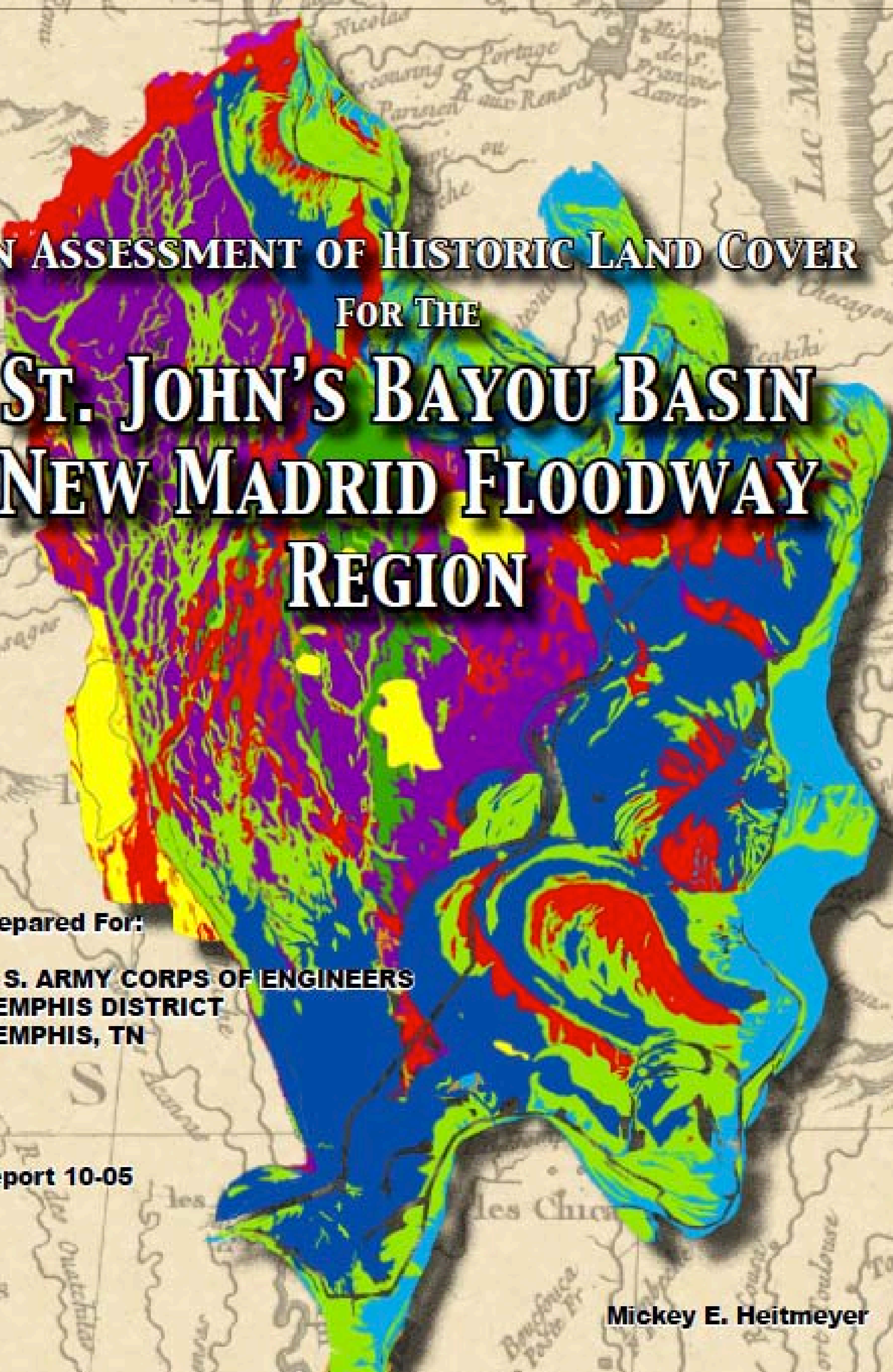
Appendix D
Part 2

Historic Conditions

U.S. Army Corps of Engineers
Memphis District



An Assessment of Historic Land Cover For The St. John's Bayou Basin New Madrid Floodway Region

Prepared For:

U. S. ARMY CORPS OF ENGINEERS
MEMPHIS DISTRICT
MEMPHIS, TN

Report 10-05

Mickey E. Heitmeyer

July 2010

AN ASSESSMENT OF HISTORIC LAND COVER FOR THE ST. JOHN'S BAYOU BASIN/NEW MADRID FLOODWAY REGION

PREPARED FOR:

U.S. ARMY CORPS OF ENGINEERS
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CONTENTS

USACE

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers proposed St. John's Bayou Basin and New Madrid Floodway Project, located in portions of Scott, New Madrid, and Mississippi counties in southeastern Missouri (SJNM) seeks to protect agricultural lands from frequent backwater flooding from the Mississippi River and reduce headwater flooding in the St. John's Bayou Basin in the vicinity of East Prairie. The SJNM project is being designed to include features that will promote landscape-level natural resource conservation and management strategies. This project objective requires an understanding of historic and current landscape conditions in the SJNM. This report provides hydrogeomorphic evaluation to:

1. Determine the historic condition and ecological processes of the SJNM region using a variety of historical and current information including geomorphology, soils, topography, hydrology, faunal and floral accounts, maps and other information sets.

2. Identify changes to physical, biotic, and ecological process components of the SJNM region from the historic condition.

A hydrogeomorphic matrix of understanding of which plant communities historically occurred in different geomorphic, soil, topographic, and hydrological settings was developed to map potential historic vegetation communities in the SJNM. This matrix was developed using comprehensive scientific data discovery and field validation using published literature, vegetation community reference sites, and state-of-the-art understanding of plant species relationships to hydrogeomorphic landscape attributes. This matrix essentially identifies community type and distribution, juxtaposition, and driving ecological processes that created and sustained them. Contemporary geospatial information described the current soil, hydrology, vegetation community structure and function, and resource availability to key animal species. Comparing current landscape condition with predicted historical community type and distribution identified how much the SJNM landscape has changed and which community types have been most altered or destroyed. This information is useful to understand the resiliency of specific communities to environmental changes, the potential impacts of the SJNM project, and potential opportunities to reverse or mitigate/minimize degradations and to restore communities if that is desired.

Major natural communities/habitat types that historically were present in the SJNM included: 1) the main channel and islands of the Mississippi River and its major tributaries; 2) river chutes and side channels; 3) bottomland lakes, often referred to as oxbows; 4) riverfront forest that was dominated by early succession tree species such as willow, silver maple, cottonwood, and sycamore, 5) bottomland hardwood forest (BLH) that contained diverse hardwood tree species including green ash, American elm, box elder, sugarberry, and several oak species; 6) terrace hardwood forest dominated by relatively water intolerant hardwood trees such as post oak and cherrybark oak; 7) slope forest on alluvial fans with mixed upland and floodplain tree species; 8) sand prairie; and 9) sand savanna.

Soil type, geomorphic surface, and hydrology were highly correlated with, and predictive of, the historic community distribution and area in the SJNM. Forest covered over 93% of the Presettlement SJNM. Riverfront forest historically covered 9.3% of the SJNM and was distributed primarily in a band parallel to the active Mississippi River channel on fine sandy loam soils. Most of the current batture of the Mississippi River was historically, and currently is, riverfront forest. Low BLH including bottomland lakes covered about 115,000 acres of the SJNM and was present mostly in the Holocene meander belt of the Mississippi River and had Sharkey and Alligator clay soils. Intermediate BLH was widely distributed over 23.8% of the SJNM in the Holocene meander belt and some valley train relict channels where flooding occurrence was 1-2 year frequency in the growing season and soils were silty-clay-loam Mollisols and Inceptisols. High BLH was present on about 65,000 acres of the SJNM in several floodplain geomorphic surfaces where growing season flood frequency was 2-5 year occurrence and soils were silt loams. Terrace hardwood covered about 109,000 acres of higher elevation terrace and valley train surfaces with > 50 year flood occurrence and sandy-loam Entisol soils. Slope forest was limited to a few small alluvial fan sites adjacent to the Commerce Hills. Prairie and savanna historically were distributed on the highest elevations of the SJNM where fine loamy sand soils were present on braided stream terraces and the Sikeston Ridge. These two communities may have comprised nearly 33,000 acres in the Presettlement period.

Many changes have occurred in the SJNM landscape from the 1700s to the present. Current land cover in the SJNM is dominated by agricultural cropland, except in the batture areas. Essentially all historic prairie and savanna are gone and total forest area is only 6% and 7.8% of total area in the St. John's Bayou Basin and New Madrid Floodway, respectively. Comparisons of historic forest communities with contemporary aerial photographs that show remnant forest tracts identified that remaining tracts are primarily riverfront forest communities with small tracts of BLH scattered in the region. The only large forest tracts remaining in the SJNM are scattered riverfront forest communities in batture lands and BLH forests at Donaldson Point, Big Oak Tree, and Bogle Woods that is adjacent to the Ten Mile Pond Conservation Area. All of these BLH tracts currently are in public ownership.

The development of potential Presettlement vegetation community maps in this study provides the foundation for understanding the SJNM ecosystem, both past and present. These maps provide a basis for determining which communities belong in specific geomorphic, soil, and hydrological settings and how contemporary alterations may, or may not, allow these communities to be restored in historic locations if that is desired. The hydrogeomorphic analyses also identified the fundamental driving ecological processes that must be present if restoration of specific communities is attempted.

USACE

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) proposed St. John's Bayou Basin and New Madrid Floodway Project (USACE 2009a,b) includes lands in the St. John's Bayou Basin, New Madrid Floodway, and Mississippi River Batture lands in portions of Scott, New Madrid, and Mississippi counties of southeastern Missouri (hereafter SJNM, Fig. 1). The project seeks to protect over 500,000 acres of mostly agricultural land in the region from frequent backwater flooding from the Mississippi River and to reduce headwater flooding in the St. John's Bayou Basin in the vicinity of East Prairie, Missouri. The project also seeks to manage water to enhance natural resource conservation and recreation opportunities using infrastructure that would be constructed for the project through various water management techniques/strategies (USACE 2009b). The project is based on the Flood Control Act of 1954, which authorized closure of a ca. 1,500-foot gap in the Mississippi River Frontline Levee at the southern end of the New Madrid Floodway and the Water Resources Development Act of 1986, which authorized improvements to drainage channels in the St. John's Bayou Basin including the construction of the St. John's Bayou and New Madrid pump stations.

The SJNM region was formed by numerous fluvial dynamics associated with large volumes of outwash and melt water from continental glaciers and subsequent drainage from the historic and current Mississippi and Ohio rivers (Saucier 1994). The contemporary SJNM landscape reflects various sequential periods of extensive scouring, sediment deposition, and migration of drainage channels especially in the Pleistocene period. During the pre-European settlement period of the mid to late 1700s (hereafter Presettlement period) the region supported extensive forest communities with some sand-type Prairie

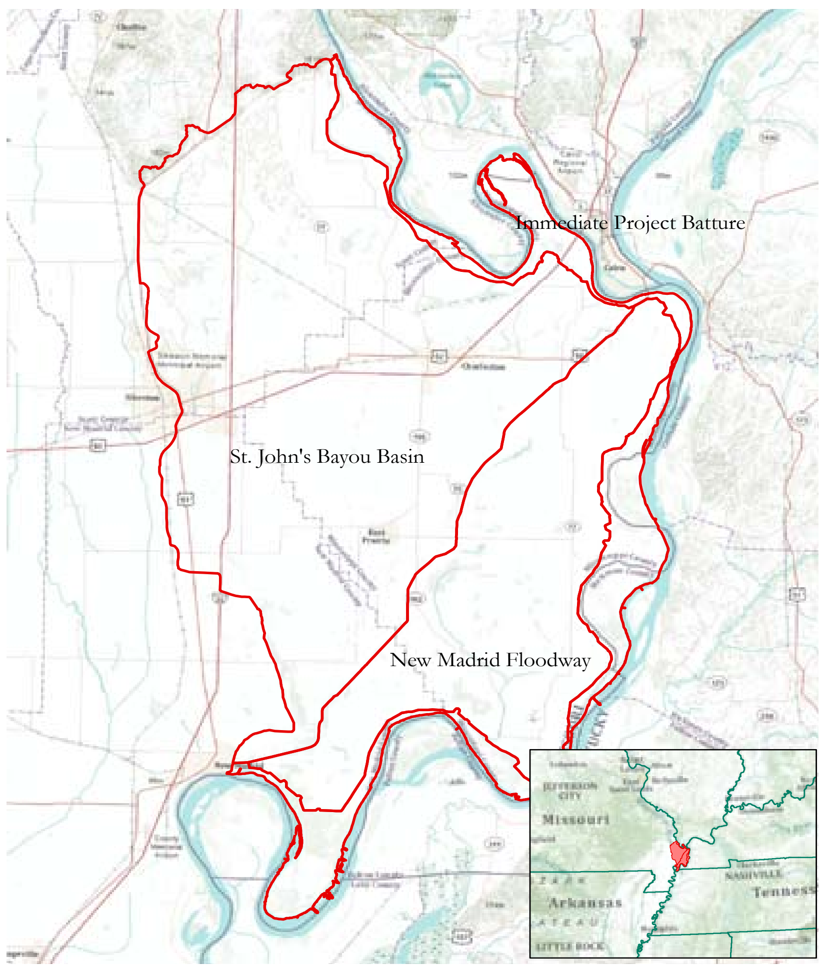


Figure 1. Location of the SJNM and major hydrogeomorphic regions and areas.

and Savanna on higher ridges (GLO 1817-1840, Nuttall 1821 and others). These plant communities provided many econiches and highly abundant and diverse resources that supported diverse animal communities. The primary ecosystem processes or "drivers" that sustained this ecosystem were seasonal backwater flooding from the Mississippi River and its local tributaries, regular deposition of nutrients to rich alluvial soils, occasional scouring and reworking of floodplain sediments, and vegetation disturbance from fire, wind, and herbivory (e.g., Heitmeyer et al. 2005). In the last 100 years, the Presettlement landscape of the SJNM has been greatly altered by changes in topography, hydrology, and conversion of most native habitat areas to extensive agricultural production (e.g. Korte and Fredrickson 1977).

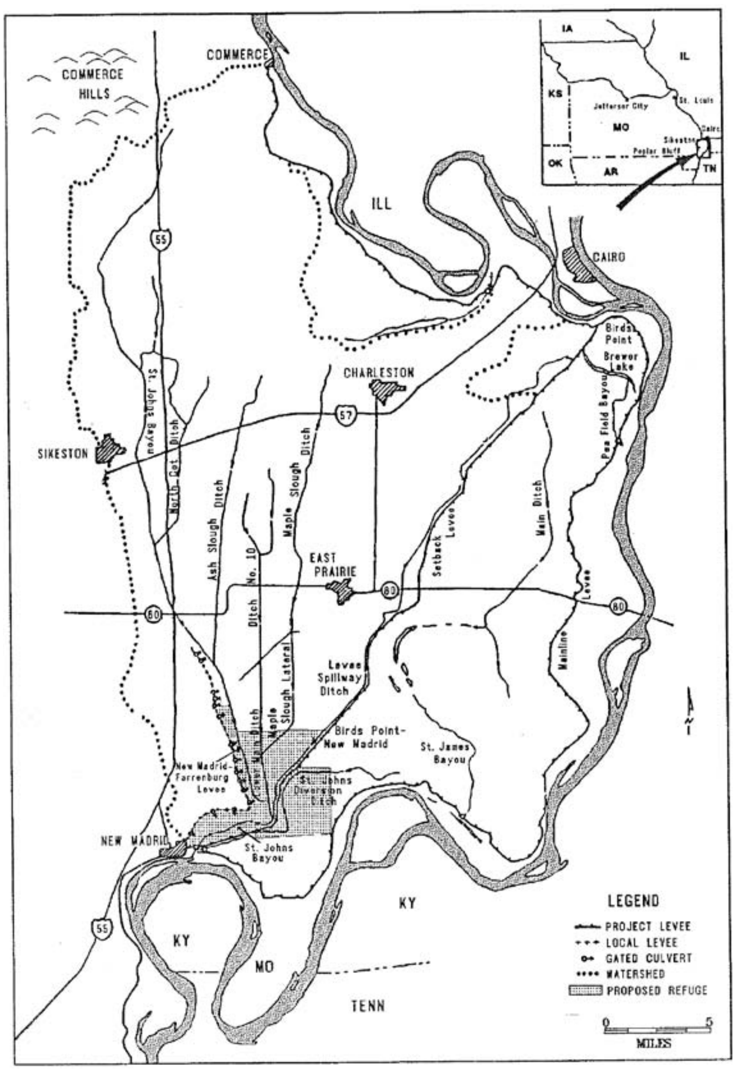


Figure 2. Location of major flood control and drainage ditches and levees in the SJNM (modified from USFWS 1993).

Currently, large areas in the SJNM flood annually as the Mississippi River rises and causes backwater flooding into the region (USACE 2009a). Efforts to reduce annual flooding of agricultural lands and occasional flooding of towns including East Prairie, Charleston, New Madrid, and Pinhook began coincident with extensive agriculture and settlement of the region in the late 1800s and early 1900s (Douglass 1912) and intensified following large floods in 1927 and 1937 (USACE 2009a). In the 1920s and 1930s a levee was built from New Madrid to the southern part of Sikeston Ridge (usually referred to as the New Madrid-Sikeston or New Madrid-Farrenburg Levee), a large mainstem/frontline levee was constructed along the Mississippi River from Commerce to New Madrid, and a setback levee was built from Birds Point to New Madrid (usually called the Birds Point-New Madrid Levee) to establish the New Madrid Floodway (Fig. 2). This levee construction separated the SJNM into three distinct hydrological regions: 1) Batture along the Mississippi River, 2) New Madrid Floodway, and 3) St. John's Bayou Basin. Initially, a 4,200 foot gap was left in the southern end of the St. John's Bayou Basin levee. Later this gap was closed with a levee extension, and floodgates were installed at the gap closure site in 1953 (USACE 2009a). The floodgates are left open to allow for interior drainage except during periods of high Mississippi River stages. During flood events, the floodgates are closed to prevent Mississippi River backwater flooding. Although closing the floodgates prevents this backwater flooding, it also blocks interior drainage and causes flooding behind the levee and floodgates. This headwater accumulation from the St. John's Bayou watershed can inundate about 10,056 acres, of which 6,312 acres are croplands. The south end of the New Madrid Floodway also left a 1,500 foot gap that did not join the frontline Mississippi and setback Birds Point-New Madrid levees. Although the gap in the levee provides drainage to the New Madrid Floodway, it also allows backwater flooding from the Mississippi River to enter the SJNM. Since 1960, large backwater floods from the Mississippi River into the SJNM have occurred in 1961, 1962, 1964, 1972, 1974, 1975, 1979, 1983, 1984, 1993, 1994, 1995, 1996, 1997, 1998, 2002, and 2008 (USACE 2009a). During 1996-98 floodwaters inundated large areas in the SJNM through late June each year and caused major losses of agricultural production. Based on previous analyses conducted by the USACE, a 2-year recurrence Mississippi River flood in the New Madrid Floodway inundates approximately 17,316 acres, of which 11,843 are agricultural croplands (USACE 2009a). In 2002, combined Mississippi River and local stream flooding covered about 77,000 acres, of which 61,400 were croplands, in the SJNM. Lost agricultural production obviously impacts local economies. Altered hydrology also has compromised management and restoration of certain remnant BLH sites including Big Oak Tree State Park (Flader 1993, USACE 2009a).

The SJNM Project is being designed to include features that will promote landscape-level natural resource conservation and management strategies along with providing season flood control protection. Incorporation of natural resource conservation features and objectives in the SJNM Project requires an understanding of historic and current landscape conditions including the basic physical and biotic structure, ecological processes, and landscape-scale interactions that control ecosystem characteristics, functions and values. Hydrogeomorphic methodology (see Heitmeyer 2007) now is commonly used to evaluate ecosystem restoration and management options in large river floodplain ecosystems in North America (e.g., Heitmeyer 2008, Heitmeyer et al. 2002, Heitmeyer and Fredrickson 2005, Heitmeyer and Westphall 2007, Heitmeyer et al. 2009). This Hydrogeomorphic methodology obtains and analyzes historic and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrological regimes, 5) plant and animal communities, and 6) physical anthropogenic features of landscapes ranging in scale from site-specific tracts to large watersheds. The Hydrogeomorphic perspective is valuable for the SJNM to determine the historic landscape context and configuration of the region and the subsequent changes to this system that have led to the contemporary condition. This report provides data and analyses to meet two basic objectives:

1. Determine the historic condition and ecological processes of the SJNM region using a variety of historical and current information including geomorphology, soils, topography, hydrology, faunal and floral accounts, maps, and other information sets.

2. Identify changes to physical, biotic, and ecological process components of the SJNM region from the historic condition.

METHODS

The first objective of this report identifies and predicts landscape context and potential community type and distribution for the SJNM by developing a Hydrogeomorphic "matrix" of understanding of which plant communities historically occurred in different geomorphic, soil, topographic, and hydrological settings (see e.g., Heitmeyer et al. 2002, Heitmeyer 2008, Klimas et al. 2009). The "baseline" for the "historic" condition in the SJNM used in this report is the time immediately prior to major European settlement in the area in the mid to late 1700s. While some settlers occupied the SJNM prior to the late 1700s, little alteration to native vegetation communities, regional hydrology, or topography had occurred by then (see e.g., Douglass 1912, Ogilvie 1967 and other references in a later section in this report).

The Hydrogeomorphic matrix of understanding, and prediction of, potential historic vegetation communities is developed from comprehensive scientific data discovery and field validation using published literature, vegetation community reference sites, and state-of-the-art understanding of plant species relationships (i.e., botanical correlation) to geomorphology, soil, topography and elevation, hydrological regimes, and ecosystem disturbances (e.g., Nelson 2005). These plant-abiotic correlations are in effect the basis of plant biogeography and physiography whereby information is sought on where plant species, and community assemblages, occur throughout the world relative to geology and geomorphic setting, soils, topographic and aspect position, and hydrology (e.g., Barbour and Billings 1991). The Hydrogeomorphic matrix allows maps of potential historic vegetation communities in the SJNM to be produced in an objective manner based on the botanical correlations that identify community type and distribution, juxtaposition, and "driving" ecological processes that created and sustained them. Obviously, the predictions of type and historic distribution of communities can only be as good as the understanding and documentation of plant-abiotic relationships and the geospatial data for the abiotic variables for a location and period of interest, such as Presettlement period.

In the Upper Mississippi Valley ecoregion that includes the SJNM, the major vegetation communities that were present during the Presettlement period are known (Nigh and Schroeder 2002, Nelson 2005) and the botanical relationships of these communities with abiotic factors are extensively documented and robust (e.g., see reviews in Wharton et al. 1982, Conner and Sharitz 2005, Klimas et al. 2009). For example, the relationships of BLH species to seasonal and annual flooding regimes and local topography in the Upper Mississippi Alluvial Valley (MAV) have been widely studied (e.g., Hall and Smith 1955, Broadfoot and Williston 1973, Bedinger et al. 1979, Fredrickson 1979, Keeley 1979, Black 1984, Hook 1984, Heitmeyer et al. 1989, 1991, and many others). As a specific example, the distribution of pin oak (*Quercus palustris*) and willow oak (*Quercus phellos*) is centered in sites with silt-clay-loam soils, dormant season flooding for up to 3 months, and within the 2-5 year flood frequency zone (Heitmeyer et al. 1989, 2006, Fredrickson and Batema 1992, Klimas et al 2009). The interrelationships among abiotic factors for the Upper MAV also are well understood and documented. For example, the type and spatial position of soils generally are closely related to geomorphic surface and formation. As a specific example, Crevasse sandy soils are found on the inbank sides of natural levee crests (Autin et al. 1991: 572). Excellent detailed maps of the geomorphology (Saucier 1994), soils (U.S. Department of Agriculture, SSURGO databases), and topography (LIDAR surveys conducted by the USACE) of the SJNM are available. In contrast, historic hydrology information for the SJNM is less available. Long-term river gauge data dating to the late 1800s and early 1900s are available for the Mississippi River at New Madrid and Thebes, respectively and to the early 1900s for the Ohio River at Cairo. Unfortunately, the stage-discharge relationships and the recurrence intervals of various river levels that caused backwater and headwater flooding into the SJNM prior to construction of the initial mainstem levees in the region are not known.

The robust vegetation community relationships in the Upper MAV enable a well-validated understanding of where historic major plant communities in the SJNM are located relative to geomorphic setting, soils, and hydrological regime. Consequently, even though Presettlement hydrology data area not available for the region, the confirmed relationships of species to other abiotic variables provide strong inference as to what the historic hydrological regime was for various locations. The primary communities in the SJNM are BLH and Sand Prairie/Savanna. These communities have relatively long generation cycles and their occurrence at sites indicates long-term response and adaptation to repetitive inter-annual and seasonal patterns of hydrology. If confidence is reached in understanding the position of a historic community type based on historic maps and botanical correlation with other abiotic variables including specific geomorphology, soils, and topography, then by default, the historic hydrological regime for a site also can be safely predicted. For example, if a historic site supported High BLH, then by default the site had (long-term average) short duration dormant season flooding within a 5-year flood frequency zone.

The sequence of methodology used to prepare the Hydrogeomorphic matrix and map of potential historic communities for the SJNM was:

1. The general distribution of major vegetation community/habitat types including Forest, Prairie, Bottomland Lake, river channels and chutes, etc. (Nigh and Schroeder 2002, Nelson 2005, Heitmeyer 2008) was determined from GLO surveys (General Land Office 1817-1840), historic cartography (e.g., Hutchins 1784, Collot 1826, De Finiels maps from the 1800s in Ekberg and Foley 1989, Colton 1857, Couzens 1861, Warren 1869 Mississippi River Commission 1881, 1893-1904, Brauer et al. 2005, Heitmeyer et al. 2006), and early settlement/naturalist accounts (e.g., Brackenridge 1814, Nuttall 1821, Schoolcraft 1825, Flint 1828, Flagg 1838, Wild 1841, Beckwith 1887, Douglass 1912). A generalized map of the historic distribution of communities using the above collective information was then overlain on contemporary geomorphology (Saucier 1994), soils (U.S. Department of Agriculture (USDA) SSURGO soils data), flood frequency (data from USACE, Memphis District), and LIDAR topography maps (from USACE, Memphis District).

2. The general correspondence of Presettlement vegetation communities from the above map sources with contemporary abiotic geomorphology, soils, and topography layers was determined where possible. Confidence in this "map" correspondence was best when geo-referenced digital maps were available, such as the GLO surveys, and was weakest when older maps and cartography are used. Despite the imprecision of some older maps and accounts, analyzing habitat information from these sources provides useful information to determine the general distribution of communities. Using this first-step overlay of map information, relationships between communities and abiotic factors sometimes became clearly defined by one or two factors. For example, in the SJNM all chute-and-bar surfaces (Woerner et al. 2003) with recently deposited and scoured sandy

soils (USDA SSURGO data) along the current Mississippi River channel were historically Riverfront Forest. Often, however, it was necessary to use multiple abiotic variables to understand botanical relationships.

3. Remnant native vegetation communities in the SJNM were identified from aerial photographs and other sources (e.g., Missouri Natural Areas Committee 1996). Select sites were visited in 2009 and 2010 to document vegetation characteristics, such as species composition, and to determine if the sites matched the community types predicted from step #2. If the historic maps and contemporary field data were consistent, then the field sites were considered a reference site of former community types (e.g., Nelson 2005, Nestler et al. 2010).

4. Major forest community types were subdivided into ecologically distinct sub-communities using botanical information for the respective communities where possible. For example, BLH communities in southeast Missouri and northeast Arkansas typically are distributed along topographic/hydrologic gradients and can be separated using the combination of soils, geomorphology, and topography (e.g., Nelson 2005, Heitmeyer et al. 2006, Klimas et al. 2009). BLH Forests in the SJNM occupied divergent geomorphic, soils, topographic, and hydrological settings ranging from natural levees, point bar ridges and swales, relict valley train channels, and Holocene depressions and isolated abandoned channels. For example Hpm1 Point Bar areas in the inside bends of abandoned Mississippi River channels contained meander scrolls with alternating parallel bands of lower elevation swales and higher elevation ridges. Swales in these sites typically had silt-clay soils with 1-2 year flood frequencies whereas ridges contained sandy- or silt-loams soils with 2-5 year flood frequencies. Consequently, by mapping soils and topography on point bar surfaces, BLH forest areas could be sub-divided into swale-type Intermediate BLH communities that have more water tolerant species such as overcup oak (*Quercus lyrata*), red maple (*Acer rubrum drummondi*), sugarberry (*Celtis laevigata*), and green ash (*Fraxinus pennsylvanica*) vs. the ridge-type High BLH communities that were dominated by American elm (*Ulmus americana*), winged elm (*Ulmus alata*), box elder (*Acer negundo*), pin and willow oak, and pecan/water hickory (*Carya aquatic*).

5. A matrix of predicted community types in relationship to the geomorphology, soils, topography, and flood frequency variables discovered in steps 1-4 above was prepared.

6. The position of predicted communities from the Hydrogeomorphic matrix on the composite digital geo-referenced maps of geomorphology, soils, topography, and flood frequency was mapped,

7. Aerial photographs were used to identify remnant habitats of the map predicted types (i.e. Sand Prairie, BLH and Riverfront Forest communities, Bottomland Lake, etc.) and reference sites and remnant habitats were revisited to determine the vegetation that was present. This field data collection was similar to step #3 in finding reference sites that represented and verified various communities.

8. Based on field and map data developed in steps 6 and 7, the matrix was refined and areas or communities were identified where correspondence with various abiotic factors were weaker. For example, geomorphic surface, soil and topography data predicted a greater extent of Sand Prairie and/or Sand Savanna on Sikeston Ridge and Pvl1 surfaces (Fig. 3) than was shown on the GLO maps. Some older accounts and maps from this area also suggest a greater extent of Prairie or more Open Woodland that likely was Savanna on these geomorphic surfaces in the late 1700s compared to GLO maps made from 1817-1840 (Hutchins 1784, see also Schroeder 1981). In this specific case it was necessary to overlay historic maps from the Pvl1 surface onto current digital maps to produce an estimate of the Presettlement Prairie and Savanna communities and how their distribution was related to current landscape features.

9. A map of potential historic vegetation communities was prepared by sorting the SJNM landscape relative to the Hydrogeomorphic matrix parameters. For example, Riverfront Forest was plotted where the unique matrix combination of geomorphic surface, soil types, topography, and known or assumed hydrological regime occurred.

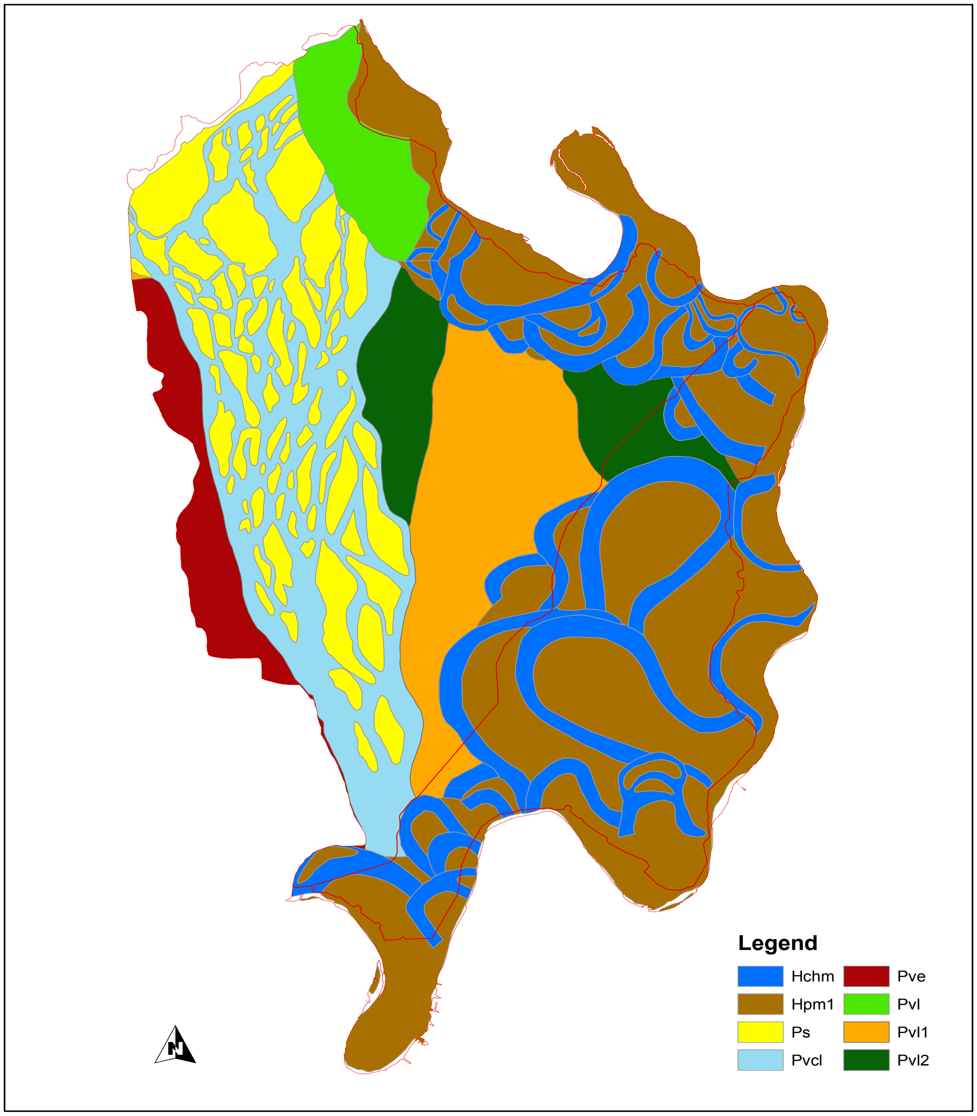


Figure 3. Geomorphic surfaces in the SJNM (from Saucier 1994). Hchm – abandoned channels of the Mississippi River, Hpm1 – point bar (meander scroll) deposits of Mississippi River meander belt 1 (newest age), Ps – sand dune fields and eolian deposits on valley trains, Pvcl – relict channels of Late Wisconsin stage valley trains, Pve – Early Wisconsin stage valley train, Pvl – Late Wisconsin valley trains where levels (ages) are separately delineated, Pvl1 – Late Wisconsin stage valley train level 1 (newest age) includes interfluves and relict channels unless channels are separately delineated, Pvl2 - Late Wisconsin stage valley train level 2 (next newest age) includes interfluves and relict channels unless channels are separately delineated.

The second objective used contemporary geospatial map information to describe alterations to the historic ecosystem attributes in relation to land form and soils, hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species. A major part of this objective is determining how much of the Hydrogeomorphic-predicted Presettlement vegetation communities have been lost and converted to other land types. Overlaying the matrix potential historic community map (Step #9 above) on 2009 USDA National Agricultural Inventory Program (NAIP) photographs provides this template and analyses in conjunction with field visits to remnant communities. This evaluation and comparison of historic vs. current land cover provides an objective way to assess current conditions and types and magnitude of changes. This comparison identifies which communities have been most destroyed or degraded and is useful to understand the resiliency of specific communities to environmental changes, the potential impacts of the SJNM project, and potential opportunities to reverse or mitigate/minimize degradations and restore communities if that is desired (e.g., Heitmeyer et al. 2006, Heitmeyer 2008).

THE HISTORIC SJNM ECOSYSTEM

The current geomorphology and surficial architecture of the SJNM are products of fluvial dynamics of sediment and water discharge primarily during the last glacial-interglacial cycle within the MAV (Autin et al. 1991, Saucier 1994). Wind and tectonic action further shaped land forms and surfaces. The SJNM region is underlain by deep basement rock deposited by Cretaceous marine deposits and sediments from surrounding uplands that filled in a continental rift that created the Gulf of Mexico in the Late Triassic and Early Jurassic times (Buffler 1991). Jackson, Wilcox, and Clairbone deposits from the Eocene period overlie the basement Cretaceous rock and occasionally subcrop to the surface of Upper MAV areas (Saucier 1994). The New Madrid Seismic Zone also runs under or near the SJNM and is an ancient rift fault that did not completely develop or separate (Fig. 4). This Seismic zone extends from ca. Cairo, Illinois to near Helena, Arkansas and caused the most severe earth tremors ever recorded in North America in late 1811 and early 1812, with the epicenter near New Madrid (Russ 1982).

The MAV, including the SJNM, was created by cyclic Pleistocene glaciation events. Although continental ice sheets did not extend into the MAV, they caused deranging pre-glacial drainage on several occasions and created southward-trending rivers and floodplain valleys that carried large volumes of glacial meltwater and outwash from the Interior of North America to the Gulf Coast (MaGill 1980, Saucier 1994). The SJNM includes parts of the St. Francis Basin and the Holocene Mississippi and Ohio River meander belts and includes numerous former channels and courses of both rivers that were braided in a valley train network (Fig. 3, Saucier 1974, Autin et al. 1991). Most of the SJNM is within the Cairo Lowlands (also commonly called the Charleston Lowlands),

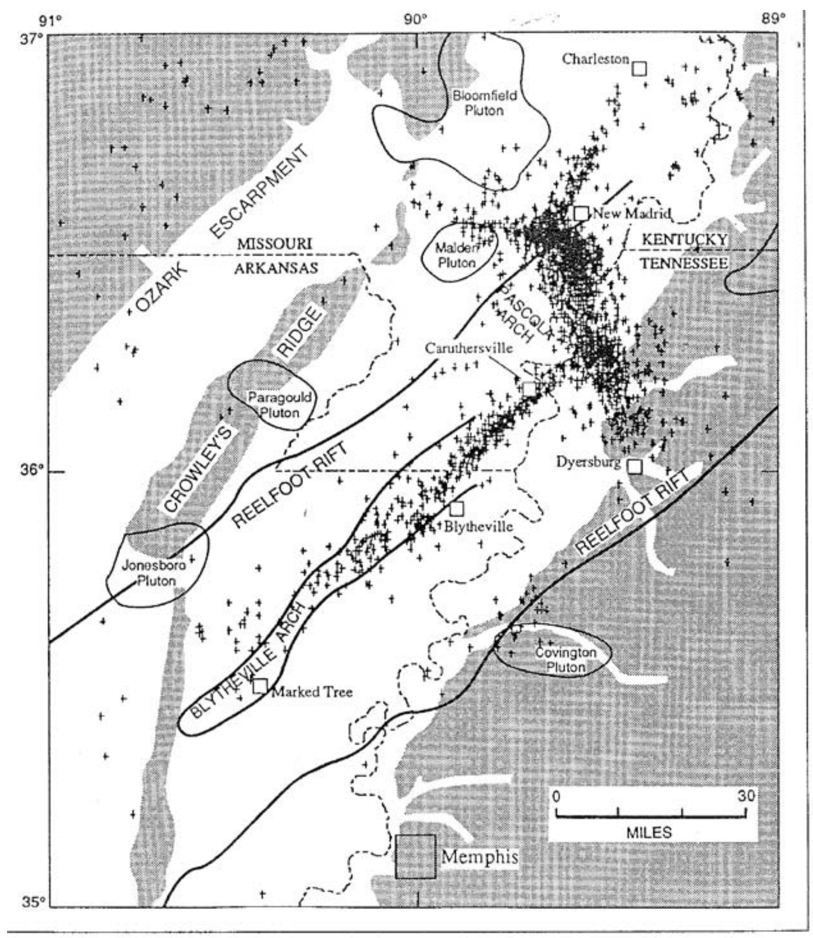


Figure 4. Map of seismic activity and epicenters of earthquakes in the Lake County Uplift zone along the New Madrid fault zone (from Saucier 1994).

which contains elevation alluvial surfaces bounded by Sikeston Ridge to the west, the Mississippi River to the south and east, and the Commerce Hills on the North (Saucier 1990).

Prior to continental glaciations a large percentage of runoff from northern parts of North America drained northward through the Great Lakes region (Frye et al. 1965, Simons et al. 1974). Most pre-glacial rivers that drained south into the Mississippi Embayment (the present MAV) were small and drained from relatively small watersheds. When glacial ice sheets formed and blocked northern drainage routes, glacial melt waters were forced south and carried large volumes of water, silt, sand, and gravel. These waters and suspended materials subsequently formed various channels and floodplains of the Missouri, Mississippi, and Ohio rivers. The historic Mississippi River flowed south along the southern edge of the Ozark Escarpment and changed course many times following glacial melt periods (Saucier 1974). Current landscapes along the Mississippi River mostly reflect river movements post-Wisconsin glaciation during the last 18,000 years (Saucier 1968, 1994). During this period the Mississippi River initially flowed southwest along the Ozark Escarpment and followed a path south along the current Black and White River floodplains to a point near Helena, Arkansas where it joined the Ohio River. Concurrently, the Ohio River flowed southwest in a braided course through the Cache Lowland of southern Illinois into the alluvial valley where it turned south and stayed east of Sikeston Ridge and occupied the current Mississippi River floodplain, including the SJNM region, to Helena (Gough 2005). Sikeston Ridge represents a 30-mile long remnant valley train terrace deposited in the mid-Wisconsin period about 40,000 to 60,000 years BP by the Ohio River as it discharged from the Cache Lowland into the St. Francis Basin (Saucier 1994). Sikeston Ridge is surrounded by Late Wisconsin Mississippi River glacial outwash as depocenters shifted east and the active outwash plain surface degraded to a lower elevation.

Both the Mississippi and Ohio rivers were small and somewhat restricted in early Wisconsin times, but expanded as the Wisconsin ice sheet began to melt and became large rivers during summer when melt waters peaked. From late fall to spring, before melting commenced each year or after it slowed, water levels dropped and the rivers followed many separate braided channels known as Valley Trains (Saucier 1994). This braided characteristic created a mosaic of channels and adjacent interfluve floodplain terraces often superimposed on older historic alluvial deposits.

When the Laurentide (Wisconsin) ice sheet began to rapidly melt about 18,000 years before the present (BP), a major increase in meltwater and outwash moved south in the Mississippi River floodplain (Saucier 1994). This volume of glacial runoff increased progressively, but in an episodic manner for several thousand years and by 14,000 BP the volume of water in the Mississippi River was over five times the current discharge. Accumulation of sedimentary material in the former Mississippi River floodplain through the Advance Lowlands in southeast Missouri gradually created a dam between Crowley's Ridge and the Ozark Escarpment near Puxico, Missouri and created a glacial lake known as Lake Girardeau in the Advance and Drum Lowland (Saucier 1968). When melt waters reached and filled this glacial lake, water began overflowing and eroding points in Crowley's Ridge and carved a new Mississippi River channel through the Bell City-Oran Gap and southward through the Missouri Bootheel region as early as 16,500 BP. As the volume of water through the Bell City-Oran Gap escalated, the river reworked a large area of Early Wisconsin age outwash and constructed a new Valley Train geomorphic complex (Pvcl, Ps, and Pvl2 surfaces shown on Fig. 3) at a slightly lower elevation than had existed previously. Relict Valley Train channels (Pvcl) remain obvious in a north-south band east of Sikeston Ridge and Pvl2 surfaces extend to the more recent Holocene Meander Belt. O'Bryan Ridge is a more pronounced slightly higher elevation area south of Wilson City. The Ohio River apparently abandoned the Cache Lowland at this time and adopted its present course past Cairo (Esling et al. 1989). No valley train deposit in the St. Francis Basin during this time can be attributed to the Ohio River, but the braided Ohio River flowed near the base of eastern floodplain bluffs and continued to merge with the Mississippi River near Helena (Saucier 1994).

At about 12,000 BP the Wisconsin glacial period ended and the postglacial period began. At this time a sudden shift in atmospheric circulation patterns initiated a strong trend toward warmer and drier conditions in the Upper MAV. After a relatively brief warming period ice sheets readvanced in the Great Lakes region about 10,500 BP. This ice sheet closed the St. Lawrence Valley outlet for the Upper Mississippi River and caused increased meltwater flow back into the Lower Mississippi River Valley

(Saucier 1994). This increased outwash flow of the Mississippi River was then able to spill through and rapidly widen and deepen a small existing upland drainage feature in the Commerce Hills south of Cape Girardeau, Missouri. This erosion through the Commerce Hills ultimate created the Thebes Gap that subsequently became the main channel of the Mississippi River. A depositional alluvial fan that contained a braided stream terrace configuration (Pvl1, Fig. 3), known as the Charleston Fan, subsequently formed immediately downstream from Thebes Gap where river water slowed and dropped sediments over a ca. 150 square mile area as it exited the constricted gap. This relatively new Charleston Fan extended south to Bayouville and contained the higher elevation Barnes Ridge at its south end.

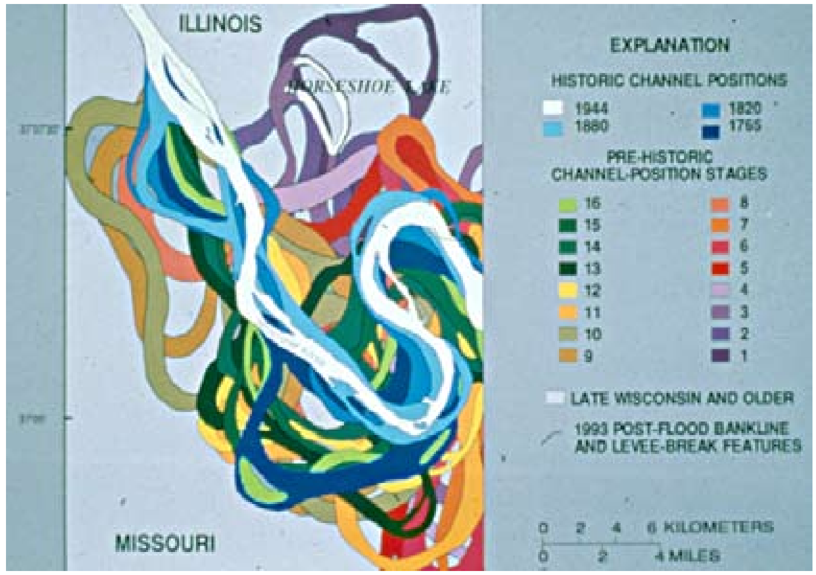


Figure 5. Possible historic sequence of Mississippi River channel migration in the northern part of the SJNM (modified from Fisk 1944).

After the Mississippi River channel cut through Thebes Gap it then occupied the former channel of the Cache River in southern Illinois and subsequently joined the Ohio River at Cairo, Illinois. At this time the Mississippi River also changed from a braided stream system to an actively meandering main channel regime between Cairo and Memphis about 10,000 years BP. Various geomorphic investigations have identified nearly 15 channel changes in the SJNM region in the last 10,000 years, four of which occurred since the mid 1700s (Fig. 5). Each channel change was accompanied by the development of new natural levees along the river channel, reworking of former alluvial and channel belt sediments, and establishment of sediment plugs in former channels that then created abandoned channel "oxbows."

The active Seismic Zone in the SJNM area also has influenced surface and subsurface geology, topography, and hydrology in the region. On the Holocene floodplain and adjacent Valley Train surfaces, the New Madrid earthquakes have caused liquefaction-induced ground failures over nearly 10,000 km2 in southeast Missouri and northeast Arkansas (Fig. 6, Saucier 1977, Obermeier 1989). Sand boils, lateral spreads, ground fissures, and localized distortion and warping of ground surfaces are common seismic-caused features. In the SJNM region, earthquake-induced liquefaction occurs in areas where a thin cohesive bed overlies a noncohesive bed, so that susceptibility is greatest where ground water saturates the noncohesive layer (Autin et al. 1991). Patterns of ground failure then are controlled by liquefaction, susceptibility, earthquake magnitude, and ground response characteristics.

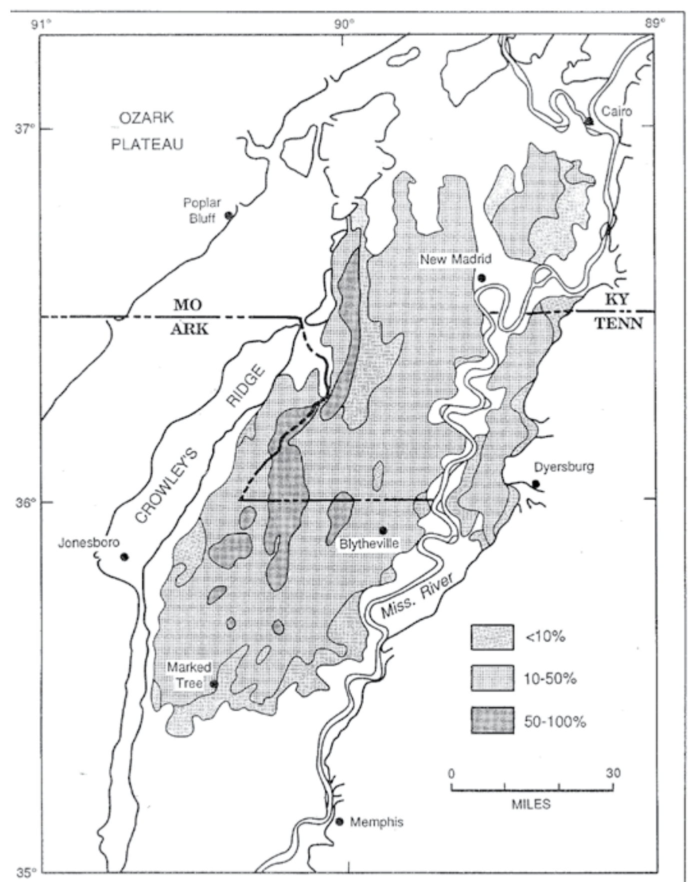


Figure 6. Distribution of seismic liquefaction features in the New Madrid Seismic Zone (from Saucier 1994).

Earthquakes in the region remain highly active since the large 1811-12 event; nearly 500 earthquakes with a magnitude of 3.0 mb or higher occurred from 1812 to 1974 (Saucier 1994:290). Twenty of these earthquakes measured 5.0 to 6.2 mb. Earth movements caused by seismic activity in the Lake County Unit block that includes the SJNM; suggest that low-order streams adjust their gradients to corresponding uplift patterns (Merritts and Hesterberg 1994).

In summary, the extremely active fluvial history of the Upper MAV created the contemporary heterogeneous geomorphologic surface context in the SJNM (Fig. 3). The contemporary land sediment assemblage map for the SJNM includes and identifies: 1) the eastern edge of Sikeston Ridge (Pve) on the far west side of the SJNM that was created 40-60,000 years BP by the Ohio River, 2) relict channels and interfluve terrace sand deposits (Pvcl and Ps surfaces) created by an active valley train drainage complex 12- 6,000 years BP and subsequently became partly reworked following the diversion of Mississippi River water through Thebes Gap, 3) late Wisconsin-age braided stream networks where levels are not distinguished (Pvl2), 4) the Charleston alluvial fan (Pvl1) created about 10,000 years BP that was deposited on top of Pvl2 surfaces, 5) the recent (10,000 years BP to the present time) meander belt of the Mississippi River channel and its floodplain including point bars and meander scrolls (Hpm1), and 6) numerous abandoned channels (Hchm) and accompanied relict natural levees.

SOILS

Most of the SJNM is covered by nearly 200 feet of alluvial deposits of gravel, sand, silt, and clay (Luckey 1985, Saucier 1994). Soils in the region reflect the age and source of alluvial material and include a heterogeneous array of Alfisols, Entisols, Inceptisols, Mollisols, and Vertisols (Fig. 7). The deposition of sand sediments in Valley Train areas was followed by a period when well-developed Alfisols formed on higher "ridge" areas on the Sikeston Ridge and the edge of the current Holocene Mississippi River meander belt (Autin et al. 1991). Minimally developed Entisols are sites of continuous deposition and unweathered colluviums materials on higher terrace elevations in the Valley Train braided stream terrace regions of the SJNM. Entisols cover all of the higher elevation portions of the Charleston Fan (Pvl1) and interfluve areas of western Ps and Pvl2 surfaces. Mollisols contain more developed soil horizons and often include loam-clay veneers of varying depth. These soils developed in relict valley train channels of Pvcl and Pvl1 and 2 surfaces and on higher elevation ridge-and-swale surfaces on point bar meander scrolls. Inceptisols are present on Holocene Mississippi River natural levee areas and typically have more coarse sediments with little clay present. Vertisols occupy large areas of the Holocene

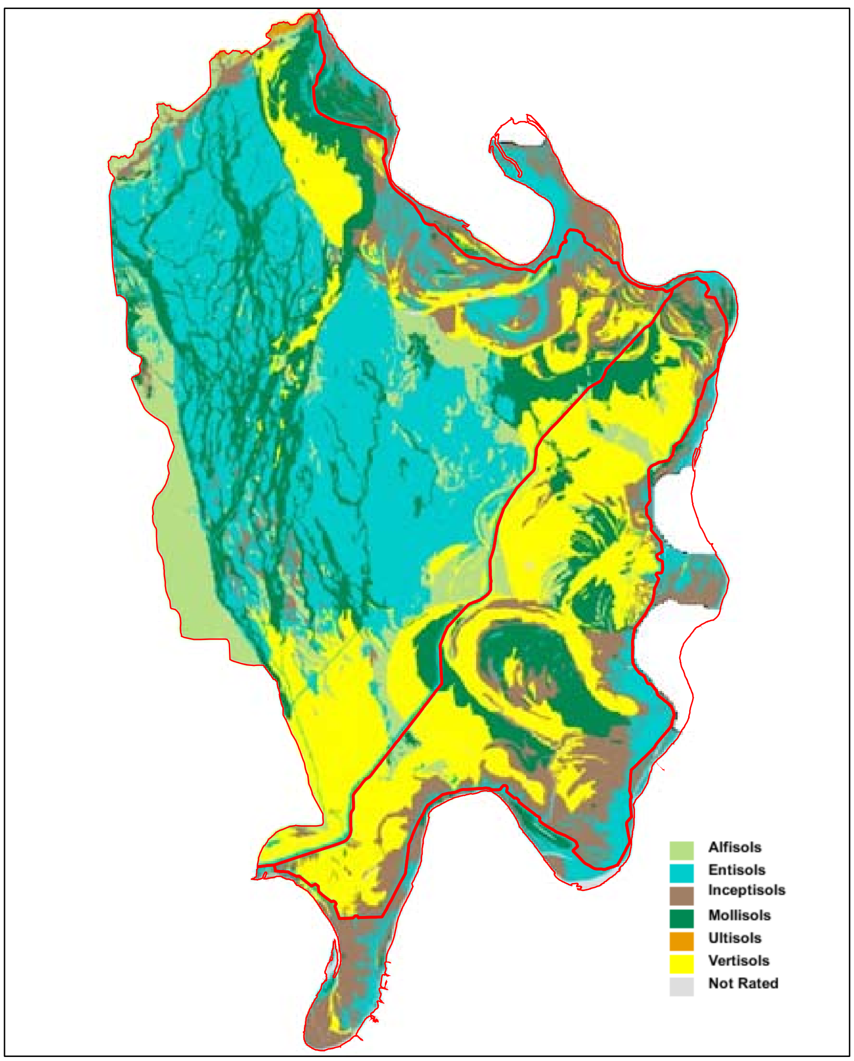


Figure 7. Broad soil taxonomy of the SJNM (modified from Mayhan 2001).

meander belts of the Ohio and Mississippi River and contain expansive clays that occur in the numerous abandoned channels and lower floodplain depression areas of the SJNM. Clay layers in these Vertisols are usually 10-20 feet thick and overlie 120-150 foot thick sands and gravels.

Nearly 60 individual soil types occur in the SJNM (Fig. 8) and reflect their age and affiliation with the fluvial-geomorphic history of individual locations. Sharkey-Alligator thick clay Vertisols dominates most Holocene abandoned channels and floodplain depressions. Sharkey-Alligator clays are heavy expansive sediments deposited in calm water areas including the bottoms of abandoned channels, backwater depressions, and some point bar swales. In contrast, Caruthersville sand loams and Commerce silty clay loams are present in Hpm1 Inceptisols that cover areas with strong water currents near recently scoured edges of river channels and natural levees, respectively. Braided stream terraces and sand dunes (Ps, Pvl) typically are covered with younger, less well developed, Entisols that primarily are Scotco sand, Boskett sandy loam, Clana loamy fine sand, and Lilbourn find sandy loams. Bosket fine sandy loam also covers most of Sikeston Ridge. Relict valley train channels (Pvcl) contain Mollisols with more clay and loam than the terraces and are usually dominated by Sikeston loam and Diehlstadt sandy clay loam soils. Sand-based Clana soils cover most of the Charleston Fan. Mollisols also cover much of the inside meander scroll ridge surfaces of abandoned channel point bars and include many silt-loam soil types such as Acadia, Dundee, Falaya, Reelfoot and Towosaghy.

TOPOGRAPHY

Land surface elevation in the SJNM ranges from 280 to 325 feet above mean sea level (amsl) (Fig. 9). Topography in the region is complex and reflects the geomorphic surfaces present. The combination of ridge-and-swale point bar surfaces, abandoned channels, and natural levees on the east part of the SJNM create elevation differences of up to 10-20 feet, and dramatically different flood frequencies, within short distances (Fig. 10). For example, natural levees along deeper abandoned channels may be 20 feet higher than the bottom of the channel. Likewise, the intricate valley train network of braided stream terraces created mosaics of relict channels and interfluves ridges that vary by over 10 feet locally. The Sikeston Ridge on the far west side of the SJNM is up to 30-40 feet higher than the surrounding Late Wisconsin Mississippi River glacial outwash valley train configurations (Pvl2). The Charleston Fan Pvl1 surface also is > 10 feet higher than the adjacent Pvl2 valley train complex and the Hpm1.

CLIMATE AND HYDROLOGY

The climate of the SJNM is characterized by warm summers and relatively mild winters. Average monthly temperatures range from the high 20s (degrees Fahrenheit) in January to about 90 degrees in July (Fig. 11). The frost-free growing season ranges from 174 days in 9 of 10 years up to 212 days one of every 10 years (Festervand 1981). During summer the sun shines 80% of the time while it shines about 50% of winter days. Average relative humidity in mid-afternoon is about 60% in summer with occasional 90% humidity levels occurring. Annual precipitation has ranged from 27 to 80 inches during the period of record, with an average of 47.2 inches of rainfall and about 8 inches of sleet and snow. The wettest months typically are March through May while August and October are dry (Fig. 12). Frontal systems associated with low pressure systems provide the majority of local rainfall. During summer, convection clouds caused by high daily temperatures and humidity levels often cause afternoon showers. Thunderstorms occur about 50 days each year (Festervand 1981). The prevailing wind is from the southwest. Long term precipitation data from New Madrid indicate somewhat alternating patterns of high vs. low annual precipitation in the region. For example, dry years with < 40 inches of rainfall occur about every 6-8 years, while wet years with > 60 inches of rain occur about every 8-10- years (Fig. 13). This alternating pattern of annual precipitation is relatively similar to the 6-8 year pattern in the Mingo Basin about 60 miles to the northwest (Heitmeyer et al. 1989).

Annual discharge in the Mississippi River Reach of the SJNM varies seasonally and annually. Mean monthly discharge at Thebes typically exhibits a unimodal pattern of highest flow in April and May followed by a gradual decline to relatively low stable levels from August to January (Fig. 14). This pattern reflects increases in precipitation and snowmelt in the Upper Mississippi River watershed in spring and corresponding decreased precipitation and runoff from summer through winter. While the average seasonal pattern of river discharge is fairly unimodal, the monthly ranges of discharge are

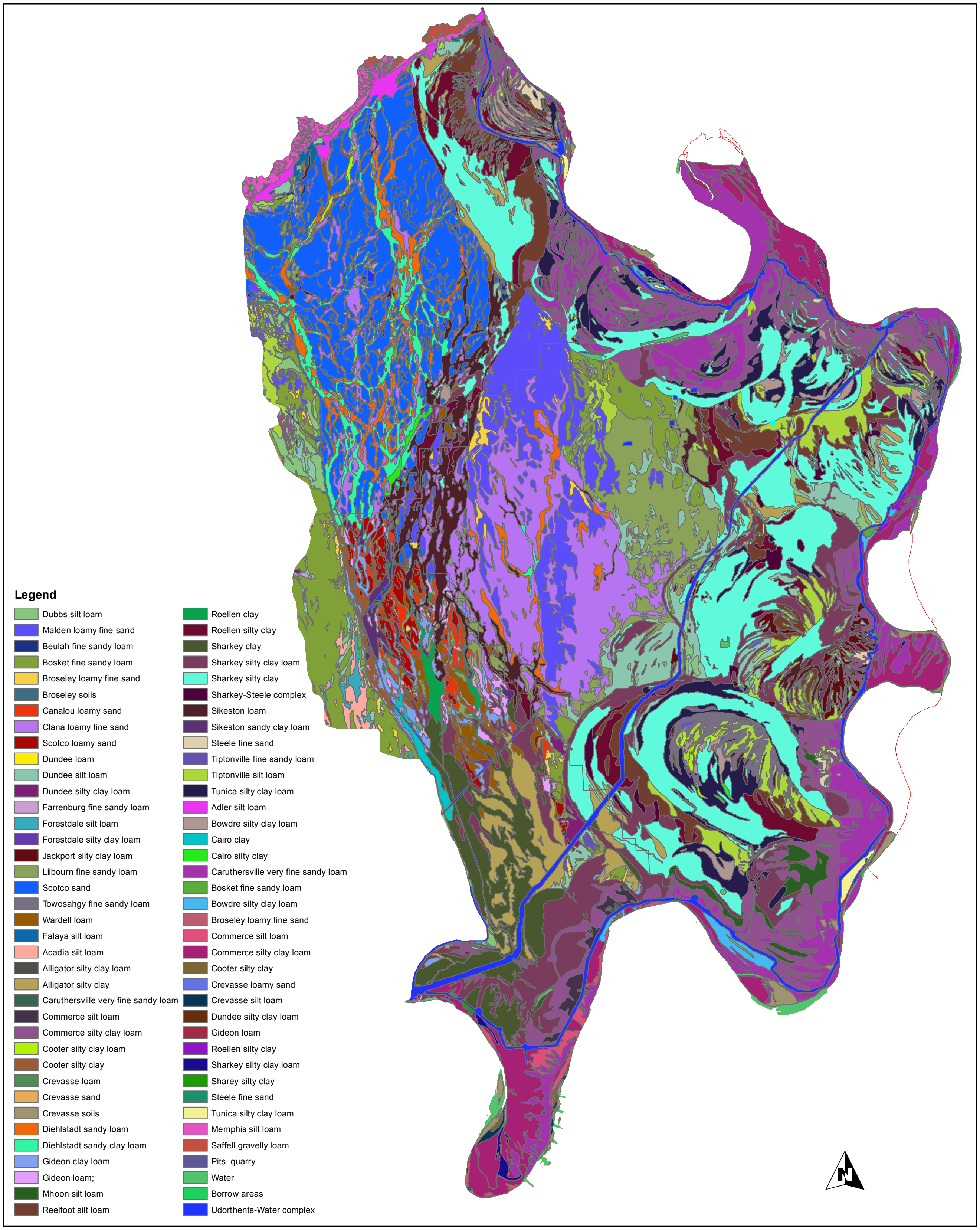


Figure 8. Soil types in the SJNM (from USDA SSURGO).

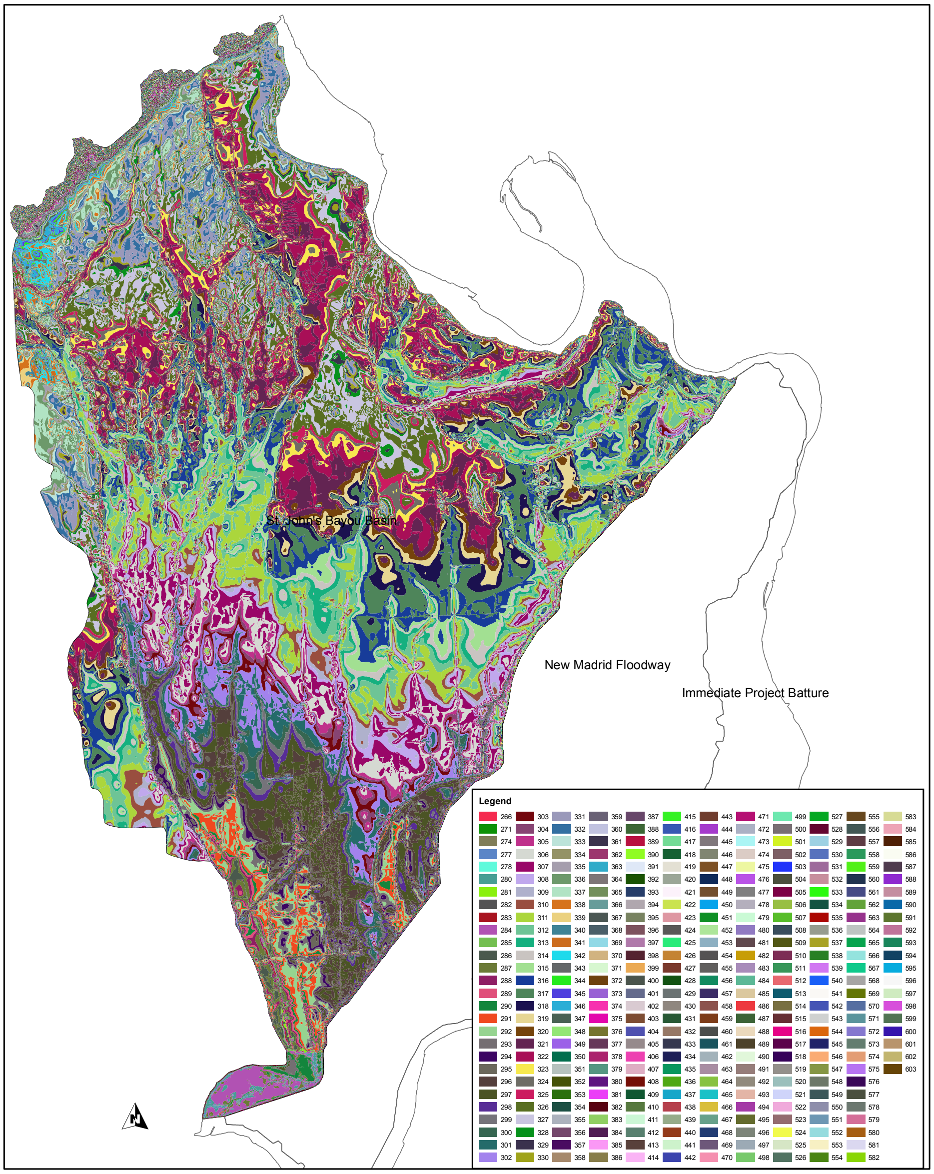


Figure 9. One-foot topographic contour elevation map of the St. John's Basin derived from LIDAR analyses (U. S Army Corps of Engineers, Memphis District).

wide, with occasional high discharge occurring even in late summer and fall (Fig. 14). Mean annual discharge also exhibits alternating patterns of low vs. high river levels and that the system appears to gradually be getting wetter (Fig. 15).

Overbank flooding of the Mississippi River (in association with Ohio River flows) into the SJNM prior to the presence of mainstem-river and interior-floodplain levees undoubtedly followed natural seasonal and annual patterns of alternating high vs. low and wet vs. dry discharge and precipitation levels locally and in the watershed above the region. Unfortunately, historic Mississippi River stage-discharge correlations for the SJNM are not available for mid-late 1800s periods. However, mean monthly water elevations in the St. John's Bayou Basin and New Madrid Floodway from 1943 to 1974 describe rising and falling Mississippi River water levels and annual average periods of inundation by elevation (Tables 1, 2). Analyses of this regional stage-elevation information and known overbank flooding levels of the Mississippi River at Thebes (494,000 cubic feet/second (cfs), a 33 feet gauge reading, and 300 feet NGVD29 elevation) and New Madrid (34 feet gauge reading and 289.48 feet NGVD29) and the Ohio River at Cairo (50 feet gauge reading and 270.9 NGVD29), suggest that some spring backwater flooding into lower elevations < 280 feet NGVD29 including depressions, relict valley train channels, and abandoned river channels probably occurred almost every year. Higher flood events also caused regular, sometimes prolonged flooding, of higher elevations > 295 feet.

Existing flood frequencies in the St. John's Bayou Basin and New Madrid Floodway using 1943 to 1974 period of record information indicates over 25,000, 65,000 and 87,000 acres of inundated land in 2-, 5-, and 10-year event floods, respectively (Table 3). Large flood events > 600,000 and 800,000 cfs at Thebes have occurred in 24 and 9 years, respectively since the late 1920s (Fig. 16). Historical river crests at Thebes have been over 40 feet stage in 1844, 1973, 1985, 1987, 1993, 1995, 2002, and 2008 (www.crh.noaa.gov/shps2/crests.php). At New Madrid, river crests > 41 feet stage (> 296 and up to 304 feet amsl) occurred in 1913, 1937, 1950, 1975, 1979, 1983, 1995, 1997, 2002, and 2008. All historic large flood events in the SJNM have occurred in spring and early summer; fall and winter flood events are rare (Fig. 17). For example, only 2 overbank stage river

Table 1. Mean monthly surface water elevations in the St. John's Bayou Basin, 1943-1974 (from USACE 2009a).

Month	Existing Conditions No Pump Elev, Ft NGVD	Authorized Project Conditions 1000 cfs Pump Elev, Ft NGVD	Alternative Project Conditions 1000 cfs Pump Elev, Ft NGVD
Jan	274.4	284.7	284.7
Feb	277.1	275.5	276.1
Mar	281.5	279.2	279.9
Apr	282.8	280.3	280.9
May	280.1	277.9	278.6
Jun	274.1	273.0	273.4
Jul	270.5	269.7	270.0
Aug	265.9	265.5	265.5
Sep	264.0	263.3	263.3
Oct	263.9	263.3	263.3
Nov	266.1	265.5	265.5
Dec	270.1	279.3	279.3
Mean	272.5	273.1	273.4

Table 2. Mean monthly surface water elevations in the New Madrid Floodway, 1943-1974 (from USACE 2009a).

Month	Existing Conditions Open & No Pump Elev, Ft NGVD	Authorized Project Conditions Closure & 1500 cfs Pump Elev, Ft NGVD	Option 1 & Option 2 Closure & 1500 cfs Pump Elev, Ft NGVD	Option 3 Closure & 1500 cfs Pump Elev, Ft NGVD	Option 4 Closure & 1500 cfs Pump Elev, Ft NGVD
Jan	274.6	282.3	282.3	282.7	282.8
Feb	278.1	273.1	274.8	275.2	275.3
Mar	282.2	274.9	277.5	277.8	277.8
Apr	283.7	275.7	278.5	278.6	278.6
May	280.0	275.0	277.2	277.2	277.2
Jun	274.5	272.3	273.3	273.4	273.5
Jul	270.7	269.5	270.2	270.3	270.4
Aug	265.9	265.7	265.8	266.3	266.6
Sep	264.0	264.0	264.0	265.1	265.6
Oct	264.4	264.3	264.3	265.5	265.9
Nov	266.1	265.9	266.0	266.9	267.2
Dec	269.9	277.6	277.6	279.0	279.3
Mean	272.8	271.7	272.6	273.2	273.3

levels occurred at New Madrid from December to February in the 60 year period 1939-40 to 1998-99 (Heitmeyer 2006).

Surface inundation and water elevations in the SJNM are not totally dictated by overbank or backwater flooding of the Mississippi River and its tributaries. The relatively porous nature of geomorphic surfaces that contain deep sand stratigraphy layers (Saucier 1994) causes groundwater levels in many locations to rise and fall in correspondence to Mississippi River levels (Luckey 1985). Consequently, Mississippi River levels that are above floodplain land elevations can create a hydraulic pressure head sufficient to cause groundwater to move from the river into and through subsurface land/gravel layers and discharge into depression areas. It is common for certain wetland depression sumps in the SJNM to be shallowly flooded when Mississippi River levels rise even if no local/regional precipitation has occurred for some time.

The SJNM is underlain by consolidated aquifers of Paleozoic age and unconsolidated aquifers of Mesozoic and Cenozoic age (Luckey 1985). The older McNairy aquifer ranges from 0 to 600 feet thickness in southeast Missouri and is > 1,000 feet below the land surface in the SJNM. This aquifer has a large artesian head and low iron and hardness concentration (Luckey 1985). The Wilcox Group lies < 300 feet below the surface and is up to 600 feet thick in the region. This aquifer is recharged from the overlying alluvial aquifer near the subcrop of the Wilcox Group. The alluvial aquifer is 100-200 feet thick and is locally capable of yielding more than 3,000 gallons/minute from wells. The aquifer is recharged from local precipitation and the Mississippi River flows and discharges by evapotranspiration and to the surface water system. The potentiometric surface of the alluvial aquifer is near the ground surface in many SJNM locations (Fig. 18).

VEGETATION COMMUNITIES

Paleoclimate Vegetation

During the late Wisconsin full-glacial interval (ca. 18,000 BP), the Upper MAV including the SJNM was covered mostly by boreal forest communities (Delcourt and Delcourt 1981, Delcourt et al. 1999). Apparently, a Spruce-Jack Pine-Willow forest type was present on the Valley Train braided stream terrace geomorphic surfaces of the region that was created by glacial meltwater flowing down the Mississippi and Ohio River corridors. Post glacial warming of the region about 14,000 BP caused the jack pine-dominated community in the Upper MAV to recede northward, however some evidence suggests that considerable Spruce-Willow communities were retained at least in areas east of Crowley's Ridge in Missouri (Delcourt et al. 1999). By 12,000 BP, warming temperatures allowed expansion of Oak-Hickory forests onto SJNM abandoned stream terraces. Subsequently, by 10,000 BP vegetation in the region had shifted to temperate to warm temperate types and a Sweetgum-Elm forest type perhaps similar to contemporary Intermediate BLH communities (see below) apparently occupied areas along the Mississippi River channels; some giant cane (*Arundinaria gigantea*) also was present on natural levee locations. Willow (*Salix sp.*) and other early succession tree species including cottonwood (*Populus deltoids*), sycamore (*Platanus occidentalis*) and maple (*Acer rubrum* and *Acer saccharinum*) (similar to the contemporary Riverfront Forest - see below), occupied newly scoured and regularly inundated areas along the active river channels (Delcourt et al. 1999). Bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatic*) were present along with water tolerant shrubs occupied edges of abandoned channels and other deeper depressions including relict Valley Train channels. An Oak-Hickory forest similar to the contemporary High BLH communities appears to have expanded onto higher elevation braided stream terraces at this time.

Beginning about 8,000 BP, continental climate warmed and dried and created the "Hypsithermal" or "Altithermal" period through about 4,000 BP (Saucier 1994, Delcourt et al. 1999). Drought-tolerant tree species expanded and most of the Oak-Hickory forest that had previously dominated higher elevations

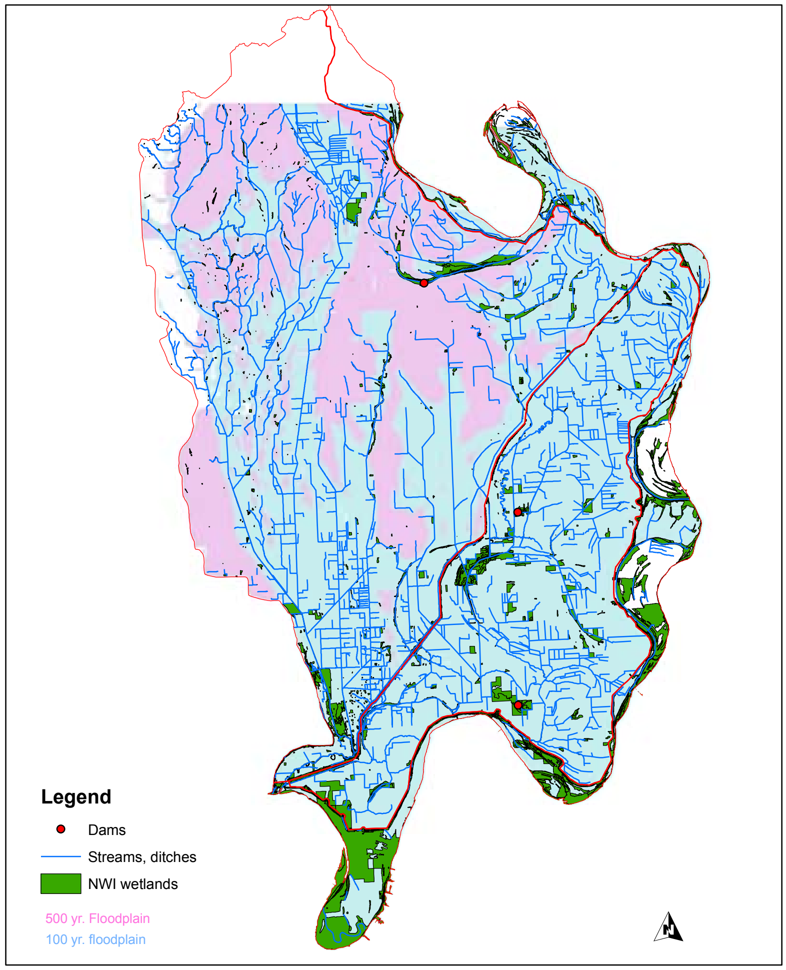


Figure 10. 100- and 500-year floodplain designation, streams and ditches, and certain forest areas delineated by the USFWS National Wetland Inventory in the SJNM.

Table 3. Existing flood frequencies (annual probability of flood recurrence) and inundated acres in the St. John's Bayou Basin and New Madrid Floodway (from USACE 2009a).

Event (year)	St. Johns Bayou Basin (acres)	New Madrid Floodway (acres	Total
2	10,056	17,316	27,372
5	30.032	35,381	65,413
10	34,155	53,519	87,674
25	40.073	70,108	110,181
30+	55,000	75,078	130,078

probably shifted to a Savanna community with interspersed Prairie occurring on higher and drier elevations and soils, especially the Sikeston Ridge, interfluve Ps dune areas in older Valley Train complexes, and on the Charleston Fan. Wetter areas along the Mississippi River probably contained a diverse BLH community likely dominated by sweetgum (*Liquidambar styraciflua*), elm, ash, and willow with giant cane present on natural levees and some floodplain ridges (Delcourt et al. 1999). Bald cypress and water tupelo also apparently remained in floodplain depressions and abandoned channel locations.

Starting about 4,000 BP, climate in the SJNM moderated to a milder and wetter condition (Delcourt et al. 1999). The Sweetgum-Elm forest apparently re-expanded onto lower floodplain terraces and Riverfront Forest communities widened along active river channels. A diverse Terrace Hardwood-type Forest community likely expanded on higher elevation terraces and Prairie and Savanna areas likely decreased in extent at this time. The continuous channel migrations of the Mississippi River in the SJNM undoubtedly shifted the positions of Holocene floodplain vegetation communities regularly as water flow pathways, sediment, and scouring actions reworked and redistributed soils and water regimes. By about 1,000 BP certain portions of higher elevations in the SJNM apparently were covered by perennial grass and old field vegetation (Delcourt et al. 1999). These areas may have been sites disturbed or farmed by Native people and represented succession of abandoned fields (Lafferty and Price 1996, Lafferty 1998).

Presettlement Period Vegetation

The heterogeneity of geomorphic surfaces, soils, and topography in the SJNM in the 1700s created diverse and highly interspersed vegetation communities distributed across elevation and hydrological gradients (Fig. 19). Major natural community/habitat types that historically were present in the SJNM included: 1) the main channel and islands of the Mississippi River and major tributaries, 2) river "Chutes" and "Side Channels", 3) Bottomland Lakes often

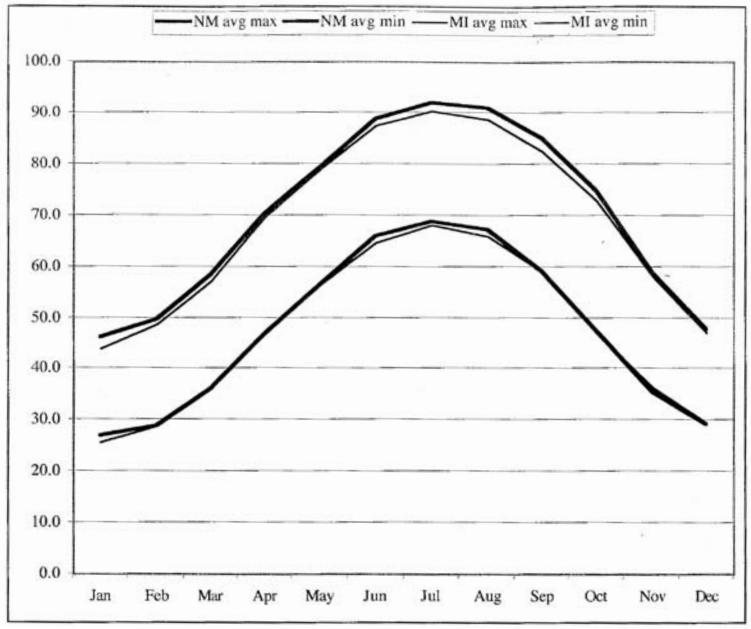


Figure 11. Average daily minimum and maximum temperatures for the SJNM (adapted from Buchner et al. 2009).

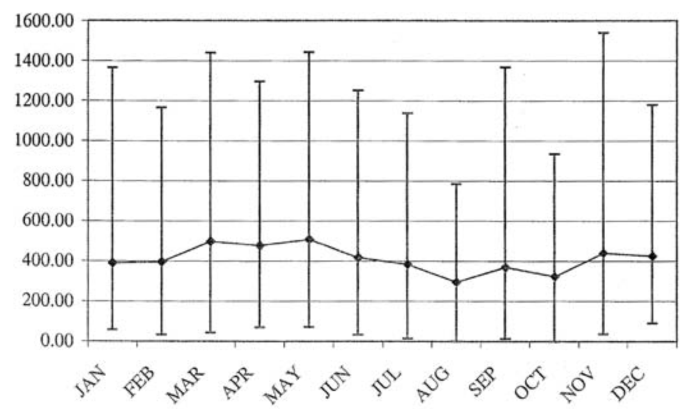


Figure 12. Mean monthly precipitation and range at New Madrid, Missouri (from Papon 2002).

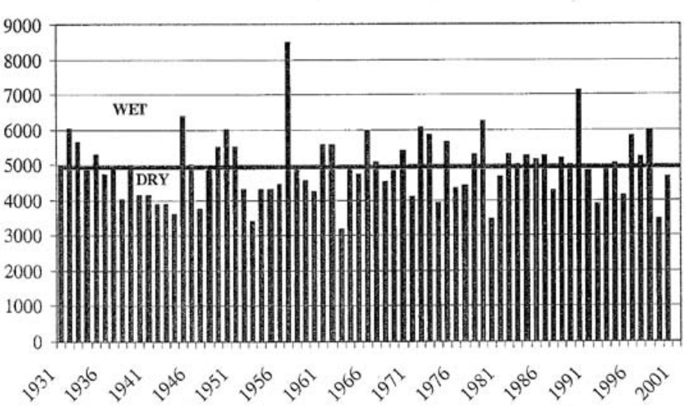


Figure 13. Annual precipitation and long-term mean precipitation at New Madrid, Missouri 1931-2001 (from Papon 2002).

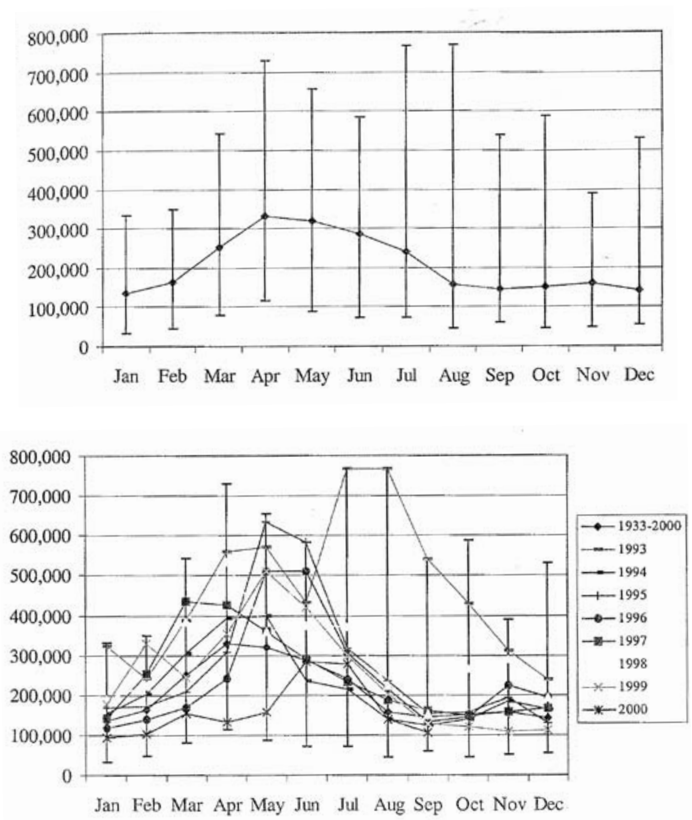


Figure 14. Mean monthly discharge of the Mississippi River at Thebes, Illinois 1933-2000 (from Papon 2002).

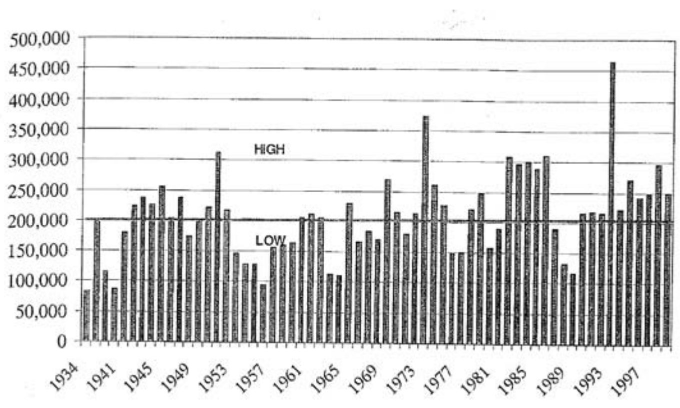


Figure 15. Mean annual discharge and long-term mean of the Mississippi River at Thebes, Illinois 1934-2000 (from Papon 2002).

referred to as oxbows or abandoned channel depressions, 4) Riverfront Forest, 5) BLH Forest, 6) Terrace Hardwood Forest, 7) Slope Forest, 8) Sand Prairie, and 9) Savanna (Nigh and Schroeder 2002, Nelson 2005). Lists of fauna and flora for these habitats are provided in Terpening (1974), Nelson (2005), and Heitmeyer et al. (2006).

The main channels of the Mississippi River and its major tributaries (e.g., Black Bayou, St. John's Bayou) contain open water with little or no plant communities other than phytoplankton and algae (Theiling 1996). During low river levels in late summer and early fall, some river Chutes and Side Channels become disconnected from main channel flows and have stagnant water that supports sparse herbaceous "moist-soil" plants that germinate on exposed mud flats. During high river flows Chutes and Side Channels become connected with the main channel and scouring action of river flows prevents establishment of rooted plants in these habitats. The extent and duration of river connectivity is the primary ecological process that controlled nutrient inputs and exports, primary and secondary productivity, and animal use of Chutes and Side Channels. A wide variety of fish historically were present in the Mississippi River and tributary rivers and their Side Channels (e.g., Pflieger 1975), and these habitats also were used by many amphibians, a few aquatic mammals, and some water and shorebirds (Smith 1996). Many remnant and active river chutes and side are present in the SJNM; representative sites include those around Wolf Island, Seven Island, along Donaldson's Point, and Islands 2, 3, and 4.

Few large permanent "islands" historically occurred within the Mississippi River or tributary channels in the SJNM, but "bars" were common on the edges of the Mississippi River channel, especially on the downward side of major bends (Fig. 20, Mississippi River Commission 1881, 1893-1904, Brauer et al. 2005). Most "islands" in the SJNM actually were extensions of floodplain chute and bar geomorphic surfaces and usually were separated from the floodplain by narrow, often highly sedimented, older Side Channels. During dry periods these "islands" became extensions of terrestrial floodplain surfaces. Vegetation on islands and bars depends on size, configuration, and connectivity to banks (Turner 1936). The degree and duration of flooding and connectivity to either the river or floodplain controls ecological attributes and animal use of islands and river bars. Most islands and bars historically were 1-4 feet below adjoining floodplain elevations and were overtopped during annual high flow periods (Brauer et al. 2005). During floods, river bars often become extensively scoured or destroyed, and new bars subsequently are created in other locations. Vegetation on bars is mostly pioneering plants that germinated on newly deposited alluvium. Annual herbaceous plants and seedlings of cottonwood, sycamore, and willow are the most common plants. Larger islands in the SJNM including Wolf, Seven, and Powers Islands contained Riverfront Forest communities with some aquatic and herbaceous wetland plants in interior swales and sloughs.

Bottomland Lakes were present throughout the SJNM during the Holocene period and occupied abandoned Mississippi River channels (Saucier 1994). The location, age, and size of Bottomland Lakes determined depth, slopes, and consequently composition and distribution of vegetation communities. Bottomland Lakes in the SJNM historically were surrounded by BLH Forest and usually contained embedded or narrow bands of Bald cypress/water tupelo and/or shrub/scrub (S/S) vegetation along their edges (Heitmeyer 2008:19). S/S communities represent the transition area from more herbaceous and emergent vegetation in the aquatic part of Bottomland Lakes to higher floodplain surfaces that support trees. S/S habitats typically are flooded a few inches to 2-3 feet deep for extended periods of each year except in extremely dry periods. S/S habitats in the SJNM are dominated by buttonbush (*Cephalanthus occidentalis*), swamp privet (*Forestiera acuminate*), and willow. A natural levee usually is present along the edges of Bottomland Lakes and these areas support diverse composition less water tolerant forest species as a unique High BLH type (see below). The ends of some Bottomland Lakes contain Riverfront Forest species that germinate on coarse-grain materials that had "plugged" the old abandoned channel (Saucier 1994). Representative remnant bottomland lake ecosystems in the SJNM include more recent larger abandoned channels at Ten Mile Pond and Robert G. Delaney Lake CA's and smaller older sites are present near the Eagle's Nest USDA Wetland Reserve Program (WRP) site in Mississippi County. Water regimes are managed on each of these sites, but vegetation communities still contain the range of open water, S/S, Bald cypress/water tupelo, and seasonal herbaceous edge habitats. Few, if any, bottomland lakes retain natural hydrologic regimes.

Most newer and deeper Bottomland Lakes in the SJNM during the Presettlement period probably had central areas of permanent "open water" that contained abundant aquatic "submergent" and "floating-leaved" vascular species such as pondweeds (*Potamogeton sp.*), coontail (*Ceratophyllum demersum*), water milfoil (*Myriophyllum sp.*), American lotus (*Nelumbo lutea*), spatterdock (*Nuphar luteum*), and duckweeds (including *Lemna, Spirodella, Wolfia*) (Heitmeyer 2008). The edges of these lakes typically dry for short periods during summer and contain extensive herbaceous wetland vegetation and minor components of emergent wetland plant species. Emergent vegetation in these areas includes arrowhead (*Sagittaria sp.*), cattail (*Typha latifolia*), rushes, river bulrush (*Scirpus fluviatilis*), sedges (*Carex sp.*), and spikerush (*Eleocharis sp.*). Herbaceous vegetation is dominated by smartweed (*Polygonum sp.*), millet (*Echinochloa sp.*), panic grass (*Panicum dichotomiflorum*), sprangletop (*Leptochloa sp.*), sedges, spikerush, beggartick (*Bidens sp.*), and many other perennial and annual "moist-soil" species. The distribution of emergent and herbaceous communities in Bottomland Lakes depended on length and frequency of summer drying. In drier years, herbaceous communities would have expanded to cover wide bands along the edges of Bottomland Lakes, while in wetter periods herbaceous plants were confined to narrow bands along the edges of deeper open water.

Bottomland Lakes support a high diversity of animal species. Historically, fish moved into these lakes for foraging and spawning (Jackson 2005) when they became connected with the Mississippi or Ohio Rivers during flood events. Many fish subsequently moved back into the main channel when flood water recedes or after they spawn or fatten during flood events; some fish then remain to populate the deeper lakes (e.g., Sparks 1995). Bottomland Lakes also support high density and diversity of amphibian and reptile species and some species, such as turtles, move into and out of these lakes similar to fish (e.g., Tucker 2003). Aquatic mammals regularly

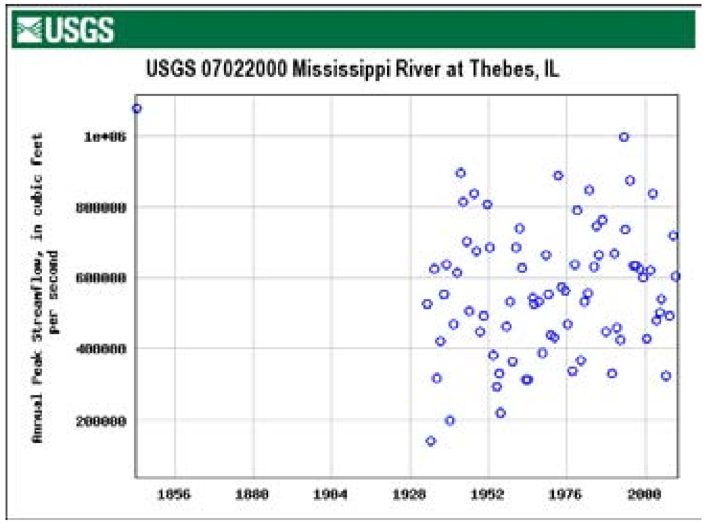


Figure 16. Peak annual streamflow (cubic feet/second) of the Mississippi River at Thebes, Illinois 1930-2009 (from http://nwis.waterdata.usgs.gov).

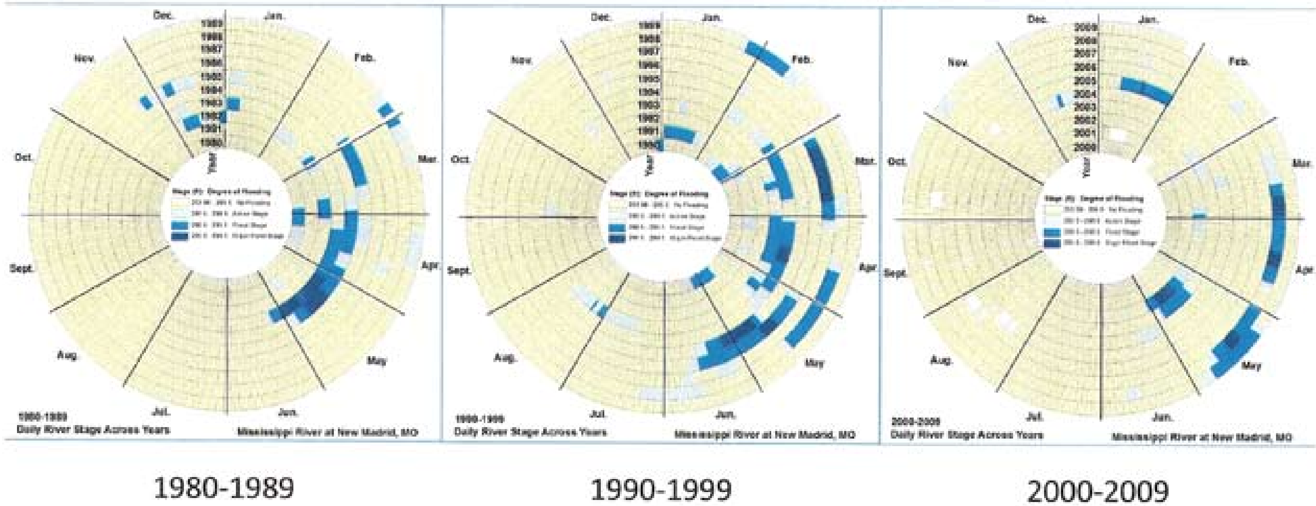


Figure 17. Ring-map of periods of overbank flooding duration of the Mississippi River at New Madrid by decade from 1980-89 to 2000-09.

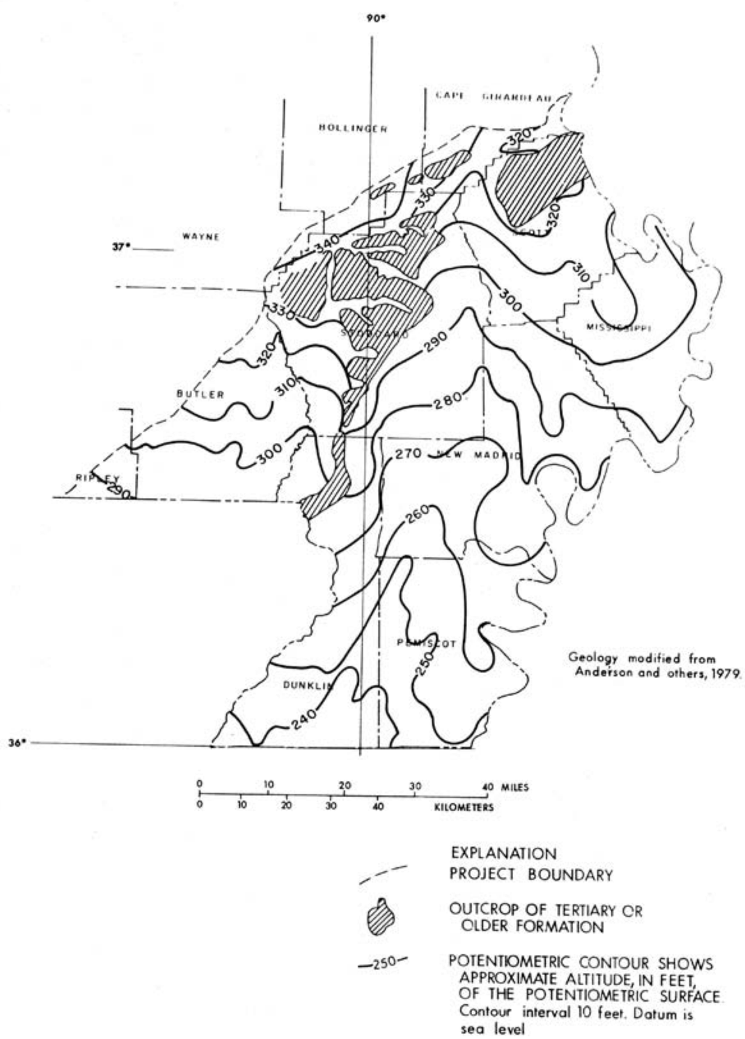


Figure 18. Generalized potentiometric surface of the alluvial aquifer in southeast Missouri during spring 1976 (modified from Luckey 1985).

use Bottomland Lakes and more terrestrial mammals travel in and out of these areas for seasonal foraging, breeding, and escape cover during dry periods. Bird diversity in these lakes is high, and extremely high densities of waterfowl, rail, shorebirds, and wading birds use these habitats for foraging, nesting, and resting sites (Heitmeyer et al. 2005).

Forest covered much of the SJNM and other nearby Mississippi River floodplain areas during the late 1700s (Hutchins 1784, Collot 1826, GLO 1817-40, Nuttall 1823). The distribution of tree and woody shrub species was arrayed along geomorphic/topographic and hydrological gradients (e.g., Coulter 1904, Steyermark 1962, Hosner and Minckler 1963, Voight and Mohlenbrock 1964, Fredrickson 1978, Robertson et al. 1978, Leitner and Jackson 1981, Klimas 1987, Mohlenbrock 1989, Nelson 1997, Conner and Sharitz 2005). Generally, a continuum of Riverfront Forest, BLH and Terrace Hardwood communities was present from the edges of the Mississippi River channel to Sikeston Ridge (Fig. 19). These communities transcend the Riverfront Forest, Wet Bottomland to Mesic Bottomland Forest, and Bottomland Flatwood Forest categories described in Nelson (2005).

Riverfront Forest (also called "Riveredge Forest" in some older botanical literature) was present on recently deposited and/or scoured coarse sediment chute and

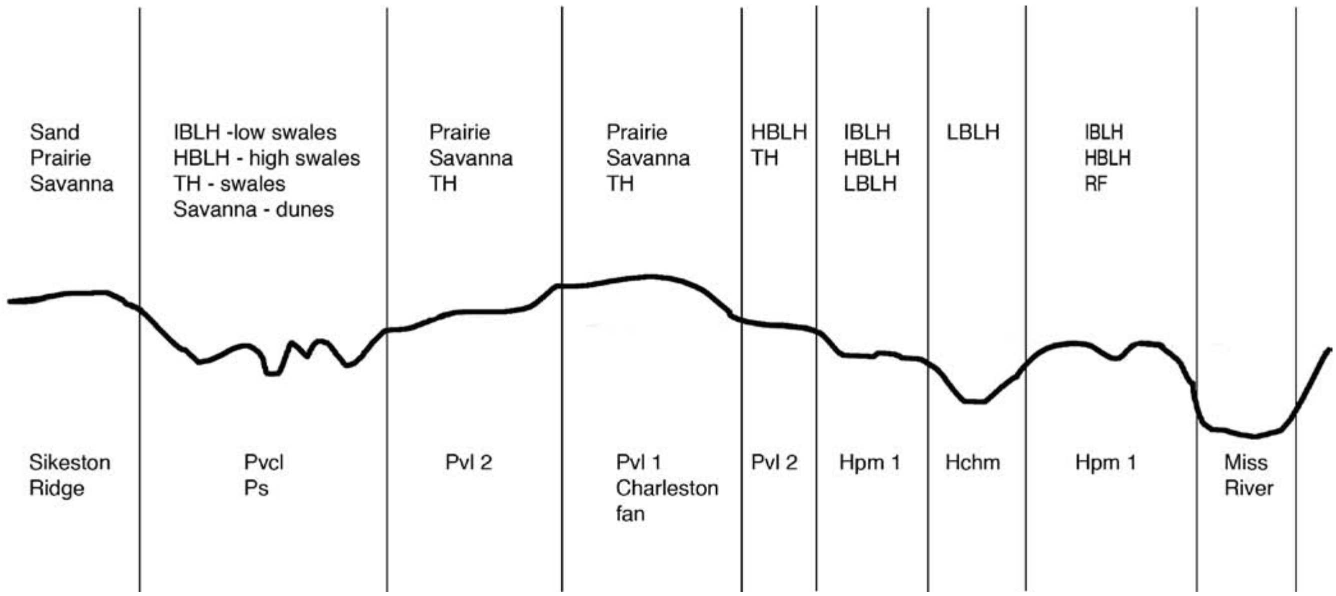


Figure 19. Cross-section schematic of vegetation community types across geomorphic and elevation surfaces in the SJNM. (See text for habitat and geomorphology acronyms.)

bar surfaces, some point bar areas near the current channel of the Mississippi River, and along the edges of some abandoned channels (Thomas 1841, Gregg 1975, Klimas 1987, Mohlenbrock 1989, Nelson 1997, Nelson 2005, Heitmeyer 2008). These geomorphic surfaces contain recently accreted lands and were sites where river flows actively scour and deposit silt, sand, gravel, and some organic debris. Soils under Riverfront Forests, especially on recently created chute-and-bar surfaces (Woerner 2003), are relatively young, annually overtopped by flood waters, highly drained, influenced by groundwater dynamics as the Mississippi River rises and falls, and often contain thin veneers of silt over sands and gravel. The most common soil under Riverfront Forest in the SJNM is Caruthersville sandy loam and Commerce silt loam (Fig. 8).

Riverfront Forest communities are dominated by early succession tree species and range from water tolerant species such as black willow (Salix nigra) and silver maple along the river channel and in low elevations and swales to intermediate water tolerant species such as green ash, cottonwood, sycamore, box elder, pecan, and sugarberry on ridges. Swamp white oak (*Quercus bicolor*) and pin oak occasionally are present in higher elevations in Riverfront Forest areas, but these species have high mortality during extended flood events and oak patches in historic Riverfront Forest communities probably were small and scattered (e.g., Hall and Smith 1955, Bell and Johnson 1974, Black 1984, Nelson and Sparks 1998). Shrubs and herbaceous vegetation in Riverfront Forests is sparse near the Mississippi River but dense tangles of vines, shrubs, and herbaceous vegetation are present on higher elevations away from the river where alluvial silts were deposited. Typical shrub and vine species are poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), grape (V*itis sp*.), and dogwood (*Cornus sp*.). Giant cane occasionally is present on these higher elevations, but repeated river flooding and scouring limit its occurrence and persistence (e.g., Gagnon 2007). The dynamic scouring and deposition in chute and bar areas also limits the tenure of many woody species except on the highest elevation ridges where species such as cottonwood and sycamore often become large mature stands (e.g., Hosner and Minckler 1963). Remnant, representative Riverfront Forest sites are present in many areas in the SJNM batture lands along the Mississippi River such as Seven Island and Wolf Island, the end of the Robert Delaney Lake CA, and other remnant river chutes in the floodplain.

Riverfront Forests are used by many animal species, especially as seasonal travel corridors and foraging sites. Many bird species nest in Riverfront Forests, usually in higher elevation areas where larger, older, trees occurred (Papon 2002). Arthropod numbers are high in Riverfront Forests during spring

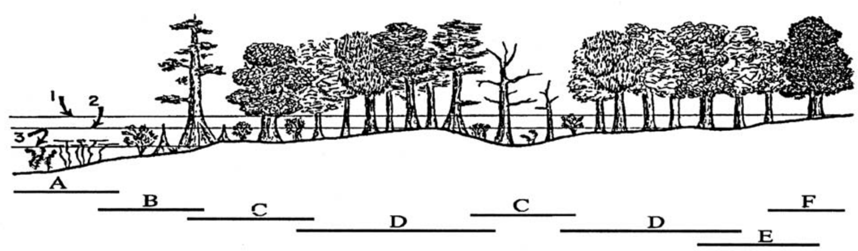
Figure 20. Location of bar and river chute habitats on the Mississippi River in 2003 in relation the channel position from 1812 to 2003 (modified from Brauer et al. 2005).

and summer and these habitats also contain large quantities of soft mast that is consumed by many bird and mammal species (e.g., Knutson et al. 1996). Few hard mast trees occur in Riverfront Forests, but occasional “clumps” of pecan or oak provide locally abundant nuts. The very highest elevations in chute and bar areas provide at least some temporal refuge to many ground-dwelling species during flood events (Heitmeyer et al. 2005).

BLH communities historically covered extensive areas of the SJNM, especially in the Holocene meander belt, and lower elevations of valley train channel complexes. Consequently BLH in the SJNM occurred in several soil types and contained diverse mixtures of species (Conner and Sharitz 2005, Heitmeyer et al. 2006). Tree species composition in BLH communities in the SJNM can be separated along elevation and flooding gradients (Fig. 21). Low BLH communities occur in floodplain sites that range from being flooded for extended periods each year, and occasionally year round, to being flooded for 4-6 months in winter and spring. The lowest elevations in the SJNM historically contained bald cypress, water locust (*Gleditsia aquatic*), pecan, water elm and water tupelo (e.g., Coulter 1904). At slightly higher elevations in Low BLH communities slightly less water tolerant trees such as overcup oak, green ash, red maple, and pecan with scattered pin oak are present. Woody shrubs in Low BLH sites include buttonbush, swamp privet, and planer tree/water elm (*Planera aquatic*). Many understory vines typically are present in Low BLH communities and include rattan vine (*Berchemia scandens*), Ladies’ eardrops (*Brunnichia ovata*), greenbrier (*Smilax retundifolia*), crossvine (*Bigonia capreolata*), and poison ivy. Ground herbaceous cover usually is sparse in Low BLH because of extended flooding, but sedges, beggar ticks, swamp smartweed (*Polygonum hydropiperoides*), water pepper (*Polygonum hydropiper*), butterweed (*Diodia teres*), and rice cutgrass (*Leersia oryzoides*) often are abundant during dry periods. Low BLH historically was present in deeper point bar swales, older abandoned channels and river chutes, backswamps, and depressions behind small natural levees (e.g. Coulter 1904, Steyermark 1962, Nelson 1997). Soils in Low BLH communities in the SJNM are Sharkey, Jackport, and Alligator clays. Remnant examples of Low BLH in the SJNM include areas on Ten Mile Pond and Robert G. Delaney CA’s, areas near the Eagle’s Nest WRP site, and scattered depressions on private lands.

Intermediate BLH (similar to the Wet-Mesic Bottomland Forest of Nelson 2005) in southeast Missouri occurs mainly in floodplain areas that typically flood 2-4 months annually during the dormant season and into early spring (Heitmeyer et al. 2006, Heitmeyer 2008). Soil saturation in Intermediate BLH often becomes extended for 3-4 months in wet years, but surface flooding may not occur in extremely dry years. Soils in Intermediate BLH in the SJNM are dominated by silty-clay loams (Appendix A). Tree species composition in Intermediate BLH is diverse and includes pin oak, Nuttall oak (*Quercus Nuttalli*), swamp chestnut oak (*Quercus michauxii*), bur oak (*Quercus macrocarpa*), green ash, slippery elm (*Ulmus rubra*), pecan, sugarberry, American elm, box elder, sweetgum, and some widely scattered swamp white oak. Small depressions in Intermediate BLH zones, such as vernal pools, include overcup oak, green ash, maple, and pecan. Giant cane is occasionally present in some floodplain forest locations, mostly on higher ridges (Brantley and Platt 2001, Gagnon 2005). Common privet (*Ligustrum vulgare*), honeysuckle (*Ionicera japonica*), grape, trumpet creeper (*Campis radicans*), greenbrier, and poison ivy are common understory plants in Intermediate BLH. Early explorers often commented on the relatively "impenetrable" nature of these floodplain forests (e.g., Collot 1826). The Intermediate BLH in the SJNM resembles in many ways the Floodplain Forests, with low oak composition, that historically covered large expanses of the Middle Mississippi River Corridor floodplain on point bar surfaces and along tributary streams (Hus 1908, Telford 1927, Gregg 1975, Robertson et al. 1978, Klimas 1987, Brugam and Patterson 1996, Nelson 1997, Yin 1999, Heitmeyer 2008). Typical Floodplain Forests in northern parts of the Mississippi River Valley represent a transition zone from early succession Riverfront Forest located on coarse-sediment chute and bar surfaces to BLH forests that occur in silt-clay soils in floodplain depressions. Northern Floodplain Forests typically develop on mixed sandy loam soils where older point bar "ridge-and-swale" topography occurred. Most of these older point bar surfaces were within the 1-2 year flood frequency zone. Some botanical literature calls this forest type the "sugarberry-elm-sweetgum" zone (e.g., Lewis 1974, Gregg 1975). Remnant examples of Intermediate BLH are present in Big Oak Tree State Park, forested areas northwest of Ten Mile Pond CA, a few privately-owned relict channels in Pvcl surfaces, and slough banks and natural levees along the mainstem Mississippi River levee.

High BLH communities in the SJNM similar to the Mesic Bottomland Forest category in Nelson (2005) are present in floodplain, natural levee, and terrace locations that flood for up to a few weeks annually during most years; slightly longer duration flooding occurs during wetter periods and during major Mississippi River flood events. Some High BLH sites typically are dry for several years during dry periods, but soils in High BLH usually are saturated for some periods annually. Soils under High BLH communities in the SJNM are mainly silt loams in Hpm1 surfaces (except natural levee sites) and sandy loams on terraces, relict Valley Train channels, and natural levees (Appendix A). Dominant plant species in High BLH include willow, pin, and cherrybark oak (*Quercus pagoda*); shagbark (*Carya ovate*) and shellbark (*Carya laciniosa*) hickory; sweetgum; and American elm. Some High BLH on the edges of Pvl surfaces probably contained scattered post oak and winged elm. High BLH on natural levees often is somewhat distinct from lower floodplain or terrace locations in part because of sandy soils and includes sycamore, cottonwood, willow, pecan, box elder, sug-



Duration of flooding	Herbaceous plants	Woody plants
(A) Permanent	Water Milfoil Watershield American Lotus	Common Baldcypress
(B) Semi-permanent water	American Lotus Duckweed Swamp Smartweed	Common Baldcypress Water Tupelo Water Elm Buttonbush
(C) 3 to 8 Months	Swamp Smartweed Lizard's Tail Sticktights Arrowarum	Common Baldcypress Overcup Oak Red Maple Waterlocust Possomhaw Holly
(D) 1 to 6 Months	Lizard's Tail Sticktights Sedge	Overcup Oak Willow Oak Pine Oak Cherrybark Oak Sweetgum Blackgum Tupelo
(E) 0 to 2 Months	Spotted Snapweed Nettle Giant Cane Nightshade	Sweetgum Blackgum Tupelo Sugar Hackberry Shagbark Hickory American Elm Swamp Chestnut Oak
(F) Once in 10 years	Spotted Snapweed Nettle Giant Cane Wildrye Pokeberry	Sweetgum Sugar Hackberry Shagbark Hickory White Oak Flowering Dogwood

Figure 21. BLH species composition across elevation and hydrological gradients (modified from Fredrickson and Batema 1982).

arberry, willow and water oak (*Quercus nigra*), and winged elm. Herbaceous cover often is extensive in historic High BLH sites where understory plants include dense stands of poison ivy, climbing dogbane (*Trachelospermum dirrorme*), crossvine, and Virginia and trumpet creeper. Giant cane patches often are present in many remnant BLH habitats in the MAV, usually on the higher ridges or older natural levee surfaces (Gagnon 2007). Only a few scattered remnant High BLH sites remain in the SJNM on private lands and ridges on the northern Charleston Fan and inside older point bar meander scrolls and natural levees.

Animal diversity is high throughout BLH community types because of the deep alluvial soils, seasonal flooding regimes, diverse plant communities, high structural complexity, and rich detrital food bases (Heitmeyer et al. 2005). Most foods within BLH become available in seasonal "pulses" that provide many different types of nutrients used by many trophic levels and within many niches. Consequently, this community supported large numbers of animal species and individuals. The primary ecological process that sustain BLH communities and their productivity is seasonal, mostly dormant-season, flooding. Regular disturbance events also help sustain this ecosystem through periodic extended flooding or drought, wind storms, and rarely fire in at least the higher elevations.

Terrace Hardwood Forest historically occurred in the SJNM on the edges of Pvl and Pve surfaces where overbank and backwater flooding from the Mississippi River was rare (> 100 year recurrence elevations) and soils graded into sandier Entisols including Clana, Bosket, Scotco, Broseley, Canalou, Farrenburg, and Lilbourne types (Appendix B). These communities are often called "Flats" (Klimas et al. 2009) or "Bottomland Flatwoods" (Nelson 2005) because they occur on old high elevation terraces that often are subject to ponding of rainwater or short duration local stream flooding. During extremely high Mississippi River floods, these high terraces are inundated, usually for short periods in spring. Dominant canopy trees in Terrace Hardwood Forests are pin oak, cherrybark oak, post oak, willow oak, hickory, winged elm, and persimmon (*Diospyros virginiana*) (Nelson 2005). Trumpet creeper and climbing dogbane are common shrubs and sedges, goldenrod (*Solidago sp*.), bedstraw (*Galium asprellum*), spider lily (*Lycoris sp*.), and wood sorrel (*Oxalis acetosella*) are common herbaceous species. As with High BLH, almost all Terrace Hardwood Forest has been destroyed and converted to agriculture in the SJNM, but a few small remnants exist around the town of East Prairie and on private land in Pvl1 and Pvl2 surfaces.

A small area of Slope Forest apparently occurred in the SJNM on alluvial fans that eroded from the Commerce Hills in the extreme north part of the region. Slope Forests contain unique mixes of trees representing both upland and floodplain communities that occur adjacent to alluvial fans. Some authors refer to this habitat as the "shatter zone" between upland and river valley floor plant associations (Gregg 1975). The diverse tree species present in Slope Forests includes hickory, sugarberry, swamp white and swamp chestnut oak, white oak (*Quercus alba*), bur oak, southern red oak (*Quercus falcate*), black walnut (*Juglans nigra*), hawthorn (*Cretaegus sp*.), persimmon, honey locust (*Gleditsia triancanthos*), Kentucky coffeetree (*Gymnocladus dioica*), and slippery elm. Many other woody species are present in the understory and as occasional canopy trees. Herbaceous cover often is extensive in Slope Forest (Chmurny 1973, Gregg 1975), especially on the lowest elevations of alluvial fans and includes columbine (*Aquilegia Canadensis*), spikenard (*Aralia racemosa*), wild ginger (*Asarum canadense*), spring beauty (C*laytonia virginica*), pepperroot (*Dentaria laciniata*), cleavers (*Galium aparine*), sensitive fern (*Onoclea sensibilis*), sweet jarvil (*Osmorhiza Claytoni*), pokeberry (*Phytolacca Americana*), may apple (*Podophyllum peltatum*), great Solomon's seal (*Polygonatum canaliculatum*), and false Solomon's seal (*Smilacina racemosa*) (Zawacki and Hausfater 1969).

Slope Forests are not flooded except during extreme Mississippi River floods. Even during extreme floods, only the low elevation bottom parts of the alluvial fan slopes historically would have been inundated. Most water flows off alluvial fan slopes in a wide overland sheetflow manner and only minor drainages originate from these areas. Many alluvial fans have seep areas where upland groundwater exits. In the Prairie-Forest-Savanna transition sites that may have occurred in these northern SJNM areas (see discussion below) it is likely that some Savanna was present as narrow bands at the bottom of alluvial fan slopes and probably was maintained by occasional fire. Fire in these areas may have originated in either the higher elevation terrace (Pve, Pvl, Pvl1, Pvl2) or upland Commerce Hills. Soils in alluvial fans in the SJNM are unique erosional gravelly loams (Appendix A).

Many animals use Slope Forest and these sites also were preferred sites for Native American and early Anglo-European settlements (e.g., the town of Commerce, Missouri). These sites contained rich floral communities, multiple food types, and relief from periodic flooding and bothersome insects in the floodplains. These areas also provided natural sloping movement corridors from floodplains to uplands.

Prairies historically occupied extensive areas on the Sikeston Ridge and Charleston Fan in the SJNM (GLO 1817-40, Schroeder 1981). The exact composition of these prairies is unknown, but most probably were drier Sand-type prairies located on higher sandy ridges and new Pvl1 terraces (Schroeder 1981, Hendershott 2004, Nelson 2005). All historic Prairies in the SJNM were underlain by fine sandy loam Bosket and Malden soils (Appendix A). The distribution of Prairie in the SJNM probably was determined by the dynamic "line" of where: 1) fine sandy soils occurred, 2) floodwater ranged toward higher elevations in floodplains and 3) the elevation "line" where fires originating from uplands and higher elevations moved into the wetter lowlands (Nelson 2005). Historically, Sand Prairie vegetation was partly maintained by fire occurring at about 5-8 year intervals (e.g., Hendershott 2004) caused by lightning strikes or intentionally set by native people and by seasonal herbivory from elk (*Cervus canadensis*), bison (*Bison bison*), white-tailed deer (*Odocoileus virginianus*), and many rodents. This herbivory cropped and recycled prairie vegetation and also browsed invading woody shrubs and plants. Sand Prairie was characterized by little bluestem (*Schizachyrium scoparium*), splitbeard bluestem (*Andropogon ternaries*), broomsedge (*Andropogon virginicus*), fall witch grass (*Digitaria cognate*), bead grass (*Paspalum setaceum*), woolly three-awn (*Aristida lanosa*), sand dropseed (*Sporobolus cryptandrus*), sandbur (*Cenchrus longispinus*), tickseed coreopsis (*Coreopis lanceolata*), nodding spurge (*Chamaesyce maculate*), sand milkweed (*Asclepias amplexicaulis*), and others. Several rare species occur in this habitat including Baldwin's sedge (*Cyperus croceus*), Plukenet's umbrella sedge (*Cyperus plukenetii*), many-spiked umbrella sedge (*Cyperus polystachyos var. texensis*), flatsedge (*Cyperus hystricinus*), St. John's wort (*Yypericum adpressum*), warty panic grass (*Panicum verrucosum*), butterfly bush family (*Polypremum procumbens*), puccoon (*Lithospermum incisum*), sand milkweed (*Asclepias amplexicaulis*), and sand three-awn (*Aristida desmantha*).

Perennial plants of Sand Prairies tend to have narrow leaves and tiny hairs to limit water loss. Plants also tend to have deep roots and grow in tufts to reduce exposure to wind. Annual plants also have slender leaves and few branches. Animals using these prairies also have special adaptations or are usually only seasonal visitors. Two frogs well adapted to Sand Prairies are the Illinois chorus frog (*Pseudacris streckeri illinoensis*) and eastern spadefoot (*Scaphiopus holbrookii holbrookii*) (Johnson 2000). Both spend most months burrowing and feeding underground and they only come to the surface to breed during the wet spring months. Their eggs hatch faster, and tadpoles metamorphose faster than those of other frog species in Missouri. Northern (*Neocurtilla hexadactyla*) and prairie mole (*Gryllotalpa major*) crickets also live in Sand Prairies and similar to the frogs, live mostly underground. Bison and elk formerly were present in the region but apparently were extirpated by 1860 (Beckwith 1887 cited in Hendershott 2004). Other common upland species in these habitats are bobwhite quail (*Colinus virginianus*), grassland songbirds, fence lizard (*Sceloporus undulates hyacinthinus*), white-tailed deer and rabbits.

At the higher elevations of the SJNM floodplain, especially on terraces, sand-type Prairie often transitioned into zones or patches of Sand Savanna (Nelson 2005). Soils under Sand Savanna are similar to Sand Prairie sites. Sand Savannas contain post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), and black (*Carya texana*) and mockernut (*Carya tomentosa*) hickory as common tree species. The herbaceous layer of these Savannas contains species similar to Sand Prairies and is dominated by little bluestem. Rare plant species in these habitats are sand hickory (*Carya pallida*), corydalis (*Corydalis micrantha*), blue curls (*Trichostema setaceum*), wooly three-awn, and umbrella sedges. The irregular occurrence of fire likely defined the upper boundary of Savanna and conversely, the lower elevation boundary that graded into Terrace Hardwood or High BLH was determined by a transition of soils to more loamy types and occasional backwater flooding from the Mississippi River. Given the position of Sand Prairie and Savanna, animal species common to both forest and prairie are present. These sites also were common camp or occupation sites for native peoples because of their higher, less flood prone, location; the presence of grasslands where small cultivation areas could be easily maintained; locally available wood for fires;

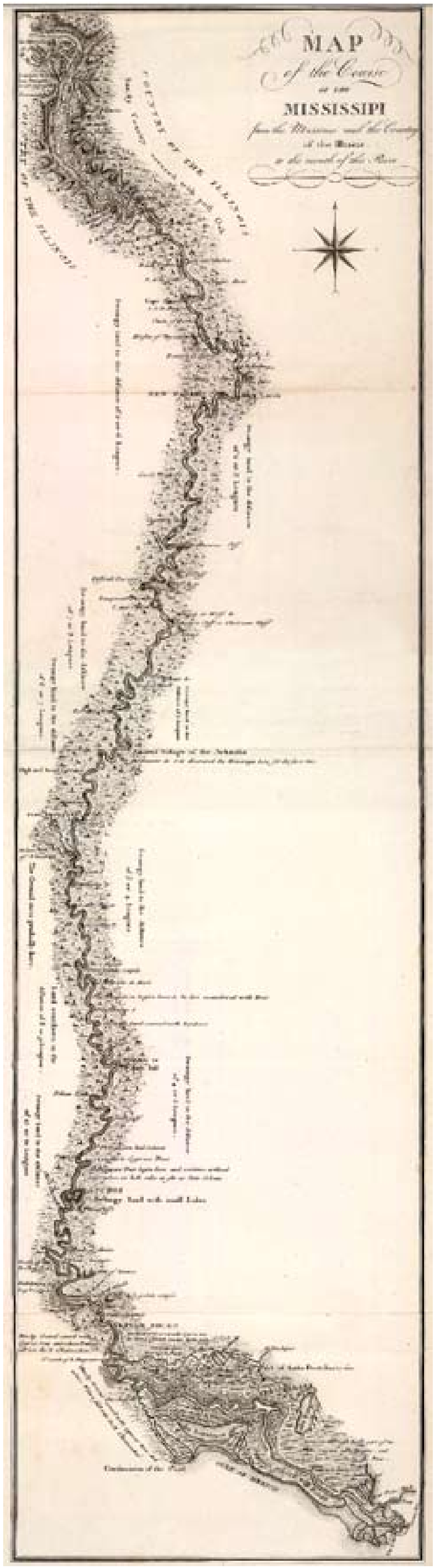


Figure 22. Map of the Middle Mississippi River corridor produced by Victor Collot in the late 1790s (from Heitmeyer 2008).

and natural travel corridors between uplands and floodplains (Lafferty and Price 1996). Few examples of prairie and savanna are present in the SJNM – most was converted to agricultural production in the 1800s. Representative Prairie and Savanna presently occur on small sites on Sikeston Ridge, Sand Ridge local cemeteries, and the Charleston Baptist Camp land in Scott County (Nigh and Schroeder 2002, Nelson 2005).

DISTRIBUTION AND EXTENT OF PRESETTLEMENT HABITATS

The exact distribution of specific vegetation communities (habitat types) in the SJNM prior to significant European settlement in the late 1700s is not known. However, the above discussion identified the many sources of information about the geography and distribution of major vegetation communities for the SJNM and similar nearby Upper MAV geomorphic regions. These data include historic cartography, botanical data and accounts, and general descriptions of landscapes from early explorers and naturalists. While the precise geography of early maps (e.g. river channel boundaries) is often flawed, these maps provide general descriptions of relative habitat types, distribution, and configuration.

Apparently, the first maps of the Mississippi River (and parts of its floodplain) in the SJNM were made during French governance of the region by the French cartographers Franquelin (produced in 1682), De L'Lsle (1703 and 1718), d'Anville (1746 and 1755), and Bellin (1755) (Wood 2001). When the British Regime succeeded French rule of the area in the mid-1700s, new maps of the Middle Mississippi River Valley including the SJNM were prepared. The first known British map was drawn by Philip Pittman in 1765 and it essentially was a compendium of the earlier French maps (Thurman 1982). Although it was not highly original, the Pittman map became the accepted "standard" for geography of the Middle Mississippi River region; subsequent maps expanded coverage and descriptions to lower course tributaries (e.g., the Ross map produced in 1867) and floodplains (Hutchins 1784). The Hutchins' map relied heavily on Pittman's map and his book "A topographic description of Virginia, Pennsylvania, Maryland, and North Carolina" published in 1778 contained the most accurate map of the Illinois Country at that time. The journal from Hutchins' mapping trip and that of Captain Harry Gordon at the same period offered detailed description of many important floodplain features. Subsequent to Hutchins' map was the excellent map of General Victor Collot prepared from field surveys in the late 1790s and published in 1826 (Fig. 22). This "Collot" map provided expanded notes and coverage of vegetation and larger wetlands in the SJNM floodplain and became the basis for additional maps and naturalist accounts of Nicolas de Finiels in the early 1800s (Ekberg and Foley 1989).

In the early 1800s, following American occupation and rule, the Mississippi River Valley including the SJNM was mapped by the U.S. General Land Office (GLO) to establish a geometric system of land ownership and governance (i.e., the Range-Township-Section system developed by Thomas Jefferson and codified in the Land Survey Ordinance of 1785). These GLO surveys established right-angle "section lines" in a geometric land grid system, and the surveyors also documented vegetation and "witness" trees at section corners and center points between the corners (GLO 1817-40). Consequently, the GLO maps and surveys established a "georeference" of locations and distribution of SJNM features including general habitat types (Fig. 23). GLO surveyors usually described vegetation communities in broad categories (e.g., forest, bottomland, prairie) and grouped witness trees in general taxonomic groups (e.g., black vs. white oak). Consequently, considerable interpretation often is needed to determine the exact species composition that was noted. Most likely, the "black oaks" described in GLO notes for the Middle Mississippi River Regional Corridor were "red oak" species such as pin, willow, and cherrybark oaks because true black oak (*Quercus velutina*) does not grow in floodplains (Settergren and McDermott 1977) and the "white oaks" probably were a collection of overcup, swamp white, post, and swamp chestnut oak. GLO notes that describe general habitat types of forest, bottomland, prairie, open water, etc. do not describe composition of forests nor do they delineate small areas of trees or herbaceous wetlands within bottomland settings (Bourdo 1956, Hutchinson 1988). GLO surveys probably mapped savannas as forest, but this is unclear because many savanna areas may have contained larger amounts of prairie or other grasses. In the SJNM, GLO notes and maps often mix the terms "bottomland", "woodland", and "forest". Most "bottomland" appears to have been BLH communities, however, the scale of mapping, and definition of communities often is gross and inconsistent. Further, GLO notes suggest travel through, and precise documentation of, vegetation in low elevation, wet, floodplain locations (such as abandoned channels and floodplain depressions) was difficult and somewhat cursory. Notes in these areas often refer to lands simply as "water", "wet", "swampy", "marais", or "flooded."

In addition to the GLO surveys, many other cartographers, naturalists, and explorers produced maps (often small- scale maps of a local area) and provided natural history accounts and botanical records for many southern Middle Mississippi and Upper MAV areas (Hutchins 1784, Brackenridge 1814, Nuttall 1821, Schoolcraft 1825, Flint 1828, Flagg 1838, Wild 1841, Warren 1869, Allen

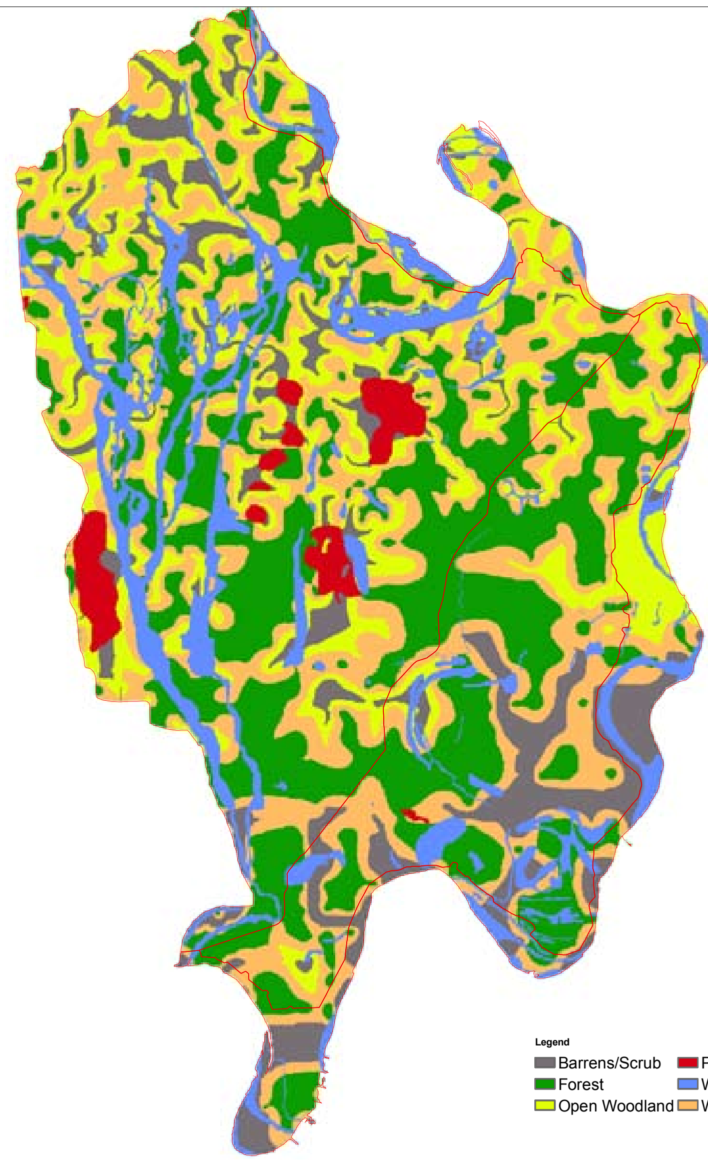


Figure 23. Model of vegetation communities in the SJNM during the early 1800s compiled from General Land Office survey maps (from CARES 2010).

1870, Brink and Co. 1875). In the late 1800s the Mississippi River Commission (MRC, 1881, 1893-1904) produced the first complete set of maps for the Mississippi River from New Orleans to Minneapolis. This map set included detailed descriptions of the Mississippi River channel, side channels and chutes, tributaries, floodplain habitats (general habitat types), floodplain lakes, and settlements (Fig. 24). Other maps from the early 1900s also delineated low elevation "swamp" and "lowland" areas where abandoned channels and floodplain wetland occurred (Fig. 25).

Collectively, the above maps, historical accounts, and published literature suggest historical vegetation communities in the SJNM were distributed along elevation, geomorphology, and hydrological gradients similar to current plant physiographic of the community species. Similar community distribution associations also occur in other nearby Mississippi Valley floodplain areas and help validate information for the SJNM (e.g., Heitmeyer et al. 2006, Heitmeyer 2008, Klimas et al. 2009). The extensively documented relationships between community types and the abiotic attributes of Upper MAV geomorphology, soils, topography, and flood frequency zones were used to prepare Hydrogeomorphic matrices that identified the potential distribution, composition, and area of Presettlement habitats in the SJNM (Table 4). The methods of determining these relationships were presented earlier in the report and involved a series of steps of overlaying data layers from historical and current maps and then validating relationships using remnant representative field reference sites (see Klimas et al. 2005, 2009; Nestler et al. 2010). This methodology culminated in production of a map of potential Presettlement vegetation community distribution in the SJNM (Fig. 26).

In the late 1700s, several Mississippi River side channels, chutes, and bars were present in the SJNM, but their location was constantly changing as the river frequently migrated (e.g., Fig. 20, Brauer et al. 2005). More stable position Bottomland Lake communities historically were present in many abandoned channel areas in the SJNM during the late 1700s. More recent abandoned channels likely contained more open water habitats while older ones filled with alluvial sediment gradually became dominated by bald cypress-water tupelo and Low BLH habitats. All Bottomland lakes have Sharkey and Alligator clay soils and are flooded annually, sometimes for extended periods over several years.

Table 4. Hydrogeomorphic (HGM) matrix of historical distribution of major vegetation communities/habitat types in the St. John's Bayou/New Madrid Floodway region in relationship to geomorphic surface, soils, and flood frequency. Relationships were determined from land cover maps prepared from the Government Land Office survey notes taken in the early 1800s, historic maps prepared by Hutchins in 1784, Collot in the 1790s, de Finiels in the early 1800s, and the Mississippi River Commission in 1890; U.S. Department of Agriculture soil maps, geomorphology maps prepared by Saucier in 1994; flood frequency data provided by the U.S. Army Corps of Engineers, Memphis District; and various naturalist/botanical accounts and literature.

Habitat Type	Geomorphic surface[a]	Soil type[b]	Flood frequency
Bottomland lake	Hchm	Clay	Annual to Permanent
Low BLH	Hchm, Hpm1	Silty-clay	Annual, 4-6 months
Intermediate BLH	Hpm1, Pvl1,2, Pvcl	Silty-clay loam	2-3 months, dormant season
High BLH	Hpm1, Pvl's, Pvcl	Silt loam	1-2 months, dormant season
Terrace Hardwood	Pvl's, Pvcl, Pve, Ps	Sandy loam	> 5 year
Riverfront forest	Hpm1,Bar-and-chute	Sandy loam Loams, fine sand	Annual 1 yr
Savanna	Pve, Ps, Pvl1	Loamy sand	> 10 yr
Sand prairie	Pve, Pvl1	Fine sandy	> 100 yr loam

[a] Pve – Sikeston Ridge, Pvcl – relict channels Valley Train, Ps – interfluves sand dunes, Pvl – undifferentiated Holocene Valley Train braided terrace, Pvl1- Late Holocene Valley Train braided terrace, Pvl1 – Early Holocene Valley Train braided terrace, Hpm1 – Holocene Point Bar meander belt, Hchm – abandoned Mississippi River channels.

[b] See Appendix B for complete list of soils associated with vegetation communities in various geomorphic surfaces.

Figure 24. An example of a Mississippi River Commission map (1881) prepared for the SJNM.

The numerous abandoned channels in the SJNM caused Bottomland Lake communities to be distributed throughout the region and they historically covered over 20,000 acres (Fig. 3).

Forests covered over 93% of the historic SJNM landscape and were a heterogeneous mix of Riverfront, BLH, and Terrace Hardwood communities (Table 5, Fig. 26). Riverfront Forest historically covered 9.3% of the SJNM and was distributed primarily in a band parallel to the active Mississippi River channel, but it also occurred in limited sites in older abandoned channel locations and along basin tributaries. Most of the current Batture of the Mississippi River was historically Riverfront Forest and occurred on fine sandy loam soils. Low BLH, including Bottomland Lakes, covered 115,419 acres of the SJNM and was present mostly in the Holocene Meander Belt of the Mississippi River (Hpm1), with Sharkey and Alligator clay Vertisol soils, and a one-year flood recurrence regime. Intermediate BLH was widely distributed over 23.8% of the SJNM in the Hpm1 and some valley train relict channels of the Pvcl of the SJNM where flooding occurrence was 1-2 year frequency and soils were silty-clay-loam Mollisols and Inceptisols. High BLH was present on about 65,000 acres of Hpm1, Pvcl, Pvl1 and Pvl2 surfaces with 2-5 year flood frequencies and mixtures of Mollisol and Entisol silt-loam soils. Terrace Hardwood covered extensive areas (108,755 acres) of higher elevation Ps and Pvl1 surfaces with > 50 year flood recurrence and sandy-loam Entisol soils. Slope Forest was limited on a few small alluvial fan sites adjacent to the Commerce Hills.

Table 5. Area (acres) of major vegetation communities/habitat types present in the St. John's Bayou/New Madrid Floodway region during the Presettlement period predicted by Hydrogeomorphic matrix mapping compared to current conditions.

Community type[a]	Presettlement	Current
Low BLH	115,419	1,400
Intermediate BLH	114,574	700
High BLH	62,070	400
High BLH-Natural Levee	2,879	100
Terrace Hardwood	108,755	250
Riverfront Forest	44,901	1,500
Slope Forest	694	70
Sand Savanna	21,617	50
Sand Prairie (GLO) (Hydrogeomorphic matrix)	13,687 11,405	100

Prairie and Savanna historically were distributed on the highest elevations (> 500 year flood recurrence) of the SJNM where loamy fine sand soils were present on braided stream terraces and the Sikeston Ridge. The precise extent of Prairie vs. Savanna in the SJNM during the Presettlement period is unknown. Prairie shown in Fig. 26 includes the Prairie area (13,687 acres) mapped by GLO surveys (GLO 1817-40). Hydrogeomorphic analyses suggested a slightly smaller area of pure Sand Prairie (11,405 acres) but a larger area of Sand Savanna (21,617 acres) that had a strong Prairie component (Table 5). By the time GLO surveys were conducted in the early 1800s, the extent of pure Sand Prairie undoubtedly was greatly reduced and disjunct compared to the Prairie area that probably occurred during maximum Prairie extent period of the Altithermal over 4,000 years BP (Delcourt et al. 1999). The Hydrogeomorphic-derived matrix produced in this study suggests a wider distribution of Prairie or mixed Prairie-Savanna in the mid to late 1700s than the GLO surveys recorded in the early 1800s. By the early 1800s, it also appears that some former Prairie areas had already been converted to agriculture (Schroeder 1981). Notes from the GLO surveys and some older maps suggest the areas surrounding remnant Prairie recorded in the early 1800s was a more open forest landscape often with post oak, blackjack oak, and hickory recorded (see also Schroeder 1981, Hendershott 2004). Consequently, it is likely that much of the high elevation sandy terrace and ridge landscape of the Ps and Pvl1 was Savanna, albeit perhaps in transition to a more complete forest cover by the late 1700s. Given the uncertainty of the exact Prairie and Savanna distribution in the SJNM in the late 1700s, Fig. 26 identifies a fairly large Savanna area that may have included small patches of pure Prairie or relatively open, sparsely treed, Savanna.

Figure 25. Map of low “swamplands” in southeast Missouri in 1903 (historic base map obtained from Little River Drainage District files, Kent Library, Southeast Missouri University, Cape Girardeau, Missouri; georeferenced/shapefile created).

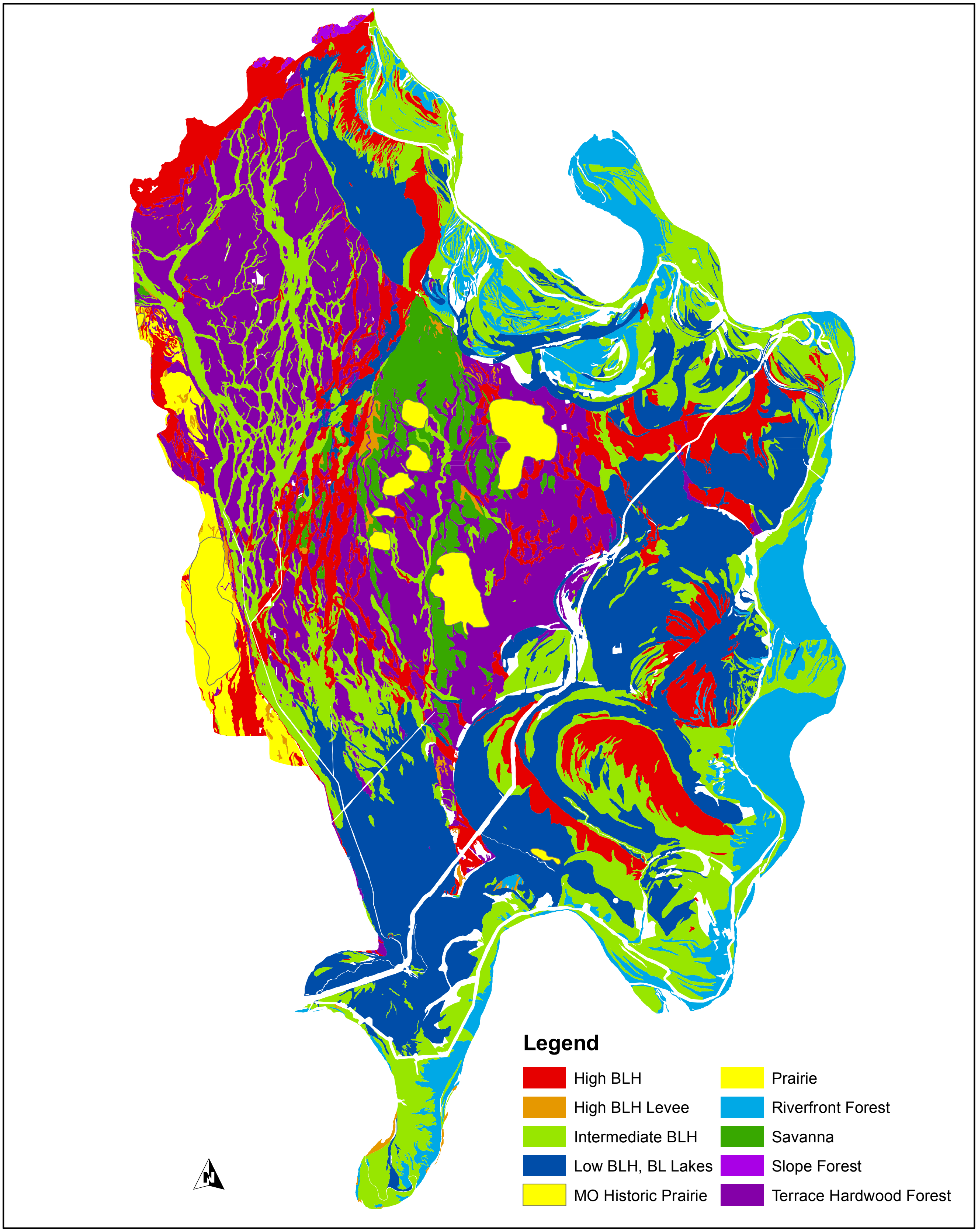


Figure 26. Map of potential distribution and types of vegetation communities in the SJNM.

CHANGES TO
THE SJNM ECOSYSTEM

REGIONAL LANDSCAPE CHANGES

Settlement and Early Landscape Changes

The chronology of human occupation in parts of the SJNM is reviewed in Buchner et al. (2009) and several other archeological publications (e.g., Lafferty and Price 1996, Lewis 1996, Lafferty 1998). A summary of occupations and potential use of, and effects, on natural resources and communities is provided in Fig. 27 and below.

The first evidence of initial permanent occupation of the SJNM by native people is from the Middle Archaic period (Buchner et al. 2009:67) although Paleoindian and Early Archaic peoples undoubtedly traveled through the SJNM prior to that time (Lafferty and Price 1996). Glacial outwash was still being actively deposited in the region prior to the Altithermal period (4,000 to 8,000 years BP) and seasonal movement of people to exploit econiches in the SJNM garnered from a hunter-gather lifeway dominated this era. The advent of the Altithermal apparently caused the region to become warmer and drier and Prairie and Savanna expanded into the higher elevations of the region. At this time native people appear to have congregated at a limited number of higher elevation locations mostly on natural levees near permanent water areas of Bottomland Lakes or river channels. The Late Archaic period (3,000 to 500 years BP) was a time of great expansion of native populations at numerous sites as the climate ameliorated. At this time cultural elaboration caused settlements to become more specialized to exploit certain resources at specific times of the year and areas became occupied seasonally as populations shifted from dispersed to aggregated settlements. The end of this period also marks the development of horticulture and the introduction of pottery into the SJNM. Many animals were utilized including white-tailed deer, small mammals, migratory birds, fish, and amphibians (Buchner et

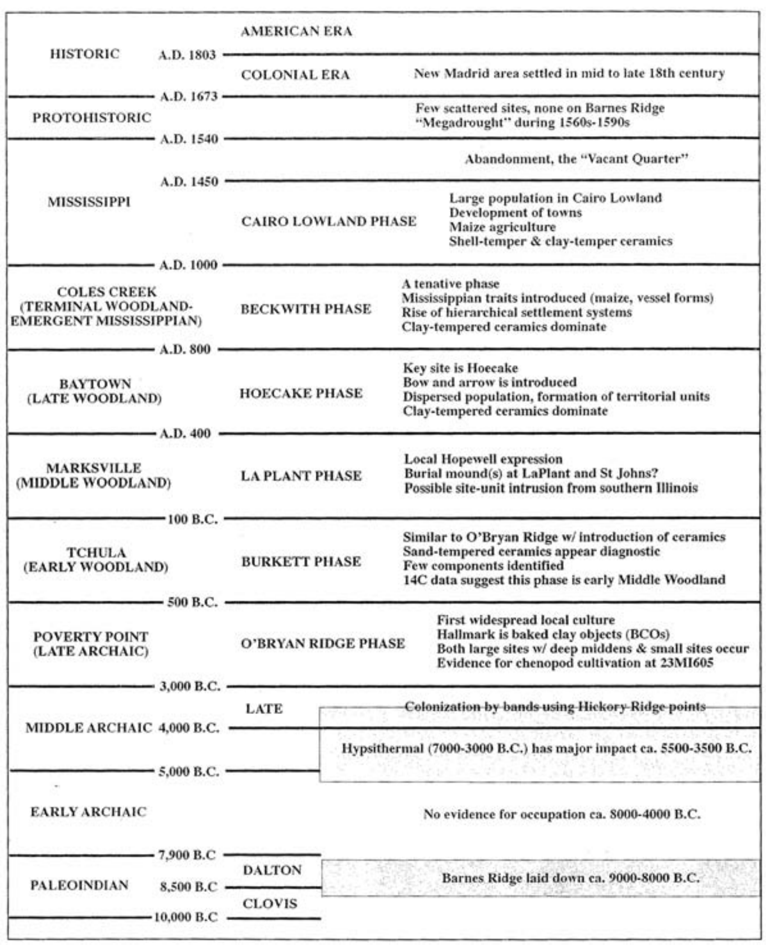


Figure 27. Cultural chronology of the SJNM (from Buchner et al. 2009).

al. 2009). Ridge locations were usually chosen for camps and settlements because surrounding floodplain areas were seasonally inundated and contained dense swamp-type vegetation. Evidence suggests that people were highly mobile hunter-gathers well adapted to seasonal floodplain resource availability through the Late Archaic period and likely had little effect on vegetation community distribution or disturbances (Lafferty and Price 1996).

During the Woodland period, horticulture intensified on the higher ridges of the SJNM and other developments included construction of earthworks, reorganization of social structure, and elaboration of artistic expression and burial rituals (Griffin 1967). The Early Woodland period (2,100 to 2,500 years BP) marked initial use of ceramics and some expansion of horticulture including more expansive maize production in the SJNM. By the Middle Woodland time, burial ceremonialism and artistic expression were elaborated and "mound" construction apparently occurred in some more permanently settled areas. By the Late Woodland period (1,600 to 1,200 years BP) many cultural shifts began occurring including substructure mound-and-plaza complexes, two-tiered social hierarchy, formation of territorial units, increased reliance of maize production, new technologies such as the bow and arrow, and tempered ceramics. The Lilbourn and Towosahgy sites were two of the largest civic ceremonial locations during the Late Woodland and Early Mississippian periods (Lafferty and Price 1996). It is possible that this time period represented the maximum prehistory occupation of the SJNM by native people and that some areas on higher ridges, natural levees, and Valley Train terraces were converted to agriculture and settlements with regular disturbance of surrounding habitats using fire and perhaps limited clearing (Buchner et al. 2009).

During the Mississippian period the final climax of native cultural development occurred in the SJNM region and it is possible that the region supported one of the largest populations in the southeast U.S., not far behind the huge population center at Cahokia (Phillips 1970). At this time populations expanded in the region, intense settlements occurred on high ridges in the floodplain, more emphasis was placed on agricultural production, earthworks were constructed based on celestial alignments, inter-regional exchange of items occurred, shell-tempered ceramics were made, and some regional warfare was present to protect territories (Buchner et al. 2009). These developments led to the conscripted, complex socio-political system known as chiefdoms (e.g., Milner 1998). Undoubtedly larger occupation sites caused anthropogenic effects on local ecosystems and plant communities including more widespread clearing and maintenance of agricultural fields and local high exploitation of fish and wildlife populations. A general abandonment of the Mississippian ceremonial centers and villages in the SJNM occurred after 1550. While the region may not have been completely vacant, it appears populations dispersed and relocated.

The Protohistory period 1540-1673 is generally considered to have the first appearance of Europeans in the southeastern U.S. De Soto visited several chiefdoms in the St. Francis Basin in 1541 but when Marquette and Joliet descended the Mississippi in 1673, no natives were encountered in the SJNM project area (Marquette 1954). They did encounter Quapaw settlements on the west bank of the Mississippi River upstream of its confluence with the Arkansas River. Historians believe the Quapaw had migrated through the SJNM area from their Ohio River homeland earlier in the 17th century. A few scattered households, possibly villages, of Native Americans lived near the Mississippi River for at least 50 miles south of Cairo

Including the SJNM (Buchner et al. 2009:91), but general abandonment of the region existed perhaps partly because of increasing pressure of Iroquois raids beginning about 1650. During the Early Historic Period the SJNM probably was claimed as hunting ground by the Illini, Shawnee, Osage, Quapaw, and Michigamea (Satz 1998). As the SJNM became unoccupied, former agriculture fields and settlement sites likely regenerated back to forest communities and vegetation species composition probably graded from early succession or disturbance-type species early on to more complex floodplain/BLH communities thereafter (King et al. 2005).

Southeast Missouri was part of Louisiana (New France) during most of the Colonial Period 1673 to 1803. In 1756 the Seven Years' (French and Indian) War broke out as France sought to fortify the Ohio Valley. Prior to France's defeat by the British and their allies in 1763, France secretly ceded Louisiana to the Spanish, and although the region was subsequently returned to France in 1800, many Spanish officials still held office until 1803. French settlements were typically clustered along the Mississippi River, but locations often were moved or destroyed (e.g. early New Madrid) as the river migrated. Most Colonial settlements were founded on fur trade; the bend of the river where New Madrid currently is located was known as L'Anse a la Graiss, meaning a cove of "fat" (Houck 1908) or greasy bend, where Indian hunting camps were located and bear and buffalo grease was boiled down (Foley 1989).

In 1783, two French Canadians, Francois and Joseph Le Sieur lived at L'Anse a la Graiss for a season and recommended establishment of a trading post there. The site offered high ground (natural levee) along the Mississippi River and a settlement became established soon thereafter. In 1789, Colonel George Morgan, an American, attempted to create a town at the location by obtaining a vast land grant – known as New Madrid – that could serve as a buffer between English colonists and Mexico. However, the Spanish Governor in New Orleans only offered a ca. 1,000 acre tract and Morgan abandoned his city plans, but the proposed name of New Madrid stuck and replaced L'Anse a la Graiss. The Spanish constructed a fort at New Madrid in 1789 and the city served as a Spanish port of entry until it was surrendered to American authorities in 1804 following the Louisiana Purchase.

During the late 1790s, Anglo-American settlement increased in the SJNM region and Spanish Land Grants were given generously to local citizens for settlement and farming. Many of these initial land grants were made on higher "prairie" or "savanna" ridges especially on Sikeston Ridge (Buchner et al. 2009). Other land grants usually were on higher ridge locations and some clearing of forest in these sites began to occur at this time (Douglass 1912). Combined mills and travel corridors were built to transport people, agricultural crops, and goods during this time (Houck 1908, Ogilvie 1967) – interestingly, some sites were destroyed as floods and further Mississippi River migrations occurred (e.g., Fisk 1944). By 1795, the Spanish government concluded that further attempts to develop Louisiana into a buffer from Anglo-American penetration were not possible and it became a bargaining chip in international diplomatic relations and was returned to France.

The Colonial Period ended with the Louisiana Purchase in 1803. Missouri was part of the Louisiana District and Territory until 1812 when the Missouri Territory was formed. The large New Madrid earthquakes of 1811-12 heavily damaged the town of New Madrid and discouraged additional settlement in the region for many years. After the War of 1812, Anglo-American immigration west in the U.S. increased rapidly and steamboat travel and commerce on the Mississippi River accelerated (Brauer et al. 2005, Buchner et al. 2009). Many new settlements were established along the Mississippi River between the Ohio River and New Madrid in the early 1800s, but major development of the area did not occur until the mid 1800s. Historic tribes affiliated with the project area in the late 18th century included the Shawnee, Delaware, and Muscogee Creek. According to the historian Morrow, the site of the present day New Madrid was originally a large Delaware town. During the Trail of Tears episode in the 1830's the Cherokee and Creek Indians also moved through the project area.

Early Missouri Statehood and Development of the SJNM

Missouri was granted statehood in 1821 and at that time the population of New Madrid County (created in 1812) contained about 2,200 people but the county at the time included most of what is now Scott, Stoddard, Mississippi, Dunklin, and Pemiscot counties. The very sparse population of the SJNM region and its flood prone landscape prohibited much development, and conversion of native plant communities, except on the highest elevation ridges and natural levee locations during the early 1800s. The town of New Madrid did not recover from the earthquake until about 1822 when the county seat was permanently located there; the town was reincorporated in 1834. Development of New Madrid and other regional Mississippi River settlements was stimulated by commerce from steamboat traffic in the 1840s and 1850s. Increasing steamboat traffic fostered new settlements and clearing of forest areas along the river. These settlements often began as wood yards to supply steamboats with fuel and then later became farms, plantations, communities, or landings (Powell 1975). In Mississippi County the first towns of Norfolk and Rush Ridge were established and Wolf Island also became established by Kentuckians and Virginians. St. James was established prior to 1859 at the mouth of James Bayou and supported two sawmills. Much of the timber cut for steamboats was Riverfront and BLH Forest species on natural levee surfaces that were easily accessed and delivered to the river ports.

Starting in the mid 1810s and continuing to the 1840s, the GLO surveyors subdivided the SJNM into townships and sections and prepared the first detailed georectified maps of the area. Given that only sparse human populations were present at this time, it seems likely that the GLO notes and maps represent a mostly unmodified landscape condition and reflects natural ecological processes operating in the region except on higher ridges and natural levees (see previous discussion of Prairie and Savanna distribution). The GLO surveys seldom found farm clearing > 40 acres in wooded areas, but in contrast did find larger fields and developments on more open lands where Prairie and Savanna had existed on Sikeston Ridge and Valley Train terraces north and west of the current town of East Prairie.

Large numbers of settlers began occupying the SJNM during the 1840s and 1850s; for example, 28 land patents were issued for a four-square mile area near Barnes Ridge during 1848-59 (Buchner et al. 2009:96). Most early settlement was on ridges or more open areas and corn was the dominant crop grown (Table 6). By the early 1900s, more extensive areas of the region were farmed and diversified crops were grown (Table 6). Livestock production also accelerated in the area during the late 1800s. Coincident with increasing settlement and agricultural production was construction of railroads (Willis 1933). The St. Louis and Iron Mountain Railroad was chartered in 1851 and the Cairo and Fulton Railroad was chartered in 1853. Charleston, established in 1860, became the meeting place for these two railroads and spur lines were distributed to many settlements such as Birds Point by the 1860s. By the time of the Civil War, the Cairo and Fulton Railroad extended to Poplar Bluff, Missouri. The city of Hibbard, later renamed East Prairie, was founded in 1883 by the St. Louis Southwestern Railway Company (www.eastprairiemo.net).

After the Louisiana Purchase, all lands in southeast Missouri became public domain, but land sales did not begin until 1818 and the earlier Spanish Land Grants created difficulty and controversy in dividing landscapes. Boundaries and legal standing of some Spanish Land Grants remain uncertain even today. Initially, public land was sold in 640 acre tracts but political and economic conditions eventually allowed minimum land purchase of 80+ acres. Later the Homestead Act of 1862 required a homesteader to settle on and cultivate up to a 160-acre tract for five years to obtain title. The Civil War in the 1860s created unrest in the SJNM and deterred additional settlement and clearing of forest areas or agricultural/commercial development. In 1869, Missouri passed "An Act in Relation to Swamp and Overflowed Lands within the limits of several counties." This act conveyed all un-patented "swampland" to the counties they were located in. Following the Civil War, "tenant" farming began to decentralize the old plantation system of the mid-southern U.S. including some larger plantation land holdings in the SJNM. This tenant period lasted from the 1870s to about 1950 and many small farms were established throughout the area. The small farms, coupled with land reclamation and drainage projects (see below) gradually fragmented and cleared much of the forest in the SJNM (Korte and Fredrickson 1977, MacDonald et al. 1979).

Following the Civil War technological changes shifted from steamboats to railroads and caused important shifts in commerce and mass production of consumer goods in the southern U.S. (Houck 1908). Repairs to rail lines damaged in the war and additional line expansion eventually connected larger communities in southeast Missouri and many lines, usually located on ridges or higher elevation terraces began to cross the SJNM. Increased transportation capabilities also stimulated clearing of floodplain forests and conversion of native communities to more extensive agricultural production. Coincident with the expansion of agricultural lands were efforts to drain low-lying areas.

The development and conversion of much of the SJNM to agricultural land in

Table 6. Historic statistics for various agricultural crops produced in Mississippi and New Madrid counties, Missouri (from Buchner et al. 2009)

New Madrid County				
Census Year	Corn (bu.)	Wheat (bu.)	Cotton (bales)	Tobacco (#)
1840	461,110	9,503	2†	0
1850	586,260	195	0	0
1860	802,306	20,243	0	2,400
1870	No data			
1880	1,116,696	49,273	1,649	14,243
1890	886,158	74,909	1,505	3,450
1900	1,247,050	268,010	1,602	400
1910	2,091,907	202,941	5,600	150
1920	1,476,894	736,110	7,192	–
Mississippi County				
Census Year	Corn (bu.)	Wheat (bu.)	Cotton (bales)	Tobacco (#)
1850	354,700	3,727	0	0
1860	543,095	30,074	0	0
1870	491,990	5,225	57	6,160
1880	1,509,055	110,448	132	21,010
1890	1,304,686	167,498	17	16,960
1900	1,358,380	230,040	11	340
1910	2,230,545	595,943	74	0
1920	1,054,561	733,009	298	0

† in 1840 cotton production was reported in pounds

The 1840 data are not available for Mississippi County as it was not formed until 1845.

the late 1800s and early 1900s was closely linked with flood control and drainage projects (Douglass 1904, Korte and Fredrickson 1977, Fredrickson 2005). The Swamp Act of 1850 gave Missouri 3.3 million acres of overflow land, primarily in southeast Missouri. The Act provided that proceeds from the sale of the lands would be used to construct an eventual extensive network of levees and drainage ditches (Fig. 28). Mississippi and New Madrid counties were major beneficiaries of the Act and after a major flood in 1858; work began on the construction of a levee along the Mississippi River 30 miles south of Birds Point. Its height was equal to the 1815 flood which Abraham Bird had recorded by cutting a mark on a tree. Most levee and ditch building was uncoordinated private efforts until the late 1890s, when numerous drainage districts were established by taxing land owners in the district area. One large drainage district was the St. John Levee and Drainage District that, for example assessed drainage district taxes of $0.15/acre. These early drainage districts and their projects began to substantially modify flood duration and extent in the SJNM and contributed to early conversion of historic habitats to farmland (Korte and Fredrickson 1977).

A large flood occurred over much of the MAV in 1927 and led to Congressional passage of the Flood Control Act of 1928, which authorized the Mississippi River and Tributaries Project including works in the SJNM (Barry 1998, USACE 2009a). The Act projects included: 1) construction of levees and floodwalls to contain floods, 2) floodways to pass excess flows past critical Mississippi River reaches, 3) channel improvements and stabilization to improve efficient navigation, and 4) tributary basin improvements. Levees along the Mississippi River in the SJNM were expanded, raised, and constructed starting with the New Madrid-Sikeston Ridge Levee (Fig. 2) in 1928. A second large flood control project following the Flood Control Act of 1928, known as the "Jadwin Plan" after Edgar Jadwin that presented the idea to Congress, was construction of the Birds Point - New Madrid Floodway. This Floodway was designed to lower flood stages upstream and adjacent to the Floodway during major flood events. Initial construction of the Floodway began in 1929 and was completed in 1933. It included a 130,000 acre flowage right from Birds Point to New Madrid and constructed a frontline "fuseplug" levee along the Mississippi River constructed at a height equivalent to a 57 foot Mississippi River stage at the Cairo gauge. On

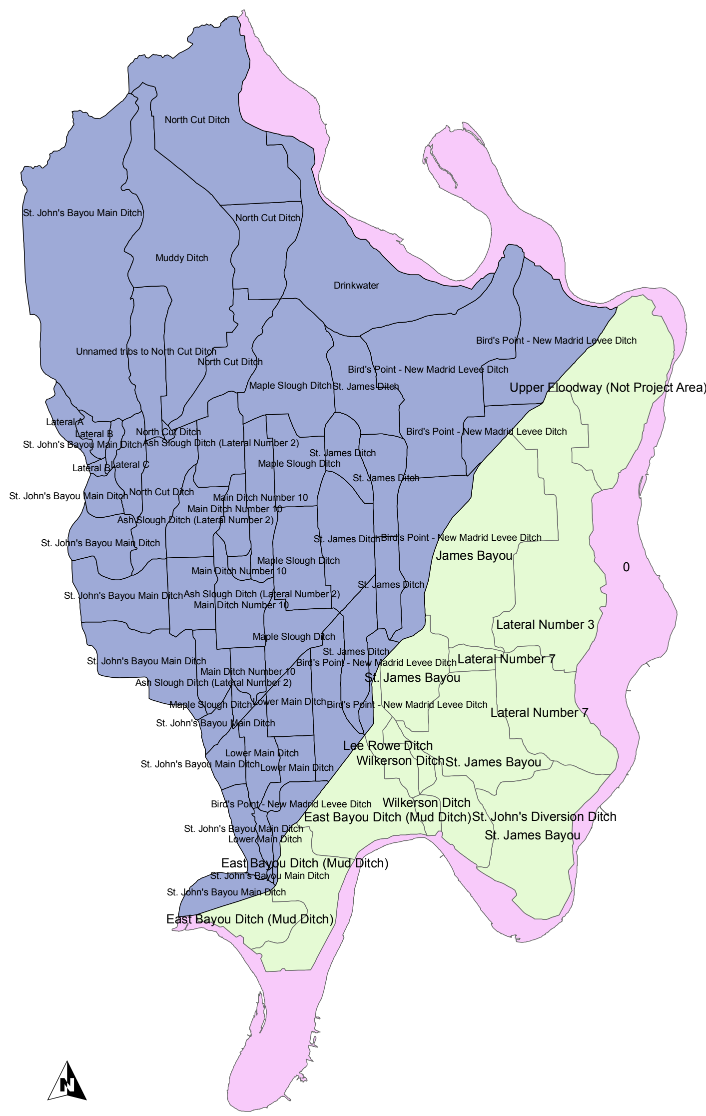


Figure 28. Major ditches in the SJNM.

the backside of the Floodway, a higher levee equivalent to a 60 foot Mississippi River stage at Cairo was constructed to protect lands to the west of the Floodway. In case of a great flood, the fuse-plug levee was designed to blow out – or it can be artificially breached (i.e., it was dynamited in 1937). The New Madrid Floodway diverts a maximum flow of 550,000 cfs (Barry 1998). At the southern end of the Floodway, the frontline and setback levees were not joined, leaving a gap of about 1,500 feet. The purpose of the gap was to provide drainage to the New Madrid Floodway via Mud Ditch. While the gap was provided as a drainage outlet, it by default also allows Mississippi River backwater to inundate the lower Floodway. Similarly, a 4,200-foot gap was left in the levee separating the New-Madrid-Sikeston and Birds Point-New Madrid levees to provide an outlet for the St. John's Bayou Basin and while it provided a flow outlet, it also allowed Mississippi River backwater to inundate the lower part of the St. John's Basin.

Another large flood occurred in the Upper MAV in January 1937 and all previous flood stage records were or would soon be broken. In an attempt to save Cairo from massive flood devastation, the fuse-plug New Madrid Floodway was breached with explosives and the Floodway lands were quickly inundated with subsequent large livestock and property losses. Relict braided stream and abandoned channels were flooded and acted as conduits for flood flows, perhaps similarly to how they transferred water during Holocene glacial outwash events.

Political fallout from the 1937 Flood eventually led to the Flood Control Act of 1946, which authorized the closure of the 4,200 foot gap in the southern St. John's Bayou Basin. A levee was constructed across the gap and six 10 x 10 feet reinforced concrete culverts built with power-operated lift gages at the outlet end were constructed across St. John's Bayou (Fig. 29). Construction was completed in 1953.

The subsequent Flood Control Act of 1954 amended the Bird's Point – New Madrid Floodway Project by authorizing modifications to the Floodway in accordance with U.S. House of Representatives Document 132, 83rd Congress. This document recommended construction of a new levee extending about 1,800 feet from the fuseplug section of the frontline levee across the existing New Madrid Floodway gap to the setback levee and the construction of a floodgate for release of interior drainage. Construction of the levee was deferred until a pumping station was authorized. Further modification to the floodway was authorized by the Flood Control Act of 1965, which recommended "raising the levees forming the east boundary of the Birds Point – New Madrid Floodway and modifying operation to include breaching of the fuseplug levee during floods that reach 58 feet and threaten to exceed 60 feet at Cairo. Whereas the plan authorized by the 1928 Flood Control Act provided for operation of the Floodway by overtopping a fuse plug levee when the Mississippi River reached 55 feet at Cairo, the 1965 Act provided for artificial breaching of the levee at 58-60 foot level. As a result of the modified plan for operation, modified flowage easements were purchased on lands > 300 feet elevation NGVD. Finally, in 1986, the Water Resources Development Act authorized channel modification and pumping stations for the St. John's Bayou Basin and the New Madrid Floodway, which currently are being evaluated with a plan formulation for the region (USACE 2009b).

Figure 29. Photograph of the floodgate structure at the south end of St. John's Bayou Basin.

Vegetation Community Changes from the late 1700s to the Present

Current land cover in the SJNM is dominated by agricultural cropland except in the Batture land region (Fig. 30, Tables 5, 7). Essentially all historic Prairie and Savanna are gone, and total forest area is only 6% and 7.8% of total area in the St. John's Bayou Basin and New Madrid Floodway, respectively. Comparison of historic forest communities (Fig. 26) with contemporary aerial

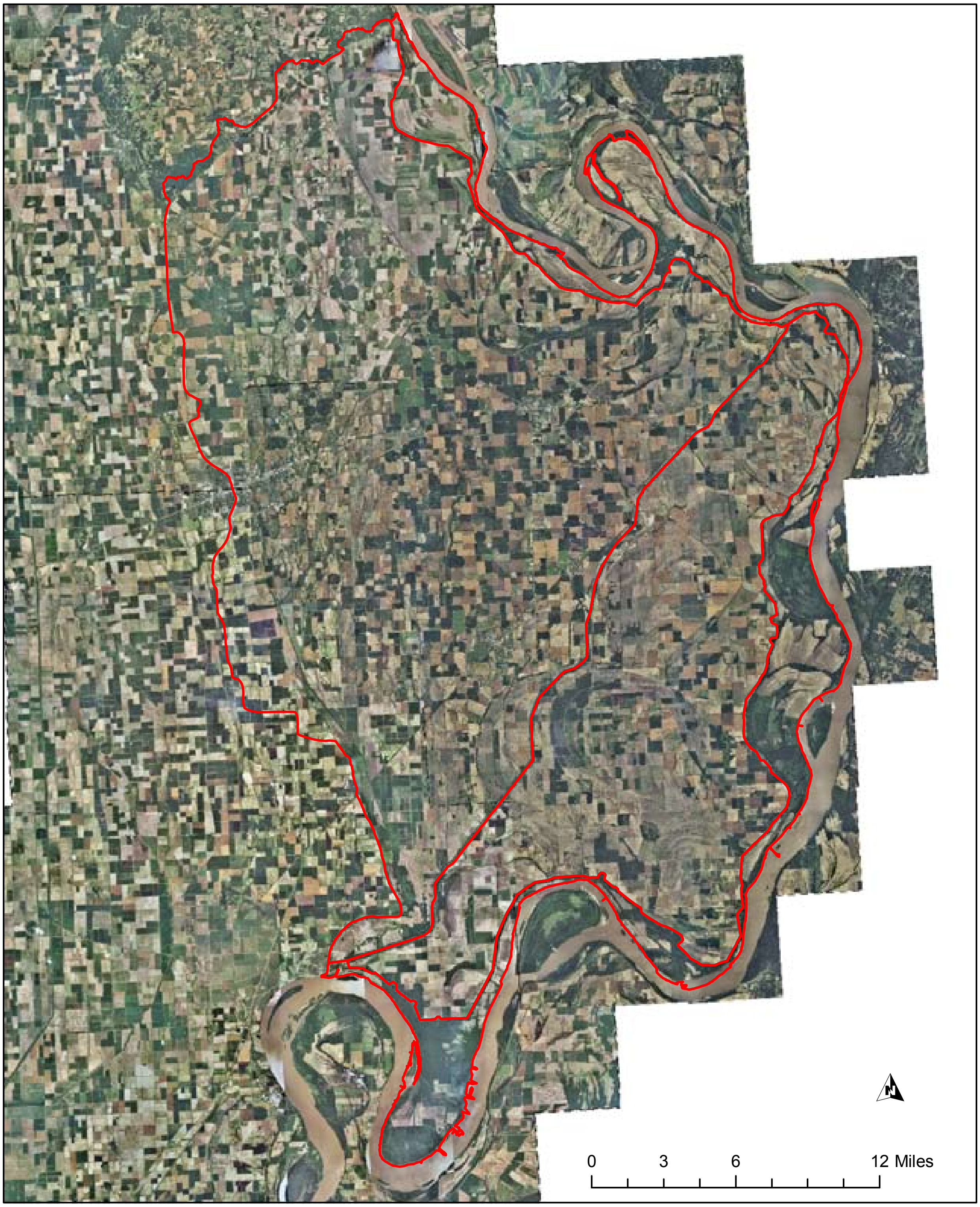


Figure 30. 2009 NAIP photograph of the SJNM identifying remnant forest communities.

photographs (Fig. 30) that show remnant forest tracts identifies that remaining tracts are primarily Riverfront Forest communities with small tracts of BLH scattered in the region. The only large forest tracts in the SJNM are scattered Riverfront Forest tracts in the Batture land and Floodplain and BLH forests at Donaldson Point, Big Oak Tree, and the Bogle Woods adjacent to Ten Mile Pond CA. These larger tracts now are all in public ownership. Mean area of remnant forest tracts in the SJNM is < 20

Figure 31. Photograph of small remnant High BLH forest tracts in the St. John's Bayou Basin.

ha, and when the larger tracts listed above are excluded, the mean area of forest tracts is < 5 ha (Fig. 31, Twedt and Loesch 1999). Less than 10 four-square mile units of land in the SJNM contain > 15% forest cover (Papon 2002, Warwick 2003).

Most Prairie and Savanna was converted to agricultural land by the late 1800s (e.g., The Mississippi River Commission maps of 1881). In contrast, extensive clearing of forest communities did not occur until the early 1900s (Korte and Fredrickson 1977). Most clearing of forests in the SJNM began on higher elevation ridges, natural levees, and braided stream terraces, but some lower elevation forests were partly cut in the early 1900s for railroad ties and barrel staves (Stanard 1993). Considerable clearing of forest area in Scott, Mississippi and New Madrid counties occurred from about 1910 to 1930 and by 1937 < 30% of Presettlement forests, especially Floodplain and BLH communities remained (Table 8). Forest loss continued to mount during the 1950s, 1960s and 1970s, and by 1974 < 3% of Presettlement

Table 7. Current land cover acres in the St. John's Bayou Basin and New Madrid Floodway (from USACE 2009a).

St. Johns Bayou Basin Total Landcover			New Madrid Floodway Total Landcover		
Land Use	**Total Acres**	**Percent Landcover**	**Land Use**	**Total Acres**	**Percent Landcover**
Forested	20,096	6%	Forested	10,368.7	7.8%
Scrub-shrub/Marsh	269.6	0.1%	Scrub-shrub/Marsh	878.2	0.7%
Cropland	280,289.8	86.5%	Cropland	113,007.3	85.2%
Pasture	1,277.4	0.3%	Pasture	922.2	0.7%
Herbaceous	21,121.0	6.5%	Herbaceous	6,624.7	5%
Open Water	944.2	0.3%	Open Water	797.3	0.6%
Sandbar	166.5	0.1%	Sandbar	6.6	0%
Urban	8.1	0%	Urban	0	0%
TOTAL	**324,172.8**	**100%**	**Total**	**132,605.1**	**100%**

Project Batture lands		
Land Use	**Total Acres**	**Percent Landcover**
Forested	23,796	50.6
Scrub-shrub/Marsh	1,083	2.3
Cropland	18,816	40.0
Pasture/Herbaceous	14	0.0
Open Water	2,123	4.5
Sandbar	1,027	2.2
Urban	188	0.4
TOTAL	**47,047**	**100**

Table 8. Chronology of loss of forest in Mississippi and New Madrid counties, Missouri (adapted from Korte and Fredrickson 1977).

County	1937	1947	1957	1967	1974	Total area[b]
Scott	-	-	14,100	7,700	2,800	217,100
Mississippi	82,000	59,000	36,300	20,000	9,600	277,700
New Madrid	99,000	74,000	49,100	25,100	10,100	446,100

[a] Includes Riverfront, Bottomland Hardwood, and Terrace Hardwood forest areas.
[b] Potential total forest area in the county.

forest area remained in these counties (Table 9). Apparently, slightly slower and less forest conversion occurred in the SJNM compared to non-SJNM areas of these counties, but nonetheless, more than 90% of non-batture SJNM forest lands were cleared by 1980. Most remnant forest communities in the St. John's Bayou Basin and New Madrid Floodway are primarily at elevations 289-298 feet NGVD where flooding is not so prolonged (> 2-5 year flood recurrence interval) as to cause mortality (Table 8). Ironically, however, these higher elevations where High BLH and Terrace Hardwood Forest are most adapted are also the sites where > 99% forest conversion to agricultural has occurred (Table 5). Remnant forest in Batture lands are almost all Riverfront Forest communities and at > 290 feet NGVD (Table 9).

About 4,000 acres of Bottomland Lake habitats remain in non-batture lands the SJNM (Table 5). The largest sites are at the Robert G. Delaney and Ten Mile Pond CA's and in other scattered abandoned channel locations. A few, very small tracts of Low BLH also remain in relict valley train channels, along ditches, and other depressions. Non-forested or non-cropland habitats in the Batture are mainly S/S and Open Water habitats along river chutes, sloughs, and side channels.

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Figure 9. Land cover- habitat type areas in Batture, St. John's Bayou Basin, and New Madrid Floodway regions of the SJNM (from USACE 2009a).

Elevation Feet (NGVD)	Cropland	Fallow	BLH	Large Waterbody	Small Waterbody
281 and below	12	343	255	636	0
282 and below	22	382	338	740	0
283 and below	37	429	424	820	0
284 and below	68	472	557	900	0
285 and below	131	527	724	967	1
286 and below	235	594	999	1,063	7
287 and below	361	658	1,340	1,131	9
288 and below	496	719	1,816	1,246	11
289 and below	687	765	2,464	1,311	13
290 and below	924	810	3,261	1,375	17
291 and below	1,253	855	4,131	1,445	20
292 and below	1,748	905	5,090	1,595	22
293 and below	2,243	955	6,005	1,637	23
294 and below	2,747	1,014	6,956	1,658	24
295 and below	3,291	1,079	7,966	1,679	25
296 and below	3,872	1,170	9,098	1,730	26
297 and below	4,542	1,267	10,324	1,803	26
298 and below	5,303	1,375	11,460	1,876	27
299 and below	5,959	1,475	12,450	1,900	27
300 and below	6,478	1,573	13,332	1,913	27
301 and below	6,895	1,659	14,193	1,927	27
302 and below	7,327	1,726	15,069	1,944	27
303 and below	7,931	1,795	15,957	1,972	27
304 and below	8,645	1,870	16,894	2,001	27
305 and below	9,685	1,933	17,873	2,024	27
306 and below	11,141	1,994	18,837	2,044	27
307 and below	12,803	2,047	19,772	2,060	27
308 and below	14,271	2,089	20,602	2,080	27
309 and below	15,356	2,122	21,262	2,104	27
310 and below	16,044	2,153	21,824	2,110	27
311 and below	16,611	2,186	22,322	2,114	27
312 and below	17,249	2,203	22,765	2,118	27
313 and below	17,773	2,218	23,125	2,120	27
314 and below	18,145	2,236	23,400	2,122	27
315 and below	18,392	2,251	23,571	2,123	27
316 and below	18,543	2,263	23,660	2,123	27
317 and below	18,684	2,270	23,711	2,123	27
318 and below	18,767	2,275	23,748	2,123	27
319 and below	18,800	2,281	23,775	2,123	27
320 and below	18,816	2,285	23,796	2,123	27

Figure 9. Land cover- habitat type areas, (cont'd.)

Elevation Feet (NGVD)	Cropland	Fallow	BLH	Large Waterbody	Small Waterbody
281 and below	229	53	258	39	93
282 and below	310	64	306	45	101
283 and below	398	78	352	48	110
284 and below	494	92	400	50	118
285 and below	1,811	247	811	113	250
286 and below	2,143	317	1,086	120	305
287 and below	2,597	362	1,320	122	322
288 and below	3,056	416	1,556	123	340
289 and below	3,570	481	1,778	125	353
290 and below	6,067	693	2,464	144	486
291 and below	7,413	834	2,676	155	526
292 and below	8,764	910	2,807	163	540
293 and below	10,942	991	2,946	168	552
294 and below	13,401	1,143	3,089	203	566
295 and below	23,389	1,941	3,797	267	639
296 and below	26,851	2,255	4,107	269	673
297 and below	29,092	2,488	4,374	272	697
298 and below	31,700	2,746	4,648	273	707
299 and below	34,562	3,073	4,872	273	714
300 and below	44,546	3,960	5,478	274	741

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CONCLUSION

The Hydrogeomorphic-matrix methodology used in this report provided an objective, science and history-based way, to map potential Presettlement land cover/vegetation community distribution in the SJNM. The SJNM region contained diverse and dynamic hydrogeomorphic attributes that ultimately created landscapes capable of supporting many communities. The specific attributes of geomorphic surface, soil taxonomy, and hydrology are strongly correlated with the distribution and type of communities and each habitat has unique distinguishing characteristics. Prairie and Savanna were historically present on nearly 34,000 acres of Sikeston Ridge, Ps surfaces on the older Valley Train drainage complex adjacent to Sikeston Ridge, and areas > 500-year floodplain on the Charleston Fan (Fig. 26). By the mid to late 1700s, the area of Prairie and Savanna may have been steadily declining from maxima during the Altithermal period ca. 4,000 to 8,000 BP because of wetter, milder, climatic conditions in recent periods. Nonetheless, these sand-based Prairie-Savanna complexes represented important communities an econiches in the SJNM during Presettlment periods. The higher elevation sand ridge and dune sites were among the first sites to be settled and converted to agricultural croplands by Europeans and most of these habitats were destroyed by the mid to late 1800s. Almost no remnant Sand Prairie or Savanna remains in the SJNM today (Table 5).

Diverse forest communities covered > 93% of the SJNM during the Presettlment period and contained a gradient of Riverfront, BLH, and Terrace Hardwood communities. A small area of Slope Forest also was present on alluvial fans along the Commerce Hills in the far north part of the SJNM. Riverfront Forest was estimated to have covered > 62,000 acres of newly scoured and deposited bar-and-chute (Woerner et al. 2003, Saucier 1994) surfaces along the Mississippi River channel. The active migration of Mississippi River channels in the SJNM during the Holocene period following erosion of the main channel through Thebes Gap about 10,000 BP has continued to provide suitable geomorphic and soil surfaces for Riverfront Forest and it has been destroyed at lesser percentages than other SJNM historic habitats (Table 5). Much of the remainder of Riverfront Forest, however, is within the Batture lands.

BLH was present on nearly 300,000 acres of the Presettlment SJNM and included Low to High BLH species composition depending mainly on soil and flooding occurrence in the Hpm1 and edges of Pvl, Pvl1, and Pvl2 geomorphic surfaces (Fig. 26). Only a few remnant patches of BLH remain in the SJNM (Table 5) and most are in public-owned or WRP easement conservation lands. In addition to clearing of most BLH for agriculture, the many hydrological alterations to the region from the St. John's Bayou Basin and New Madrid Floodway infrastructure also may have altered the ability of specific sites to support specific BLH communities, if they can at all. For example, the levees and gaps in the region may have shifted hydrological regimes in spring to wetter regimes caused for example, by closure of floodgates in the St. John's Bayou Basin that causes water to inundate areas for longer periods in spring and summer.

Terrace Hardwood forests also were present in extensive areas of higher elevations on Ps, Pvl, Pvl1, and Pvl2 geomorphic surfaces (Fig. 26). Their distribution was primarily determined by the presence of sandy-loam ridge soils that were rarely flooded from high stages of the Mississippi River, but that did receive soil saturation and some ponding in most springs from local precipitation and stream flow.

As with Prairies and Savanna on higher elevations in the SJNM, almost no Terrace Hardwood forests remain in the SJNM.

Bottomland Lake habitats historically were extensive in the SJNM and covered > 20,000 acres of abandoned Mississippi River channels (Fig. 26). Communities in Bottomland Lakes undoubtedly varied over time as the abandoned channels gradually filled and became plugged with alluvial sediments deposited during almost annual backwater flood events from the Mississippi River. New abandoned channels likely contained extensive open water and S/S communities while older ones became Low BLH habitats with open, and annually flooded, bald cypress and water tupelo-dominated canopies. Further, long term fluctuations in wetness and occurrence and extent of seasonal flooding in Bottomland Lakes likely caused at least some seasonal drying of lake margins where emergent and herbaceous wetland plants germinated and provided resources to many animals. In wet years less edge-type herbaceous vegetation was present than in dry years when perhaps large areas of the margins of the lakes dried and supported herbaceous communities.

River chutes, side channels, and bars also were present in the SJNM immediately adjacent to, or in the Mississippi River channel. The distribution and extent of these habitats was undoubtedly very dynamic as the active river channel migrations occurred in the region (Brauer et al. 2005). Consequently, it is somewhat difficult to estimate the precise area of these habitats in the late 1700s, but generally probably at least 10,000 acres of these habitats was present at any given time.

The development of potential Presettlment vegetation community maps provides the foundation for understanding the SJNM ecosystem both past and present. These Hydrogeomorphic-derived maps provide a basis for determining which communities belong in specific geomorphic, soil, and hydrological settings in the SJNM and how contemporary alterations may, or may not, allow these communities to be restored in historic locations if that is desired (Heitmeyer 2008, Klimas et al. 2009). The Hydrogeomorphic analyses also identify the fundamental driving ecological processes that must be present if restoration of specific communities is attempted. For example, restoration of Sand Prairie and Sand Savanna will require establishment of endemic grass, forb, shrub, and tree species (Savanna) on sand soils on high elevation ridges > 500-year flood frequency, and with regular (5-8 year recurrence) disturbance from fire or herbivory to maintain a large grass component of these systems. In another example, restoring Intermediate BLH will require regeneration of specific-community tree species on clay or clay-loam soils in mainly Hpm1 geomorphic surfaces where a 2-5 year flood recurrence regime from backwater flooding from the Mississippi River can occur.

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Appendix A

Soil types associated with major vegetation communities in the SJNM.

Community	Soil Number	Soil Name and Geomorphic Surface if the soil is present in a community type in multiple surfaces[a]
Prairie	82017,82018,	
	82020	Bosket Fine Sandy Loam in Pve
	82005	Malden Loamy Fine Sand in Pve
Savanna	82005	Malden Loamy Fine Sand except Pve
	82026	Broseley Loamy Fine Sand in Pve
Terrace Hardwood Forest	82000	Dubbs Sandy Loam in Pve, Pvcl, Ps, Pvl, Pvl1, Pvl2
	82015	Beulah Fine Sandy Loam
	82017, 82018,	
	82020	Bosket Fine Sandy Loam in Pvcl, Ps, Pvl1, Pvl2
	82026	Broseley Loamy Fine Sand in Pvcl, Ps, Pvl1, Pvl2
	82029	Canalou Loamy Sand
	82030	Clana Loamy Fine Sand
	82031, 82032	Scotco Loamy Sand
	82043	Farrenburg Fine Sandy Loam
	82050	Lilbourn Fine Sandy Loam
Slope Forest	82021	Crevasse Loam
	90020	Saffell Gravelly Loam
High BLH	82005	Malden Loamy Fine Sand in Hpm1, Pvcl, Ps
	82027	Broseley Soils
	82031, 82032	Scotco Loamy Sand in Pvl1, Hpm1
	82037	Dundee Silty Loam in Pve, Ps, Pvcl, Pvl1, Pvl2, Pvl
	82040	Dundee Silty Clay Loam
	82045	Forestdale Silty Clay Loam
	82057	Towosaghy Fine Sandy Loam

Community	Soil Number	Soil Name and Geomorphic Surface if the soil is present in a community type in multiple surfaces[a]
	86002	Falaya Silty Loam
	86005	Acadia Silty Loam
	86016	Commerce Silty Clay Loam in Pve, Pvl
	86045	Reelfoot Silty Loam
	86061	Sikeston Loam
	86063	Sikeston Silty Clay Loam
	86067	Tiptonville Silty Loam
	86074, 86082,	Alder Silty Loam
	90001, 90017,	
	90021, 90022	Memphis Silty Loam
High BLH Natural Levee	82026	Crevasse Loam
	86093	Crevasse Loamy Sand
	86094	Crevasse Silty Loam
Intermediate BLH	82000	Dubbs Sandy Loam in Hpm1
	82037	Dundee Silty Loam in Hpm1
	82046	Forestdale Silty Clay Loam
	82058	Wardell Loam
	86015	Commerce Silty Loam
	86016	Commerce Silty Clay Loam in Hpm1
	86019	Cooter Silty Clay Loam
	86020	Cooter Silty Clay
	86027	Diehlstadt Silty Loam
	86028	Diehlstadt Silty Clay Loam
	86029	Gideon Clay Loam
	86030, 83031	Gideon Loam
	86039	Mhoon Silty Loam
	86046	Roellen Clay
	86048,86103	Roellen Silty Clay
	86071	Tunica Silty Clay Loam
	86075, 86084	Bowdre Silty Clay Loam
	86077	Cairo Clay
	86078	Cairo Silty Clay
	86090	Commerce Silty Clay Loam
	86096	Dundee Silty Clay Loam
	86107	Tunica Silty Clay Loam

Community	Soil Number	Soil Name and Geomorphic Surface if the soil is present in a community type in multiple surfaces[a]
Low BLH	82047	Jackport Silty Clay Loam
(including Bottomland	86009	Alligator Silty Clay Loam
Lakes)	86011	Alligator Silty Clay
	86052	Sharkey Clay
	86054, 86055, 86107	Sharkey Silty Clay Loam
	86056, 86057, 86104	Sharkey Silty Clay
	86060	Sharkey-Steel Complex
Riverfront Forest	82017, 82018, 82020	Bosket Fine Sandy Loam in Hpm1
	82026	Broseley Loamy Fine Sand in Hpm1
	86012, 86080, 86088	Caruthersville Very Fine Sand
	86064, 86106	Steele Fine Sand
	86066	Tiptonville Fine Sandy Loam
	86089	Commerce Silty Loam

[a] Soil type is present exclusively in a community unless the specific geomorphic surface(s) are listed: Pve – Early Wisconsin Pleistocene Valley Train Sikeston Ridge, Pvcl – Late Wisconsin Relict Valley Train Channels, Ps – Late Wisconsin Interfluve Sand Dunes, Pvl – Late Wisconsin Braided Stream Terrace undifferentiated age, Pvl1 – Late Wisconsin Braided Stream Terrace most recent deposition on Charleston Fan, Pvl2 – Late Wisconsin Braided Stream Terrace older deposition, Hpm1 – Holocene Point Bar Mississippi River Meander Belt.