AN EVALUATION OF ECOSYSTEM RESTORATION AND MANAGEMENT OPTIONS FOR FLOODPLAINS IN THE LOWER GRAND RIVER REGION, MISSOURI

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EXECUTIVE SUMMARY

A hydrogeomorphic (HGM) evaluation of ecosystem restoration and management options was conducted for the 155,000-acre Lower Grand River region (LGR) of north-central Missouri. The LGR is comprised of the alluvial floodplains of the Grand River and its tributaries upstream from its confluence with the Missouri River. Relict glacial terraces are adjacent to the floodplain and a few remnant terraces are subset within it. Soils in the LGR are derived from a mixture of loess and glacial till eroded from upland terraces in the watershed. The Grand River Basin has a total drainage area of 7,900 miles^2 and extends over 150 miles long and 90 miles wide. The funnel shape of the basin directs surface water discharge to the narrow floodplain in the LGR and causes regular overbank flooding of the region.

Historically, the LGR was a highly diverse ecosystem with mesic and wet mesic prairies present on glacial terraces and wet prairie, woodland, and bottomland forest in floodplains. The widely meandering Grand River and its tributaries formed numerous oxbows and abandoned channel depressions in the region. This unique complex of habitat types created a mosaic of vegetation and aquatic resources that were used by many fish and wildlife species. The central position of the large north-south Grand River Basin that narrowed to the LGR made the region a natural "funnel" for movement of water and nutrients and was a major corridor of movement and stopover area for migratory birds.

A HGM matrix of relationships between vegetation communities and LGR attributes of geomorphology, soils, topography, and hydrology was prepared. This matrix was developed using historical information and on-site sampling, especially in the area near Sumner, MO. An ecological land type map was developed to represent the potential historic (pre-European settlement) distribution of vegetation communities for the area. Tall grass mesic prairie historically occupied much of the higher elevation glacial terraces of the LGR and this prairie transitioned to wet mesic prairie and oak-savanna where terraces graded into floodplains. Floodplains contained wet prairie, woodland, and bottomland forest communities depending on elevation and soils. Wet prairie was present on silt clay soils, flat topography, short duration seasonal sheetwater flow, and occasional (2-5 year) overbank flooding from the Grand River and its tributaries. The lowest elevation floodplain prairies were essentially "marsh-type" communities with mixtures of prairie cordgrass, sedges, rushes, and herbaceous moist-soil plants. Wet mesic woodland occupied broad transition zones in LGR floodplains with poorly drained silt clay soils that flooded almost annually for short durations in winter and spring. Floodplain bottomland forest was present along streams and rivers in the LGR and in shallow swales adjacent to or succeeding from old abandoned river channels and flats. Soils in these areas are poorly drained and predominantly clay. Natural levees in the LGR supported floodplain forest where clay soils were present, but contained early succession riverfront forest types where sand and gravel soils were present. Oxbows and deeper floodplain depressions contained gradients of open water, shrub/scrub, and herbaceous wetland communities from deeper middle parts of the depression to shallow edges.

The current LGR region has been highly destroyed and degraded from the Presettlement condition from the combined effects of conversion of native communities to agricultural production and other uses, topographic modification of lands, alteration to river and watershed hydrology, sedimentation and contamination of floodplains and wetlands, and invasion of non-native plants and animal species. The extensive levee, ditch, and road developments of the entire Grand River Basin, and especially in the lower end of the LGR, have intensified and accelerated water and sediment discharge, and caused more regular and prolonged overbank and backwater flooding from the Grand River into the LGR. The large Garden of Eden levee is especially degrading to the LGR and constricts the Grand River floodplain to about 2,700 feet wide just below the mouth of Yellow Creek.

The LGR currently contains about 40,000 acres of fee-title and easement lands managed for conservation purposes. These include Swan Lake National Wildlife Refuge (NWR), Fountain Grove and Yellow Creek Conservation areas (CA), Pershing State Park, and about 18,000 acres of private wetlands protected under USDA Wetland Reserve Program (WRP) easement. Development and management of Swan Lake NWR and Fountain Grove CA have been extensive since their establishment. Both areas have constructed numerous levees, water-control structures, water storage reservoirs, roads, and other physical structures. These developments have altered hydrology and ultimately caused changes in community types, distribution, and extent compared to pre-developed and Presettlement periods. Development of WRP lands also has substantially changed land and hydrology features of the sites. Development and management at Pershing State Park has been more limited compared to other conservation lands.

Efforts to restore and management ecosystems in the LGR will require multiple landscape-level actions including those that:

1. Increase programs to improve water, sediment, and land management in strategic locations throughout the Grand River Basin.
2. Restore natural (pre-alteration) water flow patterns and hydrology in the LGR where possible.
3. Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relation to topographic and geomorphic/soil position throughout the Grand River Basin and in the LGR.

4. Restore and maintain historic patterns of resource availability and abundance including nutrient cycling, seasonal energy flow, and key food, cover, reproductive and refuge resources for native animal species.
5. Accommodate multiple public uses when and where they do not compromise primary ecosystem and resource objectives.

Specific recommendations to achieve these goals are provided in this report to:

- Reduce soil erosion and sediment loading
- Restore stream corridors and drainage systems
- Restore native vegetation communities and key resources
- Protect and reconnect water flow corridors
- Expand floodways and drainage corridors
- Remove obstructions to sheetwater flow and drainage
- Restore and manage terrace and floodplain prairies
- Restore and manage floodplain woodland and forest
- Manage seasonally flooded wetlands and persistent emergent marsh
- Protect and restore oxbows, abandoned channels, and floodplain sloughs
- Change the mode of access routes
- Expand or modify refuge and sanctuary sites on public lands
- Reduce, or spatially change, consumptive activities on public lands
- Modify agricultural programs on public lands

Regular monitoring and evaluation programs and directed studies will be needed to determine the future status of the LGR ecosystem and the success or failure of restoration and management programs such as those identified in this report. Specific monitoring and evaluation needs include:

- Sediment reduction and control
- Effectiveness of restoring water flow pathways, patterns, and seasonal water regimes, especially in floodplains
- Long term changes in vegetation and animal communities related to flooding and elevation

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MDC

INTRODUCTION

This report provides a hydrogeomorphic–based (HGM) evaluation (see e.g., Heitmeyer 2007, 2010a,b) of ecosystem restoration and management options for floodplain lands in the Lower Grand River Basin of north-central Missouri (Fig. 1, hereafter LGR). The Grand River Basin is the largest river basin in Missouri north of the Missouri River and has a total drainage area of about 7,900 square miles that extends over 150 miles long and 90 miles wide (Fig. 2, MDC 2010a). Most (78%) of the basin is in Missouri and drainage is asymmetrical; almost 1/5 is to the south and 4/5 is to the north of the main stem, which serves as a collector channel for many parallel tributary basins of similar elongated configuration. The funnel shape of the basin directs discharge to the narrow floodplain in the LGR, where regular overbank flooding occurs.

The LGR contains about 155,000 acres and is located within the Central Dissected Till Plains Ecological Section of North America and contains parts of the Grand River Hills and Missouri River Alluvial Plains ecological subsections (Fig. 3). Within these broad ecological sections the LGR has four ecologically distinct zones: 1) the narrow floodplains of northern tributaries to the Grand River (hereafter referred to as Upper Tributary Floodplains), 2) the broad alluvial floodplain of the Grand River north of the Missouri River Alluvial Plain (Middle Grand River Floodplain), 3) the southern floodplain of the Grand River that is influenced by its confluence with the Missouri River (Lower Grand River Floodplain), and 4) a remnant glacial terrace that is subset within the Lower Grand River and Missouri River floodplains (Lower Basin Terrace) (Fig. 4). Each zone contains a unique combination of floodplain geology, soil and elevation configuration, and hydrological attributes that form and "drive" ecological processes

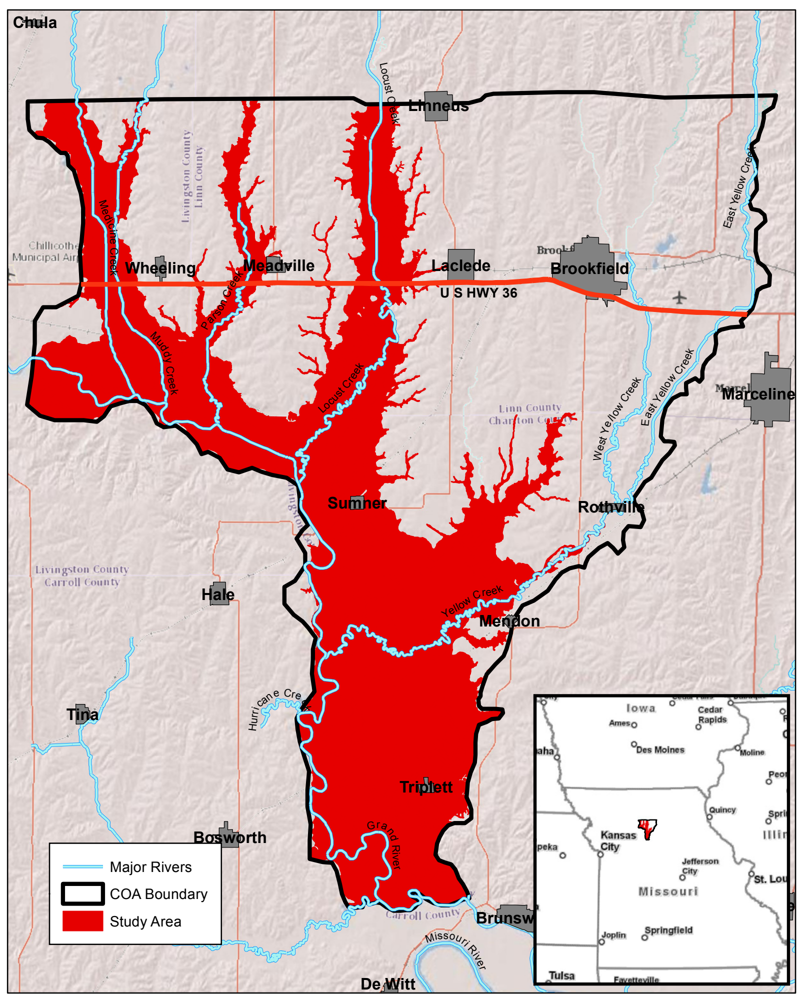

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Figure 1. General location of the LGR and its relationship to the Lower Grand River Conservation Opportunity area.

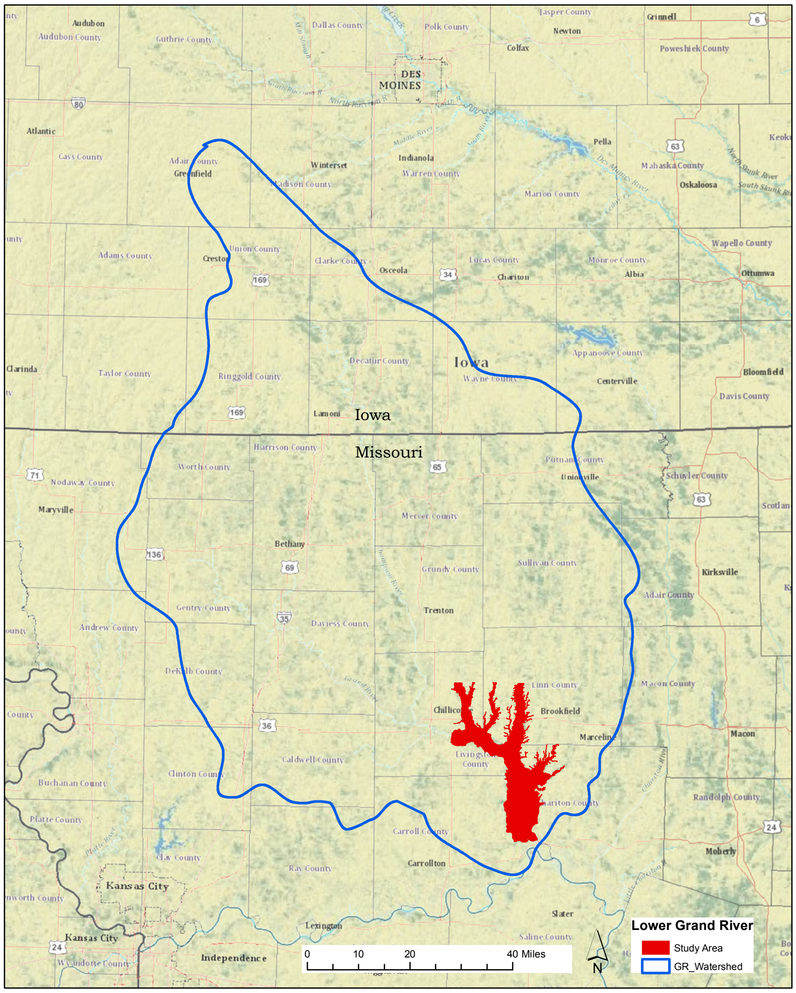

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Figure 2. Geographic location of the Grand River Basin in Iowa and Missouri.

and communities in LGR ecosystem and contribute to the regions great biodiversity and high productivity.

Historically, the LGR contained diverse complexes of river/stream channel and oxbow aquatic habitats, floodplain forest and woodland, bottomland prairie, and terrace prairie and savanna that supported rich animal communities and provided many important ecological functions and values at local to continental scales (Nigh and Schroeder 2002). Unfortunately, much of the historic LGR ecosystem has been destroyed or is highly degraded from the combined effects of conversion of native plant communities to agricultural production and other uses, topographic modification of lands, alteration of river and watershed hydrology, sedimentation and contamination of floodplains and wetlands, and invasion of non-native plant and animal species (MDC 2010a, U.S. Fish and Wildlife Service (USFWS) 2011). Despite these perturbations, the LGR has high potential to restore floodplain connectivity and function. The LGR and uplands immediately adjacent to it have been designated as the Grand River Conservation Opportunity Area, which is one of 32 priority focus areas for ecosystem protection, restoration, and management in Missouri. The LGR also is a priority area for the North American Waterfowl Management Plan Upper Mississippi River and Great Lakes Region Joint Venture (Soulliere et al. 2007) and a site of importance identified by the North American Bird Conservation Initiative (http://www.nabci-us.org/plans.htm).

The LGR contains several public and private lands that retain at least some historic communities and are variously managed for conservation purposes. Larger public land holdings include the U.S. Fish and Wildlife Service (USFWS) Swan Lake National Wildlife Refuge (NWR), Missouri Department of Natural Resources (MDNR) Pershing State Park, and Missouri Department of Conservation (MDC) Fountain Grove and Yellow Creek Conservation Areas (CA) (Fig. 5). About 18,000 acres of private lands in the LGR are enrolled in the U.S. Department of Agriculture (USDA) Wetland Reserve Program (WRP) and another 3,000 acres of privately owned lands maintain at least some native habitats in hunting clubs.

A major challenge for conservation and enhancement of the LGR ecosystem is to protect, restore, enhance, and manage critical parts of the historic LGR ecosystem and its communities given the constraints of altered ecological processes and land use. Further, management of public and private lands (e.g., WRP tracts) must seek to adopt and implement a more coordinated regional landscape ecosystem-based approach that provides and sustains resources within the context of multiple land use objectives.

Recently, hydrogeomorphic methodology has been used to understand historic ecosystems (and specific lands within an area such as a NWR) and subsequently evaluate restoration and management options for landscapes, such as the LGR, across North America (e.g., Klimas et al. 2005, Heitmeyer 2007, Heitmeyer et al 2006, Heitmeyer 2008a, b, Klimas et al. 2009, Pastore et al. 2010, Heitmeyer 2010a, b). The HGM approach (described below) seems especially applicable to the LGR because it: 1) seeks to understand the true ecological context of the region, 2) provides a basis for developing habitat/system-based objectives for conservation actions, 3) identifies options to emulate natural hydrological and vegetation/animal community patterns and dynamics, 4) offers potential to at least partly mitigate and improve alterations to the region, and 5) incorporates "state-of-the-art" scientific knowledge of ecological processes and requirements of key fish and wildlife species in the region along with identifying key uncertainties and future directed study and monitoring needs.

THE HGM APPROACH

The HGM approach used in this study to evaluate ecosystem restoration and management options obtains and analyzes hydrogeomorphic data on: 1) formative processes and basic physical properties including geomorphology, soils, and topography; 2) ecological processes or "drivers" that created and sustained communities especially hydrology, disturbance mechanisms, and community dynamics; and 3) the relative degree and type of alteration to ecosystem structure and process from a less altered state, typically the pre-European settlement (Presettlement) period. Primary objectives for this study were to:

1. Describe the historic condition and ecological processes of the LGR including its geomorphology, soils, topography, hydrology, and flora and fauna.
2. Identify physical, ecological process, and biotic changes to the LGR ecosystem from the historic condition.
3. Identify options and approaches to restore and manage specific communities and ecological conditions.

Specifically, the first objective determines and models the historic LGR landscape context and configuration by developing a matrix of plant communities that historically occurred in specific geomorphic, soil, topographic, and hydrologic settings. The matrix is developed using comprehensive scientific data discovery and field calibration using published literature, data collection at community reference sites, and botanical correlation (see e.g., Heitmeyer 2010a:3-6). For example, wet bottomland prairie

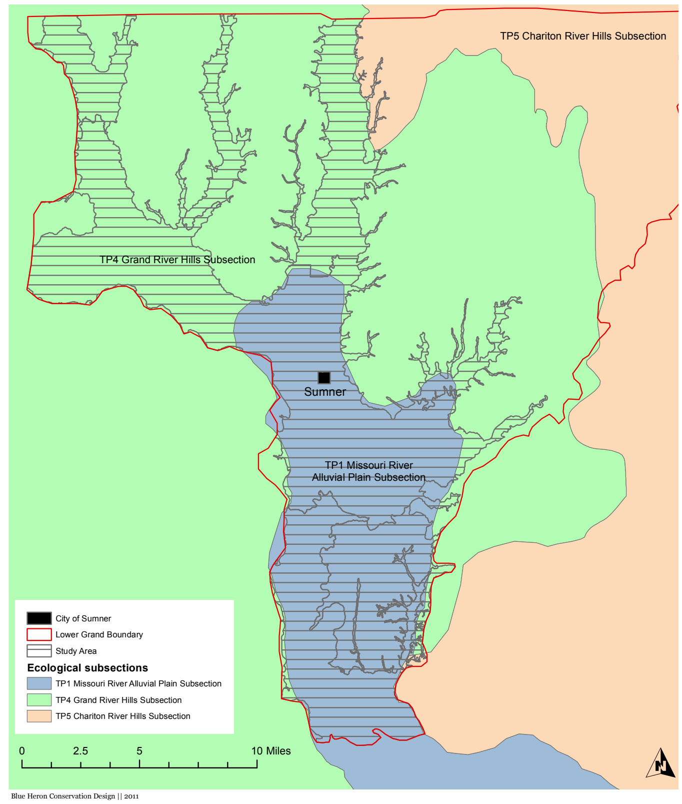

Figure 3. Ecological sections and subsections that contain the LGR (from Nigh and Schroeder 2002).

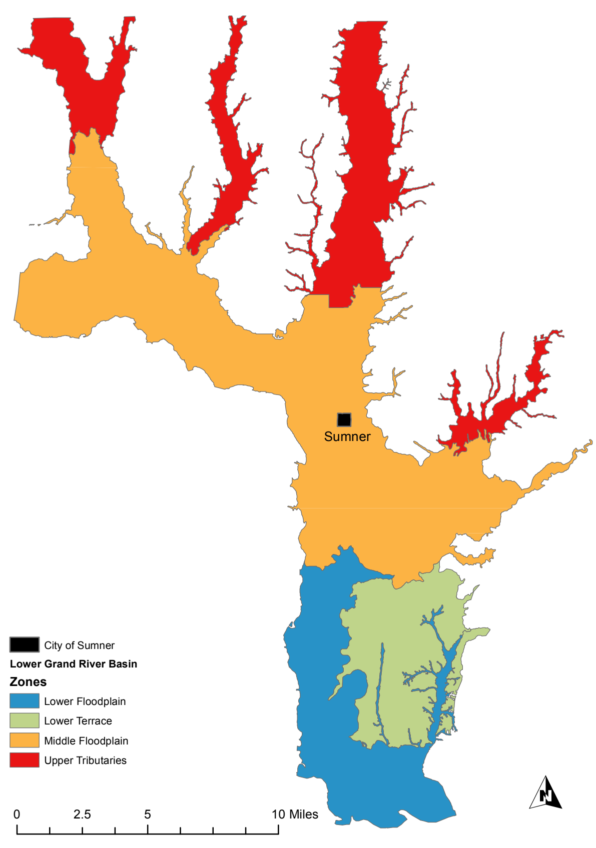

Figure 4. Ecological zones of the LGR.

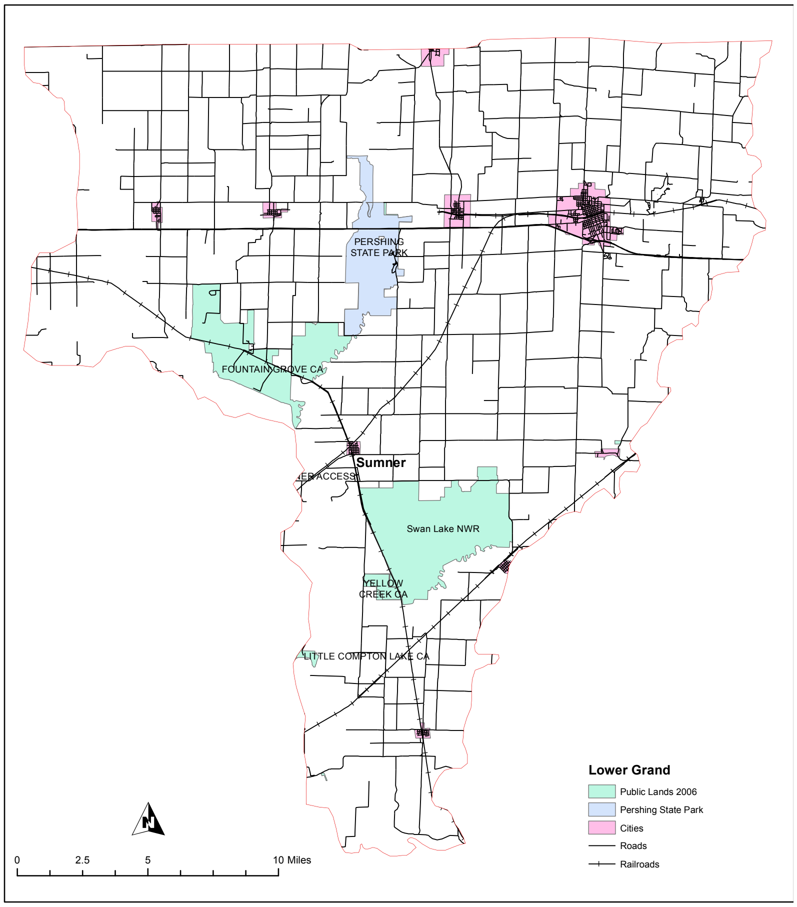

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Figure 5. Location of public conservation lands in the LGR.

in north-central U.S. large river floodplains usually is distributed on relict glacial and alluvial terraces, on silt-clay or silt loam soils, within the 2-5 year flood frequency (a 20-50 percent chance exceedance of flooding in an individual year) topographic zone, and where surface water sheetflow and occasional shallow river backwater flooding occurs (e.g., Turner 1934, Thogmartin et al. 2009, Heitmeyer 2008a, 2010b, Theiling 2010). A primary value of describing a HGM community matrix is that landscapes ranging in geographic scale from site-specific areas to entire watersheds can be mapped in an objective way based on scientific information and analyses. This information can then provide perspective on which communities were present in various locations and juxtaposition and how they have been retained, altered, or destroyed in contemporary landscape settings (e.g., Klimas et al. 2009).

The second part of the HGM evaluation approach documents alterations to the LGR hydrological condition, topography, vegetation community structure and composition, and resource availability to key fish and wildlife species by comparing historic and current landscapes. This comparison provides an assessment of current condition and the types and magnitudes of changes, including documenting which communities have been most destroyed and degraded and evaluating the resilience of various communities to ecosystem changes.

The third part of the HGM approach identifies options to restore and manage specific areas, community types, and specific sites within the landscape-scale context. The foundation of ecological history coupled with assessment of current conditions helps determine which processes (e.g., overbank flooding) and habitats (e.g., floodplain forest) can be restored or enhanced, and where this is possible, if it is at all. Clearly, some landscape changes are more permanent and less reversible (e.g., channelization of portions of the Grand River) than others (e.g., conversion of terrace prairie to cropland). Through development of the HGM matrix, owners and managers of land holdings (including Swan Lake NWR, Pershing State Park, and Fountain Grove and Yellow Creek CAs) can identify: 1) which, and where, specific habitat types have been lost or altered the most and establish some sense of priority for restoration efforts; 2) where opportunities exist to restore habitats in appropriate geomorphic, soil, hydrologic, and topographic settings including both public and private lands; 3) how restoration can replace lost functions and values including ecosystem connectivity and provision of key resources to meet life cycle requirements of endemic species; and 4) what management methods, infrastructure, and intensity will be needed to sustain restored communities. Recently, a Comprehensive Conservation Plan (CCP) was prepared to guide future restoration and management actions on Swan Lake NWR and step-down habitat management plans will be developed to implement CCP direction – which requires information on all of the above (USFWS 2011). Pershing State Park also is in the process of strategically planning future management programs (www.mostateparks.com/pershingpark/cdp.gif) and Fountain Grove CA is actively changing water management infrastructure and goals for future habitat restoration and management as part of the MDC Golden Anniversary Wetlands Initiative (Gardner 2006).

THE HISTORIC LGR ECOSYSTEM CONDITON

GEOMORPHOLOGY, SOILS, AND TOPOGRAPHY

The LGR is comprised of the drainage channels and alluvial floodplains of the Grand River and its tributaries upstream from its confluence with the Missouri River and remnant glacial terraces subset with these floodplains. The Grand River and its tributaries in the LGR essentially dissect five distinct tracts of glacial-derived upland terraces in the Grand River Hills subsection (Fig. 6). The upland terraces are blanketed with Pleistocene loess that overlies glacial till deposited by Pre-Illinoisan ice sheets that existed over 400,000 years before the present (BP) (Unklesbay and Vineyard 1992, Nigh and Schroeder 2002). The LGR is underlain by alternating (cyclical) beds of shale, thin limestone, coal, and small amounts of sandstone of Pennsylvanian age that dip gently northwest. Bedrock is > 30 feet below the surface and alluvial fill contains Pleistocene gravels, sands, and silts transported from glaciated regions to the north, overlaid by recent alluvium. Subsequent loess deposition, fluvial dynamics of the Missouri and Grand Rivers and their tributaries, and weathering and erosion of regional surface materials ultimately shaped the LGR to its current surficial geomorphic form.

The Grand River historically meandered in relatively tight bends and historic channel movements created numerous abandoned channel "oxbows" and "sloughs" throughout the floodplains of the Grand River and its major tributaries including Medicine, Parsons, Locust, and Yellow creeks (Fig. 7). The Lower Grand River Floodplain zone of the LGR contains unusually wide portions of alluvium containing wetlands and former channels of the Missouri and Grand Rivers. Surficial materials in the Lower Floodplain are sandy and silty and were formerly reworked by the meandering

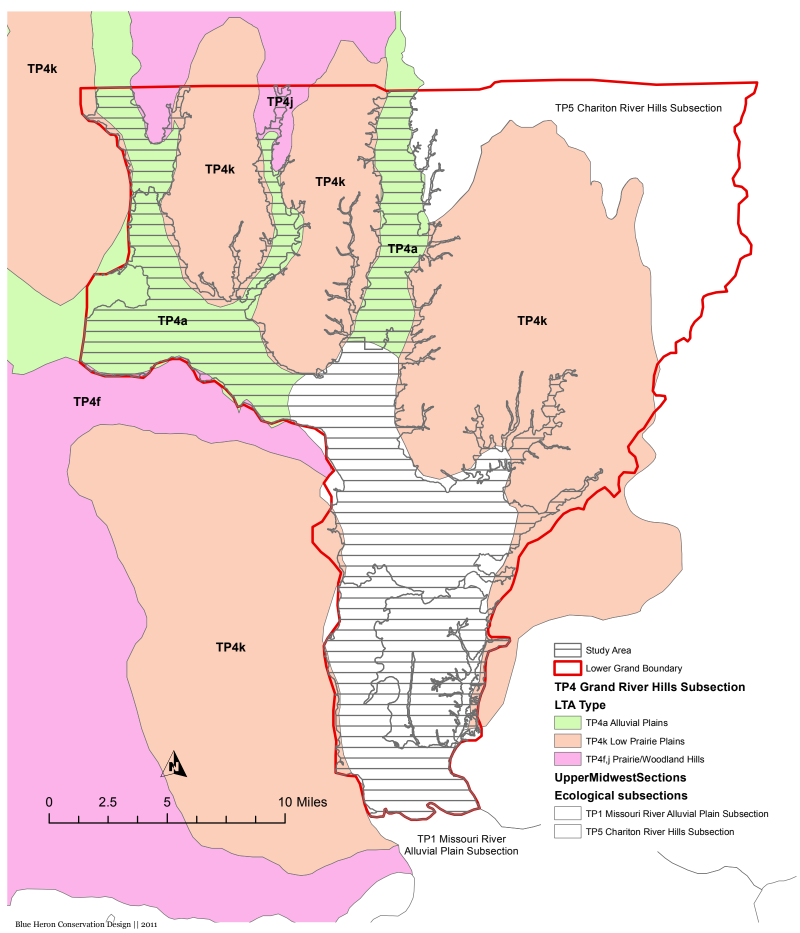

Figure 6. Location of the LGR in relation to dissected upland prairie terraces in the Grand River Hills ecological subsection (modified from Nigh and Schroeder 2002).

Figure 7. Aerial photograph of the southern Locust Creek floodplain in 1963 showing numerous abandoned channels.

Missouri River about once every 150 years or so (Nigh and Schroeder 2002).

Soils in the LGR are mostly alluvium derived from a mixture of loess and glacial till eroded from upland terraces adjacent to floodplains (Fig. 8). Soil texture and drainage in the LGR vary in relation to position within the alluvial plain or adjacent terraces. Typically, soils nearest the stream/river channels have coarser texture and are moderately to well drained such as the silty Nodaway, Tice, Dockery, and Wabash soil series (Fig. 8). Soils in floodplain depressions and backswamp sites contain mostly clay surfaces and are poorly drained, such as the Zook and Carlow series. Broad transition areas are transitional in texture and drainage, such as the Colo series. Floodplain soils in the LGR are neutral to strongly acidic, with no free carbonate rocks.

Loess silt loam soils cover most of the broad gently sloping Grand River Hills. Loess has a very low sand content and most soils in this area have silt loam surfaces with silty clay loam or silty clay subsoil. Most soils adjacent to, and on higher elevations in the LGR were formed under prairie vegetation and have thick, dark layers. These soils are dominated by Booker, Kennebec, and Dockery silt clay and silt loam types. Soils that formed under savanna or prairie-forest transition areas have thinner surface layers, particularly on lower slopes. Most prairie-type soils have seasonally perched water tables within the clayey subsoil, which dry in summer.

The topography, soils, and hydrology of the LRG reflects the historic glacial-derived geomorphology of the region and subsequent reworking of landscapes by fluvial dynamics. The Upper Tributary Floodplain zone of the LGR has sloping topography that reflects the higher drainage gradients of Medicine, Parson's, Locust, and Yellow creeks (Fig. 9a). The top (northern) end of these drainages are near 237 m above mean sea level (amsl) and fall to about 201 m amsl at their confluences with the Grand River floodplain. The upstream reaches of these tributaries have relatively narrow, more incised, channels and floodplains while southern portions have wider floodplains that contain numerous relict and recent naturally meandering channels. These southern tributary floodplains have considerable local topographic heterogeneity that reflects numerous abandoned channels (oxbows), natural levees, and alluvial deposition surfaces.

The Middle Grand River Floodplain zone is within the Holocene floodplain of the Grand River and contains 2-3 relict Pleistocene glacial terraces that are embedded in the floodplain (Fig. 9b). The floodplain areas range from about 194 to 200 m amsl and contain numerous topographic depressions associated with relict Grand River meander channels, natural levees, point bar meander scrolls, and alluvial deposits. Natural levees are especially pronounced along the current Grand River channel. The relict Pleistocene terraces are present on the northwest and southwest sides of Swan Lake and on the northern edge of the current Silver Lake area and are surrounded by floodplain surfaces, thus taking on an "island" landscape configuration. These terraces slope from a top elevation of about 213 m amsl down to about 203 m amsl.

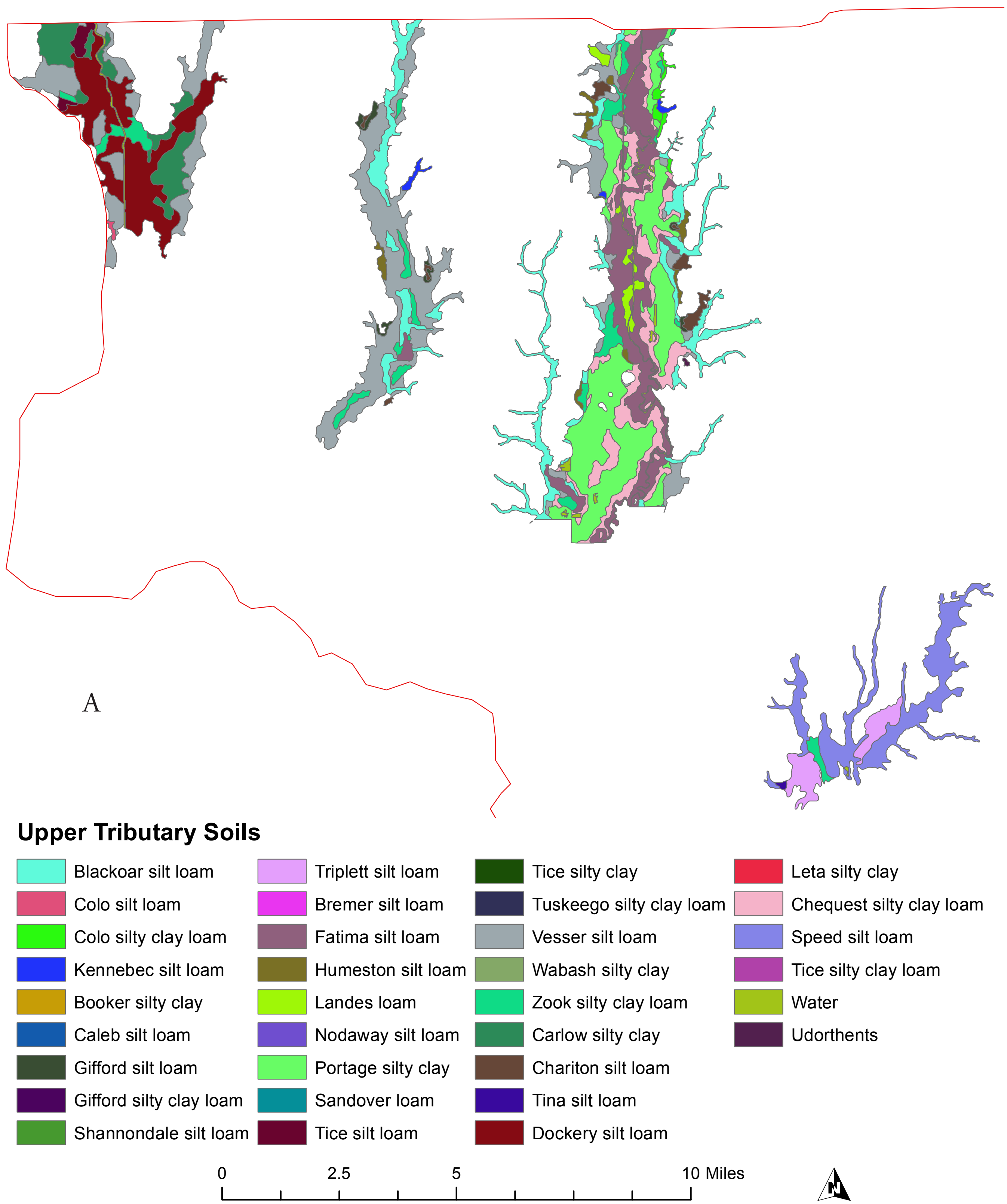

Figure 8. Soils in the: a) Upper Tributary, b) Middle Floodplain, and c) Lower Floodplain and Terrace zones of the LGR (USDA SSURGO).

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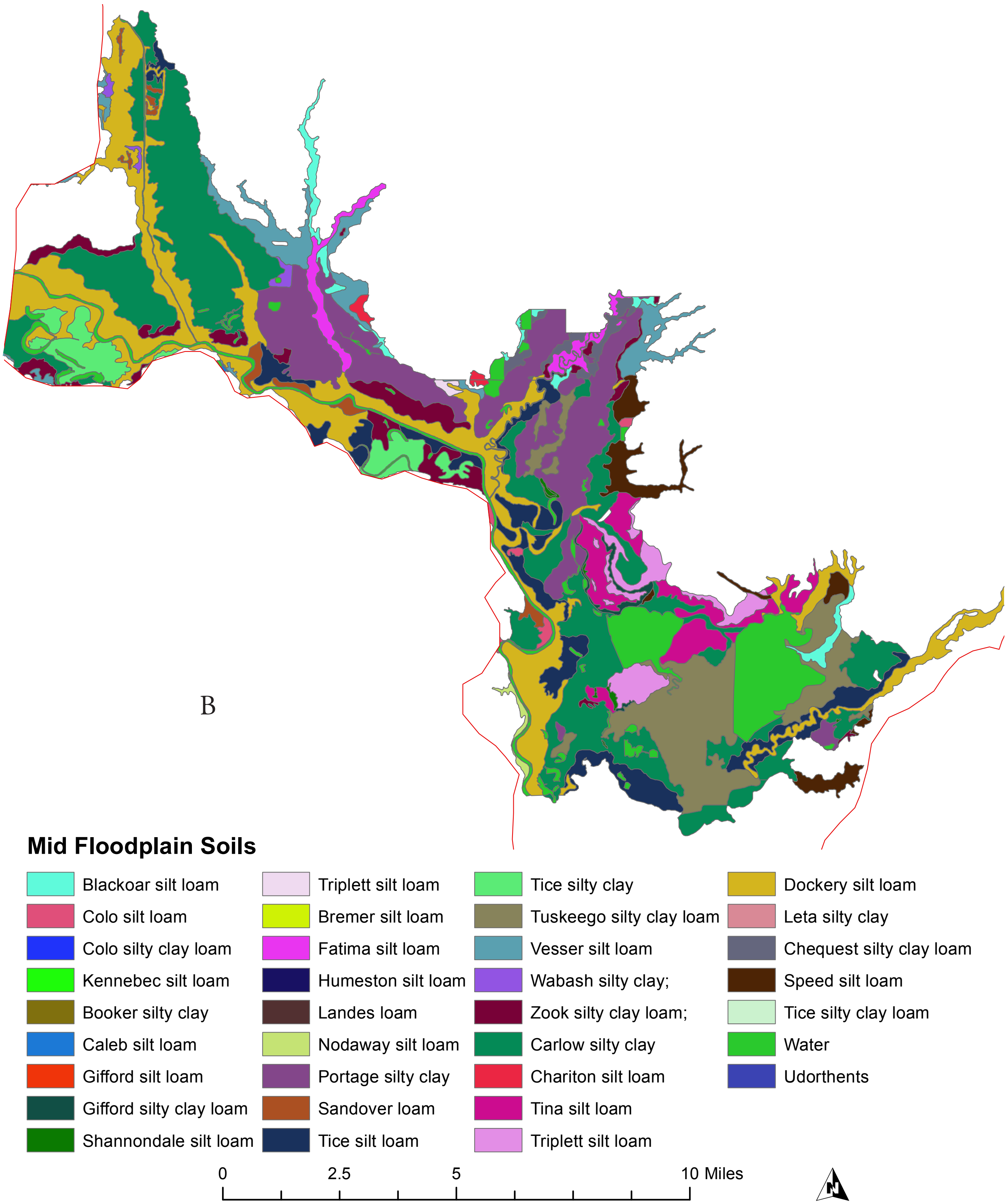

Figure 8, cont'd. Soils in the: a) Upper Tributary, b) Middle Floodplain, and c) Lower Floodplain and Terrace zones of the LGR (USDA SSURGO).

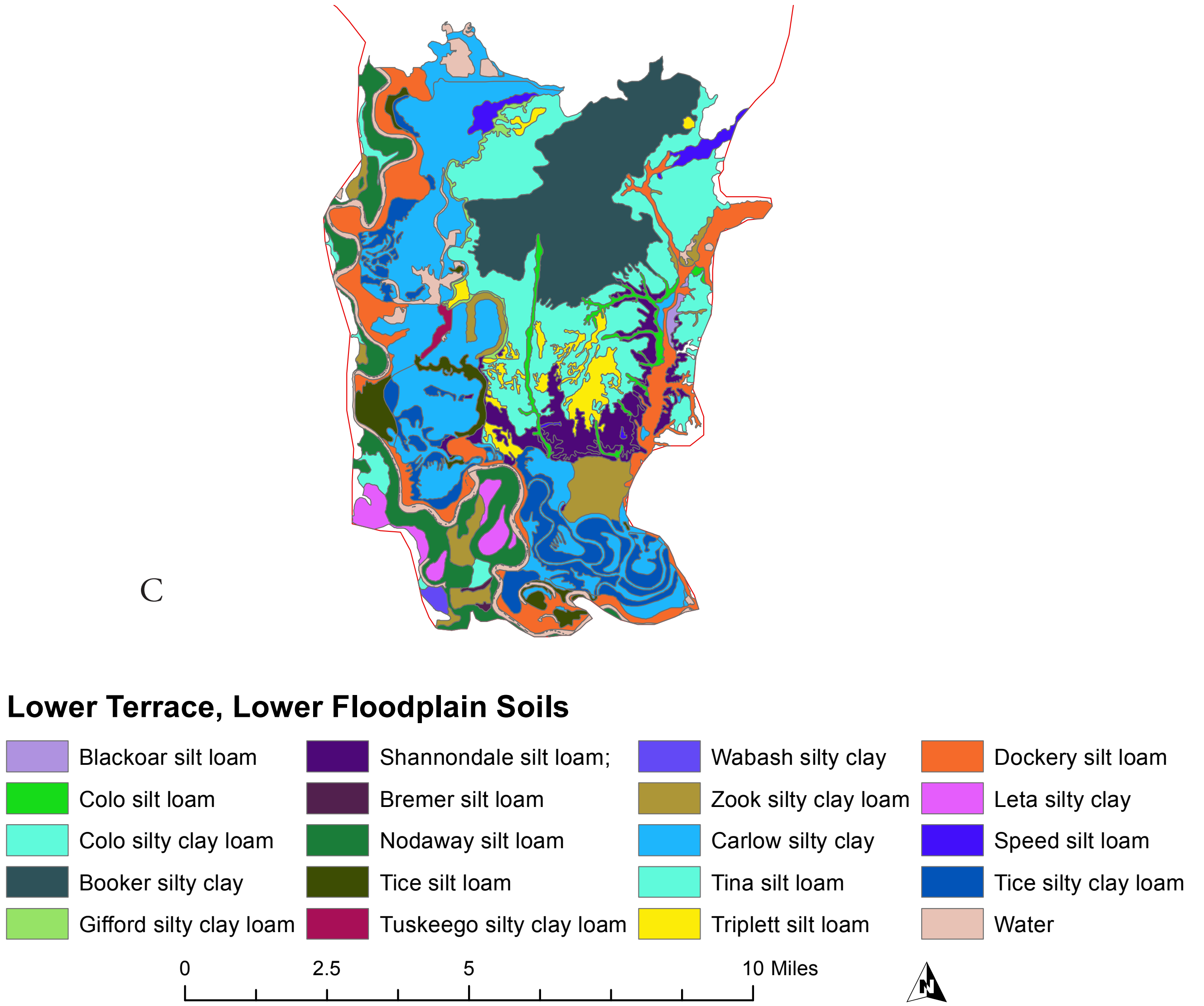

Figure 8, cont'd. Soils in the: a) Upper Tributary, b) Middle Floodplain, and c) Lower Floodplain and Terrace zones of the LGR (USDA SSURGO).

The Lower Grand River Floodplain zone represents the historic pathways of the Grand and Missouri rivers and contains elevations ranging from ca. 188 to 196 m amsl (Fig. 9c). This floodplain is bounded on the east by a large Pleistocene Lower Basin Terrace zone that rises to about 205 m amsl (Fig. 9c). The relict terrace is dissected by the local Salt and Brush Creek drainages. The Lower Floodplain zone historically contained the large Dean Lake Basin and topography and soils in the far south part of this floodplain have been greatly influenced by high water backwater events of the Missouri River. Natural levees are pronounced along the upper Grand River channel in this floodplain setting.

CLIMATE AND HYDROLOGY

The LGR is characterized by hot humid summers and relatively mild winters. Spring weather can be turbulent and thunderstorms and occasional tornados are fairly common. Average monthly temperatures at Brookfield, MO range from 23° Fahrenheit in January to about 76° Fahrenheit in July (Table 1). Average annual precipitation at Brookfield is 38.9 inches, with the heaviest amounts occurring from May through September, although rainfall of > 6 inches has occurred (during the period of record dating to 1910) in all months except December, January, and February (Table 2). Most (> 90%) precipitation in the region is from rainfall but snow fall in some years can

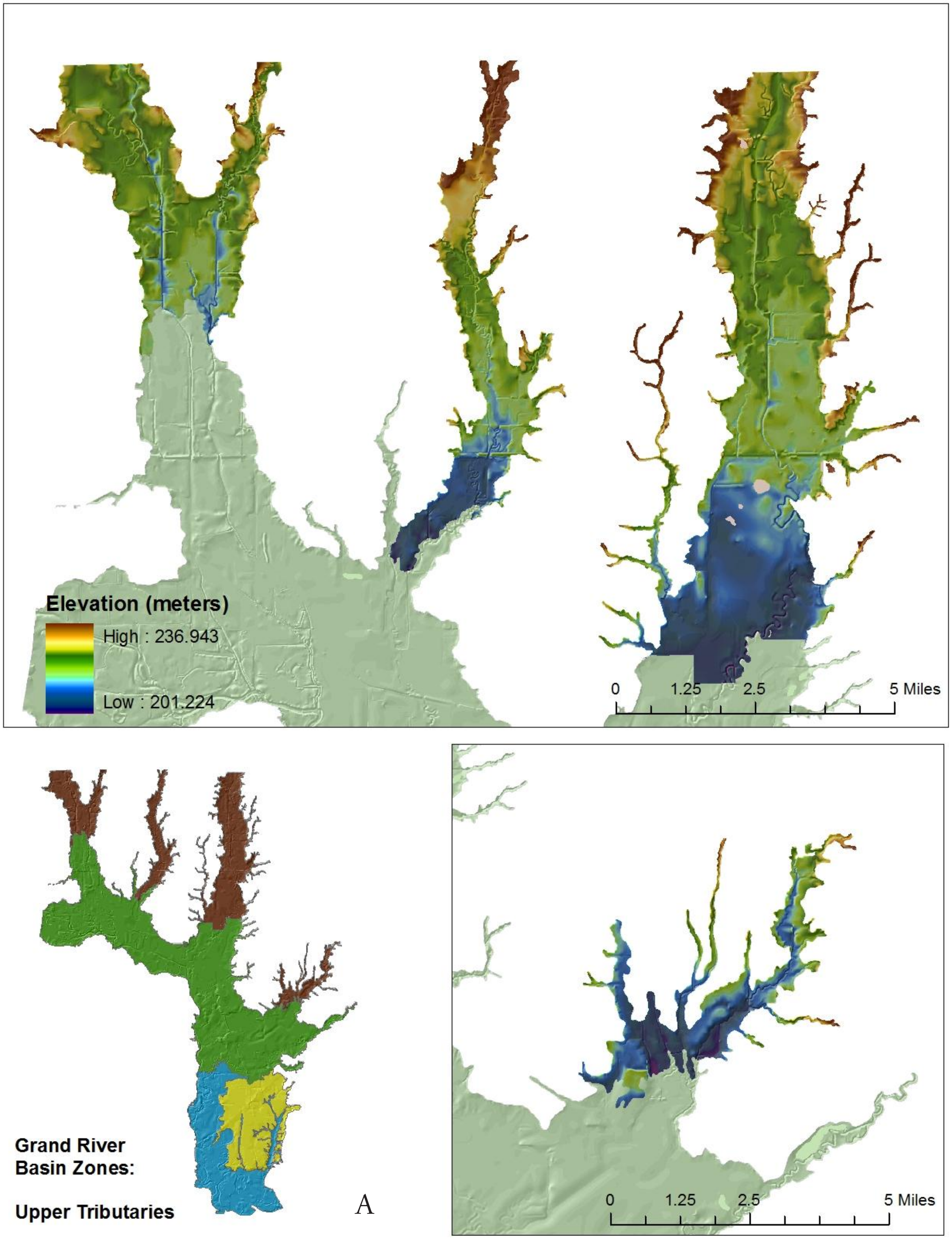

Figure 9. Elevations in the: a) Upper Tributary, b) Middle Grand River Floodplain, and c) Lower Grand River Floodplain and Lower Basin Terrace zones of the LGR.

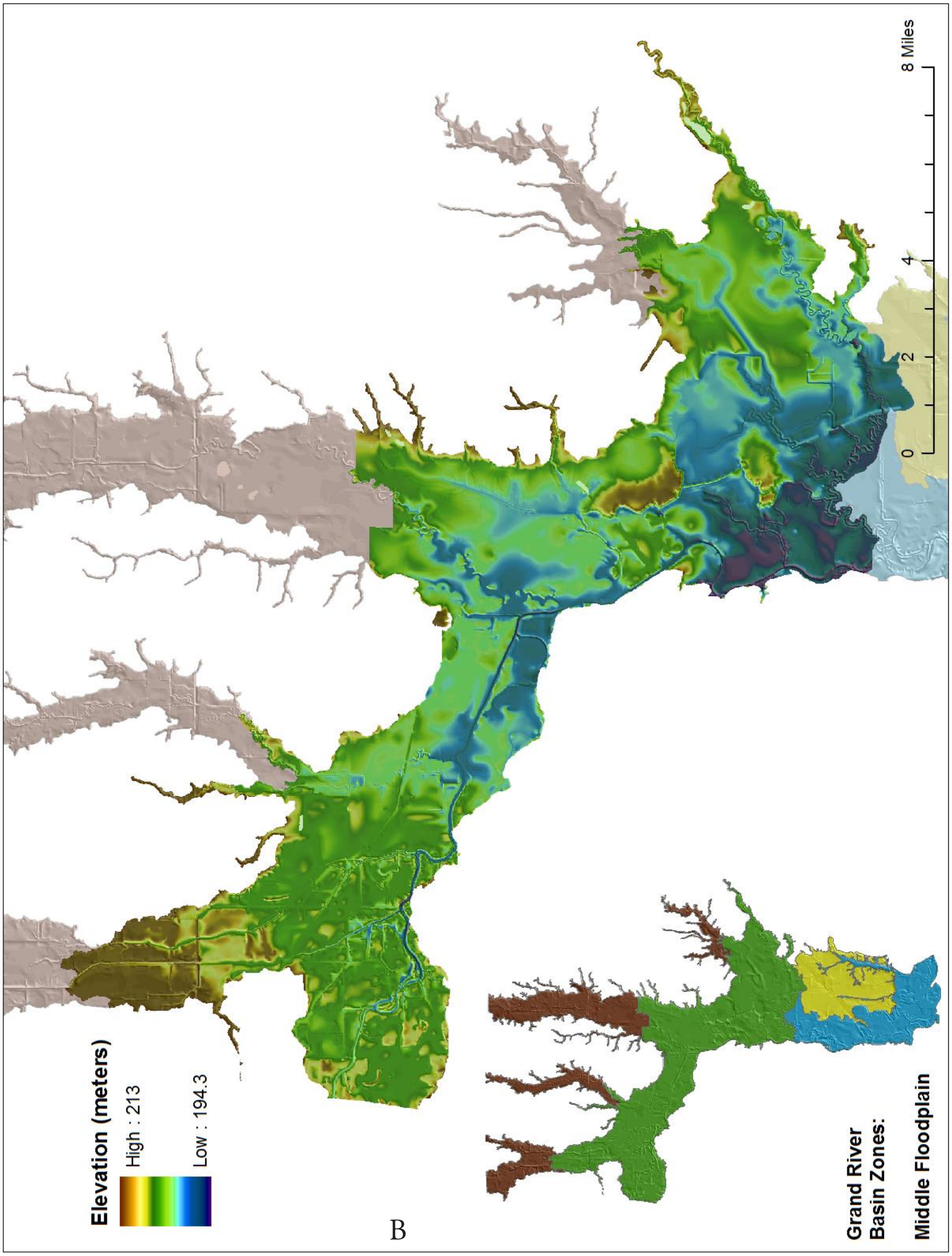

Figure 9, cont'd. Elevations in the: a) Upper Tributary, b) Middle Grand River Floodplain, and c) Lower Grand River Floodplain and Lower Basin Terrace zones of the LGR.

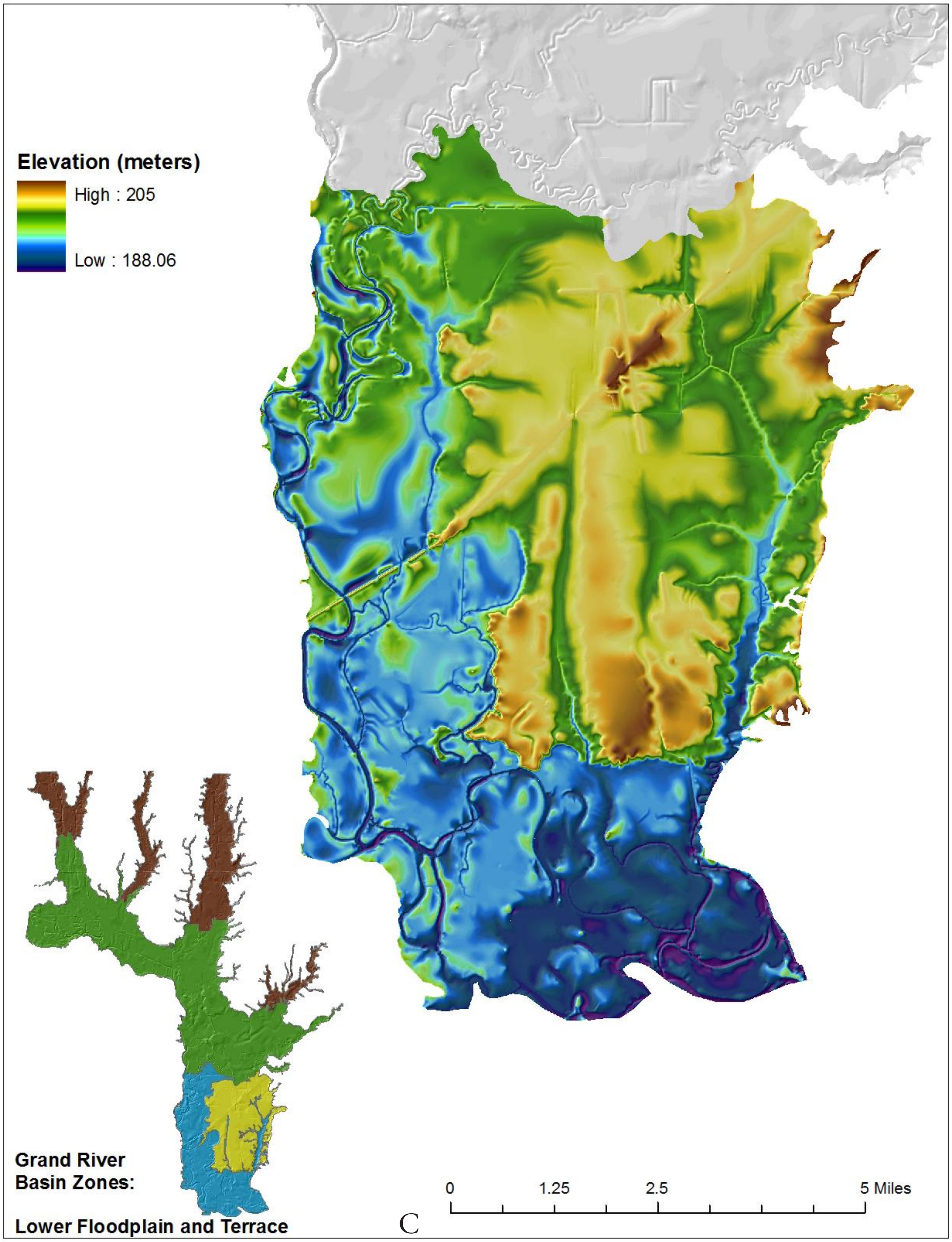

Figure 9, cont'd. Elevations in the: a) Upper Tributary, b) Middle Grand River Floodplain, and c) Lower Grand River Floodplain and Lower Basin Terrace zones of the LGR.

Table 1. Mean monthly temperature data for Brookfield, Missouri, 1971-2000 (from www.ncdc.noaa.gov).

Temperature (˚F)																					
Mean (1)				Extremes										Degree Days (1) Base Temp 65		Mean Number of Days (3)					
Month	Daily Max	Daily Min	Mean	Highest Daily(2)	Year	Day	Highest Month(1) Mean	Year	Lowest Daily(2)	Year	Day	Lowest Month(1) Mean	Year	Heating	Cooling	Max >= 100	Max >= 90	Max >= 50	Max <= 32	Min <= 32	Min <= 0
Jan	32.5	13.9	23.2	74+	1957	21	35.7	1990	-21	1982	10	9.3	1979	1296	0	.0	.0	4.0	12.3	28.1	4.3
Feb	39.9	19.1	29.5	79	1972	29	39.1	1998	-18	1979	9	15.7	1978	994	0	.0	.0	8.5	7.3	22.5	2.2
Mar	52.3	29.6	41.0	86	1986	29	46.4	1991	-15	1960	5	32.3	1984	746	0	.0	.0	18.9	1.4	15.6	.2
Apr	63.0	39.6	51.3	92+	1952	30	58.7	1981	13	1975	3	43.9	1983	417	5	.0	.2	27.1	.0	4.4	.0
May	72.9	51.2	62.1	98	1956	21	68.1	1987	29+	1976	3	56.6	1994	167	76	.0	.2	30.9	.0	.1	.0
Jun	81.8	60.6	71.2	106+	1954	25	75.2	1988	41	1988	10	66.8	1982	13	199	.3	5.5	30.0	.0	.0	.0
Jul	86.8	65.5	76.2	116	1954	14	83.2	1980	46	1971	31	71.3	1971	0	344	1.0	13.3	31.0	.0	.0	.0
Aug	85.2	63.5	74.4	108+	1984	29	81.3	1983	43+	1986	28	69.4	1992	10	299	.6	11.0	31.0	.0	.0	.0
Sep	77.2	54.3	65.8	103	1953	1	72.0	1998	30	1984	30	58.9	1974	82	103	.0	3.4	30.0	.0	.2	.0
Oct	66.6	43.0	54.8	95	1963	10	59.6	1971	16	1993	31	48.2	1976	321	6	.0	.2	29.7	@	3.2	.0
Nov	50.0	30.1	40.1	82	1950	1	49.6	1999	-7	1964	30	32.0	1976	748	0	.0	.0	16.7	1.6	14.8	.1
Dec	37.4	19.5	28.5	72	1949	12	34.8	1994	-24	1989	23	13.4	1983	1134	0	.0	.0	5.6	8.0	26.0	2.2
Ann	62.1	40.8	51.5	116	Jul 1954	14	83.2	Jul 1980	-24	Dec 1989	23	9.3	Jan 1979	5928	1032	1.9	33.8	263.4	30.6	114.9	9.0

be up to 4 feet total (Table 2). The frost-free growing season for the area averages about 210 days from mid April through mid October (Table 3).

Tributary streams to the Grand River in the LGR have rapid increases in flow in conjunction with regional rains, and quickly return to lower flow conditions when runoff stops (MDNR 1984). Most surface water drainage in tributary streams occurs in June, coincident with the greatest period of rain (average of 5.77 inches in June at Sumner). Perennial streams in the LGR, such as Locust and Medicine Creeks, are classified as "Perennial Runoff Flashy Streams" using the Hydroecological Integrity Assessment Process (HIAP) (Kennan et al. 2009). One index used in the HIAP is the base flow index (BFI), which is the ratio of base flow volume to total flow volume. The BFI values calculated for Locust and Medicine Creeks are about 0.15, which means that by volume, about 85% of the total flow in these streams occurs during runoff events. Other LGR streams such as Parson's Creek likely have similar flow dynamics.

In contrast to local streams/tributaries, discharge in the Grand River reflects precipitation and runoff events throughout the ca. 7,900 square mile watershed (MDNR 1986, MDC 2010a). The Grand River near Sumner also is classified as a "Perennial Runoff Flashy Stream" (Kennan et al. 2009). Its BFI is about 0.25, which reflects a greater base flow than LGR tributaries, but still about 75% of the total streamflow occurs during runoff events. Average discharge for the Grand River near Sumner is 3,917 cubic-feet/second (cfs) and has ranged from 367.5 cfs in 1934 to 17,390 cfs in 1993 (Table 4). Mean monthly discharge of the Grand River at Sumner is highest from March through June followed by a gradual decline to low flow conditions in December and January (Table 5). The lowest mean monthly flow recorded during the period of record (1924 to the present) was 32.1 cfs in January 1940 while the highest mean monthly flow occurred in July 1993 (87,900 cfs). The maximum instantaneous peak flow (180,000 cfs) occurred in June 1947. The river stayed above flood stage (ca. 21,500 cfs) for 5 consecutive weeks from 29 May through 3 July 1947, during which the runoff from the region was equivalent to 12 inches from the 6,880 square mile drainage area above Sumner. Peak discharge during the extreme flood year of 1993 was about 150,000 cfs at Sumner when discharge exceeded flood stage for nearly 3 months. Flows > 100,000 cfs have occurred in 10 years since 1924 and the average time between these high peak flows is about 10 years Fig. 10). Average annual discharge for streams in the Grand River Basin are estimated at $Q = 0.73A^{0.97}$, where average annual streamflow (Q) is in cfs, and drainage area (A) is in square miles (MDC 2010a). The Grand River makes up about 1.5% of the Missouri River watershed, but contributes 7% of the average annual discharge of the Missouri River (USACE 1989).

Table 2. Mean monthly and annual precipitation for Brookfield, Missouri, 1971-2000 (from www.ncdc.noaa.gov).

Precipitation (inches)																								
	Precipitation Totals									Mean Number of Days (3)				Precipitation Probabilities (1) Probability that the monthly/annual precipitation will be equal to or less than the indicated amount										
	Means/ Medians(1)		Extremes							Daily Precipitation				Monthly/Annual Precipitation vs Probability Levels These values were determined from the incomplete gamma distribution										
Month	Mean	Med-ian	Highest Daily(2)	Year	Day	Highest Monthly(1)	Year	Lowest Monthly(1)	Year	>= 0.01	>= 0.10	>= 0.50	>= 1.00	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
Jan	1.50	1.58	2.82	1965	2	3.71	1973	.00	1986	7.1	3.7	.8	.3	.10	.25	.48	.70	.93	1.19	1.48	1.85	2.34	3.15	3.93
Feb	1.48	1.39	2.43	1997	21	4.47	1997	.27	1996	6.7	3.8	.7	.2	.34	.48	.70	.89	1.09	1.29	1.52	1.80	2.16	2.74	3.28
Mar	2.74	2.71	2.02	1985	4	7.16	1973	.58	1994	9.2	6.4	1.9	.5	.83	1.09	1.48	1.81	2.14	2.48	2.85	3.29	3.85	4.74	5.56
Apr	3.61	3.39	4.14	1973	21	8.81	1973	.58	1980	10.4	7.2	2.1	.8	.76	1.09	1.62	2.10	2.59	3.10	3.69	4.39	5.31	6.79	8.19
May	4.78	4.26	3.69	1973	27	11.86	1995	1.19	1980	11.5	8.1	3.1	1.3	1.39	1.85	2.53	3.12	3.70	4.30	4.97	5.75	6.76	8.34	9.82
Jun	4.11	3.59	4.62	1981	25	11.54	1981	.30	1988	10.1	6.8	2.8	1.2	.80	1.17	1.78	2.33	2.89	3.49	4.18	5.00	6.09	7.84	9.50
Jul	4.74	3.52	7.57	1958	15	15.31	1981	.54	1975	8.9	6.2	3.4	1.6	.77	1.17	1.86	2.51	3.19	3.92	4.76	5.78	7.15	9.37	11.49
Aug	4.08	3.48	5.81	1978	2	8.77	1978	.76	1973	8.7	5.7	2.8	1.3	.91	1.29	1.89	2.43	2.97	3.54	4.18	4.95	5.97	7.58	9.10
Sep	4.38	3.52	4.48	1965	16	11.47	1973	.87	1979	8.5	6.3	2.7	1.2	1.20	1.61	2.24	2.79	3.34	3.90	4.53	5.28	6.24	7.76	9.18
Oct	3.34	3.09	5.90	1957	23	8.45	1998	.53	1988	8.0	5.2	2.3	.9	.63	.93	1.42	1.87	2.33	2.83	3.39	4.06	4.96	6.40	7.77
Nov	2.96	2.87	3.27	1984	1	7.92	1992	.14	1989	8.2	5.4	2.2	.7	.48	.73	1.16	1.57	1.99	2.45	2.98	3.62	4.47	5.86	7.19
Dec	2.01	1.80	3.23	1982	2	6.93	1982	.04	1996	7.4	4.4	1.3	.4	.26	.42	.71	.99	1.28	1.61	1.99	2.45	3.08	4.11	5.11
Ann	39.73	38.88	7.57	Jul 1958	15	15.31	Jul 1981	.00	Jan 1986	104.7	69.2	26.1	10.4	26.72	29.18	32.37	34.80	36.98	39.10	41.30	43.74	46.71	51.05	54.83

Snow (inches)																							
Snow Totals															Mean Number of Days (1)								
Means/Medians (1)					Extremes (2)										Snow Fall >= Thresholds					Snow Depth >= Thresholds			
Month	Snow Fall Mean	Snow Fall Median	Snow Depth Mean	Snow Depth Median	Highest Daily Snow Fall	Year	Day	Highest Monthly Snow Fall	Year	Highest Daily Snow Depth	Year	Day	Highest Monthly Mean Snow Depth	Year	0.1	1.0	3.0	5.0	10.0	1	3	5	10
Jan	5.9	6.0	2	1	7.8	1982	4	18.5	1997	18	1977	12	11	1977	2.6	1.6	.8	.2	.0	8.1	4.9	2.4	.1
Feb	3.7	1.2	2	1	12.0	1978	13	26.0	1978	25	1978	22	15	1978	2.0	1.0	.3	.1	.1	1.9	.4	.0	.0
Mar	2.1	.3	#	#	7.1	1990	24	12.0	1978	11	1994	1	3	1980	1.0	.6	.2	.1	.0	1.3	.7	.3	.0
Apr	.3	.0	#	0	2.0	1980	15	3.0	1997	2+	1997	11	#+	1997	.2	.1	.0	.0	.0	.2	.0	.0	.0
May	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Jun	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Jul	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Aug	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Sep	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Oct	.1	.0	#	0	2.0	1997	27	2.0	1997	2	1997	27	#+	1997	@	@	.0	.0	.0	@	.0	.0	.0
Nov	1.5	.6	#	#	5.0	1991	7	8.0	1991	8	1974	30	1	1991	1.0	.4	.2	@	.0	.9	.4	.1	.0
Dec	3.5	1.5	1	#	5.0	1978	31	14.4	2000	14	1987	15	3+	2000	2.0	1.3	.3	@	.0	3.6	1.5	.4	.0
Ann	17.1	9.6	N/A	N/A	12.0	Feb 1978	13	26.0	Feb 1978	25	Feb 1978	22	15	Feb 1978	8.8	5.0	1.8	.4	.1	16.0	7.9	3.2	.1

The LGR has a history of regular annual flooding from overbank flows of the Grand River (USACE 1963). We computed the recurrence interval for frequent (< 10 year) flood events using a peak over threshold analysis. The threshold used in this analysis was 20,000 cfs. Two adjacent peaks were considered independent if there was a minimum of 4 days between events and discharge dropped below 50% of the smaller of two adjacent peaks. Average daily flows for Water Years 1925 to 2009 were used because the needed threshold was less than previously retained peak data. The calculated discharges for recurrence intervals ranging from 0.25 to 10 years recurrence intervals were converted to water surface elevation using the stage-discharge curve relationship (Fig. 11) of 15 March 2010 and the gauge datum (Fig. 12). Essentially, all elevations in the LGR near Sumner that are less than 202.8 m elevation flood annually, with discharges up to about 46,000 cfs, mostly in spring. The 202.8 m elevation contour

Table 3. Probability of freezing temperatures and the freeze-free period for Brookfield, Missouri, 1971-2000 (from ncdc.noaa.gov).

Freeze Data									
Spring Freeze Dates (Month/Day)									
Temp (F)	Probability of later date in spring (thru Jul 31) than indicated(*)								
	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	5/12	5/08	5/04	5/02	4/29	4/26	4/24	4/20	4/16
32	4/29	4/24	4/21	4/18	4/15	4/13	4/10	4/07	4/02
28	4/16	4/12	4/09	4/07	4/05	4/03	3/31	3/29	3/25
24	4/09	4/05	4/02	3/30	3/28	3/25	3/22	3/19	3/15
20	4/01	3/26	3/22	3/18	3/15	3/12	3/08	3/04	2/26
16	3/26	3/18	3/12	3/06	3/02	2/25	2/19	2/13	2/05
Fall Freeze Dates (Month/Day)									
Temp (F)	Probability of earlier date in fall (beginning Aug 1) than indicated(*)								
	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	9/22	9/27	10/01	10/03	10/06	10/09	10/12	10/15	10/20
32	9/28	10/04	10/08	10/11	10/14	10/18	10/21	10/25	10/31
28	10/14	10/19	10/22	10/25	10/28	10/30	11/02	11/05	11/10
24	10/28	11/02	11/06	11/09	11/12	11/14	11/18	11/21	11/26
20	11/01	11/07	11/12	11/16	11/20	11/23	11/27	12/02	12/08
16	11/08	11/15	11/20	11/24	11/28	12/02	12/06	12/11	12/18
Freeze Free Period									
Temp (F)	Probability of longer than indicated freeze free period (Days)								
	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	177	171	167	163	160	156	152	148	142
32	201	195	190	185	181	177	173	168	161
28	222	216	212	208	205	202	198	194	188
24	249	242	237	232	228	224	220	215	208
20	272	264	258	253	249	244	239	234	226
16	305	293	285	277	271	264	256	248	236

* Probability of observing a temperature as cold, or colder, later in the spring or earlier in the fall than the indicated date.

for the region immediately around Sumner (Fig. 9) incorporates almost all of the Middle Floodplain zone with only the highest elevation natural levees and terraces (down to their margins with the floodplain) being unflooded (Fig. 13). Flood stage at Sumner, when overbank flooding begins, is 26 feet at the Sumner gauge, which equates to an elevation of 657 feet and 200.2 m amsl and a discharge of 21,500 cfs. Even at this minimal flood event stage over 50% of the Middle Floodplain zone would flood annually on average. The 2- and 5-year recurrence intervals are only slightly higher at 203.4 and 203.7 m amsl. The 10-year recurrence interval is about 204.5 m amsl. At this 10-year event stage, only the relict terraces in the LGR are not flooded.

The frequency of large floods in the LGR prior to 1924 when the Sumner gauge was installed on the Grand River is unknown, but early reports indicate severe flooding about every 20 years in 1844, 1866, 1883, 1903, 1909, and 1915 (USACE 1932). These floods all occurred prior to establishment of regional levee and drainage

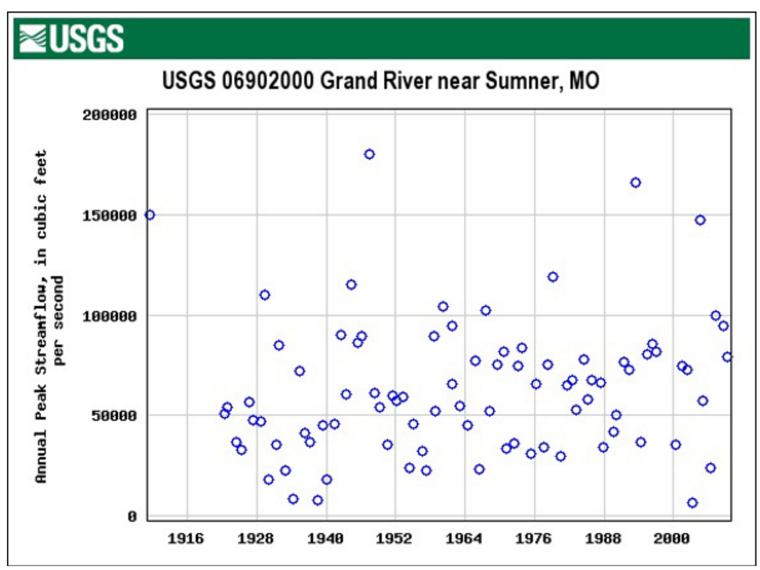

Figure 10. Annual peak streamflow for the Grand River at Sumner, MO 1925 to 2009 (nwis.waterdata.usgs.gov).

Table 4. Average annual discharge of the Grand River at Sumner, Missouri, 1925-2009 (from nwis.waterdata.usgs.gov).

Water Year	00060 Discharge cubic feet per second	Water Year	00060 Discharge cubic feet per second
1925	2420.0	1968	2247.0
1926	5785.0	1969	5403.0
1927	5227.0	1970	3858.0
1928	4090.0	1971	2825.0
1929	9945.0	1972	2125.0
1930	2086.0	1973	10020.0
1931	1686.0	1974	6118.0
1932	7055.0	1975	2713.0
1933	1539.0	1976	2475.0
1934	367.5	1977	1312.0
1935	6538.0	1978	8038.0
1936	1459.0	1979	5066.0
1937	2971.0	1980	1614.0
1938	477.6	1981	3243.0
1939	1932.0	1982	7275.0
1940	1109.0	1983	5455.0
1941	1555.0	1984	5863.0
1942	6104.0	1985	2442.0
1943	4529.0	1986	6726.0
1944	4298.0	1987	6382.0
1945	6786.0	1988	1556.0
1946	3836.0	1989	736.6
1947	9013.0	1990	4358.0
1948	2398.0	1991	4488.0
1949	3034.0	1992	5291.0
1950	2595.0	1993	17390.0
1951	5290.0	1994	2429.0
1952	3587.0	1995	6821.0
1953	1997.0	1996	4946.0
1954	760.1	1997	4382.0
1955	1868.0	1998	6072.0
1956	774.4	1999	6679.0
1957	741.1	2000	652.9
1958	4397.0	2001	6352.0
1959	5516.0	2002	2082.0
1960	7092.0	2003	462.9
1961	5598.0	2004	7148.0
1962	7659.0	2005	2676.0
1963	2154.0	2006	813.6
1964	2122.0	2007	4254.0
1965	5080.0	2008	10490.0
1966	1546.0	2009	8672.0
1967	3742.0	** No Incomplete data have been used for statistical calculation	

districts that developed flood control and drainage projects in the LGR and subsequently affected timing, depth, and duration of flooding in the LGR (e.g., Funk and Ruhr 1971). For example, at Chillicothe, the flood stage of 24 feet (gauge datum) was exceeded, with intervals of 30 days or more between crests, 87 times in 39 years from 1915 to 1962. At Sumner, during this same time frame, 48 distinct floods > 38,000 cfs occurred (USACE 1963).

PRESETTLEMENT VEGETATION COMMUNITIES

The historic LGR landscape prior to extensive European settlement in the mid 1800s (hereafter Presettlement) contained a diverse mixture of prairie, savanna, and forest plant communities with numerous small oxbows and bottomland lakes/sloughs present in bottomlands (Fig. 14 and Nigh and Schroeder 2002). Upland glacial terraces adjacent to LGR floodplains historically contained tall grass prairie. Upland prairies graded into oak savannas and woodlands on the edges of terraces and then to wet mesic prairie, herbaceous marsh, and bottomland forest communities in floodplains. Numerous oxbows and remnants of former river/stream channels were present throughout the LGR. In 1804, Meriweather Lewis described the southern portion of the LGR near the confluence of the Grand and Missouri rivers as: "Where the Grand River enters: … just above a beatifull and extensive prarle … about the entrance of this river the lands are extremely fertile: consisting of a happy mixture of prairies and groves, exhibiting one of the most beatifull and picteresk seens that I ever beheld." Similarly, Brackenridge (1814) traveling through the southern LGR in 1811 described the region as a connected mixture of prairie, marsh, forest, and streams.

Remnant glacial till terraces that are subset within or are on the edges of LGR floodplains historically were covered with wet-mesic prairie; a few very high elevation terraces sites contained drier mesic "tallgrass" prairie (Schroeder 1982). Soils on terraces that supported prairie are silt loam loess and glacial till-derived, moderately well drained, very deep (>60 inches), high fertility, and strongly acid to neutral soil reaction (5.1-7.3 pH) (Nigh and Schroeder 2002). Small relict glacial terraces within the Grand River floodplain often have rather marked (8-15%) side slopes. Historically, most terraces in the LGR were infrequently flooded (> 10-year recurrence) from

Table 5. Mean monthly discharge of the Grand River at Sumner, Missouri, 1924-2009 (from nwis.waterdata.usgs.gov).

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1924										420.1	296.2	591.3
1925	305.8	3672.0	1817.0	6592.0	1456.0	7429.0	866.6	1451.0	4565.0	6533.0	3175.0	2610.0
1926	3839.0	6349.0	2374.0	6222.0	771.0	8666.0	895.7	686.7	28090.0	15670.0	1574.0	1840.0
1927	767.9	3425.0	3141.0	24090.0	3371.0	7114.0	805.8	815.6	326.8	7380.0	575.1	381.0
1928	612.9	4488.0	1196.0	2091.0	523.9	10530.0	6591.0	3125.0	11900.0	5417.0	27780.0	4814.0
1929	2103.0	4076.0	21740.0	21190.0	4518.0	19180.0	7720.0	482.9	689.4	2927.0	3152.0	634.2
1930	369.7	4990.0	2000.0	1613.0	5349.0	2780.0	939.0	272.0	272.7	220.6	230.9	588.5
1931	131.5	174.4	1418.0	5990.0	1503.0	4225.0	452.2	334.5	5104.0	5899.0	29030.0	7210.0
1932	14750.0	3069.0	3195.0	3463.0	1475.0	6003.0	1361.0	8465.0	841.5	492.8	890.9	2471.0
1933	1597.0	862.2	1218.0	1926.0	4008.0	555.7	388.5	2143.0	1811.0	479.3	141.3	172.3
1934	156.5	128.0	262.1	888.6	351.5	307.6	52.8	214.1	1269.0	1044.0	7328.0	3446.0
1935	1892.0	3096.0	2930.0	1663.0	23750.0	28160.0	4204.0	349.1	629.3	174.0	1131.0	482.6
1936	358.8	6440.0	4824.0	670.7	1785.0	320.4	71.9	41.0	1452.0	1908.0	190.4	168.8
1937	1559.0	14360.0	6797.0	1649.0	4798.0	1649.0	2826.0	492.6	93.3	68.1	71.1	84.6
1938	101.6	130.8	214.0	804.0	1133.0	1621.0	126.0	944.8	430.5	58.0	104.4	54.6
1939	56.4	57.0	5921.0	4156.0	315.8	8168.0	2087.0	2064.0	119.4	79.7	93.2	66.8
1940	32.1	142.2	2253.0	902.1	2204.0	1071.0	989.6	5041.0	307.8	111.2	138.7	162.3
1941	1426.0	2527.0	985.9	1637.0	996.9	8949.0	618.8	112.1	1277.0	6309.0	7414.0	4668.0
1942	3442.0	8049.0	9849.0	3080.0	6150.0	19960.0	2586.0	1282.0	873.3	605.3	2118.0	5849.0
1943	1806.0	3157.0	1602.0	1541.0	8981.0	24200.0	1857.0	2344.0	484.7	211.6	195.2	164.3
1944	394.4	666.5	5033.0	22820.0	10290.0	6273.0	574.7	4111.0	1035.0	1272.0	1407.0	5457.0
1945	1198.0	4497.0	10900.0	14470.0	18110.0	19920.0	2905.0	419.1	980.9	1641.0	362.8	860.7
1946	14210.0	1504.0	10330.0	3143.0	6580.0	3187.0	2187.0	986.7	554.2	1042.0	631.4	1178.0
1947	759.2	530.3	5955.0	18900.0	6815.0	67270.0	5161.0	344.5	394.7	254.9	487.3	2240.0
1948	496.8	4598.0	11540.0	1923.0	2523.0	3332.0	821.3	399.9	185.9	103.4	144.8	123.3
1949	1261.0	9902.0	6996.0	3155.0	987.6	8230.0	3056.0	1482.0	1668.0	995.1	349.1	383.3
1950	2555.0	5208.0	2359.0	1351.0	4634.0	7614.0	1427.0	3597.0	912.6	262.9	178.2	142.2
1951	126.6	3215.0	4098.0	8423.0	11030.0	16850.0	14440.0	2392.0	2339.0	2459.0	3425.0	952.1
1952	1773.0	1524.0	14650.0	6554.0	3774.0	5118.0	1057.0	830.1	849.8	114.3	498.3	479.5
1953	281.9	1497.0	3735.0	8230.0	6619.0	1793.0	548.4	132.7	66.0	54.5	61.0	82.1
1954	45.9	100.1	187.4	1339.0	2191.0	4181.0	94.4	641.8	166.3	2949.0	164.9	119.4
1955	903.4	6903.0	3315.0	1846.0	2167.0	2155.0	1996.0	212.9	62.5	684.3	59.4	53.0
1956	38.1	105.2	112.4	67.3	130.3	360.8	3237.0	4180.0	141.8	37.1	40.3	59.3
1957	45.4	74.0	79.5	3246.0	2506.0	1577.0	727.9	274.1	230.6	1175.0	561.3	1474.0
1958	345.0	3132.0	3913.0	1329.0	4861.0	2371.0	23000.0	8107.0	2008.0	4436.0	6462.0	828.4
1959	405.0	7597.0	11370.0	9344.0	7893.0	5321.0	1857.0	5727.0	5286.0	8836.0	980.3	3176.0
1960	9104.0	4210.0	8980.0	16730.0	10420.0	7593.0	10000.0	3073.0	1776.0	1102.0	2590.0	738.5
1961	353.0	3706.0	17470.0	10730.0	5986.0	2552.0	4449.0	1941.0	15670.0	8637.0	27030.0	2426.0
1962	6280.0	19250.0	13850.0	2046.0	3928.0	6956.0	1755.0	537.2	524.7	2653.0	877.3	438.5
1963	285.8	1110.0	10080.0	2302.0	5130.0	881.5	1191.0	336.5	322.2	142.0	197.0	103.8
1964	114.2	184.6	322.8	4870.0	1806.0	8836.0	2291.0	303.1	6553.0	539.0	537.9	789.6
1965	6817.0	4593.0	9337.0	11640.0	3319.0	2355.0	6524.0	425.3	14310.0	1351.0	666.4	1930.0
1966	1595.0	1533.0	1156.0	1239.0	2945.0	3975.0	1282.0	696.9	172.9	321.7	140.2	145.1
1967	223.7	515.1	699.7	9739.0	2112.0	26680.0	3834.0	567.7	318.0	3915.0	3267.0	990.6
1968	1246.0	1360.0	715.7	8957.0	1882.0	788.3	1438.0	2087.0	403.9	665.1	935.9	1083.0
1969	3673.0	5414.0	2634.0	10090.0	6919.0	5691.0	20240.0	1371.0	6172.0	3402.0	2628.0	695.2
1970	746.7	845.6	1057.0	6225.0	7326.0	4461.0	365.1	2876.0	15820.0	6629.0	3237.0	3016.0
1971	1227.0	7860.0	6078.0	1353.0	2883.0	844.6	670.3	253.6	147.1	125.6	1301.0	2738.0
1972	929.1	992.1	1342.0	2664.0	7913.0	1198.0	1385.0	857.2	4009.0	529.4	5144.0	2778.0
1973	10310.0	13510.0	25610.0	26680.0	17900.0	3132.0	4742.0	1846.0	8528.0	20630.0	3392.0	6140.0
1974	9723.0	3895.0	3697.0	2711.0	8226.0	11330.0	1846.0	887.3	512.2	421.0	2555.0	977.0
1975	1753.0	3160.0	4975.0	7481.0	3811.0	5544.0	714.0	241.4	1161.0	152.2	289.3	2115.0

(Table 5 cont'd next page)

Table 5, cont'd. Mean monthly discharge of the Grand River.

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	440.6	1416.0	5017.0	12980.0	4853.0	1589.0	333.8	493.7	115.9	156.4	118.4	116.4
1977	45.5	222.9	801.6	1201.0	1219.0	341.0	420.8	2771.0	8379.0	13250.0	9032.0	1701.0
1978	603.6	400.0	16480.0	21560.0	16000.0	4249.0	2728.0	2381.0	7658.0	663.3	2442.0	1315.0
1979	825.3	1950.0	34220.0	7702.0	4885.0	2178.0	2484.0	956.7	629.6	306.5	507.3	234.0
1980	517.2	1473.0	4525.0	3694.0	517.5	4058.0	453.9	416.5	2810.0	351.5	244.7	4089.0
1981	487.9	808.1	736.5	2563.0	5989.0	2744.0	16600.0	3062.0	790.1	739.0	2008.0	1532.0
1982	2149.0	10130.0	11510.0	5321.0	16240.0	19380.0	5829.0	5781.0	7111.0	3940.0	4161.0	15440.0
1983	3586.0	5414.0	6448.0	15770.0	6763.0	2043.0	1499.0	240.8	156.5	209.9	3034.0	2648.0
1984	1901.0	4386.0	9096.0	15010.0	11180.0	21010.0	1739.0	359.9	196.2	870.7	3285.0	1880.0
1985	809.3	9940.0	7933.0	971.3	1137.0	1170.0	368.1	653.3	902.8	15440.0	7414.0	2116.0
1986	2547.0	3449.0	4610.0	6619.0	11700.0	2079.0	14860.0	2146.0	7296.0	13450.0	2052.0	7662.0
1987	1415.0	1598.0	10400.0	6891.0	5968.0	2414.0	12840.0	9194.0	1846.0	376.6	2807.0	6441.0
1988	1413.0	3190.0	1425.0	1828.0	477.1	176.2	144.4	331.1	122.5	48.9	84.6	85.4
1989	105.3	82.5	264.0	240.6	514.1	379.8	240.6	2031.0	4780.0	374.7	380.7	160.1
1990	638.3	1578.0	8921.0	5400.0	13390.0	14010.0	5590.0	1337.0	339.3	486.4	501.5	534.1
1991	1048.0	4576.0	6419.0	16730.0	16180.0	3790.0	3248.0	282.7	168.1	435.4	752.9	2419.0
1992	2277.0	5223.0	7489.0	16360.0	1732.0	986.9	12090.0	2960.0	11020.0	1183.0	12550.0	14680.0
1993	4594.0	5881.0	10830.0	16180.0	15150.0	12400.0	87900.0	6634.0	19230.0	3483.0	1685.0	2012.0
1994	1068.0	3417.0	4572.0	4621.0	3642.0	2744.0	1221.0	377.5	392.4	197.1	913.7	1769.0
1995	667.0	1387.0	1554.0	6628.0	43450.0	9971.0	12130.0	1941.0	420.4	291.5	397.1	283.6
1996	390.7	1916.0	1433.0	678.4	29340.0	17240.0	3491.0	2320.0	1369.0	1749.0	2890.0	1824.0
1997	668.8	13510.0	5246.0	17990.0	5652.0	2590.0	678.1	424.5	456.7	1351.0	662.9	3582.0
1998	4270.0	4050.0	14290.0	18240.0	5865.0	9190.0	5410.0	866.3	5184.0	16130.0	12080.0	3404.0
1999	1806.0	4930.0	6006.0	15180.0	12940.0	5182.0	1749.0	499.8	269.2	191.4	164.2	246.6
2000	158.7	427.7	606.5	342.0	270.4	3431.0	1314.0	381.8	339.4	399.4	517.6	200.3
2001	1548.0	13170.0	13250.0	7265.0	8946.0	24940.0	4925.0	1080.0	913.8	925.4	360.1	329.7
2002	227.2	1009.0	760.5	4139.0	14400.0	1742.0	410.9	397.0	122.2	93.8	112.0	104.0
2003	119.5	139.1	214.7	567.8	1800.0	1089.0	307.2	102.3	900.9	118.7	274.5	1877.0
2004	308.5	1282.0	14420.0	1930.0	13370.0	23710.0	4499.0	19820.0	3825.0	1263.0	1962.0	1132.0
2005	2347.0	8341.0	1465.0	4314.0	4066.0	6002.0	568.5	916.1	343.4	702.9	198.2	385.5
2006	353.8	276.6	888.4	1117.0	3219.0	968.8	215.5	884.7	485.3	348.5	276.1	805.5
2007	1287.0	3429.0	5059.0	7748.0	24200.0	3241.0	486.4	3190.0	734.7	2480.0	476.9	3852.0
2008	3741.0	5388.0	12160.0	21170.0	8029.0	30500.0	18310.0	3959.0	16390.0	5612.0	5008.0	6714.0
2009	2545.0	1750.0	17050.0	13020.0	19750.0	15330.0	3258.0	11760.0	1602.0			
Mean of monthly Discharge	1,900	3,750	6,150	7,100	6,940	7,790	4,580	2,040	3,070	2,600	2,770	2,030

** No Incomplete data have been used for statistical calculation

backwater events of the Grand River and its tributaries. Local precipitation caused sheetwater runoff across terraces and some surface water infiltrated terrace soils. Wet mesic terrace prairies typically have slightly more sheetwater flooding than mesic sites and contain some plant species slightly more adapted to extended soil saturation such as prairie cordgrass (*Spartina pectinata*) (Nelson 2005). Fire undoubtedly was a dominant ecological disturbance for the terrace prairies prior to settlement. Bison and elk were present in these sites until the late 1800s (Wells 1948) and they apparently had considerable influence on structure and composition of communities through heavy grazing. Dominant plants on terrace prairies included big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*), and rosinweed (*Silphium integrifolum*) (Appendix A). Prairie cordgrass, bluejoint (*Calamagrostis c*anadensis) and mixed sedges were present in wet-mesic terrace prairies. Common shrubs included American hazelnut (*Corylus americana*), wild plum (*Prunus americana*), and prairie willow (*Salix humilus*). Herbaceous layers included prairie dropseed (*Sporobolus heterolepis*), eastern gama grass (*Tripsacum dactyoides*), culver's clover (*Veronicastrum virginicum*), and many others. The rich diversity of plant species covered the entire terrace prairie community and grass and forb heights ranged from 5-7 feet.

Wet floodplain prairies were present throughout the alluvial deposits of the LGR mostly on silty clay soils with 0-2 percent slopes (Schroeder 1982, Nigh and Schroeder 2002, Nelson 2005). These floodplain prairies historically had short duration flooding from sheetwater flow that drained from terraces onto the floodplain and from occasional backwater flooding of the Grand River and its major tributaries. Plant communities in floodplain prairies ranged from perennial marsh-type vegetation in low elevations to more mesic-type terrace grasses and forbs in higher elevations on the edge of the floodplain. Some surface flooding occurred almost annually in low elevation floodplain prairies, but surface inundation was likely strongly seasonal, with most inundation occurring in spring and early summer. Low elevation wet floodplain prairies were present on poorly drained deep soils and had seasonally high water tables with standing water present during spring and winter or after heavy rains. Dominant plants in these low elevation prairie marshes included prairie cordgrass, smartweeds, spikerush (*Eleocharis sp.*), buttonbush (*Cephalanthus occidentalis*), false indigo (*Amorpha fruticosa*), swamp milkweed (*Asclepias incarnate*), rice cutgrass (*Leersia oryzoides*), river bulrush (*Scirpus fluvialitis)* and numerous sedges and rushes (Appendix A). Dominant plants in higher elevation floodplain prairies included Indian grass, switchgrass, big bluestem, bluejoint, and prairie cordgrass. These sites apparently had 2-5 year flood recurrence hydrology. Dominant plants in wet floodplain prairies were prairie cordgrass, numerous sedges (*Carex* sp.) and rushes (*Juncus* sp.), water smartweed (*Polygonum coccineum*), and varied herbaceous species.

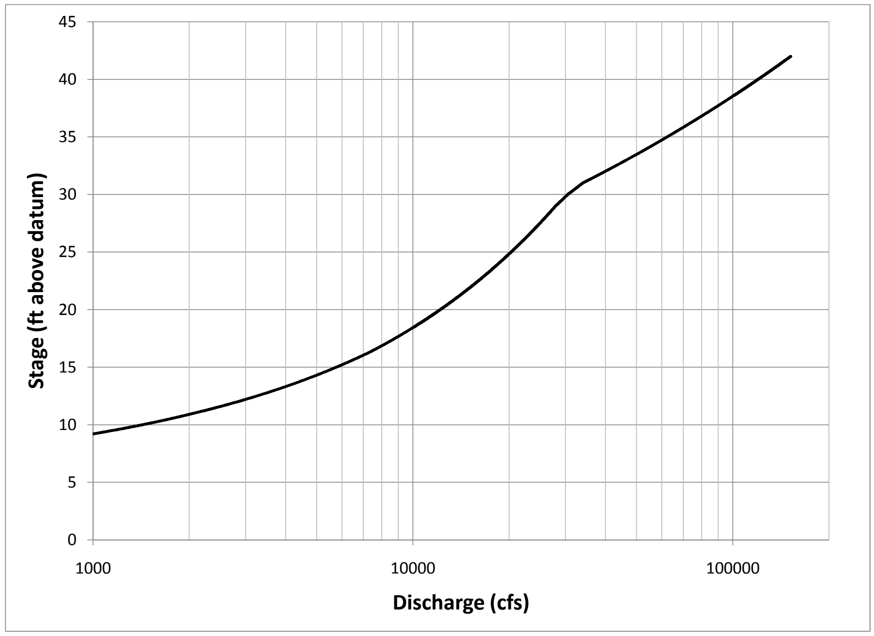

Figure 11. Stage-discharge relationship of the Grand River at Sumner, MO (waterwatch.usgs.gov).

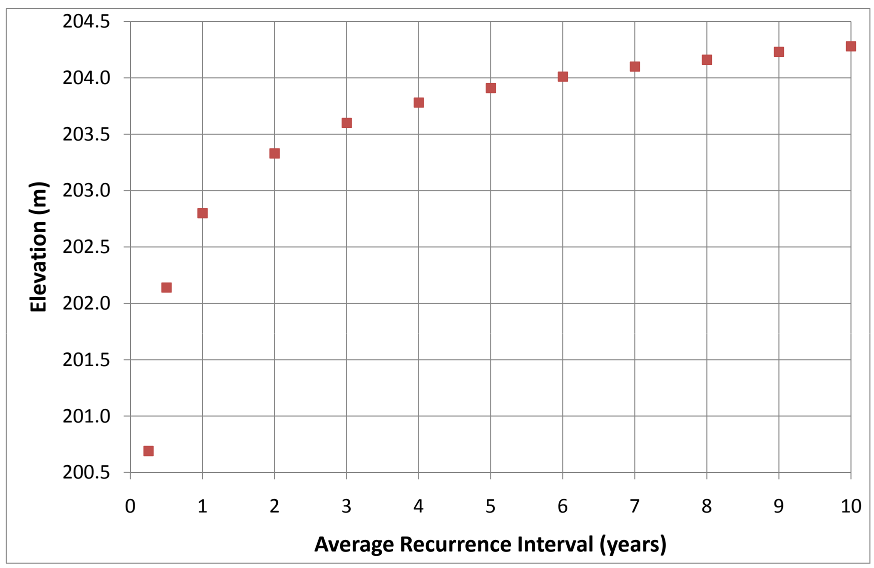

Figure 12. River elevation vs. recurrence interval for the Grand River near Sumner, MO based on peak over threshold analysis of average daily discharge for Water Years 1925-2009 and 3/15/2010 rating table for USGS gauge #06902000.

Wet-mesic woodlands historically occupied broad transition zones in LGR floodplains between terrace and floodplain prairies and true forest communities along stream and river corridors (Nigh and Schroeder 2002, Nelson 2005). Trees in woodland habitats often are open grown (orchard like) and take on a savanna-like interspersion with tall bottomland prairie grasses, sedges, and herbaceous plants covering most of the ground cover. Slopes in LGR floodplain woodlands are nearly level and soils

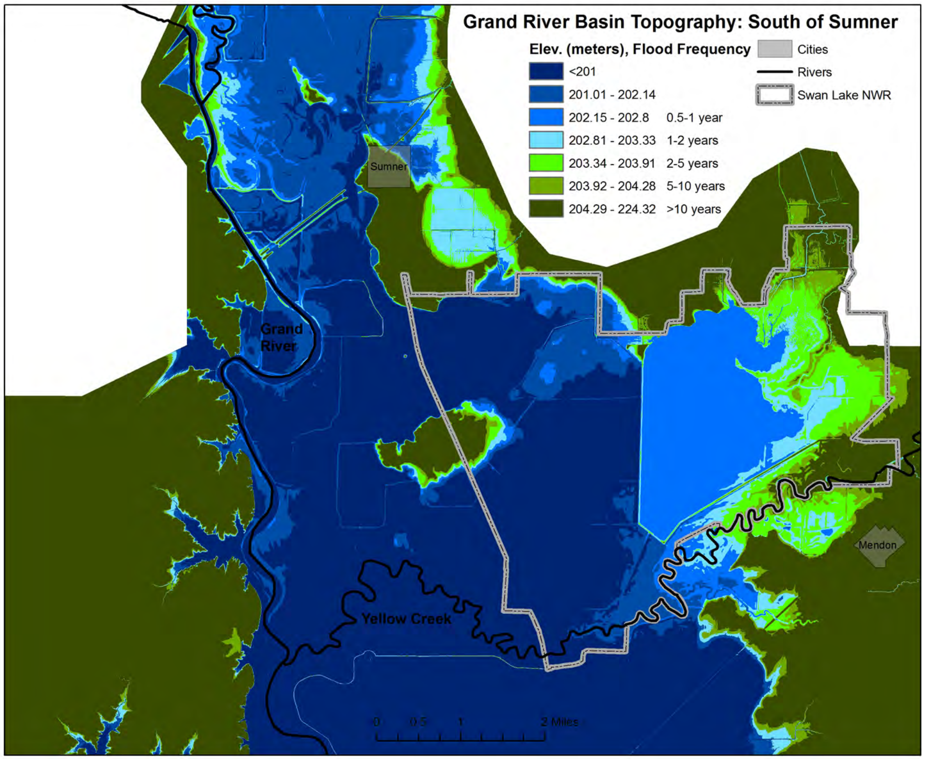

Figure 13. Flood frequency elevation contours south of Sumner, MO.

seasonal flooding and regular fire had a direct influence on the patterns of floodplain woodland distribution. During dry years fire burned into the woodlands from adjacent prairies, while shallow backwater flooding of 2-5 year recurrence was important to constrain fires and to sustain dominant woody plants. Dominant trees in LGR woodlands were pin oak (*Quercus palustris*), bur oak (*Quercus macrocarpa*), pecan (*Carya illinoensis*), cottonwood (*Populus deltoides*), and some shellbark hickory (*Carya laciniosa*) in higher areas (Appendix A). Shrubs included buttonbush and herbaceous cover contained prairie cordgrass, sedges, rice cutgrass, fowl manna grass (*Glyceria striata*), bluejoint, and numerous sedges.

are often poorly drained Carlow silty clays. Seasonal flooding occurs from both river backwater and local runoff sources especially in fall, winter, and spring. Most flooding is shallow, but can last for a month or so in higher water conditions. The combination of

Wet-mesic and wet floodplain forest was present along streams and rivers in the LGR and in swales adjacent to or succeeding from old oxbows, back-swamps, and low elevation flats (Nelson 2005). This community was present as parallel bands of forest

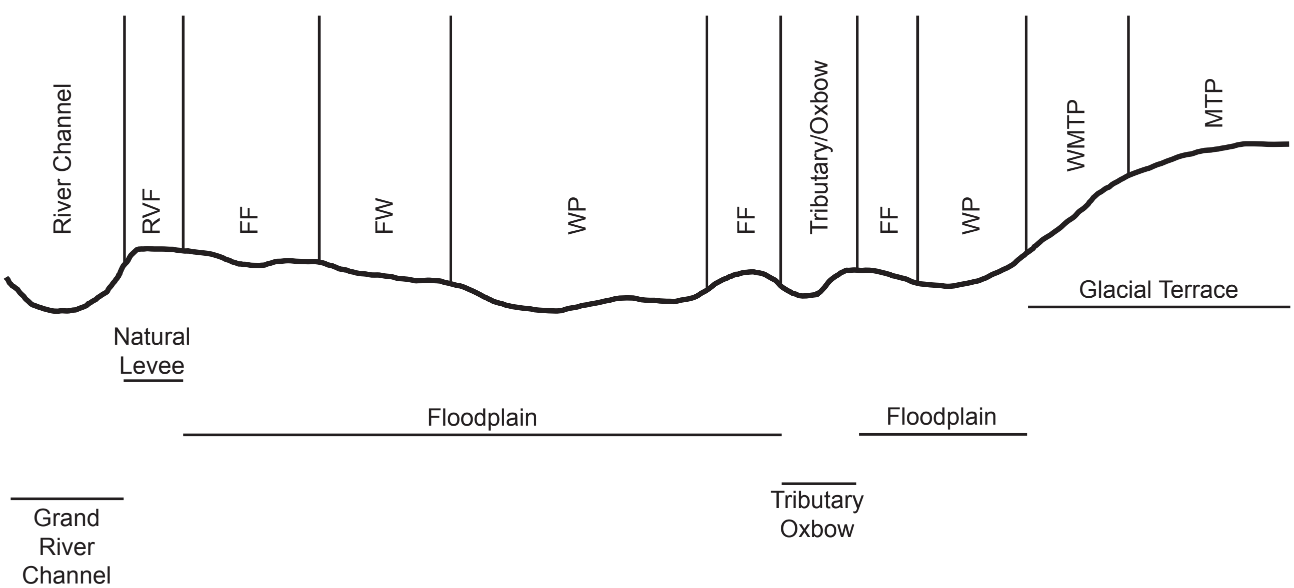

Figure 14. Topographic cross-section of vegetation communities in the Lower Grand River Region in relation to geomorphic surface. RVF – Riverfront Forest, FF – Floodplain Forest, FW – Floodplain Woodland, WP – Wet Floodplain Prairie, WMTP – Wet Mesic Terrace Prairie, MTP – Mesic Terrace Prairie.

along Medicine, Parsons, Locust, and Yellow Creeks and along the Grand River where soils were mostly silty clay loams, poorly drained, and almost annually flooded or saturated during dormant seasons and short periods of the growing season. Shallow backwater flooding historically occurred on these sites almost every year especially in fall, winter and early spring; most surface water was gone by mid growing season. These floodplain forests rarely, if ever, burned because of the more prolonged regular flooding regimes. Dominant trees in these floodplain forest bands were pin oak, bur oak, green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus Americana*), slippery elm (*Ulmus rubra*), pecan, box elder (*Acer negundo*), shellbark hickory, and sugarberry (*Celtis laevigata*) (Appendix A). Shrubs and vines included poison ivy, raccoon grape, and buttonbush. Herbaceous ground cover was variable depending on extent of flooding, but usually contained abundant sedges, smooth ruellia, and rice cutgrass.

Natural levees along the Grand River and some other sites immediately adjacent to tributaries that contain sandy loams contained riverfront forest communities (Nelson 2005). Riverfront sites have moderate to poorly structured canopies on recently accreted sediments. Coarse texture sands and silts deposited adjacent to streams and rivers are moderately well drained and vegetation occurring in these sites is subject to regular scouring and debris deposition. Deep headwater flooding occurs every 1-3 years with surface water being occasionally deep and rapid flow, albeit usually for brief periods, especially early in the growing season. Water typically recedes within a few days during high flow events on natural levees. Dominant plants in LGR riverfront forests include black willow (*Salix nigra*), cottonwood, sycamore (*Platanus deltoids*), silver maple (*Acer saccharinum*), American elm, river birch (*Betula nigra*), box elder, and sugarberry. Occasional pin oak and pecan is present in riverfront communities. Shrubs and vines include poison ivy, Virginia creeper, grape, white woodland aster (*Aster lateriflorus*), wood nettle (*Laportea Canadensis*), and several others (Appendix A.).

Oxbows and larger, deeper, floodplain depressions in the LGR contained gradients of open water, herbaceous, and shrub/scrub (S/S) communities from deeper middle parts of the depression to shallow edges. Many deeper oxbows contain surface water year round, except in the driest years. Most waters are relatively turbid in the oxbows and only limited submergent vegetation is present. Edges of the depressions typically dry during summer and support bands of annual and perennial "moist-soil" herbaceous plants. The moist-soil zone varies among depressions and years as depth and extent of surface water recedes. The outer edges of oxbows usually contain a narrow band of S/S dominated by buttonbush and black willow. These S/S areas are flooded annually usually for 6+ months, but have regular, short duration drying in late summer and early fall. S/S zones usually transition into floodplain woodland or forest communities at the upland edge of the depression.

HGM-MODELED PRESETTLEMENT COMMUNITY LAND TYPES

A fundamental part of the HGM evaluation of ecosystem restoration options in the LGR is attempting to understand relationships between major vegetation communities and the basic land attributes of geomorphology, soils, topography, and flood frequency/local hydrology (Heitmeyer 2007, Klimas et al. 2009, Heitmeyer 2010a,b). For the LGR, geospatial maps of soils and topography are available at a refined scale. In contrast, geomorphology maps are restricted to gross geological surfaces and flood frequency recurrence interval elevation maps are not available for the entire LGR area. The best combined geomorphology, soil, elevation and hydrologic HGM data are available in the region near the Sumner gauge on the Grand River. In this area stage-discharge relationships of the Grand River at Sumner (Fig. 11) provide a means to determine recurrence intervals immediately up- and down-stream of the gauge location in relation to elevation (Fig. 12). Consequently, an attempt was made to relate current and historic vegetation community distribution in the Sumner area to respective HGM data attributes and then to expand this correlation of understanding to other LGR areas.

Combined General Land Office (GLO) notes (GLO 1817-1840), botanical records and observations (Brackenridge 1814, Watkins 1921, Steyermark 1963), plat maps (Fig. 15), older photographs (Fig. 16), and early settler accounts (e.g., Hoy 1872) provided a foundation for understanding vegetation community distribution in the LGR, especially near Sumner. A previous attempt to map potential historic (Presettlement) vegetation distribution relied solely on GLO survey notes and was a start

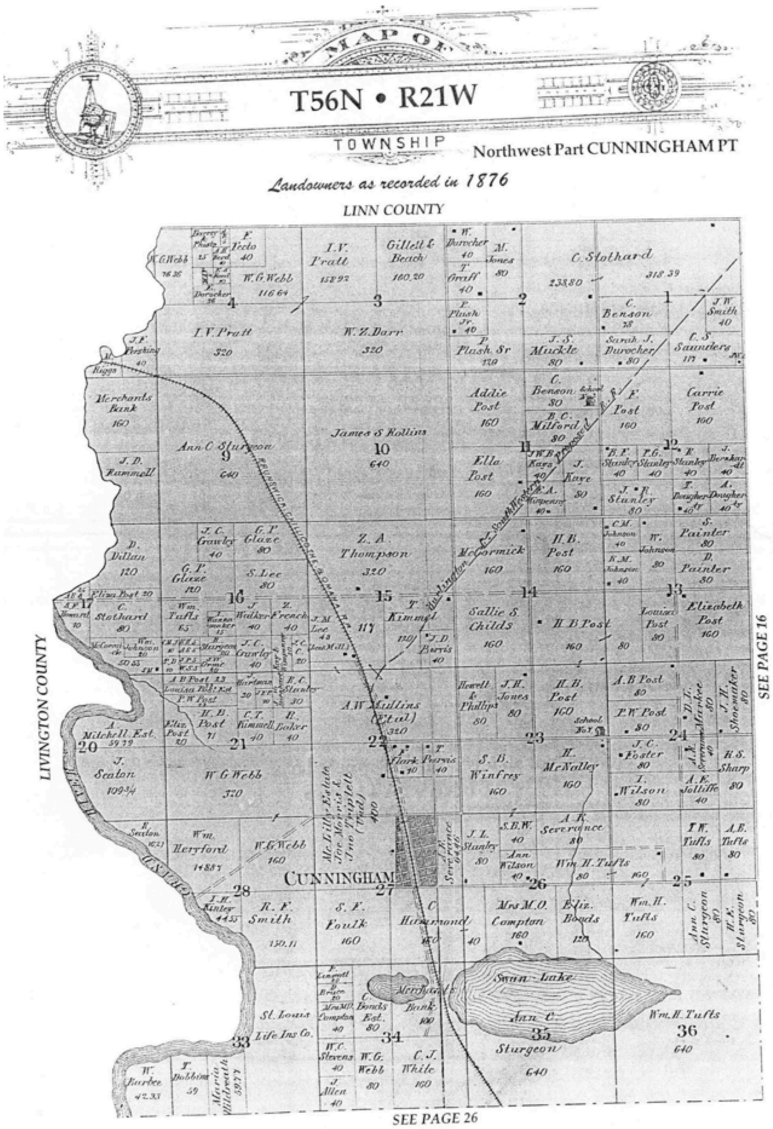

Figure 15. Land plat map for Linn County, MO in 1876 showing the historic Swan Lake area.

to understanding community relationship (Fig. 17). Caveats of GLO notes (e.g., Hutchinson 1988, Brugam and Patterson 1996, Nelson 1997, Black and Abrams 2001) prevent precise understanding of HGM relationships, however, and additional analyses of combined HGM data sets are required to understand the distribution of various Presettlement communities. Recently MDC (Nigh, previously unpublished) expanded GLO analyses to include community relationships to contemporary soil, geomorphic, and elevation surfaces for areas in Missouri (Appendix B). Based on this information we produced maps of ecological land types (ELT) for the LGR (Fig. 18). The ELT maps for the LGR provide a spatial model of the potential historic LGR ecosystem without explicit historic flood frequency/hydrology information.

In summer 2010, 14 sites that contained remnant prairie and forest communities, in the area immediately south and east of Sumner were visited to document current vegetation communities in relation to geology, soils, topography, and flood frequency determined from historic Sumner gauge data on the Grand River (Fig. 19). Additionally, remnant prairie and floodplain forest sites were visited on Pershing State Park. Documentation of plant species composition in the 14 "reference" sites and on Pershing State Park provided evaluation of correspondence with the ELT maps and determined differences, or perceived changes, from potential historical occurrence (e.g., Nestler et al. 2010). Generally, these reference data confirmed that the general distribution of primary Presettlement communities (e.g., floodplain and terrace prairie, floodplain woodland and floodplain forest) mapped by the ELT analyses was consistent between historic and contemporary periods and was best predicted by soil type. Within forested areas, the 2010 sampling did suggest some changes in forest composition (generally tending toward more water tolerant and pioneering tree species) from historic condition (see later section), but nonetheless, the primary historic community type still was present.

A matrix of HGM land attributes associated with the Presettlement vegetation communities (land types) was prepared for the area near Sumner to describe relationships of communities with geomorphology surfaces, soils, topography, and hydrological regime (Table 6). This HGM matrix and the ELT analyses provided a means to map the areas in the LGR away from the Sumner area and is the best predictor of historic communities based on the data currently available (Fig. 18).

Our potential historic vegetation community maps (Fig. 18) are based largely on soil type, which reflect soil genesis related to geomorphology of the Grand River floodplain and adjoining glacial-derived terraces and to frequency and type of flooding from river backwater and upland sheetflow events. Future analyses of flood frequency for areas distant from the Sumner gauge may refine understanding of community relationships, but the foundation of understanding community distribution related to soils in the LGR seems corroborated. The general distribution of vegetation communities in the LGR demonstrates the gradient of prairie communities from mesic types on higher terrace elevations with infrequent overbank flooding (and likely regular fires and grazing) to near marsh-type wet prairies in floodplains. In floodplain prairies a mix of 2-5 year flood frequency from overbank river flooding and annual sheetflow runoff from uplands and terraces caused regular flooding, yet drying periods between flood events allowed occasional fire to range into floodplains that sustained grass communities. Grassland communities were present on silt-loam soils in the floodplains and transitioned to open woodlands with a near savanna characteristic where soils became more clayey and with sometimes prolonged inundation in winter and spring that prevented fire from ranging into the floodplains. Woodlands then transitioned to forests dominated by pin oak, box elder, and elm along rivers and streams where heavy clay soils, regular winter and spring flooding, and natural levees were present.

The amount and distribution of ELT-modeled community types vary among the four LGR ecological zones (Table 7). Floodplain forest covered the most area of any habitat type in floodplains, but terrace and floodplain prairie communities were extensive in all zones. Floodplain woodlands were essentially absent from Upper Tributary and Lower Basin Terrace zones and were most common in the Lower Grand River Floodplain zone. The Lower Basin Terrace zone was dominated by prairie. For all LGR zones combined, forest and woodlands historically covered about 40%, and prairies covered 60%, of the LGR, respectively.

ANIMAL USE OF LGR COMMUNITY TYPES

The heterogeneous mix of river/stream, floodplain lakes and sloughs, prairie, woodland, and forest communities in the LGR provided resources that were used by a wide diversity of animal species. General lists of animal species associations with vegetation communities are provided in Appendix C. Animals using LGR communities reflect a mixture of both resident and seasonally present species. Generally, amphibian and reptile groups are present in all LGR community types, with certain species,

Table 6. Hydrogeomorphic (HGM) matrix of historical distribution of major vegetation communities/habitat types in the Lower Grand River Region near Sumner, Missouri in relation to geomorphic surface, soils, and flood frequency. Relationships were determined from land cover maps prepared by the General Land Office survey notes (GLO 1817-1840), botanical correlations (Nigh and Schroeder 2002, Nelson 2005), early plat maps and photographs from the late 1800s and early 1900s, U.S. Department of Agriculture soil maps and reports (e.g., Watkins 1921), and early explorer accounts (e.g., Hoy 1872). Flood frequency data was calculated for elevations near Sumner per Figs. 11-12 in this report).

Habitat type	Geomorphic surface[a]	Soil type[b]	Flooding frequency[c]
Open water/ Aquatic	AC, FD	SC	P/SP
Shrub/scrub	AC,FD, AF	SC	SP
Riverfront forest	NL, RE	S, SL	1 yr
Floodplain forest	AF, NL	SC, SL	1-2 yr
Floodplain woodland	AF	SL	1-2 yr-D
Wet floodplain prairie	AF, FD	SC, SCL	1-2 yr-G,D
Wet mesic terrace prairie	GLT	SL	2-5 yr
Mesic terrace prairie	GLT	SL	> 10 yr

[a] AC – abandoned river/stream channel, FD – floodplain depression, AF – alluvial floodplain, RE – river edge bar and chute deposits, NL – natural levee, GLT – remnant glacial terrace.

[b] SC – silt clay, S – sand, SL – silt loam, SCL – silty clay loam.

[c] Annual recurrence interval over period of record at the Sumner, MO gauge, G – growing season, D – dormant season.

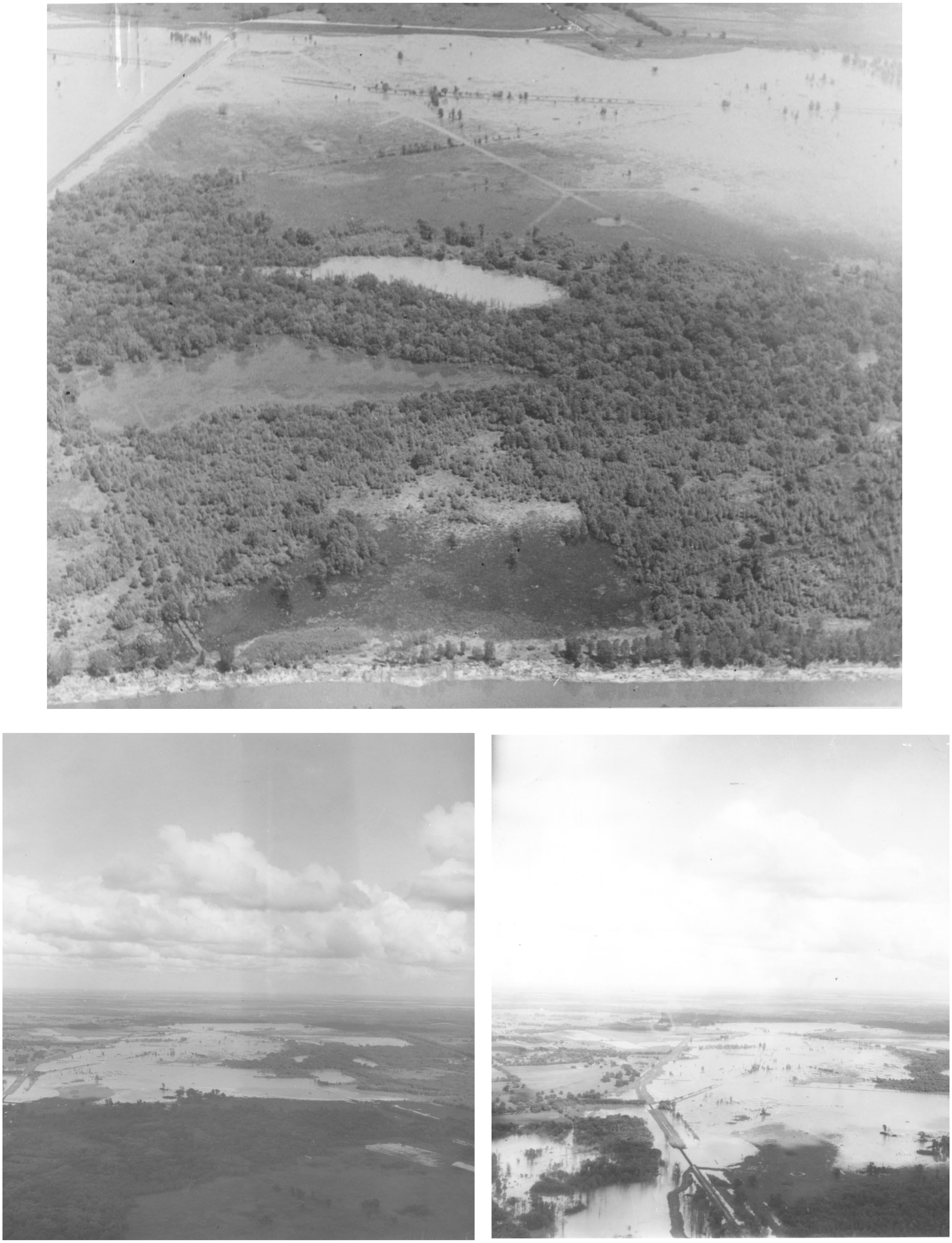

Figure 16. Aerial photographs of the Grand River floodplain on the Fountain Grove Conservation Area in 1949.

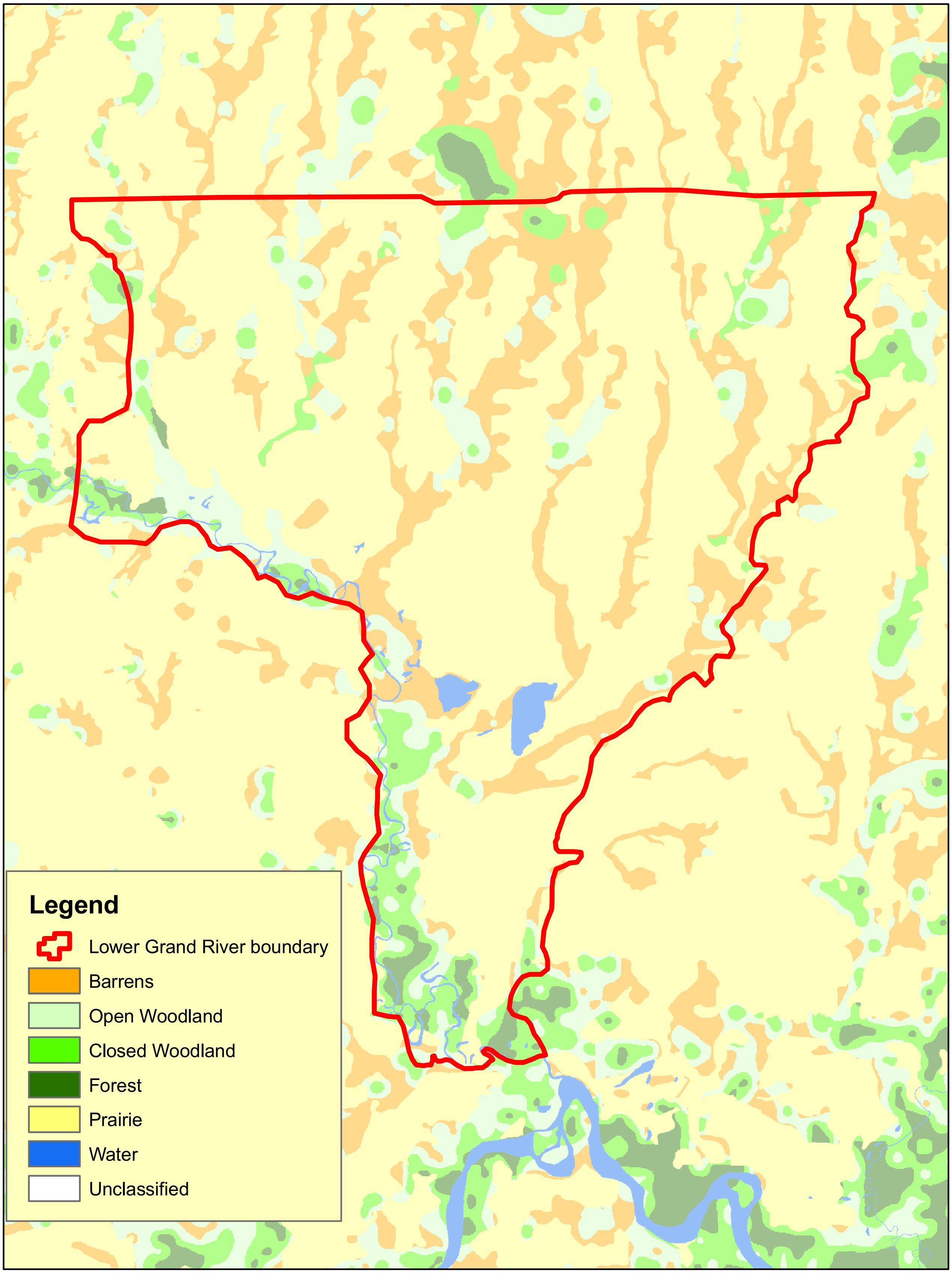

Figure 17. Vegetation map from General Land Office surveys in the Middle Grand River Floodplain region of the LGR (modified from maps prepared by G. Harlan, unpublished).

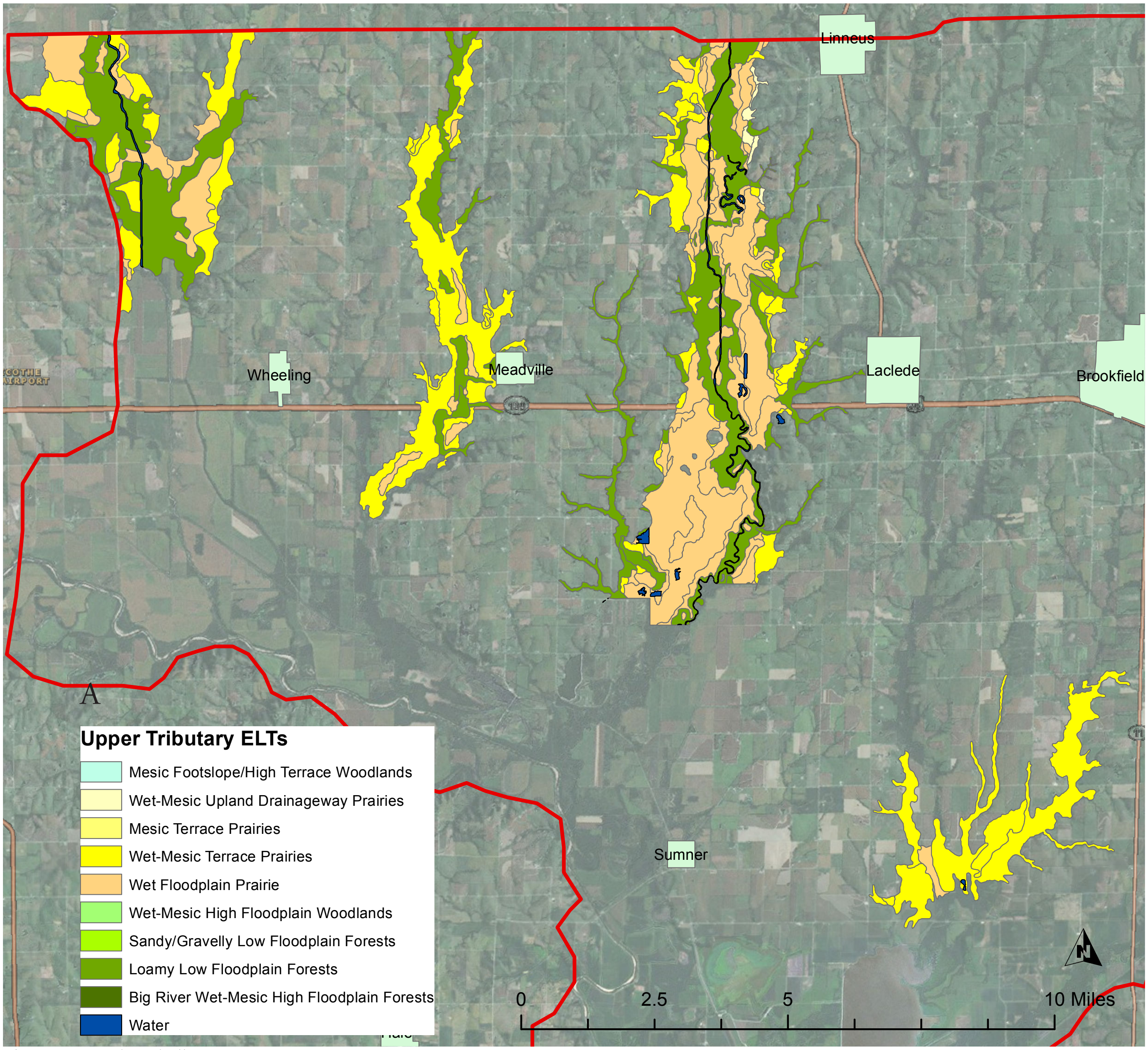

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Figure 18. Potential Presettlement Ecological Land Types (ELT) for the: a) Upper Tributary Floodplain, b) Middle Grand River Floodplain, and c) Lower Grand River Floodplain and Lower Basin Terrace zones of the LGR.

such as massasauga rattlesnakes, being confined to wet mesic prairie sites. Fish range throughout floodplains during flood events with diverse assemblages occurring in deeper abandoned channel oxbow lakes, tributary streams, and the Grand River. Mammals use all community types and species associations reflect use and adaptations of wetter aquatic vs. drier upland prairie and terrace sites. Birds in the ecosystem include diverse species in prairie and forest communities. Prairie sites are used by many neotropical bird species, both upland and wetland associated. Likewise, forest and woodland areas support many migrant species and a more modest resident and summer breeding assemblage. Few permanent wetlands (other than the historic deeper Swan Lake and abandoned channel oxbows – see Figs. 7,16) historically were present in the LGR, but these sites likely supported some breeding waterbirds including rail, bittern, herons, and wood ducks. In contrast, the increasing hydrograph and regular flooding of the LGR from fall through spring provided abundant resources for migrant waterbirds,

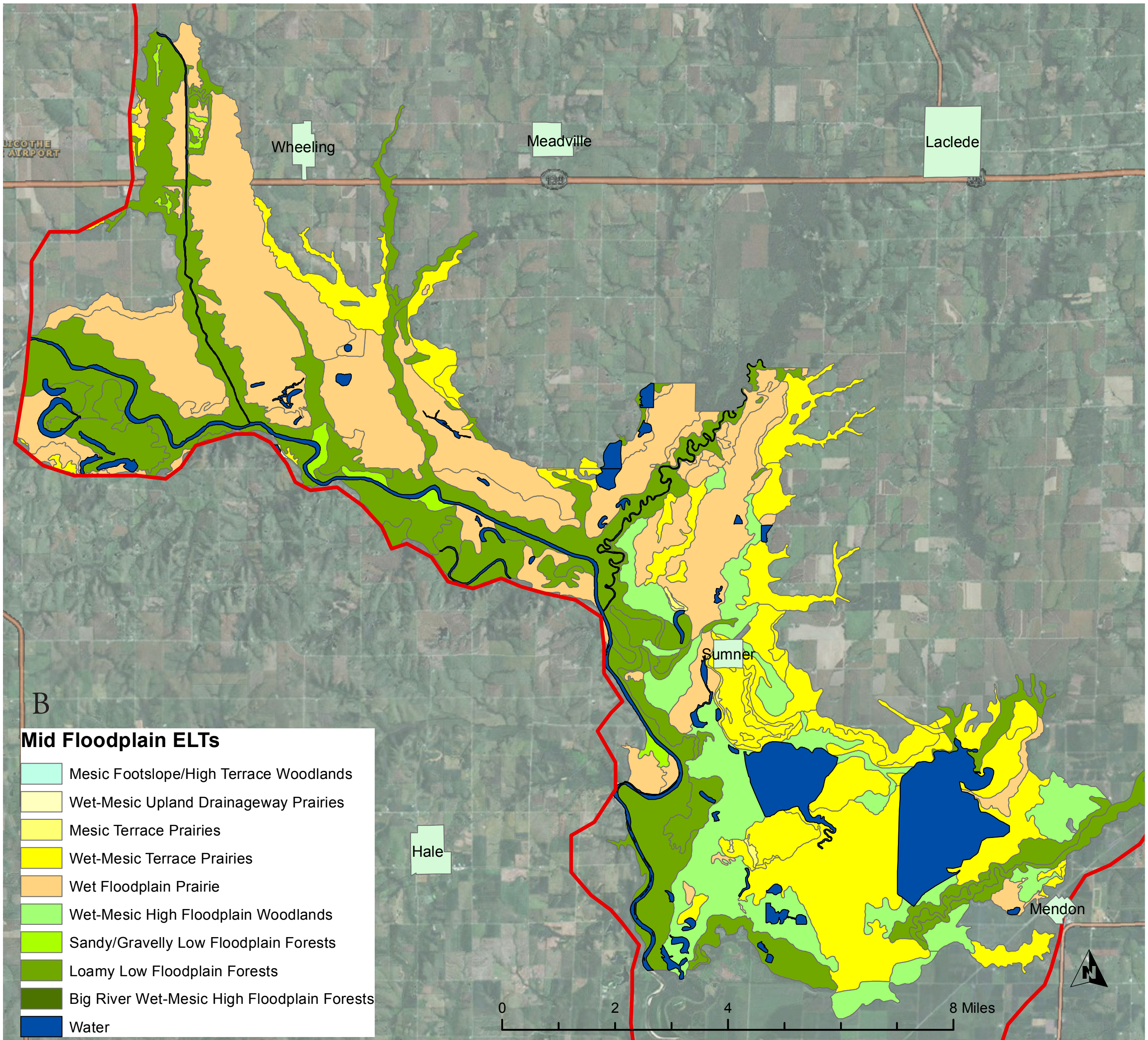

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Figure 18, cont'd. Potential Presettlement Ecological Land Types (ELT) for the: a) Upper Tributary Floodplain, b) Middle Grand River Floodplain, and c) Lower Grand River Floodplain and Lower Basin Terrace zones of the LGR. Large water areas on Swan Lake NWR and Fountain Grove CA are current man-made impoundments.

especially waterfowl. The chronology of use of LGR habitats by waterbirds was determined by timing of freezing and snow cover in fall/winter, melting and thawing of wetlands in spring, and drying of wetland habitats in summer.

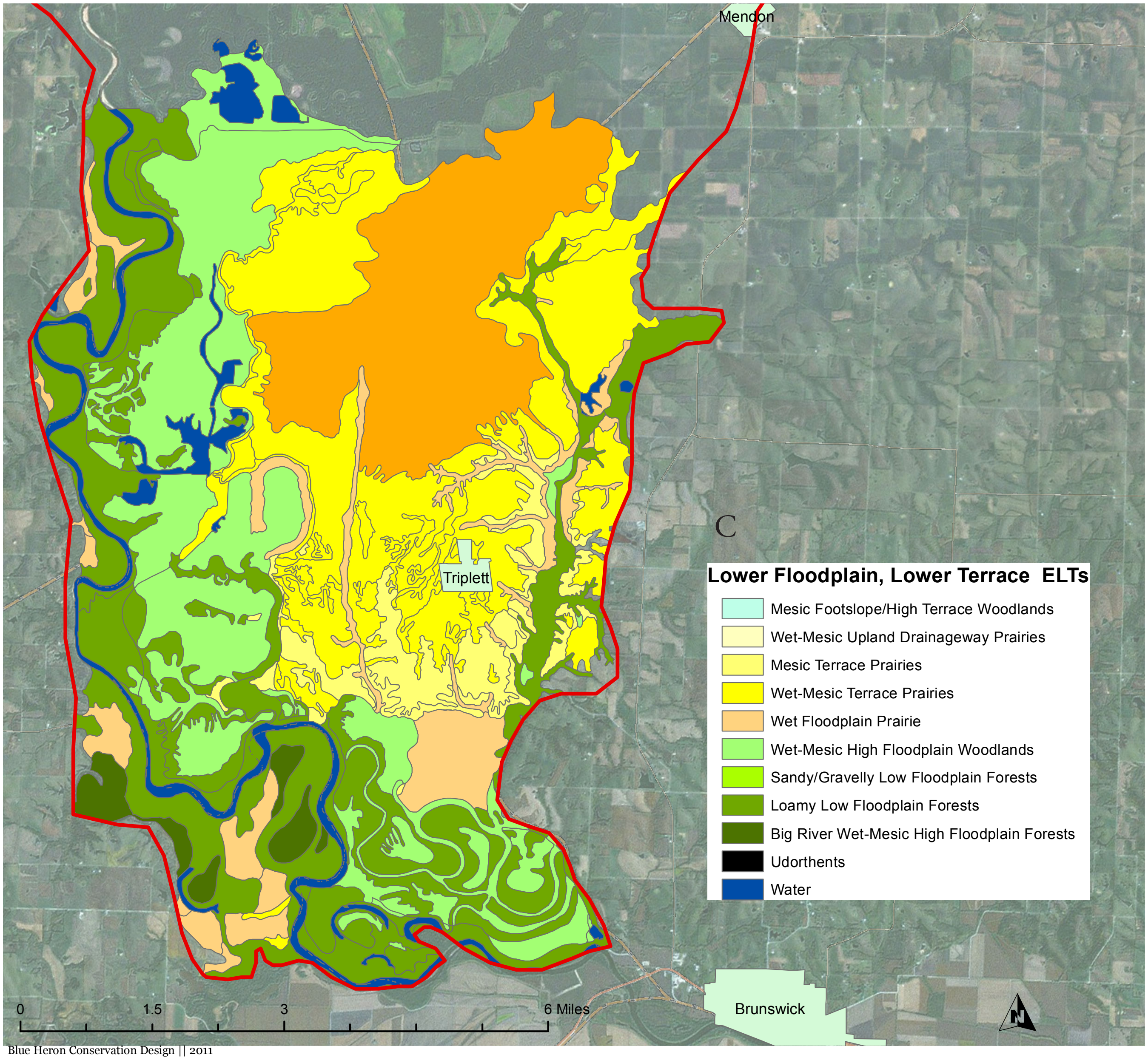

Figure 18, cont'd. Potential Presettlement Ecological Land Types (ELT) for the: a) Upper Tributary Floodplain, b) Middle Grand River Floodplain, and c) Lower Grand River Floodplain and Lower Basin Terrace zones of the LGR.

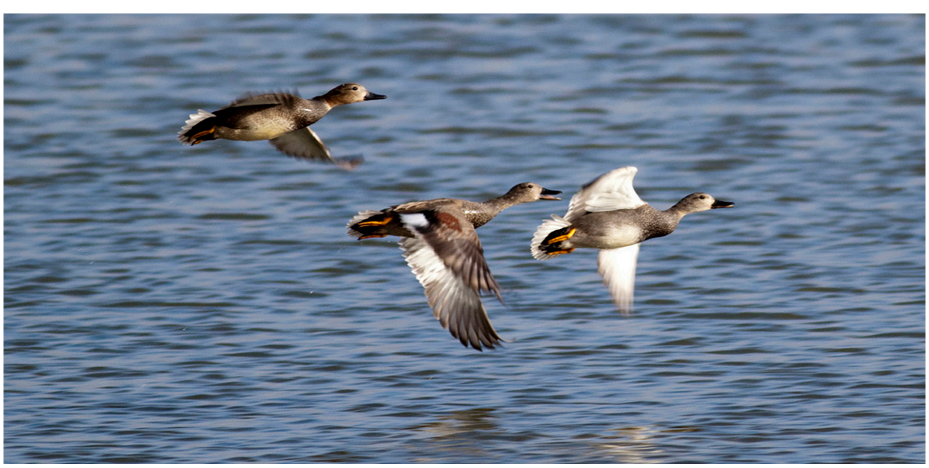

Table 7. Potential acres of historic vegetation communities in the Lower Grand River region by zone.

Location/ELT	Acres
LOWER GRAND UPPER TRIBUTARY ELT	
Wet Mesic Terrace Prairies	9,387.92
Wet Floodplain Prairies	10,029.08
Loamy Low Floodplain Forests	9,421.48
Wet-Mesic Upland Drainageway Prairies	1,136.78
Water	2,298.23
TOTAL	32,273.50
LOWER GRAND MID FLOODPLAIN ELT	Acres
Mesic Terrace Prairies	102.35
Wet-Mesic Terrace Prairies	15,454.58
Wet Floodplain Prairies	25,448.32
Wet-Mesic High Floodplain Woodlands	9,271.38
Sandy/Gravelly Low Floodplain Forests	477.06
Loamy Low Floodplain Forests	22,401.63
Mesic Footslope/High Terrace Woodlands	6.73
Water [a]	6,459.89
TOTAL	79,621.93
LOWER GRAND LOWER FLOODPLAIN ELT	
Mesic Terrace Prairies	226.76
Wet-Mesic Terrace Prairies	1,600.33
Wet Floodplain Prairies	2,512.74
Wet-Mesic High Floodplain Woodlands	7,264.63
Loamy Low Floodplain Forests	11,728.59
Big River Wet-Mesic High Floodplain Forests	648.53
Water	2,970.45
TOTAL	26,952.02
LOWER GRAND LOWER TERRACE	Acres
Mesic Terrace Prairies	1,717.15
Wet-Mesic Terrace Prairies	7,935.53
Wet Floodplain Prairies	5529.33
Wet-Mesic High Floodplain Woodlands	27.82
Loamy Low Floodplain Forests	1,117.28
Water	40.17
TOTAL	16,367.28
TOTAL ACRES	155,214.73

[a] Water reflects current man-made impoundments.

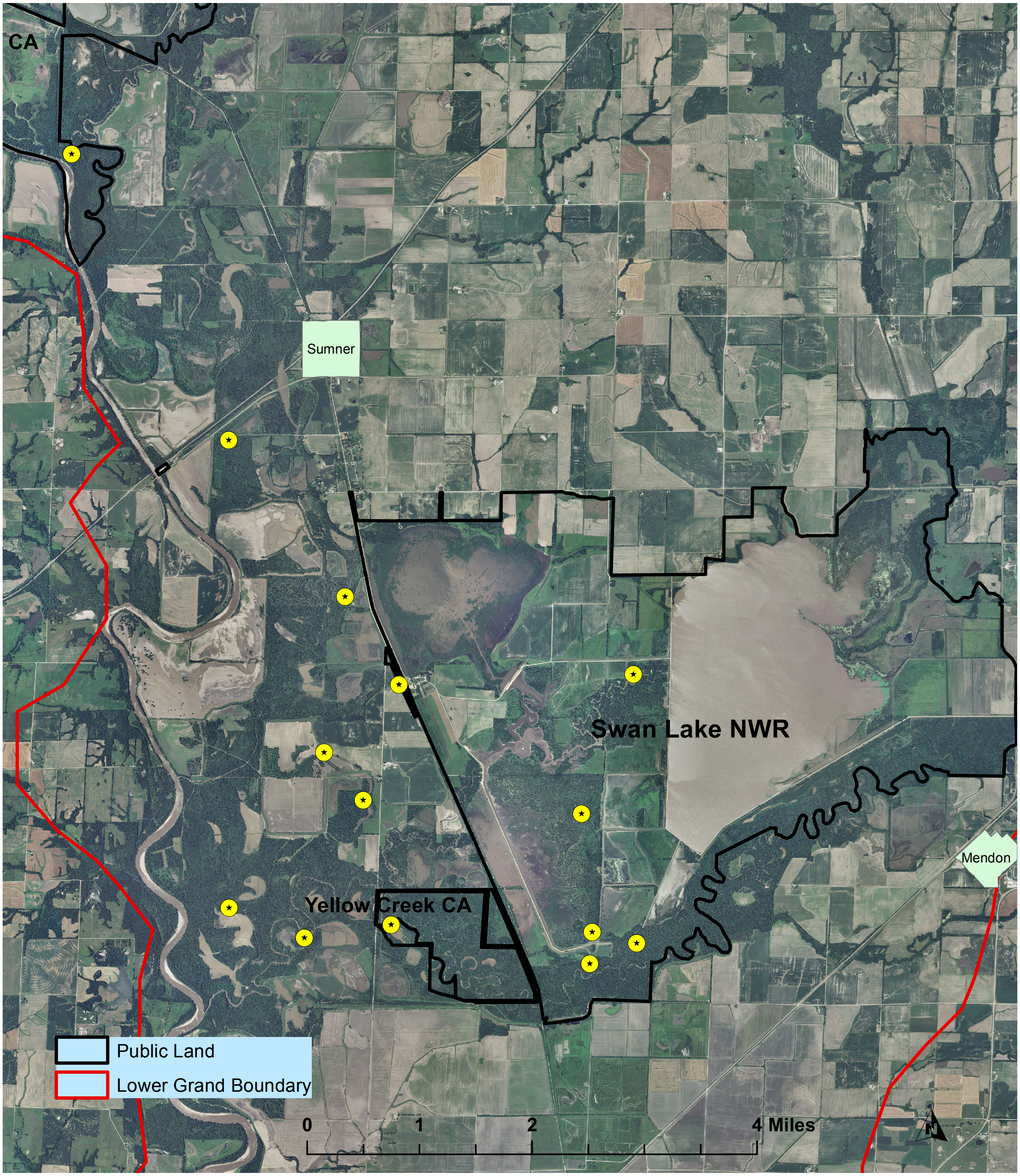

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Figure 19. Location of vegetation plots sampled in the Swan Lake area, 2010.

CHANGES TO THE LGR ECOSYSTEM

SETTLEMENT AND EARLY LANDSCAPE CHANGES

Human occupation of the Central Dissected Till Plains section of north Missouri apparently first occurred in the Paleo-Indian period 8,000 to 12,000 years before the present (BP) (Chapman 1975, 1980, Nelson 2005). Archaeological evidence from the immediate LGR area is limited (Bray 1980, Boyd 1982, USFWS 2010), but suggests seasonal camps were present in, or on the edges, of the Grand River floodplain with more permanent camps located on higher elevation terraces and adjoining uplands. Native Oneota sites represent most of the known prehistoric archeological sites in Chariton County and the surrounding LGR area. More recent Native American tribes known to use the LGR were Missouri and Osage (Bray 1980).

During the post-Wisconsin glacial period, north Missouri was changing from a boreal forest dominated ecosystem to a deciduous oak-hickory forest (Delcourt and Delcourt 1990) and small bands of native people hunted large nomadic mammals such as bison and mammoth. Climatic conditions began to dry during the Middle Archaic period (about 5,000 to 8,000 BP) and prairies expanded throughout glacial terraces and drift plains and displaced forest except along major drainages. Likely the extent of prairies in the glacial plains of north Missouri, both upland and bottomland types, reached their maximum distribution during the Altithermal period of 4,000 to 8,000 BP (Schroeder 1982). In the prairie dominated landscape, bands of native people likely were highly mobile, followed herds of large ungulates, and occupied lower elevation floodplains primarily during dry periods of summer. By the Late Archaic period 2,500 to 5,000 years BP, wetter climates prevailed and forest distribution expanded along drainages in the LGR. At this time both mobile and sedentary people began more intense harvesting of wild seeds and started some small cultivation of plants to supplement hunting and fishing along the Grand River corridor.

Climate and vegetation distribution in north Missouri during the Woodland period, 1,600 to 2,000 BP apparently were relatively similar to 19th century conditions. During this time native villages in the LGR probably became more socially oriented and relied on wild food gathering, hunting, fishing, and small cultivation plots (Chapman 1980, Nelson 2005). Large vertebrate remains found in middens of this period reflect changes in hunting technology, and maize horticulture began to occur in village sites along tributaries of the Grand River and on higher floodplain elevations. The Mississippian period of human occupation in the LGR marks the first evidence of permanent year-round villages and extensive maize agriculture about 900 years BP (Chapman 1980). The sites of maize culture likely were on silt loam prairie terrace locations that did not flood regularly. Indians from throughout north Missouri traded along the Missouri and Mississippi rivers and frequent conflicts among plains bands of people occurred.

In the last 500 years, villages of native people declined throughout the Missouri River drainage as regional conflicts, warfare, and introduction of European diseases decimated native populations. Early explorers of the Missouri River Basin, including Lewis and Clark encountered native people throughout their travels and described the LGR as a vast complex of prairie, floodplain forest, and interspersed bottomland lakes and marshes. GLO surveys in the early 1800s indicated few permanent European settlements or agricultural fields at that time. The GLO notes for the LGR commented on "a complex pattern of small lakes and ponds, wet prairie, meandering creeks that did or did not have bank timber present, and dense forest stands only along the Grand River channel near what is now Swan Lake NWR" (GLO 1817-1840).

French control of the north Missouri region influenced the LGR with scattered camps of trappers, miners, and explorers from the late 1700s through the early 1800s (Wells 1948, Dolin 2010). The earliest and furthest west outpost on the Missouri River, Fort Orleans, established French presence in the area and began to displace native Osage and Missouri Indian tribes. The first European settlers came to the Grand River region in 1817, but extensive settlement did not occur until after 1830 (Boehner 1937). Agricultural activity was restricted to some clearing of trees on natural levees along the Grand River for firewood or dimensional lumber and for small crop fields. Prairie areas, especially the wet floodplain prairie communities were not farmed because farm equipment could not plow or break the dense clay soils. Early settlers also believed that land without trees was less fertile and could not grow good row crops (Boehner 1937). Grazing and timber clearing probably had the greatest impact on the Grand River and its tributary channels until the late 1800s.

After the Civil War, increased settlement of the LGR occurred when railroads were built throughout the area in the 1870s and 1880s (Boehner 1937, Wells 1948). New immigrants laid out farms on ridges and broader prairie uplands and wire fencing established contained grazing areas. Increasing livestock production in the prairie part of the LGR also led to extensive haying and grazing of prairies, including floodplain sites. Improved farm implements facilitated both plowing and hay-cutting on prairies and gradually considerable prairie areas were converted to agricultural production by the late 1880s. Settlement and the need for transport of agricultural and other commodities ultimately led to the construction of an extensive network of roads and rail lines throughout the LGR (Fig. 20).

Increased settlement and agricultural production in the LGR in the late 1880s also eventually led to efforts to improve river commerce and flood protection in the LGR. Beginning in 1835, the Missouri legislature declared the Grand River to be navigable to the Iowa state line, and some modest attempts were made to establish steamboat travel and commerce on the Grand River (MDC 2010a). Little steamboat activity actually ever occurred upstream of Chillicothe, however, and most traffic on the Grand River was arduous because of low water conditions, shoals, snags, and irregular channel configuration and depth. The town of Bedord in Livingston County derived its name from a steam boat of that name that struck a log and was wrecked beyond repair during low water on the Grand River about 12 miles southeast of Chillicothe (Boehner 1937). Large woody debris, including substantial large oak trees also was present throughout the Grand River channel (Guyette et al. 2008). In 1848-49, the Missouri General Assembly

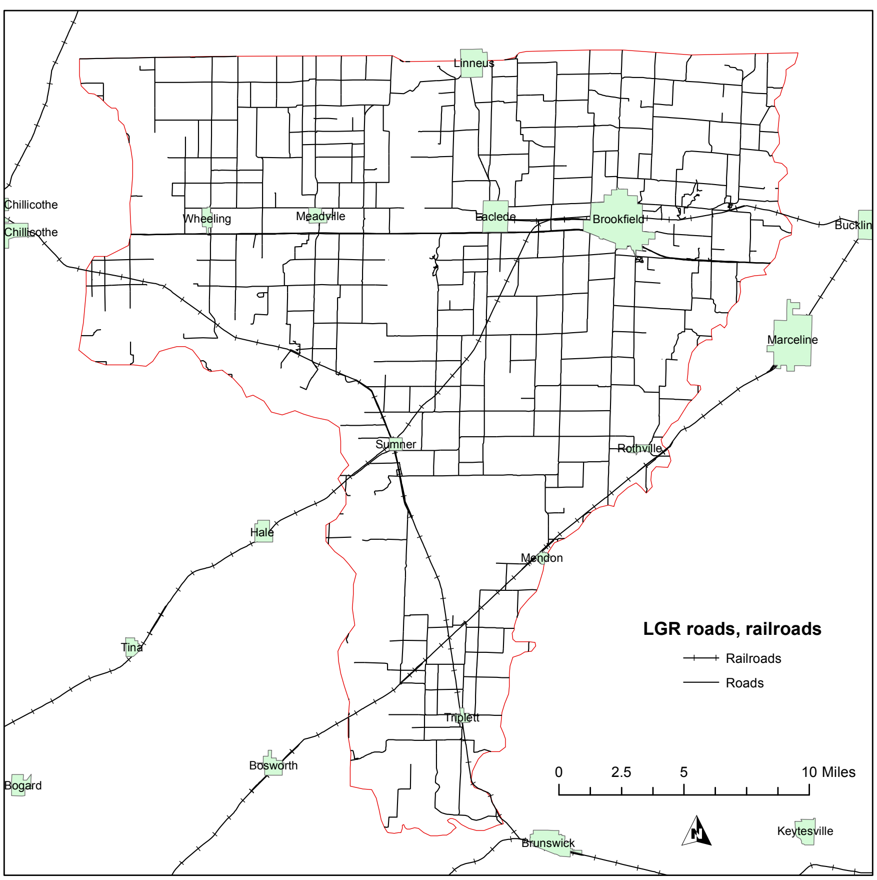

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Figure 20. Roads and railroad lines in the LGR, 2010.

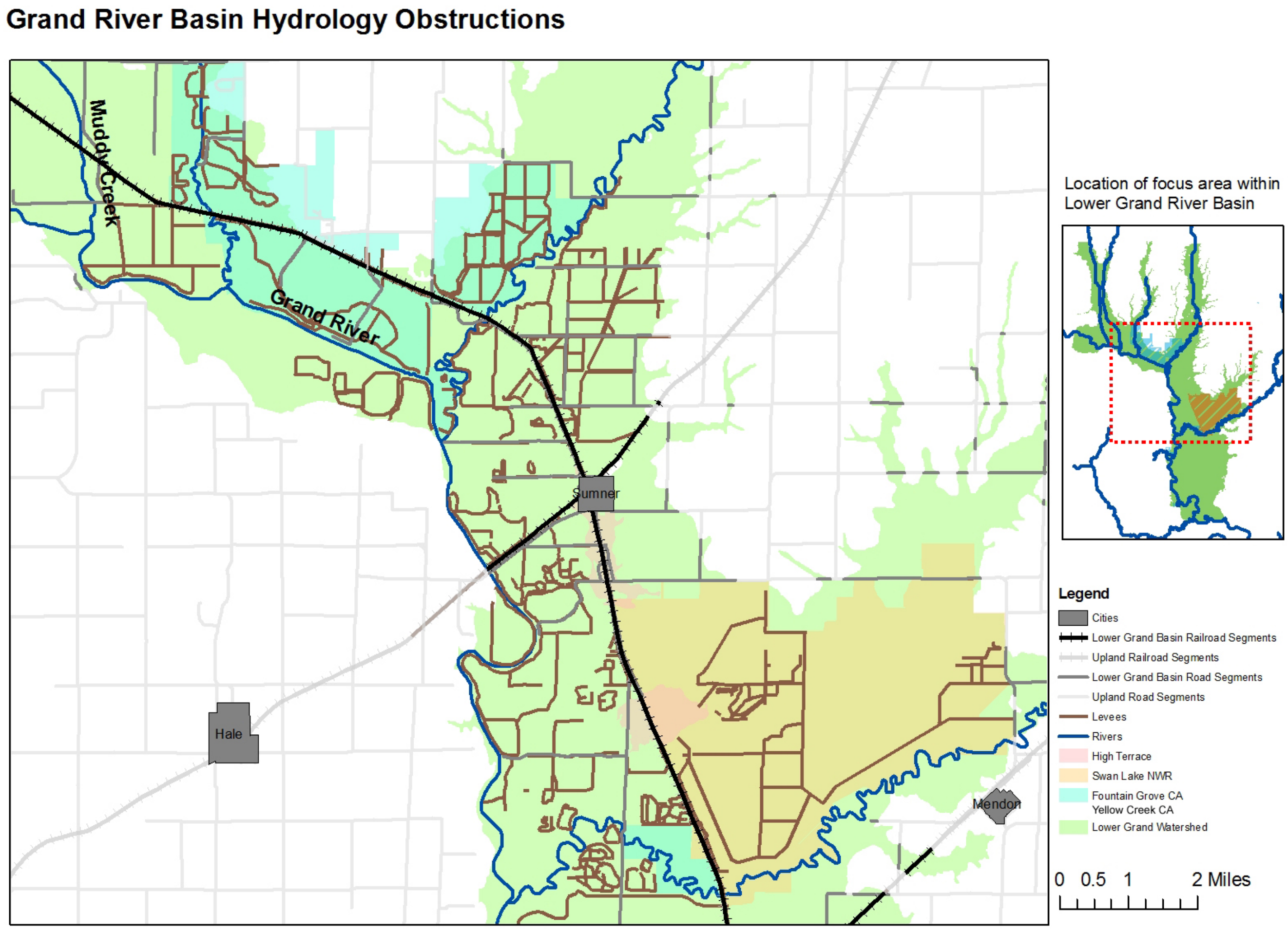

Figure 21. Location of levees that cause obstructions to surface water flows in the LGR.

appropriated $200,000 to improve the Grand River for navigation; most of the activity involved snag removal (Birdsell and Dean 1882). By 1886, portions of the Grand River were being designed for channelization and lined with jetties or rip rap to facilitate the still limited navigation and to improve floodplain areas for potential farming (St. Louis National Historical Company 1886).

In the late 1800s and early 1900s, initial channelization of the Grand River channel using pilot channels was conducted (USACE 1963). By 1915, channelization was common in many reaches of the Grand River, including the area along the south side of Fountain Grove CA, and levee and drainage districts were formed to fund and construct channelization, and eventually levee, projects (Wells 1948). Much early channelization was done in northern parts of the Grand River Basin. For example, in Grundy County, channels were dug in all major rivers and streams by the 1920s (USDA 1990). By 1930, 45 drainage districts had been formed in the Grand River Basin of Missouri and Iowa including many in the LGR.

The Garden of Eden Levee District in the Lower Floodplain zone of the LGR was organized in 1909 and final construction of the large Garden of Eden levee along the east side of the Grand River and the south side of Yellow Creek (Fig. 21) was completed in 1926 (USACE 1932). This levee narrowed the natural flood width of the Grand River floodplain to about 2,700 feet just below the mouth of Yellow Creek (Fig. 22). This district, which encompasses much of the Lower Floodplain and Terrace zones of the LGR, originally contained about 11,200 acres, of which about 1,200 was forest along the Grand River. The ca. 8,000 acres of prairie on the Lower Terrace, dominated by Booker soils (Fig. 8c) was deemed especially valuable farm land to be protected from regular spring floods. Lands between Dean Lake and Brunswick were slightly higher elevation with

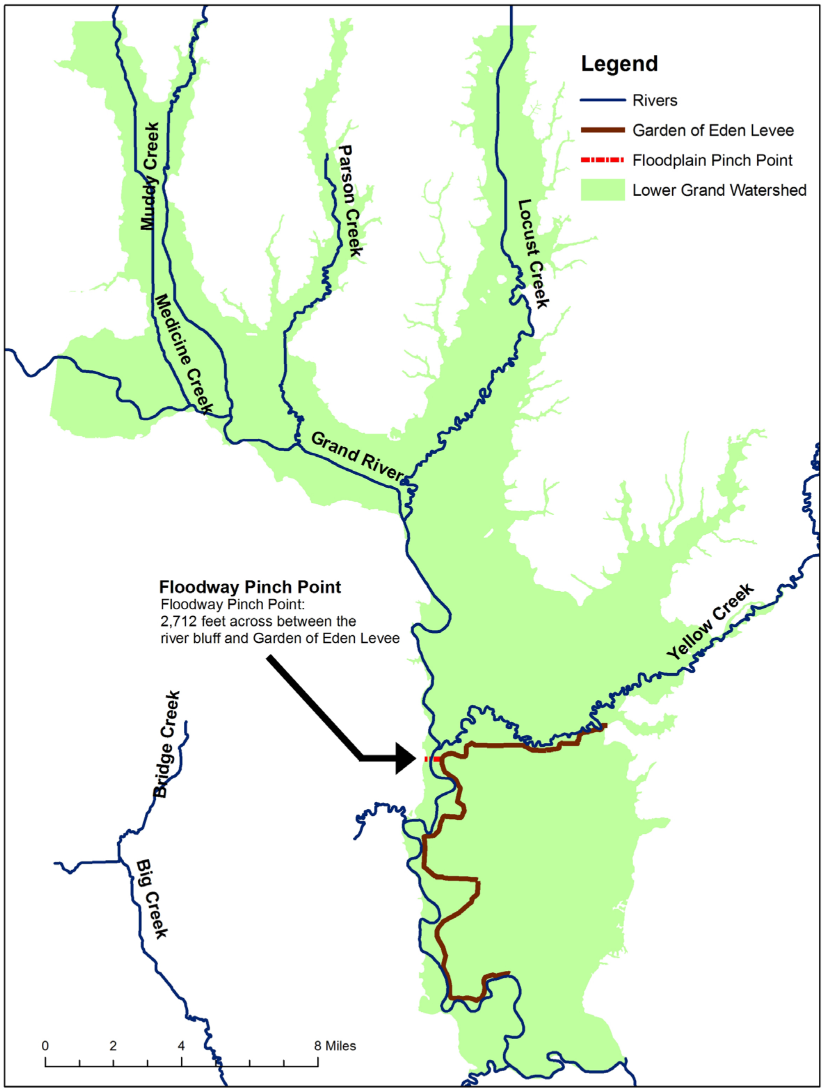

Figure 22. Constriction pinch point in the Grand River floodway caused by the Garden of Eden levee.

more sandy type soils that did not suffer from poor drainage, and these fields quickly became intensely farmed. The Garden of Eden levee was first breached by high flood flows in 1928, repaired in 1929, and broke again in 1930 (USACE 1932). Poor interior drainage within the district continued to occur until the 1930s-40s when interior drainage was improved with tile drains and extensive ditches. Currently, the nearly 12-mile Garden of Eden levee protects about 3,500 acres of farmland from flooding during high flow events of the Grand River (USFWS 2010).

The Whitham Drainage District also was formed in the early 1900s and the Whitham levee located along the south bank of Yellow Creek was completed in 1923, simultaneous with the Garden of Eden levee (USACE 1932). The narrowing of the Grand River and Yellow Creek floodplains from these levees (Figs. 21,22) caused relative rapid rises in flood flows and inundated extensive areas of the southern part of the Middle LGR Floodplain including Swan Lake NWR. The large part of the Middle LGR Floodplain lying north of Yellow Creek and south and east of Sumner was originally included in the old Yellow Creek Drainage District, which was largely inactive until the mid 1900s. Areas along the east bank of the Grand River extending up the east side of Locust Creek were at one time included in the now dissolved (in 1930) Sumner Drainage District.

The large Grand River Drainage District of Livingston and Linn Counties originally had 72,021 acres (68,000 acres tillable) and was organized in 1919 (USACE 1932). The district constructed various structures for protecting overflow floodplain lands, the most common was a system of channelized cut-offs across numerous river channel bends. A total of 35 cut-offs were eventually made that decreased the length of the Grand River from 92 to 36 miles and the average slope of the Grand River increased from 0.6 feet/mile to 1.6 feet/mile. The original cut-offs were excavated to a size sufficient to carry but a small part of the flow of the river and the increased slope and velocity was depended on to further erode the cuts to carry the bank full stream discharge. This self-eroding construction method obviously increased sediment loading and discharge in the river downstream of the cuts. Also, accelerated works of upstream drainage and levee districts greatly increased the volume of water and sediment discharge to the region and coupled with numerous wet years in the 1920s and 1930s resulted in frequent and destructive flooding of the Grand River Drainage District.

The Locust Creek Drainage District was formed in the 1920s and constructed a new channel for 24 miles of Locust Creek with an average fall of 3.7 feet/mile. The length of Locust Creek was shortened by 16 miles and the slope increased from 2.2 to 3.7 feet/mile. While this channelization, including the new Higgins Ditch that was dug to speed drainage during high flow events, did accelerate flood flows from the upper part of the drainage, it also increased overflow and flooding in southern areas upstream from its confluence with the Grand River. The increased flow and backwater effect near the confluence also greatly increased silt deposition in the Locust Creek floodplain and caused the straightened ditch reaches to begin meandering as the creek thalweg moved from side to side of the ditch. By the mid 1900s only two stretches of Locust Creek remained unchannelized, these being a 28.7 mile reach through Sullivan County and the 17.4 mile reach from the confluence of Locust Creek and the Grand River to the north boundary of Pershing State Park (Todd et al. 1994).

Another major drainage district in the LGR was the Medicine Creek Drainage District formed in the early 1900s (USACE 1932). By 1920, the Medicine Creek District had constructed several miles of levees and ditches/channels. Subsequent major construction projects of the District involved creating a new channelized stretch of the creek near Wheeling and numerous cut-offs along the old creek channel below Wheeling. An entire new created drainage channel was constructed along the east side of the Medicine Creek floodplain valley to capture flow from Muddy Creek and other small tributaries entering the district. These new channels effectively "split" Medicine Creek flows for some time until upstream districts were organized and built levees along creeks, and straightened channels that accelerated flows into the southern Medicine Creek region. Ultimately, the uncoordinated drainage district projects practically eliminated the benefits of the Medicine Creek District cut-offs and new channels and actually increased backwater flooding effects from the Grand River.

In addition to the above larger organized drainage districts, many townships and private organizations formed small drainage organizations in the early 1900s in the LGR. Projects of these drainage organizations usually included digging extensive networks of drainage ditches, small stream cut-offs, and modest channelization to move water from uplands to the Grand River floodplain and channel (Funk and Ruhr 1971). Most of these drainage organizations eventually were absorbed into larger districts, but some other areas were retained in private land holding projects.

In summary, by the early 1930s, the extensive and uncoordinated drainage and levee projects within the Grand River Basin had intensified and accelerated water and sediment discharge into, and subsequent overbank backwater flooding, of the LGR, especially in the Middle and Lower Floodplain zones. This increased flooding led to later attempts to control flooding, farm low elevation floodplains, and eventually protect some areas as conservation lands.

LATER LANDSCAPE AND HYDROLOGICAL CHANGES

In 1932 the USACE issued a report on the Grand River in Missouri and Iowa (USACE 1932) and concluded that additional projects and expenditures to improve navigation, increase flood control, and develop irrigation and power sources from reservoir construction and other projects were not justified. This report and the Depression of the 1930s slowed construction of water and flood-control projects in the Grand River Basin and likewise slowed further conversion of remnant prairie and forest in the LGR to agricultural production. The large flood of 1947 caused extensive damage to some drainage/levee district structures and levees and renewed interest in rebuilding levees to higher and wider configuration. Droughts in the 1930s and 1950s also stimulated construction of many ponds/lakes for water conservation and livestock watering throughout the Grand River Basin. About 30 lakes larger than 50 acres currently are present in the Grand River Basin and several hundred 5-10 acre watershed structures have been built on public and private lands in association with PL-566 erosion and water control projects (MDC 2010a).

Despite increased concerns about flooding and drainage, little organized maintenance of earlier constructed ditches, river cut-offs, levees, and water-control structures occurred from the 1950s until the mid 1970s when rising commodity prices and improved farm and construction equipment encouraged land owners to improve or build new flood control structures and clear/convert remnant grassland and forest to row crops. Seven large flood control reservoirs were designed by the USACE for the Grand River Basin in the early 1960s (USACE 1963), but later analyses concluded that the reservoirs and associated channel modifications were not feasible. These projects were subsequently deauthorized in 1989 (USACE 1989) but some support for reauthorization occurred after the large flood of 1993 (MDC 2010a).

While no new large state or federally-supported flood control projects have been constructed in the LGR, the era of the 1970s and 1980s was a time of substantial private levee construction throughout

Table 8. Land use in the Missouri portion of the Grand River Basin in 1987 (S.Baima, USDA-Soil Conservation Service, personal communication).

Watershed	Cropland (Acres)	Forest (Acres)	Pasture (Acres)	Other (Acres)	Total Acres in Watershed
Upper Grand (above Chillicothe)	1,019,600	92,900	574,000	143,600	1,820,100
Lower Grand (below Chillicothe)	730,100	86,200	421,900	37,000	175,200
Thompson	397,600	23,600	202,000	43,200	666,400
Total Acres	2,147,300	202,700	1,197,900	223,800	3,771,700
Percent Land Use Type	60%	5%	32%	6%	

the LGR. Currently, large areas of the Grand River and tributary floodplains have extensive networks of levees to protect specific fields and areas (USDA 1982). Despite recurring floods and regular damage to levees, regional landowners continue to support channelization and levee construction. For example, the local channelization of river/creek channels in the LGR is extensive (Fig. 23). Since 1915, about 50 organized drainage districts and 10 privately-financed organizations have spent more than $10 million on channel straightening, drainage facilities and structures, and levees to protect about 385,000 acres of land.

In the 1970s, a reservoir was proposed on Locust Creek near Milan to support a coal gasification plant. While this reservoir was not built, in 1990 the same 5,800-acre lake was proposed again for water supply and recreation. Sufficient funding was not obtained for construction of the lake, but some local interest remains in building the lake which would inundate several miles of the unchannelized Locust Creek and alter downstream flows.

By 1987, 60% of the Grand River Basin in Missouri had been converted to agricultural cropland (Table 8, Fig. 24). Another 32% of the Basin in Missouri was converted to non-native pasture and hayland. Total acreage of harvested row crops has declined slightly in the Grand River Basin since 1945 with general increases in soybean, and decreases in corn, production (Fig. 25). Detailed documentation of remnant historic LGR communities (compared to ELTs modeled in Fig. 17) in the LGR is not available, but National Wetland Inventory data and maps indicate that most remnant forest and bottomland prairie/marsh habitats are located in floodplains along the Grand River, Locust Creek, and Yellow Creek (Fig. 26). An example of extensive land community changes is demonstrated by comparisons of the Turkey, Elk, and Yellow Creek watershed draining into Swan Lake NWR between historic and current periods (Fig. 27). Almost no mesic-type prairie remains in the LGR except for a few scattered

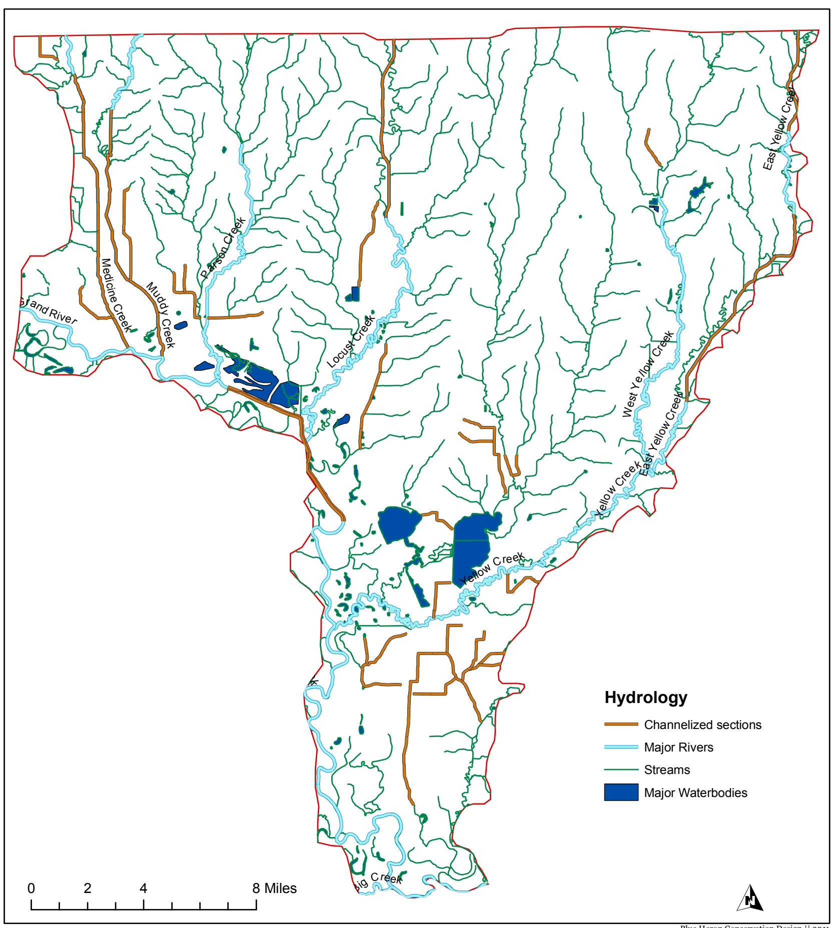

Figure 23. Major streams and ditches in the LGR indicating areas where extensive channelization has occurred.

patches on Swan Lake NWR and Pershing State Park.

Remnant forest in the LGR also appears to be shifting toward wetter-type communities compared to prior conditions. Sampling of select forest tracts near Sumner in 2010 (Fig. 19) was not random and did not conduct a systematic inventory of all forest indicators (e.g., Heitmeyer et al. 2004), however, the observational data obtained did indicate that both Floodplain Forest and Floodplain Woodland communities now contain up to 60% composition of water tolerant species such as green ash, silver maple, sycamore, cottonwood, and black willow and < 30% pin oak, bur oak, and pecan (Table 9). These floodplain forest/woodland communities probably historically had a much higher composition of oak and pecan (e.g., Nelson 2005).

The apparent changes in forest composition in the LGR most likely have been caused by the continued trend of wetter conditions in the lower Grand River ecosystem from combined upstream and local flood control and drainage projects, conversion of forest and prairie to cropland, and climate change (Tomer and Schilling 2009). Analyses of long term climate and river discharge data for the region indicate that the amount of surplus water available to be discharged into the LGR as streamflow in the Grand River and its major tributaries has increased and as humidity as also increased, the fraction of evaporative demand has decreased causing wetter hydroperiods for the region.

Changes in discharge of the Grand River were assessed by comparing flow data from two 40 year periods, 1930-69 and 1970-2009) at Sumner. Flow duration curves (Fig. 28) indicate that the discharge of the Grand River has been higher during the latter period. The curves converge for the infrequent, high discharge days, which correspond to flooding events. Spell analyses were conducted on the two 40 year periods to compare the frequency, duration, and timing of days above thresholds corresponding to the recurrence interval events calculated for the entire period of record (Table 10). For high frequency discharge events (0.25 to 2 year recurrence interval) there was a significant increase in the number of spells, but no real change in the average duration of individual events (Table 10). Most of the increase in spells occurs due to events occurring between March and July with 20 or fewer days between events and is consistent with increased precipitation and antecedent moisture. This is illustrated using the 55,000 cfs threshold corresponding to the 1-year recurrence interval (Fig. 29). No difference occurred in the 5-year recurrence interval between the two periods as the interval between events for the 15 spells throughout the period of record is as likely to be < 90 days as it is to be more than 10 years.

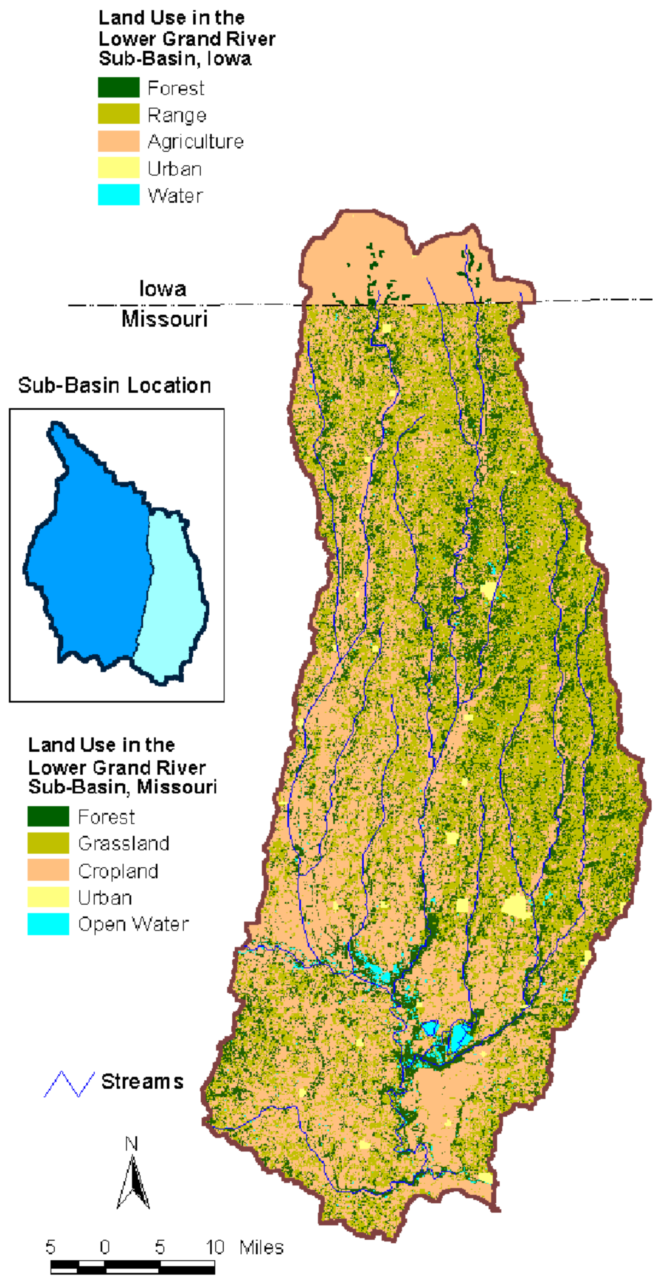

Figure 24. Current land use in the Grand River Basin of Missouri (from MDC 2010a).

Conversion of terrace prairies to extensive row crop agriculture, especially soybean production, clearing of floodplain woodlands and forests, and construction of uncoordinated drainage and levee projects throughout the Grand River Basin increased

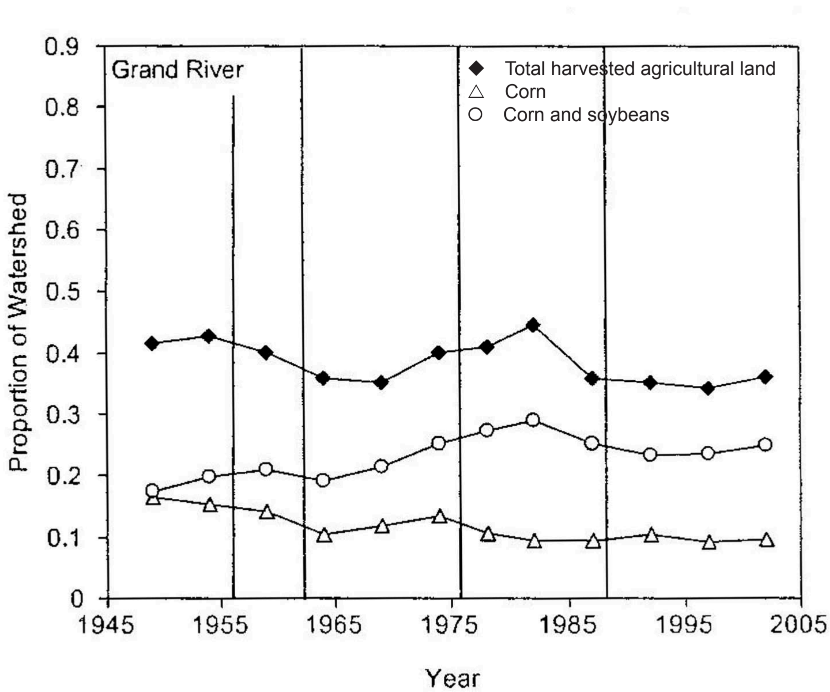

Figure 25. Changes in crop acres in the Grand River Basin 1945 to 2005 (from Tomer and Schilling 2009).

total water and sediment discharge into the LGR (MDC 2010a). Sediment surveys on Fountain Grove CA and Swan Lake in the 1970s and 1980s documented sediment accumulation of up to 2 feet and loss of 52-72% of water storage volume from sediment filling of floodplain depressions and wetlands since their original state (Aesco, Inc. 1980). The average volume of Silver Lake on Swan Lake NWR has decreased about 25% since 1983 from sediment deposition carried into the lake by Turkey and Elk creeks (USFWS 2010).

The row crop dominated landscape in the LGR and surrounding uplands also contributes runoff into the LGR that contains residue from pesticides, herbicides, and fertilizers that have been used on the fields in the watershed (MDC 2010a). Pesticide re-deposition also is well documented in northern Missouri from volatilization and wind erosion. Contaminants surveys on Swan Lake NWR in 1993 documented potential contamination problems from dieldrin, chlordane, copper, chromium, manganese, and zinc (USFWS 2010). Eutrophication of LGR wetlands from increased nutrients from nonpoint source pollution (such as confined animal facilities and heavy use of nitrogen and phosphorus in farm fields) in the LGR also is a concern (MDC 2010a, USFWS 2010).

Table 8. Acres of various land uses in the Missouri portion of the Grand River Basin in 1987 (from MDC 2010a).

Watershed	Cropland (Acres)	Forest (Acres)	Pasture (Acres)	Other (Acres)	Total Acres in Watershed
Upper Grand (above Chillicothe)	1,019,600	92,900	574,000	143,600	1,820,100
Lower Grand (below Chillicothe)	730,100	86,200	421,900	37,000	175,200
Thompson	397,600	23,600	202,000	43,200	666,400
Total Acres	2,147,300	202,700	1,197,900	223,800	3,771,700
Percent Land Use Type	60%	5%	32%	6%	

CONSERVATION LANDS PROTECTION AND MANAGEMENT

The LGR contains about 40,000 acres of fee-title and easement lands managed for conservation purposes. Nearly 18,000 acres of these lands are privately-owned WRP tracts protected and restored to wetlands, primarily along the Grand River and Yellow Creek (Fig. 30).

Other larger public lands include the 10,670-acre Swan Lake NWR, 7,154-acre Fountain Grove CA, 618-acre Yellow Creek CA, and 3,565-acre Pershing State Park. In addition to these protected conservation lands, another ca. 3,000 acres are in private hunting clubs/recreational properties without conservation deed restrictions. Certain additional public land acquisitions and WRP easements currently are proposed for the LGR.

Acquisition, development and management history of conservation lands in the LGR are provided in several documents (e.g., MDC 1963, 1983, 1989, 1998a, 2010b; USFWS Swan Lake NWR unpublished annual narratives 1938-2000; USFWS 2011; and MDNR 2010). Key management actions and developments for respective properties are provided below:

Swan Lake NWR. — Swan Lake NWR was established through Executive Order by Franklin D. Roosevelt in 1937. This NWR was the first conservation land acquisition in the LGR and its authorizing purpose was to be "as a refuge and breeding ground for migratory birds and other wildlife", "for use as an inviolate sanctuary, or for any other management purpose, for migratory birds", and "… particular value in carrying out the nation migratory bird management program" (USFWS 2010). In 1938, the Civilian Conservation Corps began work on levees to impound the waters flowing into the refuge from Elk Creek, Turkey Creek and Tough Branch. These levees and associated water control structures

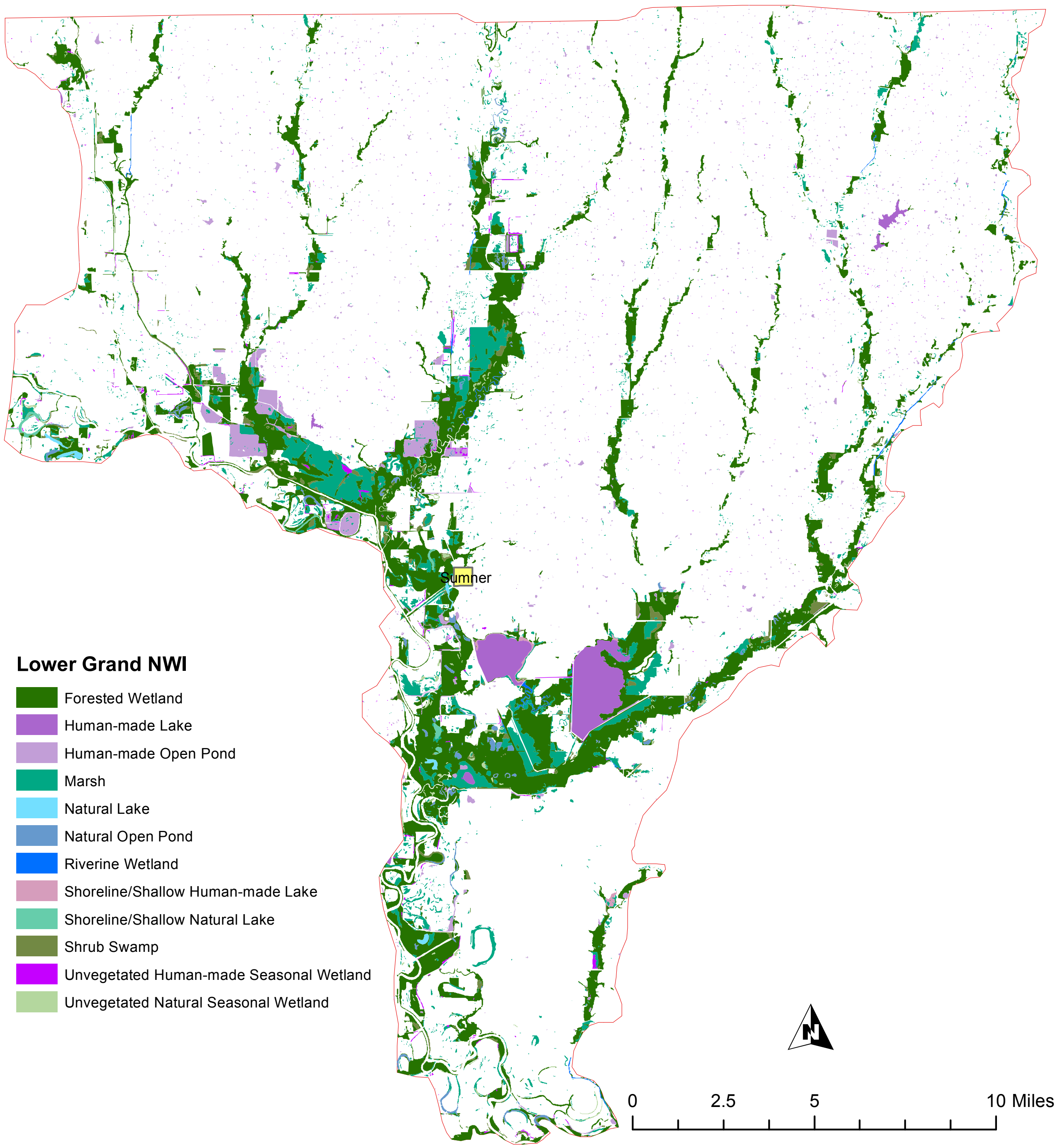

Figure 26. National wetland inventory map of wetland types in the LGR.

Table 9. Mean percentage composition of trees on 18 sample plots in the Lower Grand River Region near Sumner, Missouri, 2010 in relation to early land type (ELT) community type (Fig. 15) and historic relative composition extrapolated from botanical information in Nigh and Schroeder 2002 and Nelson 2005).

ELT Community Type and tree species	2010 Composition	ELT Historic Composition[a]
Floodplain Forest		
Pin oak	20%	50%
Pecan	15%	20%
Green ash	15%	<5%
Silver maple	20%	TR
American elm	5%	10%
Box elder	3%	< 5%
Black willow	8%	TR
Sycamore	2%	TR
Cottonwood	2%	TR
Swamp white oak	1%	TR
Bur oak	1%	5%
Locust	1%	TR
Hickory	5%	5%
Sugarberry	<1%	TR
Floodplain Woodland		
Pin oak	10%	50%
Pecan	20%	25%
Green ash	10%	TR
Silver maple	30%	TR
American elm	5%	< 5%
Box elder	8%	< 5%
Black willow	10%	TR
Sycamore	1%	TR
Cottonwood	<1%	TR
Bur oak	2%	10%
Locust	1%	TR
Sugarberry	<1%	TR

[a] TR – only trace, occasional trees of this species were present.

were completed in 1942 and created the 2,387-acre Silver Lake water storage impoundment, and the Swan Lake and South Marsh wetland management units/impoundments (Fig. 31). Silver Lake was constructed primarily to capture and hold water that then could be released or diverted via a series of ditches and natural drainage channels into Swan Lake and the South Marsh to provide flooding capability and wetland habitat for waterfowl in fall and winter.

Since its establishment, habitat management on Swan Lake NWR has consisted of water level manipulation to create seasonal herbaceous, persistent emergent, and shrub/scrub wetlands; maintain open water storage reservoirs; support agricultural production on high non-flooded terraces, maintain some scattered grassland (tame and native communities) tracts, and provide managed public hunting/fishing opportunities. From 1937 to 1948, less than 1,000 acres of high elevation land on the NWR were farmed through cooperative agreements with neighboring landowners on a sharecrop basis. As Canada goose numbers on the refuge increased in the 1940s and 1950s, farming was increased to nearly 2,700 acres in row crop and small grain production by 1961 (Vaught and Kirsch 1966). About 1,300 acres of this farmland was at higher elevation rarely flooded and these lands were primarily corn with small amounts of soybeans. The remaining 1,400 agricultural acres were used mainly for browse crops such as grasses, wheat, and clovers. Perimeter cropland on the NWR was managed cooperatively by MDC and the USFWS, while other NWR croplands were either farmed by refuge personnel or by permittee farmers. As Canada goose numbers declined on the refuge in the 1980s and 1990s, the cropland acreage on the NWR decreased to about 1,365 acres at present (USFWS 2011).

Currently, about 800 acres of Swan Lake NWR are in active moist-soil management, primarily in the South Marsh area (Fig. 31). Swan Lake proper is primarily managed as an emergent marsh and is periodically manipulated with water management, soil disturbances, and fire to enhance waterfowl food production plants. The NWR has 5 primary grassland units (920 acres) that are burned every 3-5 years to reduce woody cover and organic matter to encourage growth of native grass and forbs. Reed canary grass invasion on the refuge is treated to some extent with chemicals, fire, and tillage. Forests on the refuge currently are not managed. The 1,000-acre Yellow Creek Research Natural Area was established on the refuge in 1973 and includes remnant stands of mature floodplain forest.

Water and habitat management on Swan Lake NWR has been confounded since its inception by frequent and extensive flooding from backwater of the Grand River and Yellow Creek. The backwater flooding is exacerbated by the constriction in Grand River drainage caused by the Garden of Eden and Yellow Creek levees. During high flow events over 90% of refuge lands become inundated. Frequent floods have continued to cause damage to water-control infrastructure on the refuge and prohibited water level management desired for habitat objectives in many years.

Future habitat management plans for Swan Lake NWR will be developed to implement the broad goals and objectives identified in the current CCP (USFWS 2011). Key habitat objectives proposed under the CCP include efforts to:

- Mimic components of historic hydrologic function along reaches of Elk Creek, Turkey Creek, Tough Branch, and Yellow Creek and restore surface water sheetflow across the refuge.

- Manage about 800 acres of moist-soil habitat in 13 impoundments/units.

- Manage seasonally- and annually-variable water levels in Silver and Swan Lakes to maintain a dense mixture of native aquatic and wetland plants including emergent and submergent vegetation.

- Provide 300-500 acres of shrub/scrub habitat.

- Gradually convert a portion of existing cropland, early succession forest, and sites dominated by reed canary grass to wet meadow and wet mesic prairie habitat.

- Manage about 1,000 acres of existing native upland terrace-type prairie.

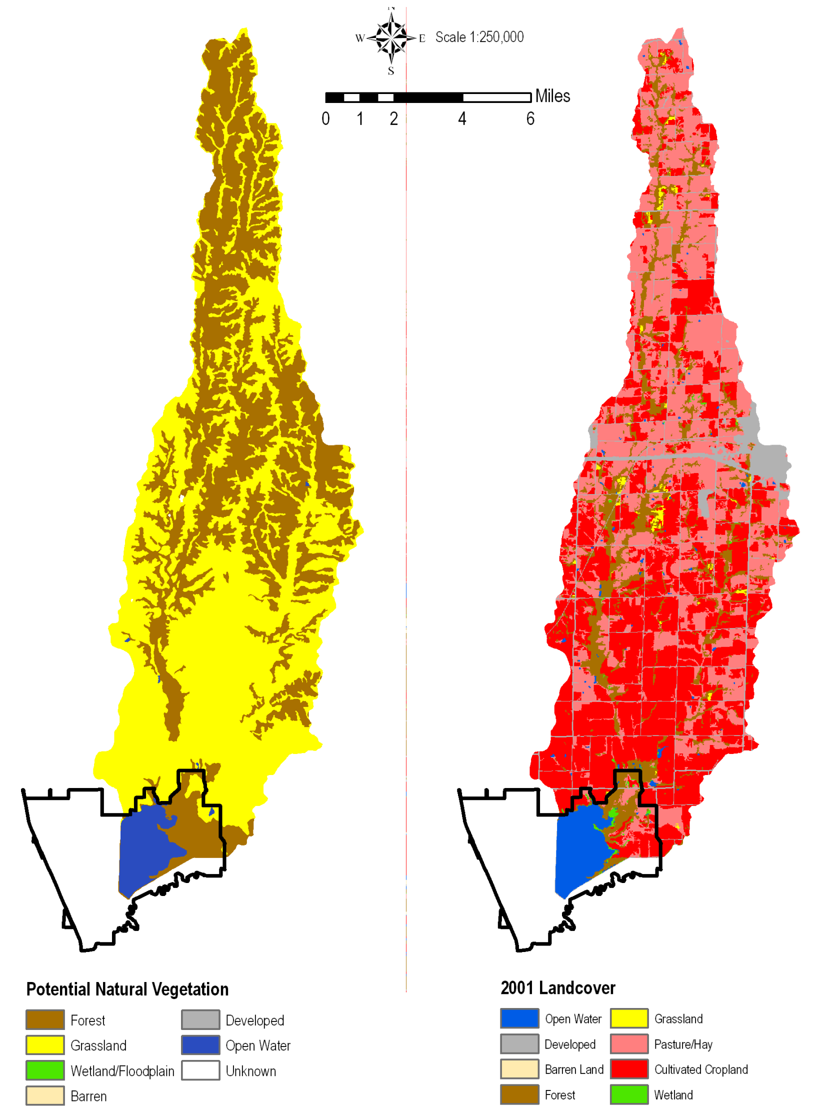

Figure 27. Comparison of potential natural vegetation and 2001 land cover in the Elk, Turkey, and Yellow Creek drainages above Swan Lake National Wildlife Refuge (from USFWS 2010).

- Maintain about 400 acres of cropland on higher elevation lands that rarely flood.

- Sustain about 3,100 acres of floodplain forest

- Quantify water needs and available water sources to meet the above management objectives and improve water quality.

Key wildlife objectives included in CCP alternatives include efforts to:

- Determine the role Swan Lake NWR plays in supporting populations of Indiana bat.

Table 10. Number of spells (events in excess of threshold values) and average duration of spells for two 40 year periods using average daily discharge for USGS Gage #06902000. Thresholds based on recurrence intervals calculated for Water Years 1925-2009.

Period of Record Recurrence Interval	Water Years 1930 to 1969		Water Years 1970 to 2009	
	Spells	Average Duration	Spells	Average Duration
(years)	(n)	(days)	(n)	(days)
0.25	110	4.1	183	4.0
0.5	55	3.4	96	3.5
1	27	3.2	60	2.8
2	18	2.4	25	2.6

- Manage habitats for key migratory and resident birds, especially waterbirds.
- Provide habitat for eastern massasauga rattlesnake.

Fountain Grove CA — Fountain Grove CA was the first waterfowl/wetland management area acquired and developed by the MDC (MDC 2010b). Acquisition and development was initiated in 1947-48 with an initial purchase of 3,433 acres. The original purpose of the area was to be a "public shooting grounds for waterfowl hunting" with management of the area's wetlands directed to support migratory populations of duck and geese. As Canada goose populations increased in the Swan Lake NWR area, MDC subsequently acquired 2,405 acres to expand Fountain Grove CA between 1948 and 1975 to enhance wetland habitats and to provide opportunity for Canada goose management and hunting. An additional 1,316 acres were added to the CA between 1978 and 1992 with general revenue including MDC Design for Conservation sales taxes monies to construct wetland developments on the east side of the area and to acquire key in holdings to enhance management opportunities for Canada geese (Mengel 2001).

Fountain Grove CA was originally developed into three large "pools", known as Pools 1-3, to be supplied with water from Parson's Creek along the west boundary of the area (Fig. 32). Approximately 1.5 miles of Parson's Creek were channelized by MDC and a water-control structure was placed across the creek so that runoff could be directed to the area. Filling the pools required running this water through Pools 1 and 2 to fill Pool 3, closing the Pool 2 structure to allow it to fill, and finally closing the Pool 1 structure to allow it to fill. The pools were generally not completely drained, and water levels were maintained at various elevations among pools to enhance smartweed production (Crail 1951), sustain pin oaks in pools, and support wild millet or planted Japanese millet.

Parson's Creek ultimately proved to be an unreliable water source, and in 1960 a water supply investigation concluded that a pump station, to be located on the Grand River, would be required to deliver water to the wetland pools in August and September. Subsequently, a pump with a capacity of 13,500 gallons/minute was located on the north bank of the Grand River adjacent to Pool 2 in 1962. This pump moved water through Pool 2 to flood Pool 3, and then water backed from Pool 2 into Pool 1 in sequence to an elevation of 664 feet amsl. Later a crisafulli pump moved water from Pool 2 into Pool 1. Subsequently, the "H" and "J" wetland pools along Parsons Creek on the northwest part of the area were developed and water was moved to these pools by pumping water from Pool 1 using a crisafulli pump. All of the wetland units drained through Pools 1-3, with the primary water control structure located in Pool 3.

An unforeseen consequence of the original area design was that the channelized Parsons Creek section and inlet structure became a high flow channel during flood events. Large flows of water moved onto the CA when Parsons Creek was at flood stage and flood flows deposited large quantities of sediment onto the area, especially in Pool 1, and it also caused scouring adjacent to and across from the main outlet for the Pool 3 drain structure. In 1999, the water-control structure on Parson Creek was removed, low water crossings that formed the Parsons Creek inlet were replaced with screw gates, and a "training" levee was constructed parallel to Parsons Creek to reduce flood flows and sediment deposition in Pools 1-3. These changes reduced the headwater flooding effect of Parsons Creek flows and creates more of a backwater flooding scenario when discharge in the creek and the Grand River are high.

In the 1980s and 1990s, land acquired on the East Side of the CA were developed into a series of wetland impoundments by constructing levees, water-control structures, and Che-Ru lake, a 160-acre reservoir that provides a water supply for about 1,200 acres in wetland impoundment "pools." Two electric pumps move water drained from Pool 3 into Che-Ru. A distribution channel moves water from Che-Ru directly into 10 separate pools and another three East Side pools are flooded by running water through another pool. Water for the northern East Side pools is supplemented by Bittern Marsh, another water supply reservoir. Most of the East Side pools can be flooded independently, but are interrelated during drawdown events. The main drain for the East Side wetlands is located in the southeast corner and discharges into Locust Creek. Che-Ru is recharged during spring drawdowns with water discharged from Pool 3 and by spring rains.

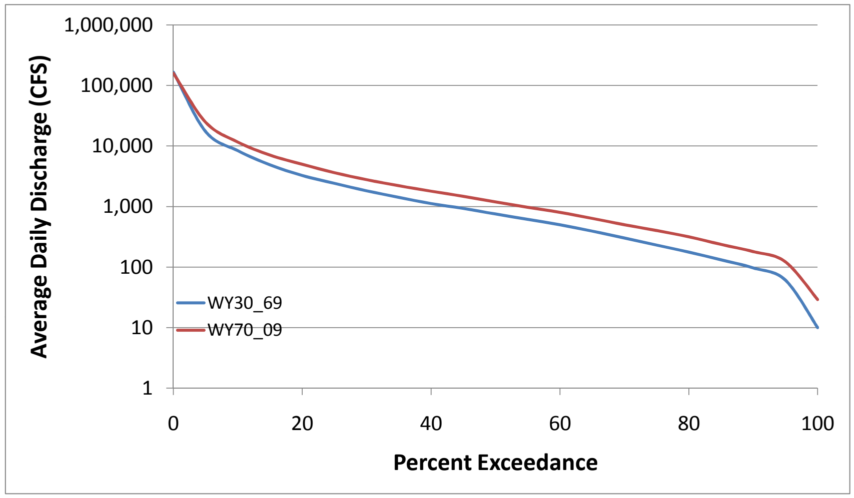

Figure 28. Flow duration curves of average daily discharge in the Grand River near Sumner, MO for Water Years 1930-69 and 1970-2009 for USGS gauge #06902000.

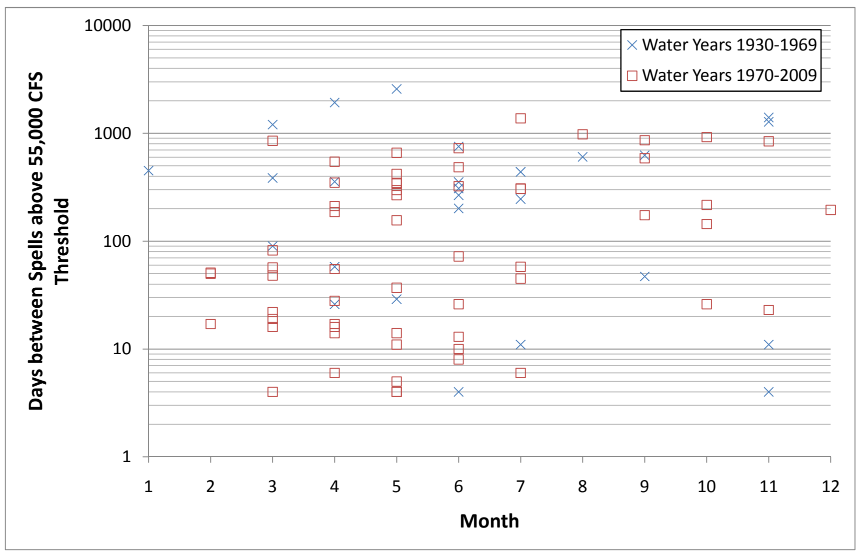

Figure 29. Occurrence of events with average daily discharge in the Grand River near Sumner, MO in excess of 55,000 cfs, shown by month for Water Years 1930-69 and 1970-2009 for USGS gauge #06902000.

Developments on Fountain Grove CA since 2005 have attempted to improve water and sediment management issues in Pools 1-3 and the Parsons Creek impoundments by replacing various water-control structures, constructing and moving select levees, improving drainage capability, and eventually replacing the primary pump station on the Grand River.

The emphasis for habitat management on Fountain Grove CA has changed over time in relation to perceived energetic needs of Canada geese, supporting diverse wetland associated species, sediment management, and Grand River wetland functions and values (MDC 1963, 1983, 1989, 1998). Management of the area has been, and remains, highly influenced by Grand River flows, sediments, and flood events. Sediment deposition on the area has decreased in recent years, but past deposition, filling of wetland pools, and continued construction of levees and water-control structures both constrain and enhance management capabilities.

Pershing State Park — The first land tracts acquired for Pershing State Park were made in 1937 to protect areas along the Locust Creek floodplain that were frequented by General John J. Pershing as a boy (MDNR 2010). The park includes a portion of Locust Creek that is unchannelized and includes diverse remnant areas of floodplain forest and woodland and the largest remaining tract of bottomland prairie in the LGR. Abandoned channel oxbows of Locust Creek are present in the park and an area along the creek is designated as a Missouri Natural Area (Fig. 33).

As a state park, the area was gradually developed to enhance public camping, hiking trails, vehicular access, day use facilities, and picnic shelters. Habitat management on the park was

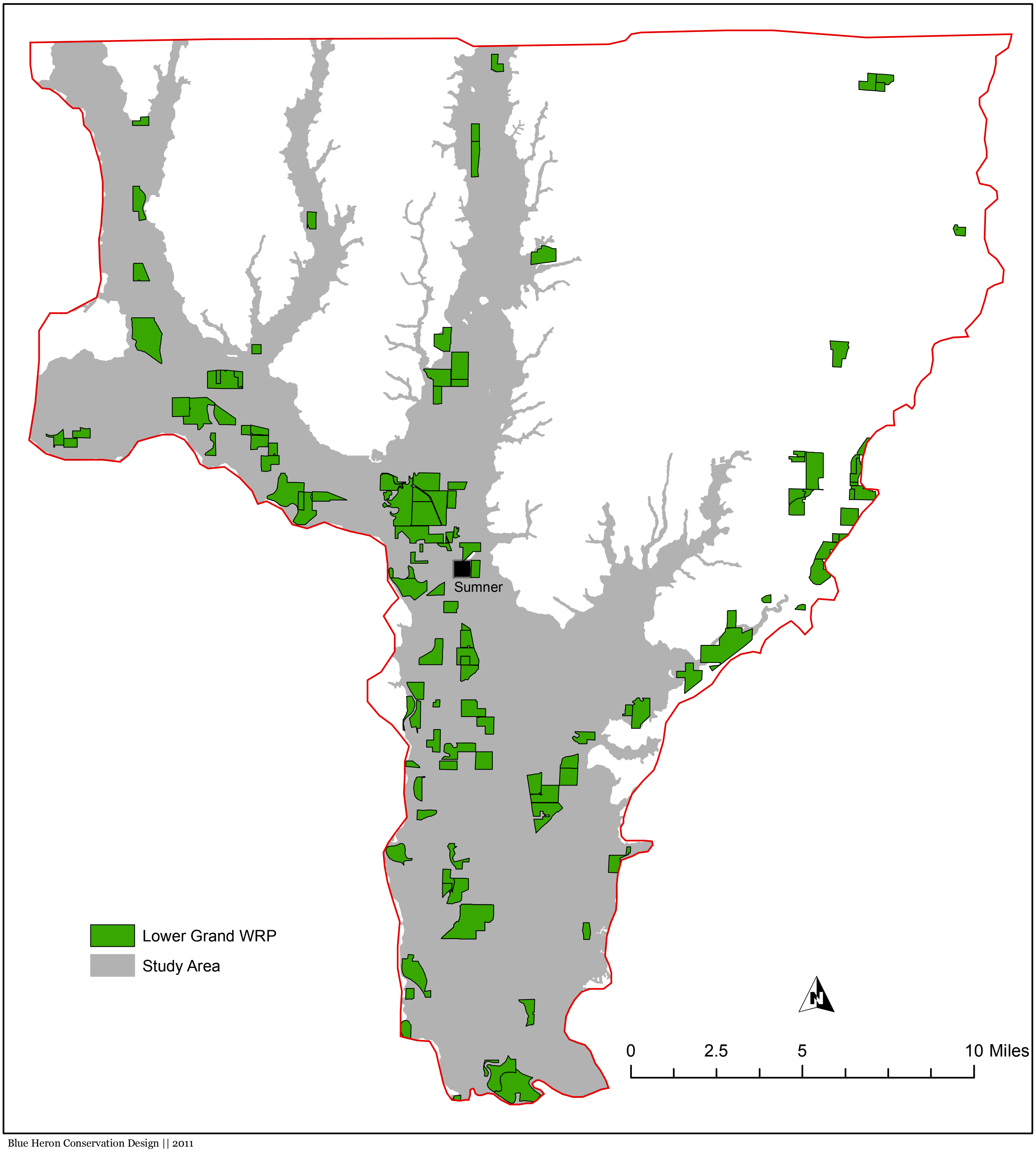

Figure 30. USDA Wetland Reserve Program easement tracts in the LGR, 2010.

largely related to protection and interpretation of the natural resources along Locust Creek. Certain small water-control structures have been constructed in the park to allow seasonal water management of some wetland areas. Fire and mechanical disturbance have been used to maintain areas of wet bottomland prairie.

Development goals for the park are directed at protecting the remnant native communities, especially wet mesic prairie and floodplain forest, providing public recreation and use facilities that are compatible with preservation of natural resources, and improving interpretive facilities. Several land acquisition opportunities have been identified to expand the park boundaries, increase watershed protection on Locust Creek, and prevent Higgins Ditch from further pirating Locust Creek flow. Management actions on newly acquired lands would help reduce drainage from Locust Creek into Higgins Ditch and help sustain the regular seasonal sheetflow that supports prairie, forest, and oxbow habitats on the park (Fig. 33).

WRP Easement Lands - Since 1985, over 50,000 acres of land have been enrolled in WRP in Chariton, Linn, Carroll, and Livingston counties in the LGR area. About 18,000 acres, in nearly 60 individual tracts currently are in WRP easements in the LGR (Fig. 30, Table 11). Development and management of these WRP properties varies among tracts, but typically has attempted to develop water management capabilities through construction of small levees, water-control structures, and restoration of natural topography coincident with restoration of native vegetation communities including wet mesic prairie, floodplain forest and woodland, emergent marsh, and seasonal herbaceous marsh. Some minor tree plantings have occurred on select WRP tracts, primarily with pin and bur oak. A few WRP tracts have removed exterior levees, ditches, roads, and berms to expand floodways and allow more natural patterns of sheet and floodwater flows. Wetland plans of operation are written for each property to direct water and vegetation management to targeted objectives.

Many early WRP developments were minimal and consisted only of small levees or water-control structures and select vegetation

Table 11. Acres of Wetland Reserve Program (WRP) land in the four ecological subsections of the Lower Grand River Region (data provided by Missouri Natural Resources Conservation Service).

LGR Subsection	Acres
Upper Tributary Floodplain	1,614.78
Middle Grand River Floodplain	9,555.30
Lower Grand River Floodplain	2,660.20
Lower Basin Terrace	4,077.70

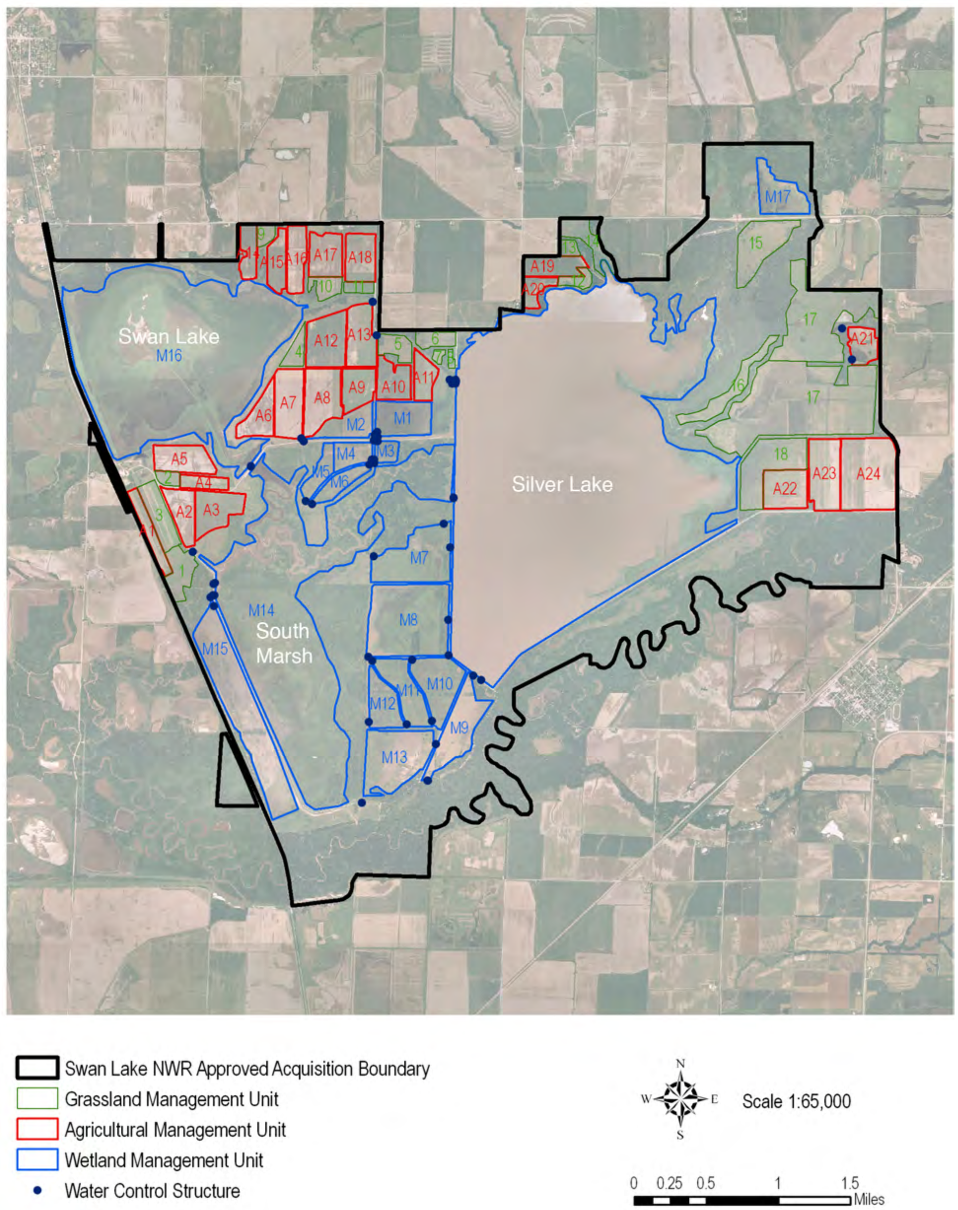

Figure 31. Major wetland areas on Swan Lake National Wildlife Refuge (from USFWS 2011).

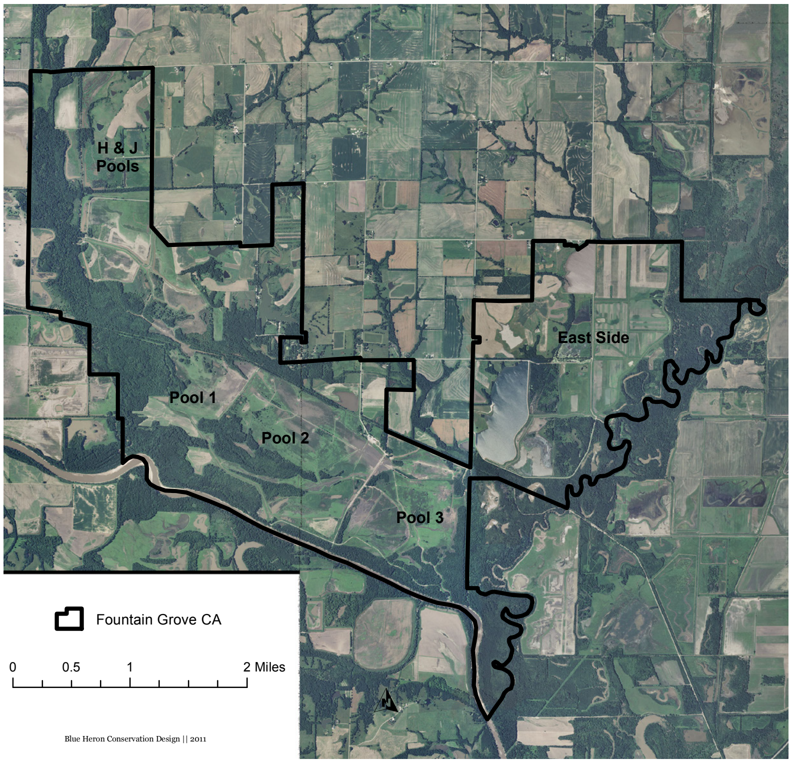

Figure 32. Major wetland areas on Fountain Grove Conservation Area (MDC 2009).

establishment. More recent developments have attempted to restore natural topographic features of sites, expand floodplains and improve natural patterns of water flow, and restore or protect native vegetation communities and distribution related to HGM land attributes, especially communities that have been highly lost or degraded including wet mesic prairie.

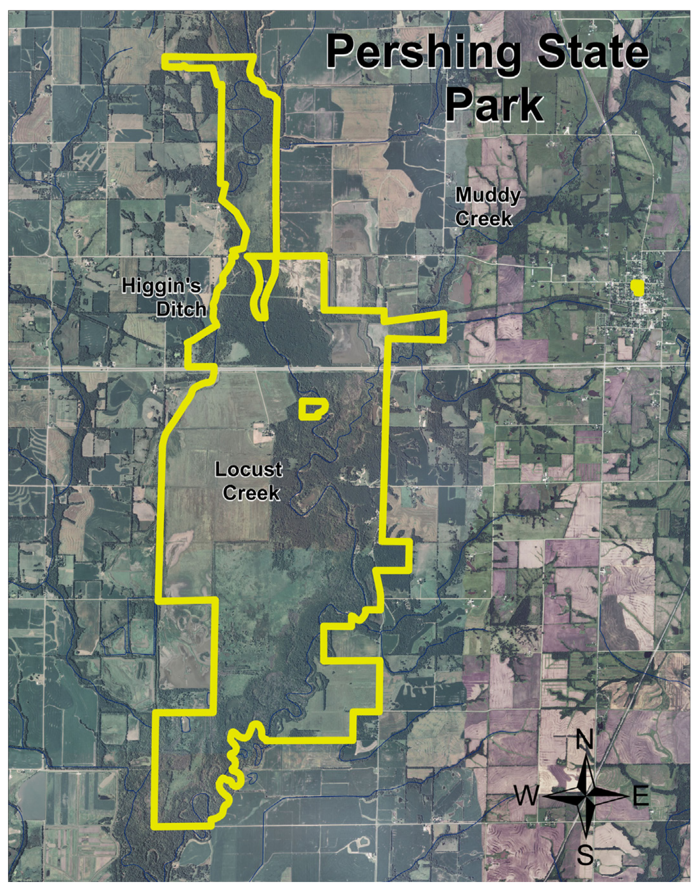

Figure 33. Major landscape features of Pershing State Park (MDNR 2010).

RESTORATION AND MANAGEMENT OPTIONS

A SUMMARY OF CONDITIONS

This study summarizes the HGM data that is currently available for the LGR and provides analyses and spatial modeling of the historic and current ecosystem conditions, including the amount and distribution of communities and the primary ecological drivers for the system. Certain HGM information such as detailed mapping of flood recurrence elevations for the entire LGR are not available and undoubtedly, obtaining this information in the future will refine understanding of community relationships and ecosystem alterations. Nonetheless, most HGM information needed for analyses were present for the LGR and these data provide the foundation for identifying future ecosystem restoration and management options given the considerable alterations to the region.

Historically, the LGR was a highly diverse and productive ecosystem where more stable mesic prairies that were present on glacially-derived terraces merged with temporally dynamic floodplains that contained heterogeneous mixtures of forest, woodland/savanna, wet bottomland prairie, and relict oxbows and river/creek channels. This unique complex of habitat types created a mosaic of vegetation and aquatic resources that were used by many fish and wildlife species. The central geographic position of the large north-south Grand River Basin that narrows into the LGR made the region a natural "funnel" for movement of water and nutrients and also was a major corridor of movement, and stopover area, for migratory birds, fish, and other migratory animals. Furthermore, the local funnel effects of numerous tributaries draining prairie uplands into the LGR floodplains provided local corridors of movement and diverse resources that supported populations of resident mammals, amphibians and reptiles, fish, and birds that used both prairie and floodplain habitats.

Many systemic changes have occurred throughout the Grand River Basin, and both local and watershed-wide land and hydrological changes have affected the capability of the LGR to support historic communities and resources, ecosystem functions and values, and contributions to continental animal populations. The most notable, and damaging, changes have been alterations to the seasonal and long term hydrology of the LGR and conversion of large amounts of native communities, especially prairie, to agricultural production. To some degree, public lands have provided a "core" of land and resources to sustain LGR functions and values, but management of these public lands has been constrained by numerous physical, hydrological, and social issues. Resource managers are challenged to recognize the system attributes that can be changed and how management actions will affect short and long-term restoration options. Key summary data and observations in this study are:

1. The LGR is located in the southern Grand River Basin within the Central Dissected Till Plains ecological section of Missouri that drains and slopes toward the Missouri River. Pleistocene loess covers much of the glacial till on terraces and uplands of the region.

2. The LGR contains remnant glacial-derived terraces and more recent Holocene floodplains of the Grand River. Major tributaries to the Grand River in the LGR include Medicine, Parson's, Locust, and Yellow creeks. The very southern part of the LGR represents the confluence of the Grand and Missouri rivers. Four ecologically distinct zones (Upper Tributary Floodplain, Middle Grand River Floodplain, Lower Grand

River Floodplain, and Lower Basin Terrace) are present in the LGR.

3. Soils in the LGR are mostly alluvium derived from glacial drift and loess; local soil characteristics are determined by stage of weathering and vegetation under which the soils formed.

4. The topography of the LGR was created by the historic glacial geomorphology of the Central Dissected Till Plains and subsequent reworking of landforms by fluvial dynamics of the Grand River and its tributaries. Upper portions of tributary drainages have relatively narrow, more incised, channels and floodplains while southern floodplains are wider and contain numerous relict and recent meandering channels and oxbows.

5. Average annual precipitation in the LGR is about 39 inches with the largest amounts of rain falling from May-September. This spring and summer precipitation caused regional streams in the LGR to have rapid increases in flow in conjunction with regional rains but then returning quickly to lower flow conditions when runoff stopped. Streams in the LGR have relatively low ground water inflow contribution because of the low hydraulic conductivity of the high clay and shale component of soil stratigraphy.

6. In contrast to local streams within the LGR, the discharge of the Grand River in the region reflects precipitation and runoff events throughout the 7,900 mile^2 watershed, about ¾ of which is in Missouri. Similar to local stream dynamics, the Grand River discharge typically is highest from March through June followed by a gradual decline to low flow conditions in winter.

7. The LGR has a history of regular annual flooding from overbank and backwater flows of the Grand River, however, inter-annual variation in extent of flooding varies substantially among years. Prior to development of extensive levee and drainage projects in the Grand River Basin in the early 1900s, annual discharge in the Grand River system had regular periods of either extremely high or conversely drought conditions in the LGR that occurring about every 20 years dating back to the mid 1800s.

8. After 1915, flooding that exceeded 24 feet at Chillicothe was exceeded (with intervals of 30 days or more between crests) 87 times through 1962. At Sumner, during the same time frame, 48 individual floods > 38,000 cfs occurred. Since the 1960s, there has been an increased frequency of 0.5 to 2-year recurrence interval flood events.

9. The Presettlement LGR landscape in the mid 1800s contained a diverse mixture of prairie, savanna/woodland, and forest communities with numerous small oxbows and floodplain lakes/sloughs present along the Grand River and major tributaries.

10. Tall grass mesic prairie historically occupied much of the higher elevation glacial terraces of the LGR and this prairie transitioned into wet mesic prairie and oak-savannas where terraces graded into floodplains. Floodplains contained diverse wet prairie, woodland, and forest depending on the elevation and soils of the site.

11. Terrace prairies had silt loam loess soils that were well drained, deep, and highly fertile. These terrace prairies received annual sheetflow of local runoff, but infrequently flooded (> 10-year recurrence interval) from extremely high backwater events of the Grand River. Fire and grazing by large ungulates were the dominant ecological disturbances in this community.

12. Wet prairies in floodplains were present on silty clay soils, with 0-2 percent slopes and were driven by short duration sheetwater flow draining from terraces and from occasional (2-5 year recurrence) backwater flooding of the Grand River and its tributaries. The lowest elevation floodplain prairies were essentially "marsh-type" communities with mixtures of grasses, sedges, rushes, and other herbaceous wetland type plants.

13. Wet mesic woodlands occupied broad transition zones in LGR floodplains between prairie/marsh and forest communities along stream/river corridors. Soils under woodlands were mostly poorly drained silt clays. This community flooded almost annually, but for short duration from river backwater and local runoff. The wet nature of these sites created a balance of fire ranging from prairies into the floodplains in dry years but more saturated conditions in wet years constrained the advance of fire. This combination of regular seasonal flooding and occa-

sional fire influenced the savanna nature of the community that was dominated by pin and bur oak, pecan, and some hickory.

14. Floodplain forest was present along streams and rivers in the LGR and in swales adjacent to or succeeding from old abandoned river channels and flats. Soils in floodplain forest areas were poorly drained and clay-based. Shallow backwater flooding occurred, often during the dormant season about every 2-5 years. These forests rarely, if ever burned because of the more prolonged seasonal flooding regimes.

15. Natural levees in the LGR supported floodplain forest where clay soils were present, but contained early succession riverfront forest types where sand and gravel soils were present.

16. Oxbows and deeper floodplain depressions in the LGR contained gradients of open water, shrub/scrub, and herbaceous wetland communities from deeper middle parts of the depression to shallow edges.

17. A HGM matrix of community attributes was developed for the area near Sumner using combined GLO survey notes, plat maps, botanical records, photographs, early settler accounts, known botanical correlations, and 14 reference sites. This information validated ecological land type (ELT) maps prepared for the LGR and a map of potential Presettlement vegetation for the entire LGR was produced (Fig. 18).

18. Presettlement ELT habitats varied among LGR zones; collectively the entire LGR contained about 40% forest and woodland and 60% prairie.

19. Diverse assemblages of animals were present in, and used mainly seasonally available resources in LGR plant communities.

20. Human occupation of the LGR apparently first occurred about 8,000 to 10,000 years BP, but native people likely had little influence on communities because of low numbers and scattered occupation; regular flooding of the Grand River floodplain, and relatively limited agrarian activity.

21. The first European settlers of number came to the Grand River region in the early 1800s, but extensive settlement did not occur until after 1830. Agricultural activity was restricted to some clearing of trees on natural levees and in some select prairie areas that did not have clay soils.

22. Following the Civil War, settlement in the LGR increased when railroads were built and improved farm implements allowed plowing and haying cutting on prairies. Gradually, native communities were converted to agriculture through the early 1900s.

23. Some transport and commerce on the Grand River occurred beginning in the mid 1800s and efforts to improve conditions for navigation began about 1850. By the late 1800s, limited portions of the main Grand River channel were channelized and lined with rip rap.

24. In the early 1900s, over 50 organized drainage and levee districts were formed over much of the Lower Grand River Basin. Larger districts that constructed levees, ditches, channelization, and substantial water-control structures that eventually greatly affected hydrology in the LGR were the Garden of Eden Levee District in the lower floodplain south of Yellow Creek, Whitham Drainage District along the south bank of Yellow Creek, Grand River Drainage District in Livingston and Linn counties, Locust Creek Drainage District, and Medicine Creek Drainage District. In addition to these large drainage districts, many townships and private organizations formed small organizations and supported projects in the early 1900s.

25. The collective effect of the many uncoordinated drainage and levee projects within and upstream of the LGR in the Grand River watershed was to intensify and accelerate water and sediment discharge, and cause more regular and prolonged overbank and backwater flooding from the Grand River, into the LGR.

26. Little additional levee and drainage project construction occurred in the LGR from 1930 to about 1960, when higher commodity prices stimulated substantial levee and ditch construction on private lands. Again, the uncoordinated construction of these levees coupled with past drainage and levee projects in and upstream exacerbated flooding in the LGR, which has continued to cause a wetter hydroperiod for the region to the present.

27. By 1987, about 60% of the total Grand River Basin in Missouri had been converted to agricultural cropland; another 32% of the basin was converted to non-native pasture and hayland. Detailed documentation of current land type in the LGR is not available, but preliminary analyses of aerial photographs suggests over 95% of native prairie and over 70% of native woodland and forest has been lost. Additionally, remnant forest communities appear to be shifting to wetter type species composition because of increased flooding and wetness of the region.

28. Conversion of prairies to extensive row crop agriculture, clearing of floodplain forests, and construction of uncoordinated drainage and levee projects throughout the Grand River Basin have increased total water and sediment discharge into the LGR. Sediment surveys on Fountain Grove CA and Swan Lake NWR in the 1970s and 1980s have documented over 2 feet of sediment deposition, and loss of 52-72% of water storage volume from sediment filling of certain wetlands.

29. The row crop dominated landscape in the LGR contributes residue from herbicides, pesticides, and fertilizers into LGR floodplains and wetlands and wetland contamination eutropication is a concern.

30. The LGR currently contains about 40,000 acres of fee-title and easement lands managed for conservation purposes. The primary conservation lands are Swan Lake NWR, Fountain Grove and Yellow Creek CAs, Pershing State Park, and about 18,000 acres of private wetland protected under WRP easement.

31. Development and management of Swan Lake NWR and Fountain Grove CA have been extensive since their acquisition and establishment. Both areas have constructed numerous levees, water-control structures, water holding reservoirs, roads, and other physical structures. These developments have altered hydrology significant on the areas and ultimately led to significant changes in community type, distribution, and abundance compared to pre-developed and Presettlement periods. Development of private WRP tracts also has substantially changed land and hydrology features of the sites, usually in an attempt to restore wetland characteristics of formerly converted agricultural lands. Development and management of Pershing State Park has been more limited compared to other public lands.

General Recommendations for Management and Restoration Objectives

The LGR ecosystem has been highly altered from the Presettlement condition by numerous interconnected land and water changes. Unfortunately, the most degrading factors have been the result of system-wide (systemic) changes throughout the Grand River Basin from Iowa to the LGR. The LGR is the recipient of the cumulative, cascading, set of changes to water, sediment, and community attributes from upstream landscapes and unsustainable land and water management practices both locally and throughout the watershed. Consequently, the ultimate solutions to the major alterations in the LGR will require changes to water and land management throughout the upper Grand River Basin watershed combined with specific changes in local LGR sites. Many of these watershed changes will require coordinated, and accelerated, programs to restore more natural hydrological conditions, reduce degrading levels of sediment and contaminant erosion from uplands and deposition in floodplains, and restore native communities both within the LGR and throughout the watershed. Some of the changes needed to restore components of the LGR landscape will be difficult to achieve because of the large temporal and spatial scale of degradations, competing land use interests and objectives, and history of land changes and subsequent uses by humans.

Solutions to improving ecosystem restoration and management in the LGR will require multiple landscape-scale actions and we recommend the following general restoration and management goals:

1. Increase programs to improve water, sediment, and land management in strategic locations throughout the Grand River Basin.

Ultimately, attempts to restore ecosystem attributes to the LGR will require changes to water and sediment inputs derived from upper watershed sources that can reduce the increased flooding and sediment deposition into the LGR. Also, improving the ecological integrity and ultimate sustainability of the entire Grand River Basin, including the LGR, will depend on restoring functional patches and connectivity of native vegetation communities. These systemic-level habitat changes will require careful evaluation of areas throughout the Grand River Basin that: 1) are most degraded, 2) contribute disproportionate amounts of water and sediments to the Grand River system, and 3) offer the best opportunity to restore system components ecologically, socially, and economically. Certain efforts have been made to develop basin-wide management plans for the Grand River (Pitchford and Kerns 1994) and specific subbasins such as Locust Creek (Todd et al. 1994) and past USDA watershed projects have been directed as specific areas. Even if implemented at modest levels, the land and water conservation projects recommended in these reports will be helpful. Generally, land treatment programs will be most successful if they implement best management practices (e.g., Anderson 1980) throughout the basin. Important land and water treatments will require: 1) soil retention practices strategically directed to areas and sites that contribute the most sediment and surface water runoff; 2) restoration of natural drainage channels, water flow pathways, channel stabilization, and flood distribution and storage areas; and 3) restoration of native vegetation communities, especially those communities that have been most destroyed/converted to agricultural production. An example of another central U.S. area with similar systemic issues and that has evaluated efforts to identify areas and specific programs to address ecosystem problems is the Cache River Basin in southeast Missouri and northeast Arkansas (Heitmeyer 2010b). In the Cache River Basin, detailed analyses of sediment loading and erosion potential of soils identified the specific areas and locations of primary sediment entry to the Cache River system from sheet-and-rill, gully, and channel bank sources (Bingner et al. 2010). Likewise, HGM evaluation in the Cache River Basin identified some select opportunities to de-channelize portions of the river and return flows to natural pathways and to restore bottomland hardwood forest communities in floodplains and adjacent terrace areas. A similar analyses is needed for the Grand River Basin

2. Restore natural (pre-alteration) water flow patterns and hydrology in the LGR where possible.

In addition to increasing conservation-directed land and water treatments in the upper Grand River watershed, many local degradations to water flow, flooding, and sedimentation need to be addressed in, and immediately adjacent to, the LGR. Water and sediment flowing into and through the LGR is impacted locally by extensive networks of levees, roads, railbeds, ditches, channelized sections of the Grand River and tributaries, and water-control structures on both public and private lands. Certain of these structures are large (e.g., the Garden of Eden levee), have huge effects on local water flow and flooding, and they will be difficult to modify or eliminate because of social and economic considerations. However, some modifications to even large structures may be possible, and numerous other structures can potentially be removed, rehabilitated, or modified to improve flooding and sedimentation conditions. For example, past proposals have been made to restore water flow and sinuosity to the original Parson's Creek channel that was straightened by MDC when Fountain Grove CA was acquired and developed (MDC 1998b). In another example, efforts to maintain water flow through the unchannelized section of Locust Creek and keep Higgins Ditch from further pirating Locust Creek flows that help maintain prairie and riparian habitats on Pershing State Park are currently underway. Many other specific restoration opportunities in the LGR are identified in the next section of the report.

Collectively, the objectives of restoration projects to restore former patterns of water flow that existed prior to major alterations and to reduce excessive sedimentation rates in the LGR will be to decrease flow and velocities in certain drainages, route water back into naturally occurring channels to sustain hydrological driving factors that are critical to maintaining various communities, moderate flood heights and duration, reduce damage potential to some infrastructure, direct sediment to more natural deposition patterns and sites, and ultimately improve ecosystem attributes to support and sustain natural vegetation communities and resources for key fish and wildlife populations.

3. Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relation to topographic and geomorphic/soil position throughout the Grand River Basin and in the LGR.

The type and distribution of vegetation communities in the LGR historically was determined by geomorphic surface, soil, elevation and hydrological regime. The balance of ca. 60% prairie trending from remnant glacial terraces into floodplains and 40% floodplain woodland and forest along drainages produced a highly diverse and productive ecosystem that provided key resources to a large variety of fish and wildlife species. This community mix and extent in the LGR has been highly altered by land clearing and conversion to non-native communities and agriculture, wetter hydrological regimes, and specific management actions on both public and private lands. Restoring more natural distribution and composition of LGR communities will require proactive efforts to restore appropriate communities in sites that can be reclaimed from past agricultural or other land uses; restore basic ecological processes, especially water regimes that emulate natural patterns; and changes in management of existing public lands where possible and desired. The potential vegetation community maps provided in this report (Fig. 18) are the basis for understanding which communities belong in, and can potentially be restored to, specific LGR sites. It will be important for conservation entities to identify specific opportunity areas that potentially can be restored to native communities (based on Fig. 18), especially for communities that have been highly destroyed such as wet mesic terrace prairie and floodplain prairie and woodland habitats. Clearly, some areas in the LGR are so highly disrupted or destroyed, or are so integral to achieving other management objectives, that they cannot be restored to native communities and topography in the near term (e.g., Che-Ru Lake on Fountain Grove CA). In contrast, many other areas such as newly enrolled WRP lands offer good restoration opportunity. Also, it may not be possible to restore some degraded sites to historic types because of more permanent or systemic changes in topography or hydrology. However, these highly degraded sites might be managed to replicate another historic basin community type, including some types that have been highly degraded. On these sites, management will need to emulate dynamics, structure, and processes of the "new" habitat type. Collectively, restoring more native communities, to appropriate distribution and management, is desirable and will help the LGR have improved representation and function/value of communities.

4. Restore and maintain historic patterns of resource availability and abundance including nutrient cycling, seasonal energy flow, and key food, cover, reproductive and refuge resources for native animal species.

Annual primary and secondary production of prairie and floodplain forest communities in the LGR was historically high, diverse, and provided key resources to many fish and wildlife species. This production in the LGR depended on having the graded interspersion of prairie and forest on terrace/floodplain transition zones; seasonal sheetwater and overbank/backwater flooding; and regular disturbance events including fire, drought, herbivory, and flooding. High primary production historically occurred because of the fertility of glacial terrace and floodplain surfaces and soils, a temperate climate, and regular (albeit moderate) inputs of sediments and nutrients from flood events. High secondary production was created by biomass dynamics of prairie vegetation and large inputs of flowering plant parts and leaves from woody vegetation. Maintaining and/or restoring more natural patterns of hydrology (Goals 1 and 2 above) and vegetation communities (Goal 3 above) are critical to maintaining rich seasonal pulses of resources with many potential foods, structural cover, refugia sites, and ecological niches for fish and wildlife species.

Food webs in the prairie-forest continuum of the LGR are complex and most animals rely on multiple food sources during the period(s) when they are present. Consequently, most but not all, common animals in the LGR are omnivorous and mobile. Connected water and nutrient flow in the Grand River ecosystem, including the LGR, enables many mobile species such as fish and waterbirds, to move throughout the system during flood events and facilitates disbursal of nutrients and sediments in various habitats. Unfortunately, the myriad levees and other modified water drainage patterns in the LGR prohibit or reduce this natural dispersal of water and nutrients and also affect movement and distribution of habitats and animals. Increased connectivity of habitats and resources is needed in the LGR to sustain "traditions" of use by seasonal animal visitors, their securement of critical resources to meet annual cycle events, and reduced disturbance, predation, and other mortality risks such as safe sites during large flood events.

The diversity of vegetation communities in the LGR historically assured that many foods and other critical resources were present and abundant in all seasons. For certain species, such as the massasauga rattlesnake, specific communities (wet mesic terrace prairie) provided most critical life cycle requisites to sustain populations. For other species, such as wood ducks, many different communities provided life cycle requisites. A key conservation need for the LGR is to restore and manage habitats that have been destroyed in the largest amounts. This includes floodplain woodland, floodplain and terrace wet prairie, and floodplain forests. Where declines in key resources and foods are identified (e.g., pin oak acorns), attempts should be made to either restore that component of the system or replace the resource with another similar nutritional type. Management of public lands must address not only site-specific resource needs of key animal species, but also sustain the contributions of public lands to providing critical resources for the entire LGR and lower Grand River Basin. In some cases, this regional management responsibility may require unpopular changes to current management of some public lands (e.g., USFWS 2011). Ultimately, conservation efforts in the LGR must recognize that long-term sustainability of animal communities will require restoration of key plant communities in appropriate HGM-determined locations throughout the Grand River Basin.

5. Accommodate multiple public uses when and where they do not compromise primary ecosystem and resource objectives.

In an ecosystem that is as diverse, productive, and visually spectacular as the LGR, it is expected and desirable for the public to visit and use its resources. Managers are challenged, however, with providing opportunities for consumptive and non-consumptive uses without compromising restoration and management of the ecosystem. Further, the local economy of the region is intertwined with sustaining LGR ecosystem processes and communities. The interface of agriculture with LGR floodplains, for example, constrains and yet provides opportunities for, ecosystem restoration. The large systemic problems in the LGR caused by extensive networks of levees, especially the large Garden of Eden Levee, provide a level of flood protection for agricultural lands yet greatly confounds flooding and natural hydrological processes and functions in the region. Also, certain water storage reservoirs, such as Silver Lake on Swan Lake NWR, provide more dependable water sources for irrigation and flooding of managed wetlands yet they compromise regional and local water movement and destroy site-specific native communities. Likewise, levees and water-control structures on Fountain Grove CA and Swan Lake NWR provide means to manage seasonally flooded wetlands yet destroy some native communities and reduce natural flood processes along Yellow Creek, Parsons Creek, Locust Creek and the Grand River.

Clearly, many conflicts in use of the LGR can occur, but restoration and management strategies and priorities must be based on resource management goals that ultimately help assure that natural processes will not be compromised further. This may require changes in land use, public use opportunity, and size and extent of both public and private lands.

Specific Recommendations for Restoration and Management of the LGR

1. Systemic-level Land Treatments Throughout the Grand River Basin

a. Reduce soil erosion and sediment loading

High soil and streambank erosion and sediment loading in the Grand River and its tributaries have historically been a primary cause of degradations in stream, floodplain, and other wetland habitats in the entire Grand River Basin. This upstream erosion ultimately culminates in sediment deposition problems in the LGR. Consequently, efforts to improve habitat at both the larger Grand River Basin and smaller LGR level must seek to reduce sedimentation by assisting with current land and water conservation programs and implementing new programs to improve stream corridor and watershed land and water management. Much of this conservation effort must be directed at private lands and soil and sediment conservation programs will be most cost and ecologically effective if they are targeted to sub watershed areas that contribute the most sediment loading. A primary objective of these activities should be to reduce the amount of sediment eroding from agricultural, riparian, and stream corridors and will necessarily include economic incentives and disincentives, regulatory control, and education. Specific programs at a watershed level with highest potential to address sediment problems include:

- Conduct a basin wide evaluation of sub watershed areas that contribute the largest amount of sediment to the Grand River and its tributaries, similar to that conducted in the Cache River watershed in Arkansas and Missouri (Bingner et al. 2010).
- Intensify support for minimum tillage of highly erodible agricultural lands and protection of sensitive lands with incentive programs such as the Conservation Reserve Program (CRP), Environmental Quality Improvement Program (EQUIP), and WRP and increase penalties and disincentives for continuing farm practices that accelerate soil erosion in sensitive areas and lands.

- Convert soybean and other small grain production lands in highly erodible areas to less intensive land use such as pasture, hayland, prairie, and forest.
- Establish vegetation buffers of at least 100 feet on both sides of stream banks through cattle exclusion, streambank stabilization, revegetation of riparian corridors, and conservation easements or farm programs.
- Implement conservation land treatment programs including grassed waterways or outlets, terraces, critical area planting, pasture and hayland planting, and contour farming.
- Eliminate and provide agricultural disincentives for tile drainage in agricultural fields.
- Construct drop pipes to collect runoff from fields.

b. Restore stream corridors and drainage systems

Alterations to the extensive stream drainage network in the Grand River Basin have increased flooding issues downstream, sediment loading in streams, bank instability, and conversion of native habitats to other uses. Especially damaging changes to streams include extensive channelization, construction of levees along streams and in floodplains, ditching and tiling fields to accelerate surface and subsurface water runoff, and clearing of riparian corridors. Efforts are needed to reverse each of these detrimental land and water uses including:

- Restore water flow through historic creek, stream and river channels and eliminate cut-off channels where possible. This will be especially helpful if meandering cutoff channels can be restored to decrease flow velocities (e.g., Heimann 2001).
- Expand floodways by removing, breaching, or setting levees back away from stream channels.
- Exclude cattle from streambanks and stabilize the channel banks through revegetation and other methods.
- Remove field tile drains and eliminate small farm ditches and drainage systems within highly erodible areas.
- Evaluate possible physical changes to bridges, culverts, and crossings on roads throughout the Grand River Basin to provide greater flow capacity in non-constricted patterns (Horton 2005).
- Evaluate redesign of ditch morphology to include a meandering channel in the ditch bottom of an appropriate size and sinuosity to pass the bankfull flow while allowing the rest of the ditch bottom to become naturally vegetated.
- Construct channel grade-control structures in areas where drainage channel deepening, head cutting, and stream pirating are occurring.
- Construct rock weirs within some channelized streams (that cannot be restored to natural channels) to provide "pool-and-riffle" bottoms to channels and enhance fish and aquatic habitats, slower stream flows, and retention of more sediment in upstream channels.

c. Restore native vegetation communities and key resources

The extensive conversion of native plant communities throughout the Grand River Basin has contributed to soil and streambank erosion, accelerated surface water runoff and downstream flooding, and reduced or degraded fish and wildlife habitats. Opportunities exist to restore native vegetation communities throughout the basin and revegetation will assist the soil and water conservation programs listed above. Restoration of native communities should be guided and planned according to the potential historic vegetation community maps provided in this report (Fig. 18). Specific restoration should seek to:

- Reforest floodplain forest and woodland communities as contiguous corridors and buffers along drainages.
- Convert marginal, highly erodible, agricultural lands on glacial terraces and slope areas with mesic and wet mesic prairie. Restoring native grassland on these terraces should be highly encouraged in USDA conservation programs such as CRP.
- Restore wet prairie communities and hydrology in the Grand River and tributary floodplains where they historically occurred.

- Restore appropriate communities on WRP lands, based on historic distribution and hydrology.
- Restore floodplain oxbows, cutoff, and abandoned channels to provide floodplain aquatic communities.

2. *Restore Historic Water Flow Patterns and Hydrology within the LGR*

a. Protect and reconnect water flow corridors where possible.

Restoration of water flow corridors within the LGR is important, in addition to efforts to restore similar flow patterns upstream in the Grand River Basin (above) to allow historic patterns of nutrient and energy flow through the system and to restore (to the degree possible) hydroperiods that developed and sustained former vegetation and animal communities. Further, restoring water flow pathways has potential to improve drainage of the area and reduce prolonged flooding in some locations. Undoubtedly, some flow corridors cannot be restored because of major physical alterations such as large ditches, roads, levees, and water storage reservoirs that are central to local commerce, transport, and agricultural or conservation objectives. Nonetheless, some slough and drainage paths and corridors can be partly or completely restored, and even major structures can be physically altered or have changed management to support desired flow conditions. Specific examples of these reconnections include:

- Evaluate the current potential to restore the 1.5 mile formerly channelized section of Parson's Creek on the northwest side of Fountain Grove CA.
- Protect all unchannelized sections of the Grand River and tributaries in the LGR from future channelization (either complete or partial) and dredging.
- Remove or modify levees, ditches, roads, railbed, and water-control structures on all public lands and WRP properties where they are degrading system-wide water flow corridors and natural drainages.
- Do not construct new levees, ditches, water-control structures, roads, or channelization in the LGR unless they are designed to accommodate flood flows and natural water movement patterns.
- Restore historic water flow pathways through Swan Lake NWR where possible (see USFWS 2011:34).
- Restore and maintain larger, unleveed floodplain and natural community areas, especially on public lands, where possible. This includes maintaining and restoring larger uncompartmentalized, wetland sites on Swan Lake NWR, Fountain Grove CA, and Pershing State Park.
- Change water management on Silver Lake on Swan Lake NWR to provide more naturally occurring seasonal water regimes/dynamics and to facilitate restoration of wet prairie and seasonal herbaceous marsh habitats in this area. Conjunctive water management to provide seasonal storage and dynamics should be pursued as identified in the CCP (USFWS 2011).
- Implement efforts to prohibit Higgins Ditch from further pirating Locust Creek flows on Pershing State Park and the east side of Fountain Grove CA (e.g., MDNR 2010, Fig. 33). These efforts should include decommissioning and at least partial filling of Higgins Ditch and routing flow back into Locust Creek, reconstruction of wider and multiple bridge crossings on Highway 36 to allow wider flood flow passage, grade-control structures in Higgins Ditch, purchase of lands or easements along Locust Creek and Higgins Ditch to provide alternate and wider, more natural flood flow, and restoration of upstream sections of formerly channelized Locust Creek.
- Restore the original Medicine Creek drainage channel and decommission the split drainage channels now present.

b. Expand floodways and drainage corridors

Constrictions to water flows within and through floodplains caused by levees and other structures (such as roads, rail beds, etc.) have increased flooding problems in the LGR and constrain efforts to sustain, restore, and manage native communities in the LGR. The extensive development of levees, in particular, along the Grand River and its major tributaries historically has been uncoordinated, poorly designed hydraulically, and maintained or expanded without adequate regulatory review or authority. At the very least, no future levee construction should occur in the LGR, and at best, all current levees and associated water control or management infrastructure should be reviewed to determine local and regional impacts and possible decommission, elimination, or modification. Specific opportunities for expanding floodways and corridors in the LGR include:

- Widen floodways along all major LGR tributaries and the Grand River by removing, breaching, or moving levees back away from stream channels. This includes removing or setting back specific levees adjacent to Parson's, and Locust creeks on Fountain Grove CA and Yellow Creek and Tough Branch on Swan Lake NWR.
- Remove, lower, and/or breach the old railroad bed that bisects Pool 1 on Fountain Grove CA.
- Evaluate possible spillway/breach sites in the large Garden of Eden Levee and purchase or negotiate conservation or flood easements on the back (protected) side of the levee to allow flood stages of certain heights to inundate an expanded floodplain and reduce flood heights and duration on the Grand River side of the levee. Similarly, evaluate possible spillway/breach sites in other large levees along Parson's, Medicine, Locust, and Yellow creeks.
- Design future, and modify existing, WRP wetland restorations in the LGR to accommodate floodwater flow into and through the site and expand floodways where possible.
- Evaluate all larger levees, roads, ditches, and water-control infrastructure on Fountain Grove CA, Swan Lake NWR, and Pershing State Park to determine if they are necessary and can be removed or reconstructed to accommodate flood flows and more historic water movement patterns.
- Conduct a thorough evaluation of the role and effects of all levees on private lands in the LGR for possible elimination or modification.

c. Remove obstructions to sheetflow through, and drainage of, the LGR

As with flood flows, the many physical alterations to the LGR landscape have greatly affected and changed how and/or if surface water sheetflow occurs across and from terraces and floodplains. Of specific interest is the importance of water sheetflow across remnant glacial terraces into floodplains and drainage systems. This sheetflow was critical to establishing the hydrology necessary to support and sustain the mesic and wet mesic prairies that covered nearly 60% of the historic LGR landscape. Now this sheetflow is altered or eliminated by roads, railbeds, ditches, conversion of native vegetation to agriculture or hayland, and numerous other water controlling structures and water diversion. Land and water changes in the LGR that can help restore sheetflow include:

- Remove all unnecessary roads, ditches, ponds, and levees from remnant terrace sites that historically supported mesic and wet mesic prairie.
- Remove any remnant tile drainage systems from terrace sites including agriculture and conservation lands.
- Provide multiple water flow pathways through roads and railbeds by constructing more culverts or openings, using permeable fill, and constructing low water crossings and spillways.

3. Restore Native Vegetation Communities and Key Resources

a. Restore and manage terrace and floodplain prairie communities

Prairie communities historically covered about 60% of the LGR in long linear fingers between streams and drainage corridors. Unfortunately, only a very small number of remnant prairie sites remain. Historic prairie habitat provided key resources for many endemic animal species and represented an important transition zone and interspersion with forests that created movement corridors for species that used both upland grassland and floodplain forest habitats to meet life cycle requisites. Remnant prairie tracts in the LGR are small, highly fragmented, have altered native species composition and woody/invasive encroachment, and have altered disturbance drivers of fire, herbivory, and sheetflow flooding. Generally, the highest terrace elevations that formerly had mesic and wet mesic prairie now are nearly entirely converted to row crop production or tame grass pasture. The once expansive historic floodplain prairies also have been extensively converted agriculture or have been modified with levee and water-control infrastructure to become wetter marsh and emergent communities. Restoration of prairie types in the LGR should match the community that historically occur on a site where possible (see Fig. 18). In the area immediately south of Sumner wet floodplain prairie seems to be sustainable and restorable at elevations < 202.1 in floodplains. Wet mesic prairie seems sustainable at elevations > 203.3 on terraces (Fig. 13). Given alterations in hydrology and fragmentation active management will be needed to sustain prairie restoration sites. Sites that seem particularly suited to prairie restoration, and key management factors for them, include:

- Terraces and higher elevations on Swan Lake NWR and Fountain Grove CA.
- Potential new land acquisitions that can expand public and WRP land boundaries as upland buffers to wetlands and that can increase prairie patch size and connectivity.
- Floodplain sites with silt-loam and silt-clay soils and 2-5 year flood frequencies.
- Some wetland impoundments on public lands and WRP tracts that formerly had wet prairie or wet mesic terrace prairie and that now can be managed with fire and seasonal flooding including sheetflow of surface water across them. An example of this opportunity is the high elevation east sides of Silver Lake on Swan Lake NWR.
- The large Lower Terrace zone that is dominated by Booker soils (Fig. 8c).
- Pasture, hayland, and marginal agricultural cropland throughout the LGR that are at least 100 acres and can be managed with periodic fire and or grazing (e.g., Helzer and Jelinski 1999). These include sites enrolled in CRP, CSP, and WRP.
- Expansion of the native wet floodplain prairie along Locust Creek on Pershing State Park and adjacent private lands including those with WRP easements
- Regular introduction of fire, herbivory and seasonal water management.

b. Restore and manage floodplain forest and woodland.

Forest and woodland historically covered about 40% of the LGR, primarily along river and creek corridors. These forest communities provided key resources for numerous fish and wildlife and their location along streams created vegetation buffers that trapped sediments and nutrients, slowed and reduced flow flows, and stabilized channel banks. About 20% of the LGR still contains some forest/woodland cover, but unfortunately this remaining forest is fragmented in many places, is narrow along many areas of stream channels, and is transitioning to more early succession and water tolerant species composition as the LGR has become more flood prone and of longer, more frequent, inundation. Restoration of forest and woodland in the LGR has many valuable benefits for sustaining this ecosystem. Areas that seem especially conducive to restoration of woodland and forest in the area south of Sumner include lands > 202.2 m elevation with > 1-year flood frequency in floodplains (Fig. 13). Remnant floodplain forest and woodland at elevations > 202.2 in the Sumner area are surviving and seem to be sustainable. Important restoration sites and considerations include:

- Riparian corridors along LGR streams and rivers that formerly supported floodplain forest including public lands, WRP tracts, and select private lands.
- Floodplain areas with > 1-year flood frequency elevation and clay soils that formerly supported floodplain woodland (Fig. 13). These sites require irregular, short duration, flooding and the capability to be occasionally burned.
- Protection of existing forest and woodland and introduction of occasional fire into former woodland sites.
- For sites that have can have more historic patterns of flooding (see above), introduction of select timber management techniques to reduce incidence of early succession species such as willow, cottonwood, sycamore, and maple and increased long-term occurrence of pin and bur oak and pecan.

c. Manage seasonally flooded wetland impoundments, persistent emergent marsh, and other managed wetlands to more closely emulate historic hydrologic regimes.

Many wetland sites on public lands, WRP tracts, and private hunting clubs now are managed as seasonally flooded "moist-soil" habitats and some sites are purposefully managed for persistent emergent marsh (PEM). Further, some larger water storage reservoirs have been constructed to provide regular, predictable, water sources for this moist-soil and PEM management. The presence of managed moist-soil impoundments provides important wetland habitat and resources for many fish and wildlife species that use the LGR and makes important contributions to local, region, and even continental populations. This moist-soil habitat also replaces native habitat historically provided in the now nearly destroyed wet floodplain prairie. It is doubtful that large expanses of PEM were present in the LGR; however some larger depressions in the floodplain such as the historic Swan Lake depression likely had expanded PEM, at least during wet years and periods. Now, PEM is a management objective for the large Swan Lake impoundment on Swan Lake NWR, Boardwalk and Lost Marsh impoundments on Fountain Grove CA, and select other sites. Stinson Marsh on Fountain Grove also is managed for a later stage successional marsh community that contains some PEM species. Maintaining the complex of moist-soil, PEM, and open water in the LGR seems desirable, but opportunities exist to improve, enhance, or expand these habitats including:

- Provide more seasonal or seimpermanent water regimes in areas that now support primarily PEM or are water storage reservoirs. For example, changing water management in Silver Lake to allow more seasonally- and annually-dynamic flooding that can vary water storage and surface coverage among years would increase moist-soil and PEM habitat potential, possibly provide some opportunity for restoration of wet mesic prairie on the edges of the reservoir area, and still provide some water supply capacity for flooding management of Silver Lake and South Marsh sites.

- Newly renovated water supply and control infrastructure at Fountain Grove CA could allow more effective water management in many of the impoundments especially Pools 1-3 and the Parson's Creek H and J Pools, depending on flooding events of the Grand River. New or modified pump stations, water-control structures, and levees will provide more independent flood and drain capabilities and potential allow managers to have greater capability to manage the units as seasonally flooded impoundments, emulate natural hydrology regimes, and perhaps even restore some wet mesic prairie sites.

- New or enhance water supply capabilities should be evaluated to reduce dependence on water storage reservoirs that provide limited habitat resources. These include groundwater wells, rotational storage of water in seasonal or PEM impoundments, stream flow, and pumping from rivers.

- More seasonal management of moist-soil and PEM sites could provide opportunity to incorporate rotational agricultural plots in the units to create soil and vegetation disturbance and provide supplemental food. This increased use of agriculture in at least some wetland impoundments might provide the opportunity to convert some upland, currently farmed, areas to natural wet mesic or mesic prairie and floodplain woodland.

- All wetland management impoundments on public lands, WRP tracts, and private non-WRP wetlands should be evaluated to determine if opportunities exist to restore topography along with restoring water and flood flow capabilities listed above. Restoration of topography would create the heterogeneity of elevations and soil site conditions that support diverse wetland vegetation communities and resources used by a wide variety of fish and wildlife species (e.g., Stratman and Barickman 2000).

d. Protect and restore oxbows, abandoned channels and floodplain sloughs

Historically, the meandering pattern of the Grand River created many off-channel depressions that provided aquatic and wetland habitats that were integral to sustaining the large diversity of fish and wildlife species in the LGR. Numerous changes to river and stream flows and channels caused by sedimentation, land use changes, and physical developments have disconnected, or conversely created near permanent inundation, of oxbows. This disconnection or conversely permanent inundation has subsequently changed water storage and area capacity, altered sediment conditions that supported various plant and aquatic communities, and generally degraded a host of other functions and values of off-channel features (e.g., Heimann

2001). It is desirable to restore ecological functions of floodplain abandoned channels and depressions in the LGR where possible. Opportunities include:

- Remove, or modify, levees, roads, and ditches in and around oxbows and sloughs to allow river backwater to enter and exit the site in more historic patterns.
- In highly altered depressions where topography and hydrologic connectivity cannot be restored attempt to manage water levels with period drawdown to increase sediment consolidation and removal, enhance nutrient cycling, and support/sustain historic vegetation communities.

4. Accommodate Multiple Public Uses Consistent with Resource Objectives

The purpose of this report and evaluation is not to address the many potential public and private uses of lands in the LGR. Nonetheless, the history of use of public lands in the LGR has been an important factor affecting resource management decisions in the region and this history and current expectations influences opportunities for future ecosystem restoration and management. Certain options, strategies, and techniques suggested in this report to restore and manage the LGR ecosystem will influence specific public uses if adopted. While some uses may be affected, the overall LGR ecosystem should be improved and become more sustainable. For those uses that cannot be accommodated to the same degree as in the past, some alternative site or opportunity may be identified, while others may not. A few public use issues that likely will be affected by ecosystem restoration options suggested in this report include:

a. Reduce, seasonally limit, or change the mode of access routes

Many of the suggestions to restore topography, hydrology, and community type and distribution will require modifications to, or elimination of, roads, ditches, levees, and water-control structures. These changes may:

- Eliminate permanent access points to or through some sites because levees, roads, and bridges are removed or modified.
- Cause access to some areas to become seasonal because levee breaches, spillways, low water crossings are constructed to allow water flow into and through areas during high flow an discharge periods.
- Design water-control infrastructure that is not conducive to regular or heavy vehicular traffic.
- Change navigation capabilities on some waterways.

b. Expand or modify refuge/sanctuary sites

Expanded restoration of native vegetation communities, water flow pathways, and provision of key resources for endemic communities may require expansion and careful strategic designation of refuge areas. For example:

- Restoration of highly destroyed habitats required by animal species of concern, such as massasauga rattlesnake, forest and grassland nesting neotropical birds, king rail, and other species is important to provide food, thermal cover, reproduction sites, and escape cover and will require unfragmented larger blocks of habitat free from, or with highly managed, human disturbance. Consequently, changing the size and location of habitats and communities to be protected as refuges may be needed to provide these resources.
- Expanded floodway capabilities through modified levees, spillways, and water-control structures will make some higher elevation areas important refugia for animals escaping high flow events. These higher flood refuges should not be disturbed during these events.
- Changes in distribution and type of wetland habitats and resources may require that waterfowl hunting refuge areas be reconfigured or expanded to assure that birds have access to important quantity and quality of resources.

c. Reduce or spatially change, consumptive activities

Providing consumptive activities on public and conservation lands, such as hunting and fishing, traditionally have been provided on LGR lands and support and encouragement of these activities is desirable in the future. However, changes in management and restoration of some habitat types and areas may require some changes to how, when, and where the activities can continue. For example:

- Conversion of at least part of Silver Lake from a total water storage reservoir to seasonally or semipermanently flooded conditions may change fish numbers and species composition in the site and not provide the same reservoir-type fishing opportunities as in the past. Conversely, improving water flow pathways and river/stream corridors in the LGR should improve opportunities for, and abundance, of riverine fishes.

- As stated above, changes in habitat types and distribution in the LGR may require changes in location, habitat type, water depth, and hunting style in waterfowl hunting vs. refuge areas.

d. Modify public land farm programs

If parts of currently farmed areas in the LGR are converted back to native vegetation, the amount and type of agricultural crops and hay/pastureland may change on both private and public land. For example:

- Restoration of prairie on terraces will reduce row crop production in some areas, but may increase grazing opportunities as a management technique to sustain prairie communities.

- Changing wetland impoundment management to more seasonally flooded regimes will provide opportunities for more agricultural crop food plots and small fields as a disturbance technique in these wetland impoundments. These changes would affect size and type of crop planted by public land managers and their permittees, if they are retained.

- Increased grassland and woodland buffers along streams and other drainages might change land use from row crop production to hay or pastureland, nut producing trees (e.g., pecan), and long term timber production sites.

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MONITORING AND EVALUATION

Regular monitoring and evaluation programs and directed studies will be needed to determine the future status of the LGR ecosystem and the success and failure of restoration and management programs such as those identified in this report. These monitoring and evaluation studies will help managers understand the short and long term changes in the LGR, provide information on uncertainties and data gaps for the ecosystem and its sustainability, and ensure institutional record and accountability of management and restoration programs. Ultimately, the success in restoring and sustaining at least parts of communities and ecological functions in the LGR ecosystem will depend on how well changes in water, sediment and land type management can emulate historic ecological processes and community type, abundance, and productivity.

Future management of the LGR, at least on some public lands, that incorporates the recommendations of this report can be done in an adaptive management framework w here: 1) predictions about community restoration are made (e.g., mesic prairie can be sustained on relict glacial terrace elevations > 10-year flood recurrence) relative to specific management actions (e.g., native species are reintroduced and fire is used to control woody encroachment and recycle grass biomass) and then, 2) follow-up systematic monitoring and evaluation programs are implemented to measure ecosystem responses to various management actions and to suggest changes or strategies based on the monitoring data. In the LGR, especially important monitoring and evaluation needs are described below.

SEDIMENT REDUCTION AND CONTROL

Reduction in soil and drainage channel bank erosion throughout the Grand River Basin is critical to mediating problems with excessive sedimentation and poor water quality in the LGR. This report identifies many systemic and local management actions that presumably can reduce the sediment runoff and loading in the Grand River drainage system and improve how and where sediment is deposited in LGR floodplains and habitats, such as abandoned channels, storage reservoirs, wetland impoundments, and other areas. Important information needs include:

- A thorough evaluation of sources and distribution of sediment entering the Grand River system. In areas where large sediment contributions are identified, more detailed studies will be needed to document amount, chronology, and composition/contamination of sediment.
- Continued monitoring of rates and chronology of sedimentation in LGR wetlands of all types.
- Effectiveness of the many sediment reduction and control programs and methods listed in this report.
- Long-term responses of plants and animals to changes in sediment loading and deposition in all community types.

EFFECTIVENESS OF RESTORING WATER FLOW PATHWAYS, PATTERNS, AND SEASONAL WATER REGIMES

The challenges to restoring natural stream corridors, surface water drainage pathways, floodwater distribution and duration, and drier more seasonal inundation regimes in the LGR are large and ultimately require systemic and local changes in land

and water management and use. Undoubtedly, restoration of certain system features, such as restoring sinuosity of flow in former natural stream channels and unchannelizing stream sections, will occur piecemeal as opportunity arises. Ideally, larger sections of stream channels, floodplains, and other lands could be changed to accommodate more natural flow and flood patterns, and conservation programs should seek to work on as large a tract as possible. Any land and water changes that potentially affect water and flood regimes in the LGR, regardless of size and location should be monitored to determine effectiveness and interactions with other factors. Especially important information is needed to:

- Monitor and model surface water movement across elevations, among management units, through natural flow channels, and measures of time required to flood and drain LGR areas, especially those where infrastructure developments and management occurs.
- Produce updated flood frequency (recurrence interval) maps for the entire LGR related to elevation and current/proposed land use.
- Obtain detailed topographic profiles for Fountain Grove CA and Upper tributary areas.
- Regularly monitor water quality throughout LGR wetlands and streams including the aforementioned sedimentation/loading, agrichemicals, and other contaminants.
- Monitor groundwater levels and interactions with surface water.
- Determine adequacy and performance of all water-control structures on public lands.
- Document all levees in the LGR, regardless of size or ownership/maintenance to determine effects on local and regional water movement and flooding.

LONG TERM CHANGES IN VEGETATION AND ANIMAL COMMUNITIES RELATED TO FLOODING AND ELEVATION

An ultimate conservation goal in the LGR is to restore functional patches of all historic communities in relation to historic distribution and contemporary land attributes. Much is unknown about the type and level of management intensity that will be required to restore and sustain specific habitat types, such as wet prairie and floodplain woodland where a fine balance of flooding, soil type, and disturbance determines if and where a community can be recreated and sustained. Further, cursory inventory of some LGR forests suggests long term changes in species composition toward wetter-type communities. And, responses of these forests to specific changes in water regimes, sedimentation, and management are not well understood. Collectively, monitoring is needed throughout the LGR to simultaneously monitor water regimes, sedimentation, and vegetation responses. Monitoring of key animal species endemic to specific LGR communities also is needed to determine if, when, and where key life cycle resources are being supplied and obtained to sustain populations. Specific monitoring needs include:

- Comprehensive inventory of floodplain forest and woodland species composition and leading indicators of forest condition (e.g., Heitmeyer 2008b).
- Evaluation of region-wide expansion or contraction of communities over time using aerial photography, satellite imagery, and ground reconnaissance.
- Effectiveness of establishment and maintenance management activities for all community types, especially prairie.
- Regular systematic monitoring of endemic and invasive plant and animal species and their responses to management and land/water use changes.

MDC

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APPENDIX A

Appendix A. Common plant species expected to occur (x) in Riverfront Forest (RF), Wet-mesic Floodplain Woodland (WBLF), Wet-mesic Floodplain Forest (MF), Wet Floodplain Prairie (WBLP), Wet-mesic Prairie (MBLP), and Upland Mesic Terrace Prairie (MLP) in the Lower Grand River region. Information on plant distribution from Steyermark (1963) and Nelson (2005).

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
TREES & SHRUBS							
Acer negundo	Box Elder	x					
Acer saccharinum	Silver Maple	x	x				
Amorpha fruticosa	False Indigo				x		
Betula nigra	River Birch	x					
Carya cordiformis	Pignut Hickory		x				
Carya illinoensis	Pecan		x	x			
Carya laciniosa	Shellbark Hickory	x	x	x			
Celtis laevigata	Sugarberry	x	x				
Celtis occidentalis	Hackberry	x	x	x			
Cephanlanthus occidentalis	Buttonbush		x	x	x		
Cornus amomum ssp. *obliqua*	Swamp Dogwood	x					
Cornus foemina	Gray Dogwood	x					
Corylus americana	American Hazelnut						x
Fraxinus pennsylvanica	Green Ash	x	x				
Platanus occidentalis	Sycamore	x					
Populus deltoides	Cottonwood	x	x	x			
Prunus americana	Wild Plum						x
Quercus macrocarpa	Bur Oak	x	x	x			
Quercus palustris	Pin Oak		x				
Quercus bicolor	Swamp White Oak		x	x			
Salix amygdaloides	Peach-leaved Willow	x					
Salix exigua	Sandbar Willow	x					
Salix humilus	Prairie Willow						x
Salix nigra	Black Willow	x	x	x			
Ulmus rubra	Slippery Elm		x				
Ulmus americana	American Elm	x	x				

Appendix A, cont'd. Common plant species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
VINES							
Ampelopsis cordata	Raccoon Grape	x	x				
Campsis radicans	Trumpet Creeper	x	x				
Parthenocissus quinquefolia	Virginia Creeper	x					
Toxicodendron radicans	Poison Ivy	x	x				
Vitis sp.	Grape species	x	x				
FERNS & HORSETAILS							
Equisetum hyemale	Common Scouring Rush	x					
Onoclea sensibilis	Sensitive Fern		x				
GRASSES, SEDGES, RUSHES							
Andropogon gerardii	Big Bluestem					x	x
Bolboschoenus fluviatilis	River Bulrush				x		
Calamagrostis canadensis	Bluejoint			x	x	x	
Carex spp.	Sedge species	x	x	x	x	x	x
Chasmanthium latifolium	River Oats	x		x			
Cinna arundinacea	Wood Reed Grass		x	x			
Echinochloa muricata	Barnyard Grass				x		
Eleocharis palustris	Spike Rush				x		
Eleocharis verrucosa	Spike Rush				x		
Elymus canadensis	Canada Wild Rye				x		
Elymus villosus	Wild Rye	x					
Elymus virginicus	Virginia Wild Rye	x					
Glyceria striata	Fowl Manna Grass		x	x	x		
Juncus spp.	Juncus species				x		
Leersia oryzoides	Rice Cutgrass				x		
Panicum virgatum	Switch Grass					x	x
Tripsacum dactyloides	Eastern Gama Grass					x	x
Schoenoplectus tabernaemontani	Great Bulrush				x		
Sorghastrum nutans	Indian Grass						x
Sparganium eurycarpum	Giant Bur-reed				x		
Spartina pectinata	Prairie Cordgrass			x	x	x	
Sporobolus heterolepis	Prairie Dropseed						x
FORBS							
Agrimonia parviflora	Swamp Agrimony				x		
Apocynum sibiricum	Dogbane				x		
Asclepias incarnata	Swamp Milkweed				x		
Asclepias Sullivanti	Prairie Milkweed					x	
Aster cordifolius var. *sagittifolius*	Blue Wood Aster	x					
Aster lanceolatus	Panicled Aster				x	x	
Aster lateriflorus	White Woodland Aster	x	x				
Aster praealtus	Willow-leaved Aster				x		

Appendix A, cont'd. Common plant species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
Bidens aristosa	Tickseed Sunflower				x		
Bidens comosa	Beggar Ticks		x		x		
Bidens frondosa	Beggar Ticks		x		x		
Bidens polylepis	Tickseed Sunflower		x		x		
Boehmeria cylindrica	False Nettle		x		x		
Boltonia asteroides	Boltonia / False Aster		x		x		
Cacalia plantaginea	Indian Plantain					x	
Campanula americana	Tall Bellflower	x					
Cardamine Douglassii	Purple Cress		x				
Chelone obliqua	Pink Turtlehead		x				
Clematis pitcheri	Leather Flower				x		
Cryptotaenia canadensis	Honewort	x					
Echinacea pallida	Pale Purple Coneflower						x
Eupatorium spp.	Boneset species					x	x
Galium obtusum	Wild Madder				x		
Helenium autumnale	Sneezeweed					x	
Helianthus grosseserratus	Sawtooth Sunflower			x	x	x	x
Impatiens capensis	Spotted Touch-me-not		x		x		
Impatiens pallida	Pale Touch-me-not		x				
Iris virginica var. *Shrevei*	Southern Blue Flag				x		
Iva annua	Marsh Elder				x		
Laportea canadensis	Wood Nettle	x					
Leersia oryzoides	Ricecut Grass	x	x	x	x		
Leersia virginica	White Grass		x	x			
Lysimachia lanceolata	Loosestrife				x	x	
Ludwigia alterniflora	Bushy Seedbox				x	x	
Lycopus americanus	American Bugleweed		x		x		
Lythrum alatum	Winged Loosestrife				x	x	
Mimulus alatus	Sharpwing Monkey Flower		x	x	x	x	
Mimulus ringens	Allegheny Monkey Flower			x	x	x	
Penstemon digitalis	Smooth Beardtongue		x	x	x	x	
Physostegia virginiana	False Dragonhead					x	
Pilea pumila	Clearweed	x	x				
Polygonum amphibium var. *emersum*	Water Smartweed				x		
Polygonum hydropiperoides	Wild Water Pepper		x	x	x		
Polygonum pennsylvanicum	Pinkweed		x	x	x	x	
Polygonum virginianum	Virginia Knotweed		x	x			
Rudbeckia laciniata	Goldenglow	x	x				
Rudbeckia subtomentosa	Sweet Coneflower					x	
Rudbeckia triloba	Brown-eyed Susan	x					
Ruellia strepens	Wild Petunia		x				
Rumex altissimus	Pale Dock				x	x	
Rumex verticillatus	Swamp Dock		x				
Sagittaria latifolia	Arrowhead				x		

Appendix A, cont'd. Common plant species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
Scutellaria lateriflora	Skullcap		x				
Scutellaria nervosa	Skullcap		x				
Senecio glabellus	Butterweed		x				
Silphium integrifolium	Rosinweed						x
Silphium laciniatum	Compass Plant					x	x
Sium suave	Water Parsley				x		
Solidago gigantea	Late Goldenrod	x	x				
Stachys pilosa	Woundwort				x		
Teucrium canadense	American Germander					x	
Urtica dioica	Tall Nettle	x					
Verbena hastata	Blue Vervain			x			
Verbesina alterniflora	Yellow Ironweed		x				
Vernonia fasciculata	Ironweed				x		
Vernonia gigantea	Ironweed			x			
Veronicastrum virginicum	Culver's Root					x	x

APPENDIX B

Appendix B. Methodology for modeling ecological land types (LTA) in Missouri (T.A. Nigh, unpublished).

METHODS

Previous efforts to define and map ELTs and ELTPs in Missouri centered on modeling of “Geo-Landforms” (Nigh, et al., 2000). Geo-landforms are easily recognizable landscape positions (e.g., summits, rigdes, backslopes, floodplains, etc.) on specific geologic parent materials. Landforms affect the development of soils and vegetation by their influence on ecological processes such as water and nutrient movement, solar radiation and evapotranspiration, weathering, and a variety of disturbance factors (e.g., fire, drought and flooding). Geologic parent materials further influence the physical and chemical properties of soil, and in turn the potential natural vegetation of a site. Geo-landforms were initially used as the principle physical framework for investigating and developing ELTs and their Phases (Figure 2).

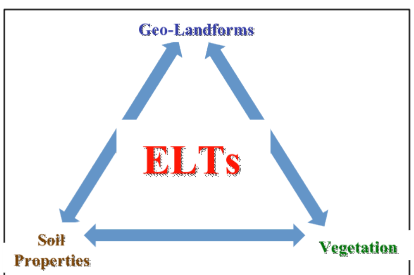


Figure 2. ELTs are defined and mapped by integrating Geo-Landforms with local Soil and Vegetation Characteristics.

The Missouri Cooperative Soil Survey is now available digitally. Soil mapping begins by recognizing landforms on different parent materials (i.e., geo-landforms). These map units are then further refined based on soil properties. While the vegetation is used to indicate map unit differences, soil mapping is by and large focused on the physical properties within a map unit. Consequently, we can derive ELT maps and definitions by starting with an existing soil survey and subsequently incorporating relevant vegetation information. This was completed for this region using the following steps (Figure 4).

1. Soil map units within the ecoregion were extracted from the statewide soil survey.
2. Soil properties considered to be the most important determinants of vegetation were appended to each map unit. Properties used were:
    a. Parent Material
    b. Landform
    c. Root Restriction Type and Depth
    d. Soil Taxonomic Differences
    e. Drainage
    f. Texture
    g. Flooding
    h. Ponding
3. Soils were first grouped by parent material and landform (geo-landform). Within each geo-landform group they were further grouped using relevant soil properties from step 2.
4. Steep backslopes (>15% slope) were split into exposed (south and west facing) and protected (north and east facing) units to account for vegetation differences related to sun exposure.
5. Terrestrial Natural Communities (Nelson, 2005) were assigned to each set of map units through field investigation and historic vegetation information.
6. Legends and maps were created to communicate these relationships.

ELT and ELTP Components

The components used to define ELT(P)s are outlined in this section and describe relevant information pertaining to the ELT(P) legend following this section. Please use the following information to understand terminology, labeling, and abbreviations.

ELTs and ELTPs

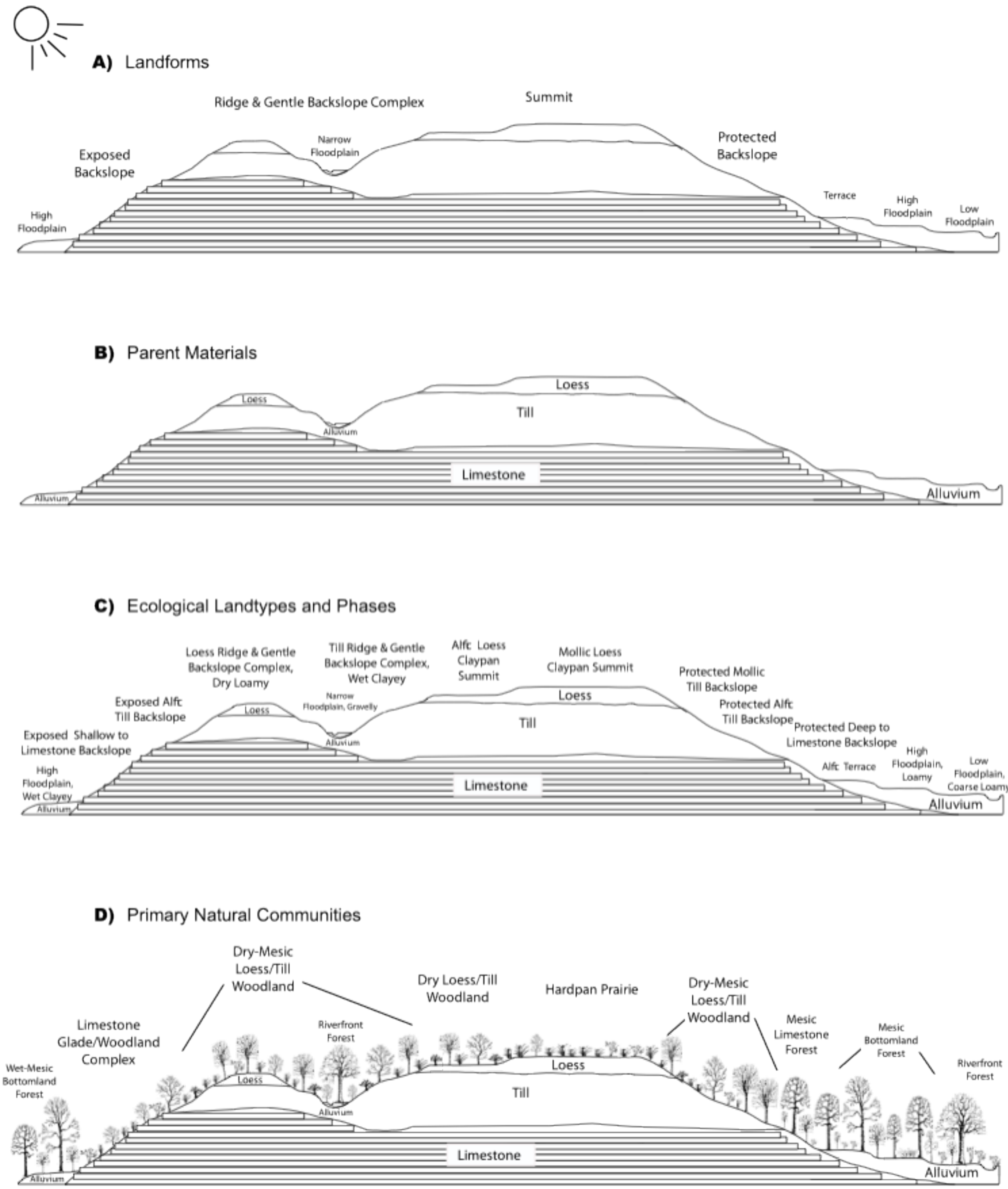
ELTs are delineated and named using three qualifiers: 1) soil/substrate, 2) landform, and 3) general natural community (Table 4). Numeric codes for ELTs are assigned beginning at the highest elevations (i.e., summit positions) and generally proceed down slope (i.e., to the flooplains).
Example: ***1 Claypan Summit Prairies***

ELTPs recognize less significant variations in soil and/or vegetation within an ELT. ELTP naming represents a physical description of redeeming soil properties listed previously and they are coded by ELT number followed by a decimal. ELT and ELTP codes are the same for units that only have one phase.
Example: ***1.1 Mollic Loess Claypan Summits, Wet Clayey***
1.2 Mollic Loess Over Residuum Claypan Summits, Dry Clayey
1.3 Mollic Loess Over Residuum Claypan Summits, Wet Clayey

Parent Materials

Parent material was a principal attribute in grouping soils into cohesive ecological groups. Similar to the ELT coding, ELT(P) legends are organized by parent materials from the top of the geologic column down. Parent material classes were derived from the soil survey (Table 1).

Appendix B, cont'd. Methodology for modeling ecological land types



4

Figure 4. Generalized schematic describing the ecological landtype development process for the Missouri Ecological Classification System. Using the Missouri Cooperative Soil Survey, soils were initially grouped by landforms and parent materials (panels A and B). Next, ecological landtpypes and phases were aligned using topography and additional soil properties (panel C). Primary natural communities were then applied (panel D) as described by Nelson (2005).

Appendix B, cont'd. Methodology for modeling ecological land types

Table 1. Parent materials used in grouping soils into ELTs.

Class	Description
Loess	Loess over 40 inches thick
Loess/Residuum	12 to 40 inches of loess over residuum, or hillslope sediments derived mainly from residuum
Residuum: shale	Residuum derived from Pennsylvanian-aged shale, mixed with limestone and sandstone
Residuum: cherty limestone and dolomite	Derived from Mississippian or Ordovician-aged limestone and dolomite containing high amounts of chert fragments
Residuum: non-cherty limestone and dolomite	Derived from Mississippian or Ordovician-aged limestone and dolomite containing few or no chert fragments
Residuum: sandstone	Derived from Pennsylvanian-aged sandstones
Colluvium	Soil material deposited at the base of a slope due to downslope movement
Gravelly alluvium	Alluvium with high rock fragment content in the subsurface horizons
Sandy alluvium	Alluvium that is mainly sand in the subsurface horizons
Coarse loamy alluvium	Alluvium that is mainly sandy loam in the subsurface horizons
Loamy alluvium	Alluvium that is mainly silt loam or silty clay loam in the subsurface horizons
Clayey alluvium	Alluvium that is mainly silty clay or clay in the subsurface horizons

Landforms

Landforms were used to further group soil map units within parent material classes and were also stratified from the top of the landscape down (Table 2).

Table 2. Landforms used in grouping soils into ELTs.

Class	Description
Summit	The highest position on a hillslope with a nearly level surface (0-3%slope)
Upland Complex	Ridge and gentle backslopes. The high, gently sloping upland surface with convex ridges and shoulders, and linear backslopes (3-14% slope)
Backslope	The steepest, inclined land surface (>14% slope); exposed (southerly, 135-315 degrees) and protected units (northerly, 315-135 degrees)
Cliff	Steep rock outcropping along stream valley, both exposed and protected
Talus	Accumulation of rock and soil material at base of cliffs, both exposed and protected
Sinkhole	Sunken depression in a karst area
Footslope/High Terrace	The lowermost, often concave portion of a hillsope, often containing a complex of abandoned terraces, structural benches, and footslopes
Upland Drainageway	Narrow, relatively high gradient, intermittent upland drainages
Stream Terrace	Abandoned floodplain, elevated alluvial steps rarely flooded today
High Floodplain	Floodplain step, nearly level, occasional flooding
Low Floodplain	Active floodplain, nearly level, frequent flooding

Grand Bluffs Natural Area near Bluffton is an outstanding example of the high bluffs and steep ravines lining the Missouri river in the Outer Ozark Border.

Soils and Soil Properties

A list of dominant soil series is given for each ELT(P). Soil series descriptions can be found at http://soils.missouri.edu/seriesinfo/missouriseries.

Soil properties were added to parent material and landform groups to further refine ecological groupings (Table 3).

Table 3. Soil properties used in grouping soils into ELTs.

Rooting Restriction Type and Depth	
Claypan	An increase of at least 25% clay between the surface or subsurface horizons and the underlying subsoil; characteristic of claypan ELT(P)s
Fragipan	A brittle, medium-textured layer that is very hard when dry; occurs at depths of about 2 feet; characteristic of fragipan ELT(P)s
Bedrock	Bare bedrock outcrop
Bedrock < 20"	Less than 20 inches to hard or soft bedrock
Bedrock 20-60"	20 to 60 inches to hard or soft bedrock
None	Greater than 60 inches to bedrock
Soil Order	
Alfisol	Light-colored surface horizons with low organic matter; moderate amounts of bases (e.g., calcium); mainly formed under timber
Mollisol	Dark-colored surface horizons with high organic matter; high amounts of bases; mainly formed under grassland
Ultisol	Light-colored surface horizons with low organic matter; low amounts of bases; mainly formed under timber
Inceptisol	Young soil with limited horizonation
Entisol	Young soil lacking horizonation
Drainage	
Wet	Water table affects vegetation; somewhat poorly, poorly or very poorly drained
Dry	Water table has little or no effect on vegetation; moderately well, well, or somewhat excessively well, or excessively well drained

Appendix B, cont'd. Methodology for modeling ecological land types

Texture	
Clayey	Clay or silty clay subsurface horizons; fine, very fine or clayey families
Loamy	Loam, silt loam, clay loam or silty clay loam subsurface horizons; coarse-silty, fine-silty, fine-loamy or loamy families
Coarse-loamy	Sandy loam subsurface horizons; coarse-loamy families
Sandy	Sand and loamy sand subsurface horizons; sandy families
Gravelly	Gravelly subsurface horizons; loamy-skeletal or clayey-skeletal families
Flooding	
Frequent	Flooding one in every 2 years; characteristic of low floodplain units
Occasional	Flooding 2 to 20 years; characteristic of high floodplain units
Rare	Over 20 years between floods; characteristic of stream terrace units
Ponding	
Long or short inundation of stagnant water on the soil surface.	

Cary Aloia

Table 4. Generalized descriptions of natural communities, adapted from Nelson (2010).

Natural Community	General Description
Prairie	Dominated by perennial grasses and forbs with scattered shrubs and very few trees (canopy cover < 10%)
Savanna	Grasslands interspersed with open-grown scattered trees, or groups of trees of various age, with shrubs (canopy cover < 30%)
Glade/Woodland Complex	Open, rocky barren areas dominated by drought-adapted forbs, warm-season grasses
Woodland	Variable, having 30-100% canopy closure with sparse understory (or midstory), rich in forbs, grasses and sedges
Forest	Closed canopy, interspersed with multilayered sub-canopy, shade-tolerant vegetation

Karen Kyle

Comments

Comments address secondary natural community types, the reliability of the ELT map and other pertinent issues.

ELT Development in major floodplains

For development of floodplain ELTs in the Lower Grand River we first grouped soils by landform. Landform assignments were made by looking at SSURGO landform classes, as well as flood frequency.The landforms were further investigated using a DEM backdrop and some revisions were made. Next, within landforms, soils were further grouped by texture and drainage classes. Finally, we looked at these groups in relationship to historic and current natural vegetation to assign ELTs.

Karen Kyle

APPENDIX C

Appendix C. Common amphibian and reptile, mammal, and bird species expected to occur (x) in Riverfront Forest (RF), Wet-mesic Floodplain Woodland (WBLF), Wet-mesic Floodplain Forest (MF), Wet Floodplain Prairie (WBLP), Wet-mesic Prairie (MBLP), and Upland Mesic Terrace Prairie (MLP) in the Lower Grand River region. Information on birds from Jacobs (2001) and USFWS (2011); mammals from Schwartz and Schwartz (1959), and amphibians and reptiles from Johnson (2000) and D. C. Mengel (unpublished data).

AMPHIBIAN and REPTILE SPECIES

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
FROGS & TOADS							
Acris crepitans blanchardii	Blanchard’s Cricket Frog				x	x	
Bufo americanus americanus	Eastern American Toad	x	x	x			
Bufo woodhousei woodhousei	Woodhouse’s Toad				x	x	x
Hyla crucifer crucifer	Northern Spring Peeper	x	x	x			
Hyla chrysoscelis - Hyla versicolor Complex	Gray Treefrog	x	x	x			
Pseudacris triseriata triseriata	Boreal (Western) Chorus Frog	x	x	x	x	x	x
Rana areolata cirulosa	Northern Crawfish Frog				x	x	x
Rana blairi	Plains Leopard Frog				x	x	x
Rana catesbeiana	Bullfrog		x	x	x		
Rana clamitans melanota	Green Frog		x	x	x		
Rana sphenocephala	Southern Leopard Frog				x	x	x
Spea bombifrons	Plains Spadefoot					x	x
SALAMANDERS							
Ambystoma texanum	Small-mouthed Salamander	x	x	x	x	x	x
Ambystoma tigrinum tigrinum	Eastern Tiger Salamander						
Notophthalmus viridescens louisianensis	Central Newt		x	x			
TURTLES							
Apalone mutica mutica	Midland Smooth Softshell	x	x	x	x		
Apalone spinifera hartwegi	Western Spiny Softshell	x	x	x	x		
Chelydra serpentina serpentina	Common Snapping Turtle		x	x	x	x	
Chrysemys picta bellii	Western Painted Turtle		x	x	x	x	x
Terrapene carolina triunguis	Three-toed Box Turtle			x			x
Terrapene ornata ornata	Ornate Box Turtle						x
Trachemys scripta elegans	Red-eared Slider		x		x		

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
SNAKES & LIZARDS							
Coluber constrictor flaviventris	Eastern Yellow-bellied Racer						x
Diadophis punctatus arnyi	Prairie Ring-necked Snake						x
Elaphe obsoleta obsoleta	Black Rat Snake	x	x	x			
Heterodon platirhinos	Eastern Hog-nosed Snake			x		x	x
Lampropeltis calligaster callegaster	Prairie Kingsnake						x
Lampropeltis getula holbrooki	Speckled Kingsnake			x		x	x
Nerodia erythrogaster flavigaster	Yellow-bellied Water Snake		x	x	x	x	
Nerodia erythrogaster transversa	Blotched Water Snake		x	x	x	x	
Nerodia rhombifer rhombifer	Diamond-backed Water Snake		x	x	x	x	
Nerodia sipedon sipedon	Northern Water Snake		x	x	x	x	
Opheodrys aestivus aestivus	Rough Green Snake	x	x	x			
Ophisaurus attenuatus attenuatus	Western Slender Glass Lizard						x
Piuophis catenifer sayi	Bullsnake						x
Regina grahamii	Graham's Crayfish Snake				x	x	x
Storeria dekayi wrightorum	Midland Brown Snake	x	x	x	x	x	
Storeria dekayi texana	Texas Brown Snake	x	x	x	x	x	
Storeria occipitomaculata occipitomaculata	Northern Redbelly Snake	x	x	x			
Thamnophis proximus proximus	Western Ribbon Snake				x	x	
Thamnophis radix radix	Eastern Plains Garter Snake				x	x	x
Thamnophis radix haydenii	Western Plains Garter Snake				x	x	x
Thamnophis sirtalis parietalis	Red-sided Garter Snake	x	x	x	x	x	x
Thamnophis sirtalis sirtalis	Eastern Garter Snake	x	x	x	x	x	x
Tropidoclonion lineatum	Lined Snake						x
Virginia valeriae elegans	Western Earth Snake			x			
Sistrurus catenatus catenatus	Eastern Massasauga Rattlesnake				x	x	x

MAMMAL SPECIES

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
POUCHED MAMMALS							
Didelphis virginiana	Opossum	x	x	x	x	x	x
SHREWS & MOLES							
Blarina hylophaga	Elliot's Short-tailed Shrew	x	x	x	x	x	x
Cryptotis parva	Least Shrew	x	x	x	x	x	x
Sorex cinereus	Masked Shrew	x	x	x			
Sorex longirostris	Southeastern Shrew	x	x	x	x	x	
Scalopus aquaticus	Eastern Mole			x		x	x

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
BATS							
Eptesicus fuscus	Big Brown Bat	x	x	x			
Lasiurus borealis	Red Bat	x	x	x	x	x	x
Lasiurus cinereus	Hoary Bat	x	x	x	x	x	x
Lasionycteris noctivagans	Silver-haired Bat	x	x	x			
Myotis lucifugus	Little Brown Bat	x	x	x			
Myotis sodalis	Indiana Bat	x	x	x			
Myotis septentrionalis	Northern Long-eared Myotis	x	x	x			
Nycticeius humeralis	Evening Bat	x	x	x	x	x	x
Pipistrellus subflavus	Eastern Pipistrelle	x	x	x			
RABBITS							
Sylvilagus floridanus	Eastern Cottontail Rabbit						x
RODENTS							
Castor canadensis	Beaver	x	x	x	x		
Geomys bursarius	Plains Pocket Gopher					x	x
Glaucomys volans	Southern Flying Squirrel	x	x	x			
Marmota momax	Woodchuck			x		x	x
Microtus ochrogaster	Prairie Vole						x
Microtus pennsylvanicus	Meadow Vole				x	x	x
Microtus pinetorum	Woodland Vole	x	x	x			
Ondatra zibethicus	Muskrat	x	x	x	x	x	
Peromyscus leucopus	White-footed Mouse	x	x	x			
Peromyscus maniculatus	Deer Mouse						x
Rattus norvegicus	Norway Rat						x
Reithrodontomys megalotis	Western Harvest Mouse				x	x	x
Sciurus carolinensis	Eastern Gray Squirrel	x	x	x			
Sciurus niger	Fox Squirrel	x	x	x			
Sigmodon hispidus	Hispid Cotton Rat						x
Spermophilus franklinii	Franklin's Ground Squirrel						x
Spermophilus tridecemlineatus	Thirteen-Lined Ground Squirrel						x
Synaptomys cooperi	Southern Bog Lemming		x	x	x	x	
Tamias striatus	Eastern Chipmunk	x		x			
Zapus hudsonius	Meadow Jumping Mouse					x	x
CARNIVOROUS MAMMALS							
Canis latrans	Coyote					x	x
Lontra canadensis	River Otter	x	x	x	x		
Lynx rufus	Bobcat	x	x	x			
Mephitis mephitis	Striped Skunk						x
Mustela frenata	Long-tailed Weasel	x	x	x			
Mustela nivalis	Least Weasel				x	x	x
Mustela vison	Mink	x	x	x	x		

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
Procyon lotor	Raccoon	x	x	x			
Spilogale putorius	Spotted Skunk						x
Taxidea taxus	Badger						x
Urocyon cinereoargenteus	Gray Fox	x	x	x			
Vulpes vulpes	Red Fox			x			x
HOOFED MAMMALS							
Odocoileus virginianus	White-tailed Deer	x	x	x	x	x	x

BIRD SPECIES

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
GREBES							
Podilymbus podiceps	Pied-billed Grebe				x		
HERONS AND ALLIES							
Ardea alba	Great Egret				x		
Ardea herodias	Great Blue Heron	x	x	x	x	x	
Botaurus lentiginosus	American Bittern				x		
Bubulcus ibis	Cattle Egret				x	x	x
Butorides virescens	Green Heron				x		
Ixobrychus exilis	Least Bittern				x		
Nyctanassa violacea	Yellow-crowned Night-Heron		x	x	x		
Nycticorax nycticorax	Black-crowned Night-Heron		x	x	x		
RAPTORS & VULTURES							
Accipiter cooperii	Cooper's Hawk	x	x	x	x	x	x
Accipiter striatus	Sharp-shinned Hawk	x	x	x	x	x	x
Buteo jamaicensis	Red-tailed Hawk			x		x	x
Buteo lagopus	Rough-legged Hawk					x	x
Buteo lineatus	Red-shouldered Hawk	x	x	x			
Buteo platypterus	Broad-winged Hawk	x	x	x			
Cathartes aura	Turkey Vulture	x	x	x	x	x	x
Circus cyaneus	Northern Harrier				x	x	x
Falco sparverius	American Kestrel						x
Haliaeetus leucocephalus	Bald Eagle	x			x		
WATERFOWL							
Aix sponsa	Wood Duck		x	x	x		
Anas acuta	Northern Pintail				x		
Anas americana	American Wigeon				x		
Anas clypeata	Northern Shoveler				x		

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
Anas crecca	Green-winged Teal				x		
Anas discors	Blue-winged Teal				x		
Anas platyrhynchos	Mallard		x	x	x		
Anas strepera	Gadwall				x		
Anser albifrons	Greater White-fronted Goose				x		
Aythya collaris	Ring-necked Duck				x		
Branta canadensis	Canada Goose				x	x	
Chen caerulescens	Snow Goose				x		
Lophodytes cucullatus	Hooded Merganser		x	x	x		
QUAIL, TURKEY, PHEASANT							
Colinus virginianus	Northern Bobwhite						x
Melagris gallopava	Wild Turkey	x	x	x			x
Phasianus colchicus	Ring-necked Pheasant						x
CRANES, RAILS & COOTS							
Fulica americana	American Coot				x		
Porzana carolina	Sora				x		
Rallus limicola	Virginia Rail				x		
SHOREBIRDS							
Actitis macularia	Spotted Sandpiper				x		
Bartramia longicauda	Upland Sandpiper				x	x	x
Calidris alpina	Dunlin				x		
Calidris fuscicollis	White-rumped Sandpiper				x		
Calidris melanotos	Pectoral Sandpiper				x		
Calidris minutilla	Least Sandpiper				x		
Calidris pusilla	Semipalmated Sandpiper				x		
Charadrius semipalmatus	Semipalmated Plover				x		
Charadrius vociferus	Killdeer				x	x	x
Gallinago gallinago	Common Snipe				x	x	
Limnodromus griseus	Short-billed Dowitcher				x		
Limnodromus scolopaceus	Long-billed Dowitcher				x		
Limosa haemastica	Hudsonian Godwit				x		
Pluvialis dominica	American Golden-Plover				x	x	x
Pluvialis squatarola	Black-bellied Plover				x		
Recurvirostra americana	American Avocet				x		
Scolopax minor	American Woodcock		x	x	x	x	x
Tringa flavipes	Lesser Yellowlegs				x		
Tringa melanoleuca	Greater Yellowlegs				x		
Tringa solitaria	Solitary Sandpiper				x		
GULLS & TERNS							
Chlidonias niger	Black Tern				x		

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
Larus delawarensis	Ring-billed Gull				x		
Larus pipixcan	Franklin's Gull				x	x	
Sterna forsteri	Forster's Tern				x		
DOVES							
Zenaida macroura	Mourning Dove						x
CUCKOOS							
Coccyzus americanus	Yellow-billed Cuckoo	x	x	x			
Coccyzus erythropthalmus	Black-billed Cuckoo	x	x	x			
OWLS							
Asio flammeus	Short-eared Owl					x	x
Bubo virginianus	Great Horned Owl	x	x	x			
Otus asio	Eastern Screech-Owl	x	x	x			
Strix varia	Barred Owl	x	x	x			
GOATSUCKERS							
Caprimulgus vociferus	Whip-poor-will	x	x	x			
Chordeiles minor	Common Nighthawk					x	x
SWIFTS & HUMMINGBIRDS							
Archilochus colubris	Ruby-throated Hummingbird	x	x	x		x	x
Chaetura pelagica	Chimney Swift						x
KINGFISHERS							
Ceryle alcyon	Belted Kingfisher	x	x	x	x		
WOODPECKERS							
Colaptes auratus	Northern Flicker			x			x
Dryocopus pileatus	Pileated Woodpecker	x	x	x			
Melanerpes carolinus	Red-bellied Woodpecker	x	x	x			
Melanerpes erythrocephalus	Red-headed Woodpecker	x	x	x			
Picoides pubescens	Downy Woodpecker	x	x	x			
Picoides villosus	Hairy Woodpecker	x	x	x			
Sphyrapicus varius	Yellow-bellied Sapsucker	x	x	x			
FLYCATCHERS							
Contopus virens	Eastern Wood-Pewee			x			
Empidonax alnorum	Alder Flycatcher	x	x	x	x		
Empidonax minimus	Least Flycatcher	x	x	x			
Empidonax traillii	Willow Flycatcher	x	x	x	x		
Empidonax virescens	Acadian Flycatcher	x	x	x			
Myiarchus crinitus	Great Crested Flycatcher	x	x	x			

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

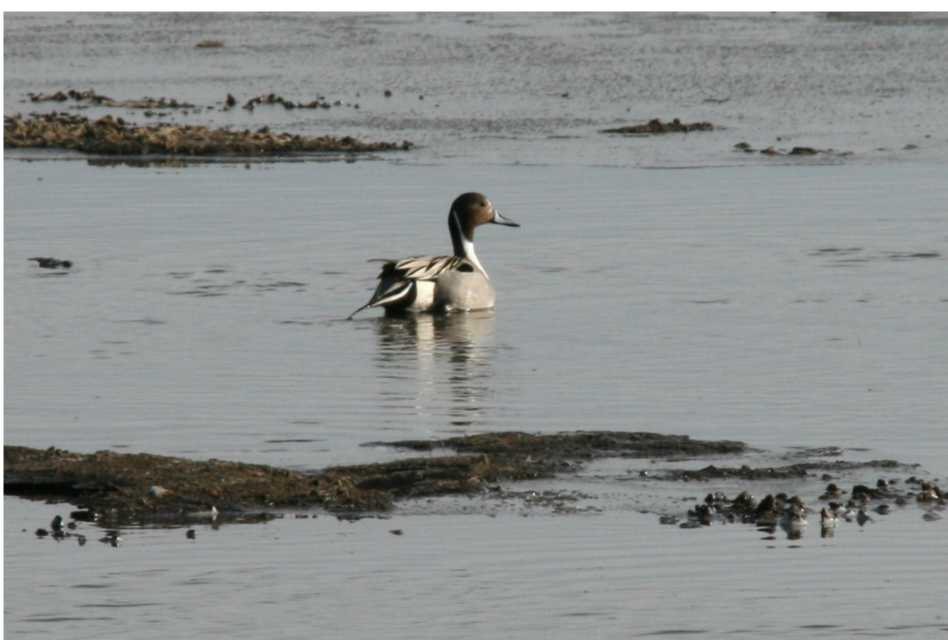
Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
Sayornis phoebe	Eastern Phoebe	x	x	x			x
Tyrannus tyrannus	Eastern Kingbird			x			x
WAXWINGS, SHRIKES, PIPITS							
Anthus rubescens	American Pipit				x		
Bombycilla cedrorum	Cedar Waxwing	x	x	x			
Lanius ludovicianus	Loggerhead Shrike				x	x	x
VIREOS							
Vireo bellii	Bell's Vireo	x	x	x	x		
Vireo flavifrons	Yellow-throated Vireo	x	x	x			
Vireo gilvus	Warbling Vireo	x	x	x			
Vireo griseus	White-eyed Vireo	x	x	x			
Vireo olivaceous	Red-eyed Vireo	x	x	x			
JAYS & CROWS							
Corvus brachyrhynchos	American Crow	x	x	x			
Cyanocitta cristata	Blue Jay	x	x	x			
LARKS							
Eremophilia alpestris	Horned Lark						x
SWALLOWS							
Hirundo rustica	Barn Swallow				x	x	x
Petrechelidon pyrrhonota	Cliff Swallow				x	x	
Progne subis	Purple Martin				x	x	x
Riparia riparia	Bank Swallow				x	x	
Stelgidopteryx serripennis	Northern Rough-winged Swallow				x		
Tachycineta bicolor	Tree Swallow		x	x	x	x	
CHICKADEES & TITMICE							
Baeolophus bicolor	Tufted Titmouse	x	x	x			
Poecile atricapillus	Black-capped Chickadee	x	x	x			
NUTHATCHES & CREEPERS							
Certhia americana	Brown Creeper	x	x	x			
Sitta carolinensis	White-breasted Nuthatch	x	x	x			
WRENS							
Cistothorus palustris	Marsh Wren				x	x	
Cistothorus platensis	Sedge Wren				x	x	x
Thryothorus ludovicianus	Carolina Wren	x	x	x			
Troglodytes aedon	House Wren	x		x			

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
KINGLETS & GNATCATCHERS							
Polioptila caerula	Blue-gray Gnatcatcher	x	x	x			
Regulus calendula	Ruby-crowned Kinglet	x	x	x			
Regulus satrapa	Golden-crowned Kinglet	x	x	x			
THRUSHES							
Catharus guttatus	Hermit Thrush	x	x	x			
Catharus minimus	Gray-cheeked Thrush	x	x	x			
Catharus ustulatus	Swainson's Thrush	x	x	x			
Hylocichla mustelina	Wood Thrush	x	x	x			
Sialia sialis	Eastern Bluebird						x
Turdus migratorius	American Robin	x	x	x	x	x	x
MIMICS							
Dumetella carolinensis	Gray Catbird	x	x	x			
Mimus polyglottos	Northern Mockingbird			x			x
Toxostoma rufum	Brown Thrasher			x			x
STARLINGS							
Sturnus vulgaris							x
WARBLERS							
Dendroica coronata	Yellow-rumped Warbler	x	x	x			
Dendroica fusca	Blackburnian Warbler	x	x	x			
Dendroica petechia	Yellow Warbler	x	x	x	x		
Dendroica striata	Blackpoll Warbler	x	x	x			
Dendroica virens	Black-throated Green Warbler	x	x	x			
Geothlypis trichas	Common Yellowthroat				x	x	x
Mniotilta varia	Black-and-white Warbler	x	x	x			
Oporornis formosus	Kentucky Warbler	x	x	x			
Oporornis philadelphia	Mourning Warbler	x	x	x			
Parula americana	Northern Parula	x	x	x			
Protonotaria citrea	Prothonotary Warbler	x	x	x			
Seiurus aurocapillus	Ovenbird	x	x	x			
Seiurus motacilla	Louisiana Waterthrush	x	x	x			
Seiurus noveboracensis	Northern Waterthrush		x				
Setophaga ruticilla	American Redstart	x	x	x			
Vermivora peregrina	Tennessee Warbler	x	x	x			
Wilsonia canadensis	Canada Warbler	x	x	x			
Wilsonia pusilla	Wilson's Warbler	x	x	x			
FINCHES, SPARROWS & ALLIES							
Ammodramus henslowii	Henslow's Sparrow						x
Cardinalis cardinalis	Northern Cardinal			x			
Carduelis tristis	American Goldfinch					x	x

Appendix C, cont'd. Common amphibian and reptile, mammal, and bird species expected to occur

Scientific Name	Common Name	RF	WBLF	MF	WBLP	MBLP	MLP
Carpodacus purpureus	Purple Finch	x	x	x			
Junco hyemalis	Dark-eyed Junco						x
Melospiza georgiana	Swamp Sparrow		x	x	x	x	x
Melospiza melodia	Song Sparrow				x	x	x
Passer domesticus	House Sparrow						x
Passerculus sandwichensis	Savannah Sparrow				x	x	x
Passerina cyanea	Indigo Bunting			x			
Pipilio erythrophthalmus	Eastern Towhee	x	x				
Spiza americana	Dickcissel					x	x
Spizella arborea	American Tree Sparrow				x	x	x
Spizella pusilla	Field Sparrow						x
Zonotrichia leucophrys	White-crowned Sparrow						x
BLACKBIRDS & ORIOLES							
Agelaius phoeniceus	Red-winged Blackbird				x	x	
Euphagus carolinus	Rusty Blackbird	x	x	x	x		
Icturus galbula	Baltimore Oriole	x		x			
Icturus spurius	Orchard Oriole	x		x			
Molothrus ater	Brown-headed Cowbird						x
Quiscalus quiscula	Common Grackle				x	x	
Sturnella magna	Eastern Meadowlark						x



Cary Aloia