcover maps
	1796 Collot maps	1796 Collot maps	1796 Collot maps
	LTRM various maps and photos	LTRM various maps and photos	LTRM various maps and photos
	1995-96 ortho photos for SAST Flow Frequency Study	1995-96 ortho photos for SAST Flow Frequency Study	1995-96 ortho photos for SAST Flow Frequency Study
	Early Lewis & Clark	Early Lewis & Clark	Early Lewis & Clark
	2004-05 NAIP maps	2004-05 NAIP maps	2003-05 NAIP maps
	Mississippi River Commission Maps	Mississippi River Commission Maps	Mississippi River Commission Maps
	Special project maps, flood event photos	Special project maps, flood event photos	Special project maps, flood event photos
	Mississippi River Charts 1866 & 1876	Mississippi River Charts 1866 & 1876	Mississippi River Charts 1866 & 1876
	Mississippi River Board Sheets 1908	Mississippi River Board Sheets 1908	Mississippi River Board Sheets 1908
	Woermann Illinois River maps		
	Infrared photos 2005	1982 Analog stereophoto pairs	Georeferenced pre-inundation photo mosaics Pools 2-5 & 9
	MO Historical Society maps	1940s, 1970s analog aerial	Infrared 2002 IA DRR
		Brauer survey photographs	Brauer survey photographs
		1927 Aerials	1989 Hard copy Mississippi River

photos are available from 1982 as are several sets of photographs taken from specific flood events (e.g., 1973, 1987, 1993). A complete set of orthophotos were taken in 1995-96 as part of the SAST flow frequency study and are 1-, 1.5-, and 2-foot pixel black and white digital ortho-rectified photography. Sequential orthophoto quadrangles (DOQ) are available from 2002 and 2004 on the Illinois River and in 2003 and 2006 on the Mississippi River (USGS LTRM 2005). Generally these photographs exist as DOQ mosaics for navigation pools and river reaches. Infrared photos are available for most Mississippi River pool regions from 2005. Special project/pool photographs are available for many specific areas in the UMRS (e.g., at Thompson Bend, Ted Shanks CA, Pool 1-10, etc.) Also, the USDA Agricultural Imagery Program (NAIP) maps of all UMRS lands are present from 2004-2006 and are flown annually.

Early historical cartography maps of many UMRS regions are available and they identify information on elevation/topography, transect bathymetry, land cover, and other ecological features such as wetland distribution. These include the Lewis and Clark maps from the 1700s (http://lewisclark.geog.missouri.edu/website/lewisclark1.htm), the Victor Collot maps of 1796, GLO survey maps prepared in the early 1800s, the "Warren" maps from 1866, Mississippi River Commission maps prepared from 1880 to the late 1890s, "Woermann" maps of the Illinois River from 1902-1904, and other site-specific maps, e.g., the de Finiels cartography of portions of the Middle Mississippi River from the early 1700s (Ekberg and Foley 1989) and "The map of the Mississippi River between the mouth of the Illinois and the mouth of the Ohio rivers" made from surveys of Reynolds and Simpson between 1870 and 1878 (Brauer et al. 2005). The previously mentioned Mississippi River Board sheet maps also are present in digital form from regular intervals 1908 to 1942. Hydrographic survey maps also date from the 1950s to the present; most are in DGN format.

Reports and Maps of Vegetation/Ecological Communities

Perhaps the most geographically extensive and quantifiable survey/map accounts of historic vegetation communities in the UMRS are from the GLO maps and survey notes. These data record tree species and other vegetation at specific locations on land survey transect lines. The GLO surveys in the UMRS were conducted in the early 1800s and now have been cataloged in a database by The Nature Conservancy (TNC). The TNC database is from 1806-1850 and includes information and summaries of vegetation along survey lines with maps of generalized vegetation communities and their distribution. Many studies have used the GLO data to analyze trends and changes in vegetation communities in specific UMRS locations (e.g.,Yin and Nelson 1996, Nelson and Sparks 1998, Nelson et al. 1998, http://biology.usgs.gov/luhna/chap7.html)

Many of the previously mentioned historical cartography maps (i.e., Lewis and Clark, de Finiels, Collot, Warren, Mississippi River Commission, etc.) have information on general vegetation communities and some include reference to specific species at certain locations (Table 7). For example, the Mississippi River Commission maps usually identify forest vs. open or prairie lands and include mention of specific trees such as oak, willow, cottonwood, elm, hackberry, sycamore, etc. at some forest locations. Some of these maps have rather precise definition of larger wetland areas with the descriptors "oxbow", "lake", "marais", "marsh", "swamp", "etang" etc. Other maps include drawings of smaller wetland swales and upland ridges that are associated with point-bar geomorphic surfaces. Collectively, these older cartography maps in association with the GLO notes and surveys offer a description of general distribution and heterogeneity of vegetation communities in the UMRS.

A variety of land cover maps have been prepared for most of the UMRS from aerial photography and other field surveys dating to the late 1800s. The USGS Upper Midwest Environmental Sciences Center (UMESC) recently created a complete land cover map from 1890 based on MRC maps and these landcover maps now have been digitized and geo-referenced. More recent complete land cover maps are available for 1975, 1989, 1991, 1994, 1998, 2000, and 2002. Also, the Mississippi River Board sheet maps from 1908 now have been completely cataloged and are available in TIFF format. Other Mississippi River chart maps exist for 1866 and 1876.

In addition to historic maps and survey notes, many older studies and published accounts offer description of vegetation and ecological communities in various regions of the UMRS. These published articles are too numerous to list, but examples include Forman (1789), Schoolcraft

(1834), Featherstonhaugh (1844), and Hus (1908). In some cases the historical literature on landform and ecological communities and their distribution have been summarized (e.g., White 2000, Havera et al. 2003) and provide a basic for understanding and evaluating changes in these areas of the UMRS.

Good information on current vegetation composition and community distribution of UMRS regions exists in digital georeferenced form for interval from the 1980s to the present (e.g., www.umesc.usgs.gov/data_library.html, www.mrlc.gov). The Mississippi River Project Natural Resources Inventory System has land cover and vegetation data from 1982 to the 1990s for the upper portions of the UMRS and includes information on forestry stand maps, dominant canopy and understory species, basal area, and age of trees. Other areas of the UMRS also have specific forest inventory data available, (e.g. at Ted Shanks CA), NWR areas along the UMRS rivers, and many state WMA areas. These areas and some others also have specific botanical and faunal survey information. The USGS LTRM program has collected certain floral and faunal information over the last decade for the Mississippi River and its floodplain from St. Paul to Cairo and these data are available at the above umesc.usgs web site. The USFWS maintains a data base on wetlands in the National Wetlands Inventory conducted in the 1980s and the USGS has a National Land Cover Database that was done in 1992. Other GIS information on forest cover and conservation planning is available for the Upper Mississippi River Basin at www.na.fs.fed.us/watershed/upper_mississippi_partnership.

An important part of constructing HGM matrices for vegetation/habitat communities is identifying "reference" sites in UMRS ecoregions that contain various combinations of geomorphology, soils, elevation, and flood frequency features and that have at least some remnant native vegetation communities.

Table 7. Availability of historic and current data on vegetation/ecological communities for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
Vegetation and Ecological Communities	Mississippi River Commission maps	Mississippi River Commission maps	Mississippi River Commission maps
	TNC compilation of GLO survey map & notes	TNC compilation of GLO survey map & notes	TNC compilation of GLO survey map & notes
	1796 Collot Maps	1796 Collot Maps	1796 Collot Maps
	1866 Warren maps	1866 Warren maps	1866 Warren maps
	Mississippi River Project Natural Resource Inventory 1982-1990s	Mississippi River Project Natural Resource Inventory 1982-1990s	Mississippi River Project Natural Resource Inventory 1982-1990s
	Many state-specific ecoregion maps & accounts	Many state-specific ecoregion maps & accounts	Many state-specific ecoregion maps & accounts
	Landcover 1890s, 1989, 2000	Landcover 1890s, 1989, 2000	Landcover 1890s, 1989, 2000
	Numerous references in books, scientific papers, reports	Numerous references in books, scientific papers, reports	Numerous references in books, scientific papers, reports
	Rivers Project Master Plan - MVS website		
	1902-1904 Woermann Illinois River maps		

Identifying a list of reference sites that match HGM matrix conditions cannot be determined until the various habitat types present in the UMRS and their HGM characteristics are determined. Consequently, it is not known whether good reference conditions exist for all communities and ecoregions. Despite this uncertainty, current land cover maps and information in state natural heritage data bases (see below) do provide the capability of "finding" reference sites and constructing floodplain community "cross-sections" (e.g., Sparks 1993, Heitmeyer et al. 2006) for many, perhaps most, habitat types in the UMRS.

Species/Habitats of Concern

All states in the UMRS have natural history/heritage inventory lists and maps of distribution of plant and animal species of concern including those state listed threatened and endangered (T & E) species (Table 8). Further the USFWS maintains inventory lists of federally listed T & E species throughout the UMRS region. Much of this data is available via agency websites, however, some state (e.g. Minnesota) and USFWS data on specific locations of species are not available to general users. Usually this data can be obtained by appropriate agencies and their agents for specific project use, but this information cannot be published. Data on many species of concern also exist from specific research and monitoring studies, (e.g. recent evaluations of pallid sturgeon, least terns, etc.) and from USGS LTRM investigations.

In addition to inventories of plant and animal species of concern, most states have identified habitats of concern that now are in limited distribution or area (e.g., Nelson 2005). States in the UMRS are in various stages of developing State Wildlife Action Plans as part of the national Comprehensive Wildlife Strategy funding project. These action plans identify many ecological areas in the UMRS as high priority ecological systems that contain high biodiversity, yet are imperiled by various land use factors. Many national conservation initiatives also identify specific regions and areas in the UMRS as high priority areas (e.g., the North American Waterfowl Management Plan, North American Bird Conservation Initiative, Partners in Flight, etc.) and have extensive data bases on many attributes of these areas and species (e.g., Lower Mississippi Valley Joint Venture 2000). Further several books and articles chronicle the history of environmental and conservation activities in UMRS regions (e.g., Scarpino 1985).

General Geographic GIS Data

HGM analyses relies on many basic geographical GIS data layers of man-made physical features. These include boundaries of roads, levees, towns, political and governmental units including levee and drainage districts, publicly-owned lands, conservation easements, FEMA and flood prone areas, planning and zoning maps, etc. These GIS data sets also provide information on specific physical features such as location and size of drainage features including as water-control structures, pipes and ditches, revetments and wing dikes, dredge placement areas, etc. Fortunately, all of these data are readily available for all areas within the UMRS (Table 9) and these and other published articles (e.g., Minton 1912) include details of construction/operation chronology, design features and capabilities, etc. Most GIS data sets have been compiled by the USGS LTRM and can be accessed at www.umesc.usgs.gov/data_library.html.

Other physical data have been compiled by the USACE Districts, especially information on project developments such as levees, water-control

Table 8. Availability of historic and current data on plant and animal species of concern for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
Species/Habitat of Concern	MO, IL, KY - T & E lists	IL, IA T&E lists	WI, MN, IA, IL T&E lists
	USFWS lists	USFWS lists	USFWS lists
	NABCI & JV maps and lists	NABCI & JV maps and lists	NABCI & JV maps and lists
	Pallid sturgeon & Least Tern habitat data		T & E licensed for MN - cannot distribute

Table 9. Availability of physical feature data for the three U.S. Army Corps of Engineers Districts within the Upper Mississippi River System.

Data	St. Louis	Rock Island	St. Paul
GIS boundary ownership shape files	Physical features, roads, levees, towns, etc.	Physical features, roads, levees, towns, etc.	Physical features, roads, levees, towns, etc.
	Levee/Drainage Districts, ArcSDE/SHP	Levee/Drainage Districts, ArcSDE/SHP	Levee/Drainage Districts, ArcSDE/SHP
	Pubic lands by agency & type	Pubic lands by agency & type	Pubic lands by agency & type
	NRCS WRP, CREP, CRP lands	NRCS WRP, CREP, CRP lands	NRCS WRP, CREP, CRP lands
	Planning Commission maps	Planning Commission maps	Planning Commission maps
	FEMA flood area maps	FEMA flood area maps	FEMA flood area maps
	LTRMP data	LTRMP data	LTRMP data
	Wing dam, dredge, etc. maps	Wing dam, dredge, etc. maps	Wing dam, dredge, etc. maps
	Post 1993 flood maps	Post 1993 flood maps	Post 1993 flood maps

and delivery structures, dredge and fill sites, ownership and management areas, and special project areas such as HREP and EMP sites. These data area available in ArcSDE/SHP files. NRCS maintains data on USDA land programs such as the Conservation Reserve Program (CRP), WRP, Environmental Quality Improvement Program (EQUIP), and Conservation Security Program (CSP). Information on public lands is available in the Protected Areas Database maintained by the Conservation Biology Institute. Housing Density data are available from Colorado State University and information on public water supply is available through state natural resources GIS offices.

1858 Davenport, IA. Rufus Wright

CRITICAL ASSUMPTIONS/LIMITATIONS OF GEOSPATIAL AND ECOLOGICAL DATA

General

Much geospatial information is available, and in a digital format easily imported to ArcMAP and ArcGIS, on the physical and biological characteristics of the UMRS. Fortunately, at least some historic information is available for most data areas. Data on current conditions of the UMRS generally are excellent with a few exceptions such as refined elevation information. Collectively, data that are needed to conduct an HGM evaluation of ecosystem restoration and management options for the UMRS are available for most subject and geographical areas. The most notable uncertainties and limitations in the data sets are:

1. Data are most complete and in an ArcGIS-friendly format for the Mississippi River part of the UMRS, generally complete for the Illinois River, and least available or accessible for the navigable tributary reaches of the Minnesota, Black, St. Croix, and Kaskaskia rivers.

2. Considerable data exists in forms that ArcGIS can easily use, however, many older maps and data are in "hard copy" form only and have not been scanned or digitized. Some information in SHP, DGN, TIFF, PDF and JPEG files has not been geo-referenced and cannot be used to generate overlaying maps and specific shape files of potential communities. Also, not all files share the same spatial reference.

3. The geographic scale of some data sets varies. For example, only one complete set of plan form maps exist at a 1:24,000 scale and other maps vary from site-specific fine scale to extensive 1:64,000 scale. Mapping scale of topographic information is most complete for 5-foot contour intervals but ranges to < 1-foot LIDAR intervals for some locations.

4. Most of the data sets are arrayed by, and available in, political physical boundaries, e.g. at Pool or Reach scales, instead of being sorted by ecological or geomorphological regions. Ultimately, HGM analyses will require sorting and collation of all data by appropriate ecoregions along each of the UMRS river systems.

5. Time series of some data and maps are .irregular and some data sets have chronological gaps between similar data. Fortunately, at least some pre-Lock and Dam information exists for most UMRS regions, however information is more limited for the period immediately after construction and operation of Locks and Dams (i.e., 1940-1960).

6. Historic surveys and information on fauna generally are sparse. Some quantification of vegetation composition, distribution, size, and age exist for UMRS forests but little such data exist for other communities.

7. The availability of key "reference" sites for specific vegetation communities in UMRS ecoregions is unknown.

8. Hydrological data and analyses of Presettlement periods are limited to short periods of record (usually late 1870s to early 1890s).

Specific limitations and assumptions of data are presented below:

Soils

The soils data for the UMRS are perhaps the most complete and readily available of any of the HGM data categories. STATSGO and SSURGO data are broad based, collected in a repeated pattern across landscapes, and can be sorted at various scales by ArcGIS. The major caveat of the soils maps is that some discrepancies exist in soil mapping across political boundaries such as county or other major geographical boundaries (e.g., across rivers, roads, levees). The STATSGO data attempts a "seamless" mapping of soils, but nonetheless some problems remain. Also, the qualifiers of soil flooding frequency are somewhat subjective and variable among survey areas. For example, many soil maps plot a single soil type as frequently, occasionally, or intermittently flooded yet no quantitative data have been used to validate these flooding categories. Finally, soil maps vary in their recent refinement or remapping intensity and timing. Consequently, some older soil maps that are integrated into STATSGO are extensive and miss inclusions of different soil types within areas mostly covered with another broad soil type. This is most problematic in recent Holocene meander belt areas where outcropping of older underlying soils occurs and in areas where recently deposited veneers of alluvium are shallow or absent.

Geomorphology

The UMRS now is one of the few larger riverine floodplain ecosystems that has complete geomorphological mapping available. Unfortunately, the detail and type of mapping varies among regions. The most complete geomorphological maps are from the lower Mississippi River region (south of Cape Girardeau, MO) and were conducted and published by Saucier (1994). Saucier also prepared some maps, but did not publish data and text on them, for the Middle Mississippi River area (Cape Girardeau to the confluence of the Missouri and Mississippi rivers) prior to his death in 1996. Woerner et al. (2003) completed Saucier's work in this region and these maps are similar to those below Cape Girardeau. Geomorphological maps for the Mississippi River floodplain and along the Illinois River have been prepared as LSA units These maps rely more on surface features and less on detailed boring along transects of the floodplain than did Saucier and Woerner. Consequently, the LSA maps often do not have intensive stratigraphy maps that accompany the surface maps. This deficiency is most critical in determining the depths and materials from the surface to older pre-Quaternary subsurface layers. Further, LSA maps often include many areas of "undifferentiated" materials where considerable uncertainty exists about origin and chronology of deposition and subsequent scouring. Further, these maps often place surfaces in broad "floodplain" types without distinguishing older point bars, backswamps, and recent chutes and bar features. They also often lack identification of veneered or buried natural levees. The differences in methods and categories used in mapping geomorphology creates a need for a common system floodplain "typology" and this now is being pursued by UMESC.

Topography/Elevation

Topographic maps for the UMRS are perhaps the most variable in geographic coverage and scale of any of the HGM data categories. At the crudest scale, all UMRS areas have digital 7.5 minute USGS quadrangle maps at a 5-foot contour scale. Mapping at less than a 5-foot scale is less common for UMRS regions, especially in floodplain areas away from the active main channels of the rivers. Historical elevation maps (e.g., Woermann) are useful but they are not available for all UMRS areas. Consequently, some UMRS areas, especially the navigable tributaries do not have good historic elevation information to enable comparisons of community distribution or changes to the present.

Excellent current topographic maps exist for specific UMRS areas, usually those sites associated with an existing or proposed project development. For example, LIDAR topographic information exists for some sites. However, even the LIDAR data have limitations if the surveys were flown in areas of forest during full canopy foliage and when deep, turbid, waters were present in a site. Ideally, a comprehensive, ground-based topographic map of UMRS areas could be conducted, but costs and logistical constraints likely prohibit this in the near future. HGM analyses is best when topographic information is coupled with hydrological data to predict frequency, timing, depth, and duration of flooding for various vegetation communities and to assess potentials for restoration in current modified conditions. These HGM community models, consequently are best when 1-2 foot contour maps are available and most crude when only 5- foot contour intervals are available.

Hydrology and Flood Frequency

Excellent data exist on stage and discharge from gauge stations along regular intervals of all UMRS rivers. Data from most Mississippi and Illinois River stations date back to the late 1800s, while the data from the Black, St. Croix, Minnesota, and Kaskaskia rivers mostly date to the early 1900s. All river gauge data sets have some gaps in coverage; most time gaps are less than 5 years of continuity and are from the early 1900s. Alterations to flows in UMRS rivers, especially the Illinois River became significant in the late 1800s and consequently, only a short time period of pre-alteration data are available for the Illinois River (1876-1889). Likewise, the term of older pre-alteration data from other UMRS rivers is short.

A major limitation of hydrological data for the UMRS is the absence of good older flood frequency maps. This limitation is primarily due to crude scale elevation maps for the UMRS floodplains (only 5-foot contour interval USGS maps are consistently available). Further, most flood frequency maps were prepared post-Lock and Dam construction and also reflect flow levels following construction or heightening of mainstem levees along the rivers. Consequently, constructing historic flood frequency maps have many inherent model assumptions about flows and dispersal. Another major limitation of hydrological data is limited, or absent, data on groundwater levels at various regions of the UMRS and its interactions with floodplain wetlands.

Aerial Photographs and Older Cartography Maps

Many historical maps and photos exist of the UMRS and current maps and aerial photographs provide regular documentation of landscape condition and recent changes. Many of the older cartography maps have somewhat distorted scale and size of landscape features and cannot be georeferenced or used for quantitative analyses (e.g., the Victor Collot map of 1796). Nonetheless, they offer important information on landscape context and heterogeneity of communities. Some older photographs are of poor quality and are difficult to interpret for fine-level details of land features. Finally, many maps have not been scanned, digitized, or geo-referenced.

Reports and Maps of Vegetation/Ecological Communities

GLO notes and maps are the most quantifiable information on the distribution of Presettlement vegetation communities in the UMRS. These GLO notes and maps have several limitations and inherent assumptions (Hutchinson 1988). The GLO surveys were not intended to describe distribution or composition of native vegetation communities, nor were surveyors consistent in identifying or recording vegetation to species levels. Notes on vegetation are most complete at section corners and mid-point lines; data mostly are absent between these points. Vegetation communities generally are described in broad categories (i.e. forest, prairie, open water, etc.) and it is understandable that monitoring conditions were difficult in low wet floodplain habitats. It appears surveyors often grouped tree species into broad categories such as elm, black or white oak, maple, etc. and the exact species they recorded often is uncertain. These attributes make reliance on GLO notes for precise mapping of vegetation communities and species composition somewhat difficult.

Similar to GLO maps, most older cartography maps such as Collot, de Finiels, Warren, MRC, etc., were not intended to map the distribution of vegetation communities and they usually only provide broad descriptions of habitats and species, if they are noted at all. The composition of bottomland forest species is sporadically mentioned on some maps, however, similar to GLO notes, trees appear to be grouped in broad categories and coverage is inconsistent. Older naturalist accounts of vegetation in the UMRS (e.g. Featherstonhaugh 1844, Hus 1908, Turner 1934) also are variable in geographic scale.

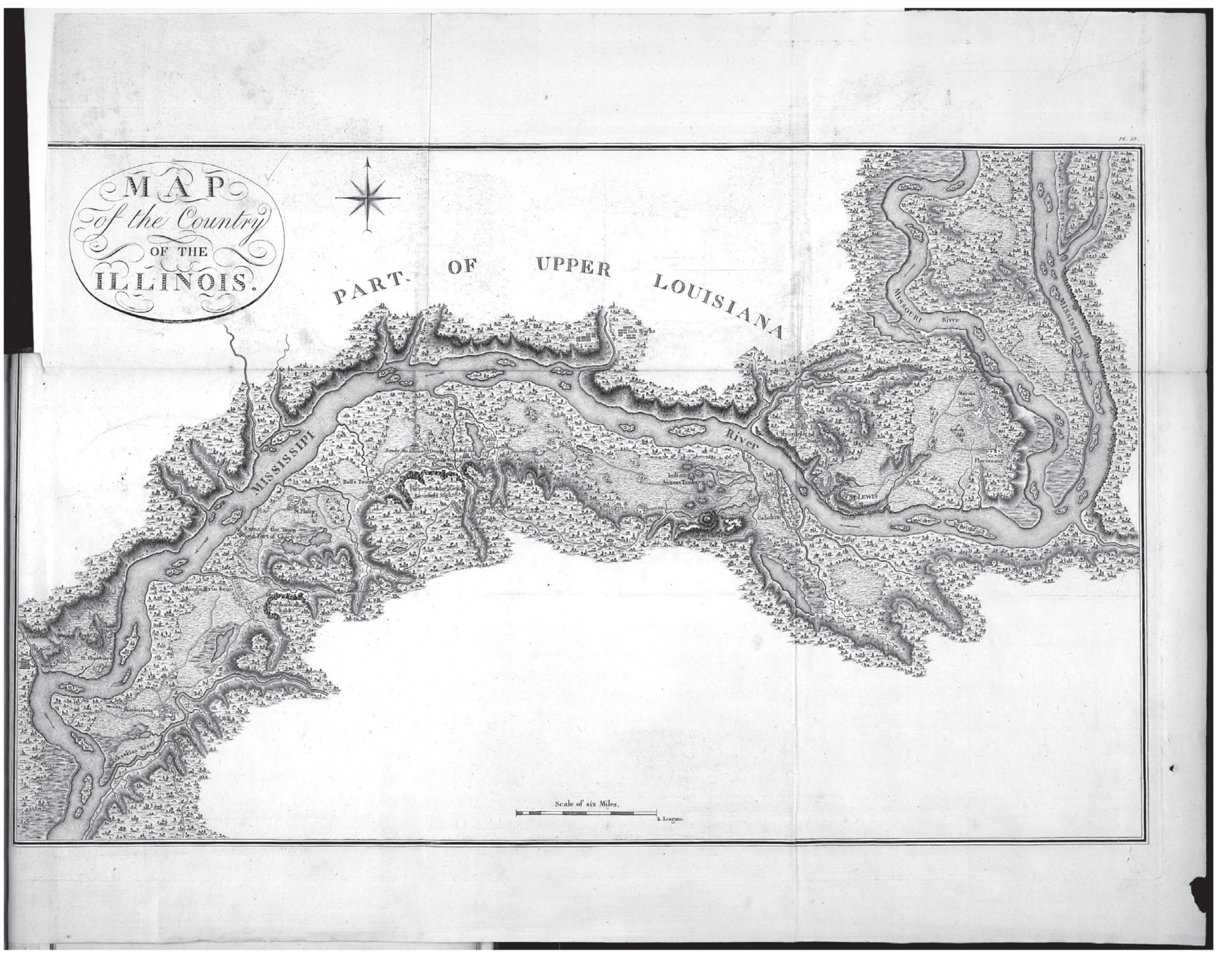
Species/Habitats of Concern

State and Federal data sets on plant and animal species of concern are complete and usually readily available. Data often are most complete for those species that are most visible or that have received attention because of imperiled status or public exposure. In a few states, and for a few species, data is not available to general users and permission must be obtained to confidentially see records and not to report on them.

In addition to species of concern, little historic information is available on population sizes or distribution/density of many animal species, especially aquatic forms. These historic data are important because they provide information to assess changes in both distribution and number and relate to the availability of key habitats and resources. If major changes in distribution or number have occurred then restoration and conservation of habitats/resources needed for key annual cycle events must be identified and some priority may be given to these areas.

General Geographic GIS Data

Most of the general geographic GIS Data needed to perform HGM analyses for the UMRS are available and in a format usable by ArcGIS. The level of detail is most complete for areas in public ownership and where USACE development projects have occurred. Information is least available for private lands and areas within privately administered levee and drainage districts, especially those in, or adjacent to, the navigable portions of the Black, St. Croix, Minnesota, and Kaskaskia rivers.



Collot, 1826

CONCLUSIONS/RECOMMENDATIONS

General Feasibility of Conducting an HGM Evaluation

The HGM process of evaluating ecosystem restoration options, especially at a large "extensive" geographical scale such as the UMRS, relies heavily on the availability of historic and current geospatial data. The cornerstone of the HGM process is developing a "matrix" of information about which vegetation communities occurred and can be sustained at different geomorphological, soils, topography, and hydrology settings. This matrix provides a means of determining historic vs. current distribution and habitat/land use changes and identifies geographical areas that offer the greatest potential to restore habitats and their functions and values. The matrix also identifies the fundamental ecological processes that can sustain these ecosystems and provides information to determine what physical developments and management actions will be needed to restore and sustain the sites.

The discovery and understanding of the geospatial and biological data from this feasibility study indicates that most of the data needed to conduct an HGM evaluation for the UMRS are available. Fortunately, all of the basic geospatial data for geomorphology, soils, topography, and hydrology are available for the broad river regions within the UMRS and further, historic information on vegetation/ecological communities are present, at least to some extent and detail. Undoubtedly, the availability of many data sets reflects the size, public exposure, ecological and economic importance, and past history of development and environmental/economic risks such as floods in the Upper Mississippi River Basin. Clearly, some data are more detailed and extensive (e.g., soils) than others (e.g., topographic surveys < 5-foot contours) and limitations occur. Also, the data are most complete for the Mississippi and Illinois Rivers river floodplain regions and less available for the navigable tributary reaches of the Kaskaskia, Black, St. Croix, and Minnesota rivers. Groups interested in supporting HGM analyses for the UMRS should begin addressing certain key data and map limitations including scanning and georeferencing historic map data, developing a consistent typology of geomorphology, and coordinating efforts to obtain system-level elevation data to at least a 2-foot contour scale.

With these caveats noted, I conclude that an HGM evaluation at an extensive scale for the UMRS is possible with existing geospatial and ecological data sets. This conclusion depends on refinement, spatial reference conversion, collation, and geo-referencing of certain GIS data sets. Given these data refinements and accessibility, an HGM analyses should be able to map potential historic ecosystem types at an extensive scale throughout the UMRS, at least to major habitat types (e.g., riverfront forest, bottomland hardwood forest, bottomland-slope forest, savanna, bottomland prairie, mesic prairie, seasonal herbaceous wetland, emergent wetland, open water, shrub/scrub). HGM evaluations of more detailed vegetation communities (e.g., low to high BLH forest communities) and their distribution at site-specific locations varies depending on the detail of specific data sets, especially topographic information at < 1 foot mapping scale. If site-specific HGM analyses are required, then the subject area will need to be evaluated independently to determine data needs and capabilities.

The UMRS floodplain area (about 2.8 million acres) is very large and is comprised of many relatively distinct ecoregions and geomorphic settings. Ecoregions are natural land divisions that have similar environmental characteristics that integrate both physical (e.g., geomorphology) and biological (e.g., vegetation communities) attributes. Typically, ecoregions are spatially hierarchial; that is, landscapes are mapped into a nested system of units from broad ecoregions to smaller subregions and from landscape scales to local sites. Consequently, an "extensive" HGM evaluation for the UMRS will need to separate the UMRS system into ecological units and construct unique HGM "matrices" for each ecoregion or subregion. For example, the ongoing evaluation of the Middle Mississippi region has divided this area into three unique ecological/geomorphological areas: 1) the American Bottoms from the confluence of the Missouri and Mississippi rivers to the entry of the Kaskaskia River, 2) the mid-river area from Kaskaskia to Thebes Gap, and 3) the upper portion of the Mississippi Alluvial Valley from Thebes to the confluence with the Ohio River at Cairo, IL.

Based on certain recent attempts to describe land divisions including those areas within the UMRS (e.g., Avers et al. 1994, Nigh and Schroeder 2002), it appears the Illinois River valley has at least 3-4 unique ecoregions; the Kaskaskia, Black, Minnesota, and St. Croix river regions are all distinct ecoregions; and the Upper Mississippi River floodplain from St. Louis to St. Paul contains 6-7 ecoregions. Consequently, HGM evaluations should systematically address each ecoregion within the context of the entire UMRS and not be confined by pool or river mile separations and boundaries. A final HGM product would integrate these ecoregions into a comprehensive systemic framework for understanding the entire UMRS system and would provide recommendations and guidance for restoration and conservation at a truly systemic level based on ecology of the region, not political boundaries.

Technology

With the advent of ArcGIS and ArcMAP software programs and capabilities, geospatial data now can be readily acquired, imported, and manipulated to provide maps and geospatial data (e.g., area, distribution, configuration, etc.) for the UMRS. The basic GIS programming for HGM analyses involves sorting data into categories that match the "matrix" characteristics of specific vegetation/habitat communities. For example, bottomland hardwood forests in many southern ecoregions of the UMRS typically are associated with natural levee, backswamp, and Holocene meander belt geomorphic surfaces, with silt loam or silty clay soils, and between the 2- and 5- year flood frequency elevations. ArcGIS can be used to sort the data sets to these criteria and identify where historic BLH was present and where sites now exist that have these characteristics. These "potential restoration" sites then can be cataloged by size, location, proximity to other BLH sites, potential connectivity or enlargement of patches and corridors, ownership, flood frequency risk or protection, and restoration/management need (e.g., whether a site will require tree planting or can be achieved via natural regeneration). Collectively, these data then can assign some sense of priority to restoration sites given different objectives related to ecological need and sustainability. For example, if a specific habitat has been destroyed to a large extent and represents critical habitat for a species of concern, then the restoration sites identified for this habitat may become a target for acquisition or restoration by a particular conservation interest group or agency. Likewise, if a critical habitat type is highly fragmented or lacks connectivity to either the river or other habitat patches, then restoration sites that potentially can reconnect either the ecological process (e.g., seasonal overbank flooding from the river) or the patch size may become priority sites.

ArcGIS and the geospatial data identified in this report also can now be readily archived and housed in central repository sites, assuming that some entity is willing and capable of managing the data. The availability of this data is increasing and an important outcome or product of an extensive HGM evaluation for the entire UMRS would be the collation of a comprehensive, readily available, geospatial data set(s) on the primary HGM data sets.

A Proposed HGM Evaluation for the UMRS

This report has identified the availability and type of geospatial data needed to conduct an HGM evaluation for the UMRS. This HGM evaluation can occur with the following objectives:

1. Identify the Presettlement, and pre-Lock and Dam, ecosystem condition of ecoregions in the Illinois, Mississippi, and navigable regions of the Kaskaskia, Black, St. Croix, and Minnesota river floodplains (UMRS).

2. Evaluate changes in the UMRS ecoregions from Presettlement, and pre-Lock and Dam, condition with specific reference to alterations in hydrology, vegetation community structure

and distribution, and resource availability to key fish and wildlife species.

3. Identify restoration and management options and ecological attributes needed to successfully restore specific habitats/locations and conditions within the UMRS.

The conduct of this extensive HGM evaluation will require:

1. Obtaining all geospatial data pertinent to HGM from the current holding agency/entity.

2. Scanning and geo-referencing certain SHP files and converting geospatial data to a consistent spatial reference.

3. Refining certain data sets, especially topographic/elevation information for specific areas, especially within the navigable sections of the Kaskaskia, Black, St. Croix, and Minnesota river floodplains.

4. Organizing all geomorphology, soils, topography, and hydrology data into ecological-and geomorphic-based ecoregions.

5. Extensive field work to identify and characterize all major habitat types, identify reference sites, and develop HGM matrices for each ecoregion.

6. Constructing HGM potential vegetation community models to determine historic distribution, size, and sustaining ecological processes of major habitat types.

7. Determining current land cover and HGM physical features to assess community changes and potential restoration sites

8. Determining options and developments/management needed to restore and sustain the ecosystem types.

The HGM evaluation should be divided into project work plans and time schedules by UMRS ecoregions, not by political or physical boundaries. Ecoregion evaluations then should be compiled by major river area (e.g, Illinois, Upper Mississippi, Middle Mississippi, navigable tributaries) and collated into an entire UMRS framework to form a comprehensive evaluation and understanding of ecosystem conservation need and strategy under the NESP. The scheduling of ecoregion evaluations can be somewhat flexible to meet funding and conservation/development needs. At the smallest scale, HGM work should be "packaged" in the broad regions of:

- Northern UMRS: Mississippi River, Rock Island to St. Paul

- Mid UMRS: Mississippi River, St. Louis to Rock Island

- Southern UMRS (often referred to as the Middle, or Open River, Mississippi Region): Mississippi River, St. Louis to Cairo, IL

- Illinois River

- Kaskaskia River (navigable region, possibly included with the southern UMRS).

- St. Croix, Black, and Minnesota Rivers.

A complete HGM evaluation of the UMRS (total of 2.8 million acres) probably can be done in 3-5 years given the caveats listed above. Some efficiencies of scale related to time, area coverage, and cost can occur if the evaluation is conducted for all areas combined. This efficiency occurs because some data sets (such as historic maps, river gauge data, etc.) may be common to multiple ecoregions and would reduce duplication of time and effort to obtain and analyze them. Conversely, the above geographical regions can be conducted separately if needed, so long as they are integrated into a comprehensive UMRS strategy at the end. The length of time to conduct HGM evaluations for each region and ecoregion within these areas will vary based on size, heterogeneity of communities, degree of alteration from Presettlement and pre-Lock and Dam condition, availability of data, and sequence of geographical evaluation.

Currently, an extensive HGM evaluation of ecosystem restoration options for the Mississippi River floodplain from the confluence of the Ohio and Mississippi Rivers (RM1) to the confluence of the Missouri and Mississippi Rivers (RM 195) is being conducted. This evaluation report is expected in FY2008. Completion of the Middle Mississippi River HGM evaluation will provide an important foundation to initiate a larger comprehensive UMRS

HGM evaluation in a sequence moving from south to north along the Mississippi River. This southern to northern priority of sequence would maximize efficiencies of data gathering and field analyses and would coordinate attempts to inherently understand ecological and physical continuities in landforms and geology; hydrological inputs, controls (i.e. locks and dams), ecological connectivity, and dynamics; climatic gradients; and spatial continuity of transitional vegetation communities. This sequence also is consistent with application of current and planned EMP, HREP, and other USACE and state and federal floodplain ecosystem restoration efforts for the Mississippi River. After HGM analyses are completed for the entire Mississippi River floodplain, then similar HGM analyses for the major tributaries (Illinois, Kaskaskia, Black, St. Croix, Minnesota) should be conducted.

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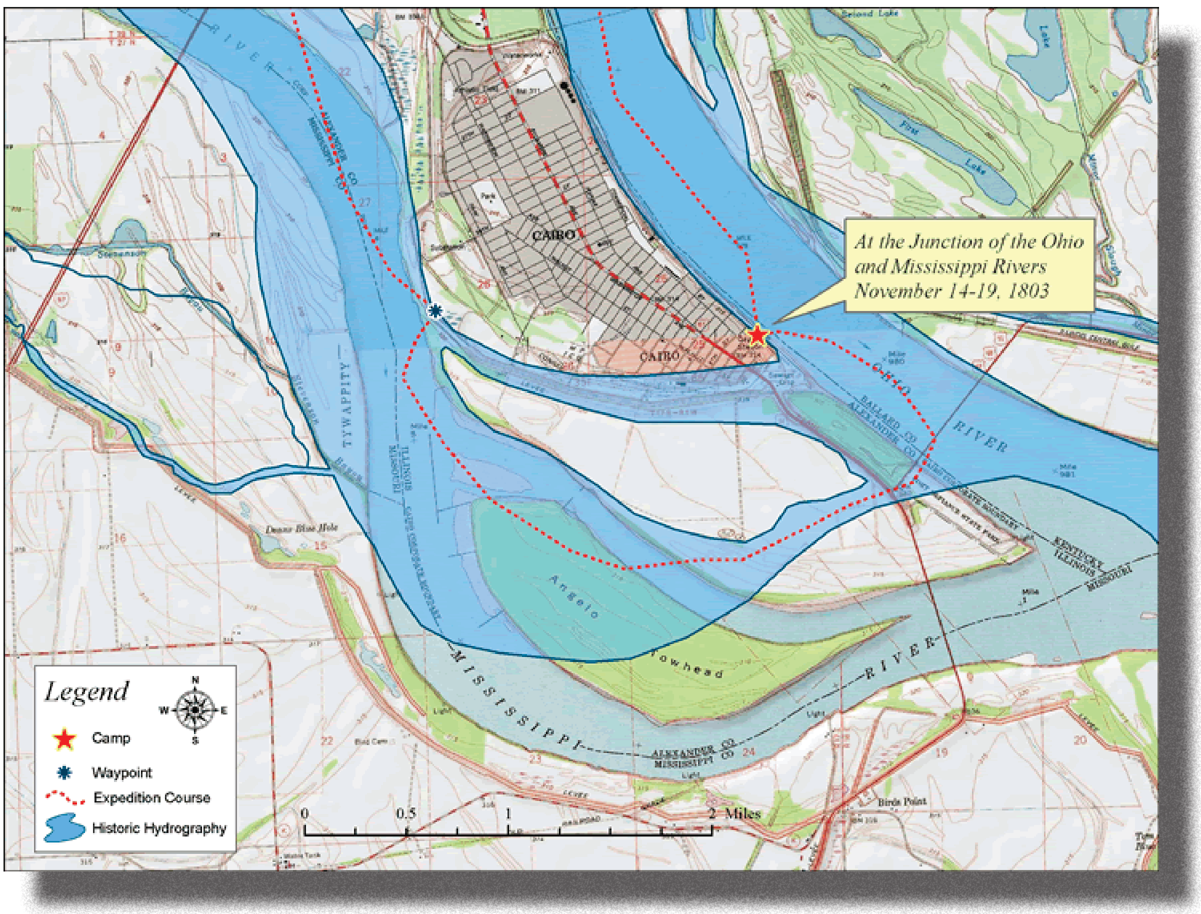

Lewis and Clark Expedition

APPENDIX

Appendix A. Questionnaire about availability of geospatial and biological information within the Upper Mississippi River System.

HGM DATA AVAILABILITY QUESTIONNAIRE

Introduction

The Navigation and Environmental Sustainability Program (NESP) Forest Management Project has initiated a Feasibility Investigation for Hydrogeomorphic Modeling (HGM) and Analysis in the Upper Mississippi River System Floodplain. A major part of this Feasibility work is to determine what data and information are available for the HGM process in the Mississippi River (and tributaries with navigation projects) floodplains within the St. Paul, Rock Island, and St. Louis Districts of the U.S. Army Corps of Engineers. The study area includes the impounded upper river Pools 1-26, the unimpounded river from Harford, IL to Cairo, IL, the Illinois River, and navigable portions of the Minnesota, St. Croix, Black, and Kaskaskia rivers. This QUESTIONNAIRE will help determine what information is available and in what form (i.e., digital, GIS, hard copy, etc.) for the study areas.

The Questions

HGM uses geographical information on geomorphology, soils, topography, and flood frequency to construct a matrix of what vegetation communities historically were present in various locations and to what extent these conditions exist now. For example, within the Middle Mississippi River area sites that are point-bar surfaces with natural levee veneers, with Calhoun soils, above 410 feet elevation and in the 2-5 year flood frequency zone support elm-sweetgum-pin oak forests. This information then can help understand and model where restoration of specific forest communities is needed and can occur in a long-term sustainable manner.

We ask whether you have information/data/reports for the items listed below within your District area for the above floodplains.. Please reply to each question item with:

1. Presence or absence of the information in your office

2. The title, dates, and form the information is in (e.g., historic photos, GIS, Excel files, availability via

the internet, etc.) and if it can easily be borrowed, copied, or obtained from your office

3. The area and scale of coverage for the specific data

4. Other possible sources for the data if you do not have

We thank you for assisting this important project.

Soils

Q1. Do you have?

- Digital soils data and maps
- Hard copies of older soil survey maps and reports for counties that floodplains are in

Geomorphology

Q2. Do you have?

- Hard copy or digital geomorphology (land form) maps
- Subsurface stratigraphy
- Alluvium geological data
- Surface geology maps

Topography/Elevation

Q3. Do you have any of the following and at what mapping scale (i.e., 1-foot contours, 2-foot, 5-foot, etc.)?

- Digital and hard copy USGS quadrangle maps
- LIDAR elevation maps
- Elevation maps for special project locations
- Historic maps for any time periods pre- and post-navigation developments (these may include Mississippi River Commission, Warren, Woermann, etc. older maps)
- Flowage survey maps

Hydrology and Flood Frequency

Q4. Do you have?

- Flow Frequency SAST data and maps
- gauge station data (and for what locations) for the study rivers that date back to pre-navigation project times, especially sites with data pre-1900.
- Maps of 11-digit watersheds and ecological drainage units

- Groundwater well or peziometer station information

Aerial Photographs or Older Cartography Maps

Q5. Do you have?

- Historic photographs for any or all parts of the study floodplains, especially older pre-navigation project periods
- Infrared photographs
- 2004-2005 National Agricultural Imagery Program (NAIP) maps
- Any other special project/pool photographs, both aerial and ground
- Early explorer maps (e.g., Lewis and Clark, Cottel, etc.)

Reports or Maps of Vegetation/Ecological Communities

Q6. Do you have?

- Any historic maps that show historic vegetation at any scale (this may be large scale like the Miss. River Commission maps or small scale for a specific site like at Thompson Lake, IL)
- General Land Office (GLO) survey maps and notes
- Land cover maps prepared by any entity for any time (e.g., recent NRCS, Corps, etc. land cover maps)
- State specific ecoregion or historic prairie/forest maps or accounts
- Books, articles, reports that provide descriptions, accounts, or maps of local, regional, or floodplain-wide vegetation

Species or Habitats of Concern

Q7. Do you have?

- State or federal databases and maps for animal and plant species of concern including T & E and related to national/state programs like areas/species identified as priorities by the National Bird Conservation Initiative, etc.

General GIS Boundary Shape files

Q8. Do you have?

- Physical feature boundaries such as roads, levees, towns
- Levee or drainage district boundaries
- Public lands by agency and type
- Private land easements including WRP, CREP, etc.
- Planning Commission maps