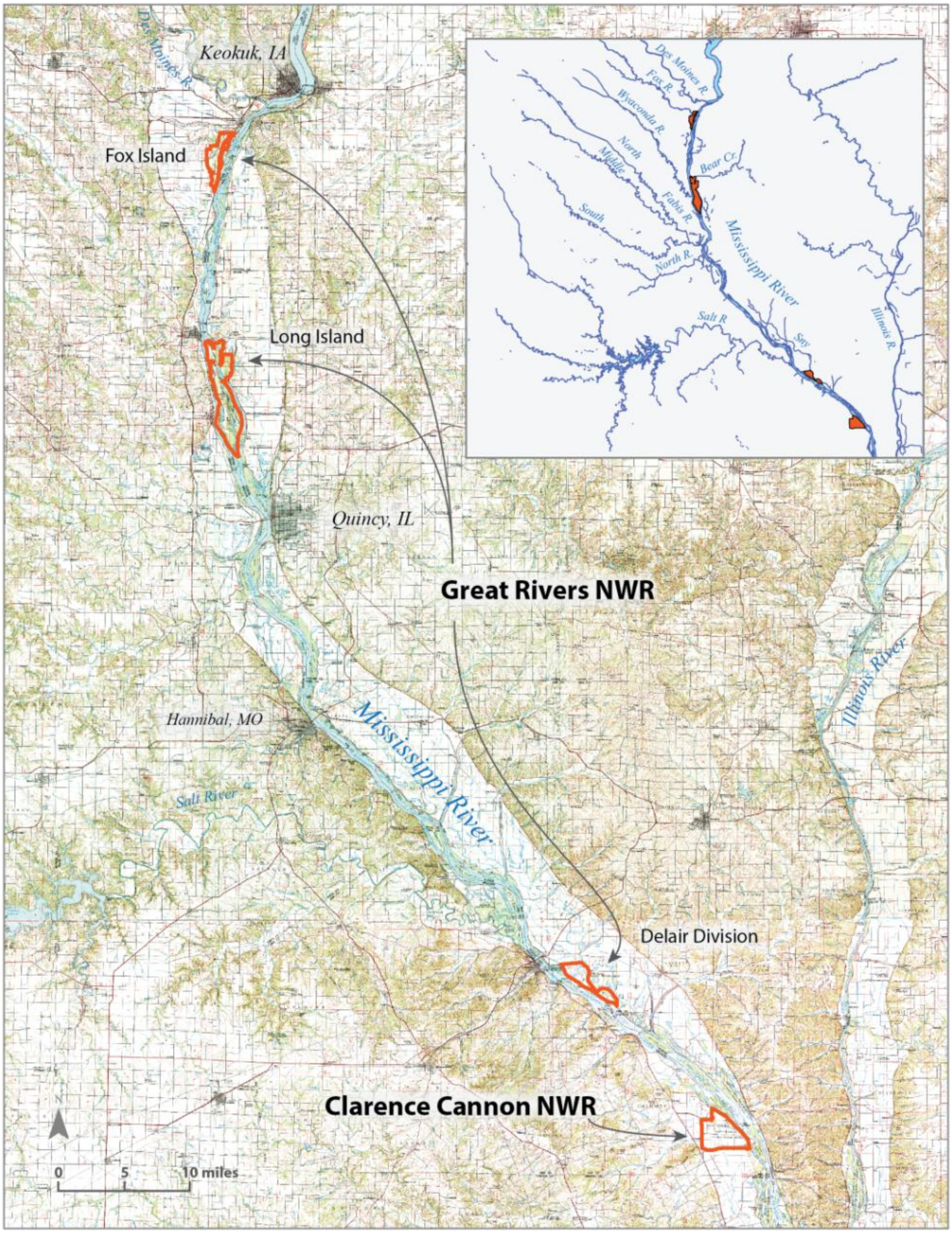
Water Resource Inventory and Assessment
Great River NWR and Clarence Cannon NWR

December 2012



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1. Executive Summary

Great Rivers NWR and Clarence Cannon NWR (GRCCNWR) have a complete Comprehensive Conservation Plan (CCP; USFWS 2004) and the more specific step-down Habitat Management Plan (HMP; USFWS 2012), which identify habitat goals and objectives. Additionally, a Contaminant Assessment Process (CAP; Herman, P. (USFWS 2010) was completed, which evaluates the potential types, sources and pathways of contaminants into the Refuges. The Water Resource Inventory and Assessment (WRIA) is a reconnaissance-level effort that inventories and assess water rights, water quantity, water quality, water management, climate, and other water resource issues. The Water Resource Inventory and Assessment (WRIA) references and is intended to supplement existing and scheduled planning documents by describing current hydrologic information and providing an assessment of water resource needs and issues of concern.

1.1 Findings

1. The Divisions within the Refuge(s) are part of a highly altered hydrologic system, where water levels and management activities are influenced by Mississippi River water level elevation and infrastructure. Water management activities strive to mimic the timing, magnitude and frequency of pre-settlement water inundation and extent. Additionally, water management attempts maximize the diversity and quality of habitat for target species based on seasonal patterns. Ideal water level management regimes (i.e. temporary, seasonal, semi-permanent) for the management units are discussed within the HMP (USFWS 2012)

2. Hydrologic connectivity to the Mississippi River, due to the presence or absence of levees, is a major factor controlling habitat type and distribution along the river. FWS lands behind levees will typically remain dry during seasonal river level fluctuations. However, large flood events that overtop levees may cause extended periods of inundation, because gravity drainage back to the River is limited and pumping of water may be required. FWS lands without levees are flooded regularly from the Mississippi River, exposed to sediment deposition and potentially poor water quality from the Mississippi River.

3. Water quality and water levels within the Mississippi River are dependent on the management of the Lock and Dams and the Refuge division location within the Mississippi River pool (i.e. riverine, deltaic, and lacustrine) relative to the nearest Lock and Dam (e.g. Theiling and Nestler 2010). At lower Mississippi River discharges, the controlled release of water through Locks and Dams releases less turbid water, which can cause erosion in the upper portions of the pools. Suspended sediment is deposited at the riverine-lacustrine transition points within the pool and other transition points where water velocities decrease. At higher discharges, the Locks and Dams do not control water flow through the Mississippi River.

4. There have been long-term increases in annual average precipitation and runoff in this area over the last century, but climate projections do not anticipate continued increases in total water runoff (Lettenmaier et al. 2008; Hayhoe et al. 2010). The expectation is for earlier and higher peak runoff from the larger snow-driven rivers in the area, but large variability in expected runoff from smaller rivers. Increased precipitation will be counter-balanced by an increased average temperature during the summer (day and night), which may lead to reductions in soil moisture through evaporation and increased evapotranspiration by plants, leading to comparatively less runoff from precipitation events.

5. Thirty-one water control structures are located at Clarence Cannon NWR and the Delair Division of Great River NWR. These structures are primarily corrugated metal with half round risers at the inlets, which use boards to control water levels in wetlands, pools and sloughs. Additional water control structures and water management features (e.g. culverts and berms) have been constructed within the Fox Island Division during 2012.

6. Water quality and quantity information specific to the Refuges is limited, with the exception of the Fox River upstream of the Fox Island Division and several locations along the Mississippi River. The WRIA process identified 53 active monitoring sites that are directly applicable to the Refuge water resources. Additionally, there are a number of historical sites with water quality data within the EPA STORET (STOrage and RETrieval) data warehouse that are inactive or contain limited data.

7. The Missouri DNR completed Clean Water Act required water quality assessments (305b assessments) for Ramsey and Bryants Creeks, which follow the northern and southern boundaries of Clarence Cannon NWR, respectively. The assessments by the State of Missouri found no impairments based on criteria established for the support of aquatic life and wildlife. The portion of the Sny River that runs through the Delair Division of Great River NWR was assessed as suitable for fish consumption by the Illinois DNR, but has not been assessed for the support of aquatic life. The Mississippi River along this stretch has fish consumption advisories and is listed on the EPAs Impaired Waters list (303d) for a variety of water quality impairments.

8. The National Wetland Inventory (NWI) for the Refuges was completed using color Infrared images (1:58k) from 1985 and 1986. Existing and desired wetlands at Clarence Cannon NWR were primarily designated as seasonal or temporary moist soil units (MSU)/marsh riverine in the HMP.

9. At Clarence Cannon NWR, the National Hydrologic Dataset (2005-2011) indicates roughly 26 miles of perennial and intermittent streams and rivers and an additional 15.5 miles of artificial flowpaths (i.e. ditches), which pass through or are immediately adjacent to the Refuge acquisition boundary (0.25 mile buffer).

1.2 Recommendations

Water resource goals and objectives were identified in the Habitat Management Plan (HMP; USFWS 2012). Specifically, HMP objectives 1, 4 and 5 focus on wetland habitats, water quality/sedimentation and floodplain management respectively.

The objectives identified and action strategies proposed within the HMP are the basis of a significant portion of the recommendations in the WRIA. Specific types of hydrologic related inventorying and monitoring are recommended, which will be further documented within an Inventory and Monitoring Plan (IMP) for the Refuges.

1. The desired natural communities and water regimes identified and delineated within the HMP should be further refined using high resolution Light Detection and Ranging (LiDAR) elevation data and derived soil drainage as modeling criteria. Geospatial layers derived from currently available LiDAR data can be analyzed to include aspect, slope and canopy height and combined with vegetation surveys.

2. Strategies for accomplishing HMP objective 1.A suggested the removal of water control structures, improvements in Clarence Cannon NWR pumping and water supplemental capacity and the feasibility of enhancing or restoring scours and backwater sloughs.

   The removal of infrastructure can facilitate the creation of appropriate and historically representative habitat, but can potentially diminish management alternatives during extended dry periods. Hydrological infrastructure modifications could include:

   1) Ditch removal, plugging or modification to two-tier ditch design
   2) Low-water crossings in lieu of culverts or structures to facilitate sheet flow
   3) Low-profile swale and berm construction

   Clarence Cannon NWR could potentially consider pumping from Ramsey Creek on the northern boundary, or enhanced pumping to the south, from Bryants Creek. However, during an extended drought period, groundwater well development would be the preferred alternative, providing a more reliable and higher quality water supply. Although, this water should be evaluated for iron content, which may be elevated in this area. The installation of continuous water level monitoring device at Bryants Creek would be useful for determining base-flow conditions and the typical hydrograph pattern in response to precipitation.

3. A strategy outlined in the HMP under objectives 1.B and 1.C is the construction of a new Mississippi River setback levee at Clarence Cannon NWR, located west of the existing levee and potentially degrading the southeast corner and/or other selected portions of the existing river levee.

   Backwater flooding is the preferred scenario, but check structures with secondary spillways and/or new water control structures should be considered to direct and slow the entrance and drainage of water. Alternatively, part of the levee on Bryants Creek could be degraded or a spillway constructed to allow for overbank flooding when the Mississippi

River backs up Bryants Creek. At elevated discharge, the Mississippi River is acting as a hydraulic dam to Bryants Creek. This project is currently undergoing planning with the U.S. Army Corp of Engineers.

4. HMP objective 4.A suggested the continuation and creation of new partnerships to reduce erosion, contaminant runoff and sedimentation, in an effort to reduce the effects on fish and wildlife within the broader basin and improve water quality.

   Additionally, the HMP recommends the exploration of improved resource management and enrollment in conservation programs with partner organizations. These activities would focus within the watersheds to reduce, divert or treat excessive loads of nutrients and sediment

   These types of efforts should be targeted based on a Revised Universal Soil Loss Equation (RUSLE) analysis or using the Soil & Water Assessment Tool (SWAT) for the Bryants Creek watershed to determine target areas. The Creek-Mississippi River 12 digit hydrologic unit code (HUC 12) could be used as a basis for this model (Figure 1; 071100041004). It is likely that a small percentage of the land is responsible for a significant portion of nutrient and sediment runoff, which could be confirmed and mitigated with BMPs such as buffer strips, temporary water retention areas and stream bank stabilization.

5. The HMP objective 4.B monitoring strategy included in the development of a monitoring program for Long Island Division backwater areas and sloughs. Also, the development of a program to monitor water quality and sedimentation at relevant Mississippi River elevations, which would enter Clarence Cannon Refuge. These efforts would evaluate water quality, sedimentation and the potential impacts on habitat and connectivity.

   To quantify sedimentation at the Long Island Division, regular scheduled elevation survey locations within the Divisions could be used to monitor sediment deposition. Additionally, concrete or ceramic slabs could be installed at a variety of locations to measure sediment deposition.

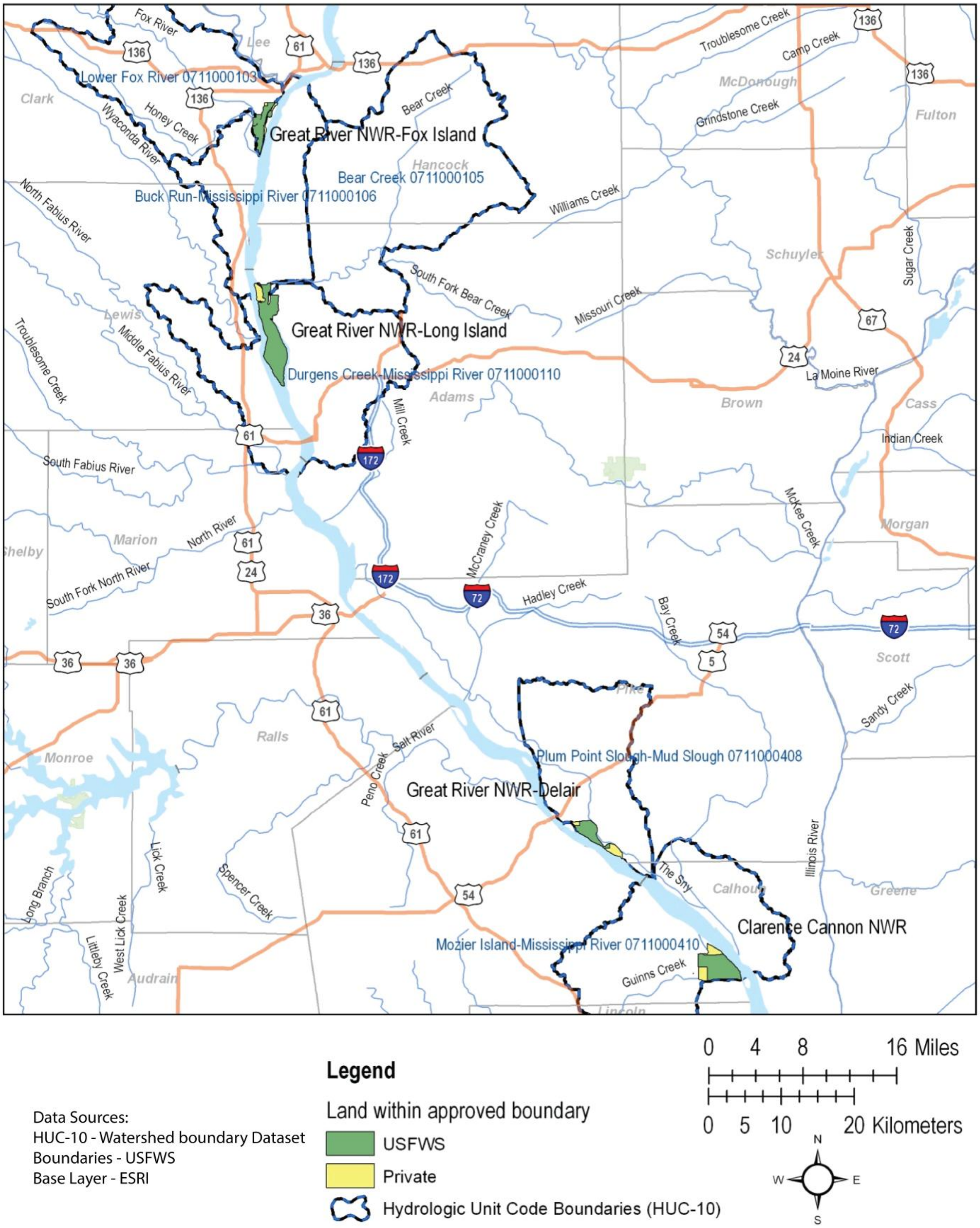
   Evaluation of historical water data along the Mississippi River at a series of water level elevation may be possible in cooperation with the USACE or USGS. Because of the necessary resources, initiating a sampling plan on the Mississippi River is an unlikely scenario.

6. The HMP objective 4.B monitoring strategy suggested a comprehensive contaminant survey of wetlands on Clarence Cannon NWR to identify potential water quality or sediment contaminant issues.

   The previous contaminant survey did not indicate alarming levels of contaminants. However, a new survey should be considered, because the initial survey was conducted prior to several large flood events. Additionally, in the last 30 years, the number of potential analytes has increased and laboratory minimum detection limits have improved substantially.

   Based on the previous data collection and the likely causes of impairment, this survey should sample for metals (e.g. iron, magnesium, and mercury), polychlorinated biphenyls (PCBs), poly aromatic hydrocarbons (PAHs) and pesticides. Additionally, sediment within wetlands should be sampled for nutrients (N and P) at multiple depths, which will be indicative of both loading and/or remobilization.

7. Inventory locations and create a relative estimate of flow (small, medium, large) for seeps within the Delair Division. Create a plan that will monitor changes in flow over time relative to groundwater levels and Mississippi River pool elevation adjacent to the Division. Seeps within the division could be located using an infrared camera in combination with a deployable thermistor.



Data Sources:
HUC-10 - Watershed boundary Dataset
Boundaries - USFWS
Base Layer - ESRI

Figure 1 Refuge locations with 10 digit Hydrologic Unit Code (HUC) boundaries

2. Introduction

This Water Resource Inventory and Assessment (WRIA) Summary Report for Great River and Clarence Cannon NWRs (GRCCNWR) describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations regarding Refuge water resources. This Summary Report synthesizes a compilation of water resource data contained in the national interactive online WRIA database. The information contained within this report and supporting documents will be entered into the national database for storage, online access, and consistency with future WRIAs. The database will facilitate the evaluation of water resources between regions and nationally. This report and the database are intended to be a reference for ongoing water resource management and strategy development. This is not meant to be an exhaustive nor a historical summary of water management activities at GRCCNWR.

The WRIA is a reconnaissance-level effort that will inventory and assess water rights, water quantity, water quality, water management, climate, and other water resource issues for each Refuge. The long-term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on Refuge System water quantity and quality in order to acquire, manage, and protect adequate supplies of water. Achieving a greater understanding of existing information related to refuge water resources will help identify potential threats to those resources and provide a basis for recommendations to field and Regional Office staff. Through an examination of previous patterns of temperature and precipitation, and an evaluation of forward-looking climate models, the U.S. Fish and Wildlife Service (USFWS) aims to address the effects of global climate change and the potential implications on habitat and wildlife management goals for a specific Refuge.

Water Resources Inventory and Assessments have been recognized as an important part of the NWRS Inventory and Monitoring (I&M) and is identified as a need by the *Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change* (USFWS 2010a, b). I&M is one element of the U.S. Fish and Wildlife Service's climate change strategic plan to address the potential changes and challenges associated with conserving fish, wildlife and their habitats (USFWS 2011). Water Resource Inventory and Assessments have been developed by a national team comprised of U.S. Fish and Wildlife Service water resource professionals, environmental contaminants Biologists, and other Service employees.

The WRIA will be a useful tool for Refuge management and future assessments, such as a hydro-geomorphic analysis (HGM), and can be utilized as a planning tool for the Comprehensive Conservation Plan (CCP), Habitat Management Plan (HMP) and Inventory & Monitoring Plan (IMP).

3. Refuge Information- Clarence Cannon NWR and Great Rivers NWR

The two Refuges span roughly 100 miles of the Mississippi River, including four Divisions encompassing roughly 15,000 acres located within the Upper Mississippi Alluvial Plain L4 Ecoregion (72d; Omernik 1987) and the Eastern Tallgrass Prairie & Big Rivers Landscape Conservation Cooperative (LCC). The Long Island Division of Great River NWR was the first Refuge Division established, in the 1940's following construction of the lock and dam system ($\approx$1938-1939) in this region. Clarence Cannon NWR was purchased with Duck Stamp funds in 1964. The Delair Division was acquired in 1965 and partly in 1976. Most of Fox Island was acquired in 1989. Additional Refuge tracts were added following the Mississippi River flood of 1993.

Initially, Clarence Cannon NWR, Fox Island, Delair and Long Islands were part of the Annada District of the Mark Twain National Wildlife Refuge. In 2000, Mark Twain NWR was split into five separate refuges and the Annada District became Great River NWR, which is managed out of Clarence Cannon NWR. The applicable CCP was written for these units while they were still a part of Mark Twain NWR.

The Great River NWR Divisions are under mandates from five legislative authorities: Migratory Bird Conservation Act, Fish and Wildlife Coordination Act, Refuge Recreation Act, Emergency Wetlands Resources Act of 1986, National Wildlife Refuge System Administration Act. Clarence Cannon NWR purpose is designated under the legislative authority of the Migratory Bird Conservation Act and Refuge Recreation Act.

The Hydrologic unit boundaries (HUC-10) were used as a basis for collecting water chemistry, water quantity and climate data (Figure 1). HUC boundaries are based on a successively smaller classification system based on drainage that is adapted from Seaber et al. (1987). The HUC-10 boundary is considered the potential zone of hydrologic influence and a relevant region for the collection of water quality and quantity information for the WRIA. The smaller HUC-12 boundaries were also evaluated as specific catchments relevant to Refuge source waters.

3.1 Clarence Cannon NWR

Clarence Cannon NWR (CCNWR) is located in Pike County, MO, about one mile east of Annada, MO, at Pool 25 on the Mississippi River, approximate Mississippi River miles 263-261 above the Ohio River confluence. Water levels are controlled by a combination of releases from Lock and Dam No. 24 (river mile 273.4) and Lock and Dam No. 25 (river mile 241.4). The Lock and Dams are controlling water levels in the Mississippi River, roughly 75-85% of the year. The Refuge acquisition boundary is located in the FEMA 100-year flood zones, within the Mozier Island-Mississippi River hydrologic unit HUC-10 (Figure 1; 0711000410). All of the acquired units are located within the smaller Bryants Creek-Mississippi River HUC 12 (Figure 1; 071100041004).

CCNWR covers approximately 3,750 acres of Mississippi River floodplain and is formerly part of an agricultural levee district. Currently, all but a few hundred acres are encompassed by a levee. Land is primarily managed as marsh riverine/moist soil units, floodplain forests and wet bottomland prairie. In addition to water level manipulation, the wetland management units are disked, burned, mowed and rolled to maintain a diversity of plants, which provide forage for migratory shorebirds, marsh birds and waterfowl.

3.2 Great River NWR-Delair Division

The Delair Division is located in Pike County, Illinois, near Louisiana, MO at Pool 24, approximately between Mississippi River miles 279-282 above the Ohio River confluence. The Division is located entirely within the Plum Point Slough-Mud Slough 10 digit HUC (0711000408) boundary. The Division is separated from the Mississippi River by a levee maintained by Sny Agricultural Levee District, which is the oldest drainage district in Illinois. This levee drainage district was partially breached during the 1993 flood event and not at all in during the 2008 flood.

The sandy soil texture and low elevation permits constant seepage of groundwater into the Division. Except during high water levels, the management of Lock and Dam No. 24 (river mile 273.4) is the primary control on water levels on the Mississippi River. Water elevation in the Mississippi River may be affecting groundwater levels and the rate of seepage into the Division.

Of the 1,715 acres on the Division, semi-permanent and permanent water bodies make up 480 acres providing feeding and resting areas for waterfowl and many other wetland bird species (USFWS 2012). Water level management, mowing and discing are used to create a variety of vegetative habitats within the wetland units. Primary source water is obtained from several diversion ditches, the Sny River and groundwater seeps/springs.

3.3 Great River NWR-Long Island Division

The Long Island Division is located six miles north of Quincy, IL, in Pool 21 between Mississippi River miles 340-332, above the Ohio River confluence. This approx. 6,300-acre division is located within the Durgens Creek-Mississippi River 10 digit HUC (0711000110) and includes the outlet and a small portion of the Bear Creek 10 digit HUC (0711000105). The Division is a complex of islands, which include Barnes, Shandrew, Flannigan, Long and LaGrange. Habitat consists of 4,670+ acres of bottomland forest, with marsh riverine, sloughs and some small areas of shrub/scrub (USFWS 2012). Water management is primarily passive, as primary source water supply is from overbank flooding along the Mississippi River. Except during high water levels, the management of Lock and Dam No. 20 (river mile 343.1) is the primary control on water levels on the Mississippi River at the Division.

3.4 Great River NWR-Fox Island Division

The Fox Island Division is located in Clark County Missouri, five miles south of Keokuk, Iowa. The Division is adjacent to river miles 356-353 in Pool 20 of the Mississippi River, within the Lower Fox River (0711000103) and Buck Run-Mississippi River 10 digit HUC (0711000106). The Fox River runs through southeastern Iowa and northeastern Missouri, bisects the Division, and empties into the Mississippi River at the southern tip of the Division. The Division consists primarily of 2,100 acres of wetlands, marsh areas, a lake, slough channels and forested wetlands. Remnant sloughs were partially restored by blocking historical agricultural drains with water control structures and plugs. Only a small percentage of the Refuge units are protected by a levee making the Division prone to flooding from both the Mississippi River and Fox River. Mississippi River water levels outside of the Division are a function of the tailwater release from Lock and Dam No. 19 (river mile 364.2) and discharge from the Des Moines River which joins the Mississippi River upstream of the Division (river mile 361.5).

4. Natural Setting

Historically, the lands that now comprise these Refuges were located within the floodplain of the Mississippi River, which was a dynamic continuum of sloughs, islands, sandbars, and open water. Annual floods changed the course of the river, and created new wetlands, deposited nutrient-rich sediments on forests and prairies, and provided spawning habitat for fish. Summer low water enhanced the growth of wetland vegetation.

The entire watershed has been modified through land conversion, drainage and development. The lands along the Mississippi River have been affected by the construction of flood levees, a series of locks and dams, wing dams, and other efforts designed to maintain a 9-foot deep navigation channel. Maintenance of this channel has increased typical low water Mississippi River discharge when compared to historical values (e.g. prior to 1938) in all of these stretches.

These human-caused changes to the Upper Mississippi River have dramatically affected fish and wildlife habitat. The anthropogenic changes to the landscape have increased soil erosion, sediment deposition, reduced water clarity, and destroyed fish habitat. Hydrologically, the isolation and management of the Mississippi River from its historic floodplain has in some areas increased the likelihood of flooding at higher elevations, through the reduction of upstream buffering areas.

The units included in Clarence Cannon NWR and Great River NWR are generally managed to mimic pre-settlement flood regimes and habitats. These Refuges represent some of the few remaining natural areas along the Mississippi River from Pool 20 to Pool 25.

4.1 Topography

High-resolution bare-earth (LiDAR) data (1 m cell size) is currently available from the U.S. Geological Survey (USGS) Upper Midwest Environmental Sciences Center (UMESC) for all of the Divisions of GRNWR (Figure 2). This information will be available for Clarence Cannon NWR in 2013. Generally, the topography for the Refuges is very flat with subtle micro-topographical features apparent in high-resolution data. These features are a combination of historical Mississippi River flow paths (Holocene) and anthropogenic modifications. There are a number of current/historical flowpaths, small ditches and low berms apparent in the LiDAR data set.

In addition to bare earth elevation, first return LiDAR is available, which can be used to analyze vegetation height and density for these units. The currently available data has undergone initial processing and cursory evaluation, with no guarantee of the accuracy of the data. All of the LiDAR products are currently in the first phase (Tier 1) of processing and have not undergone secondary product development. Elevation from the Digital Elevation Model (DEM) may potentially require additional survey checks. Secondary processing will typically include the removal of structures and hydro flattening using break lines, as typically LiDAR does not penetrate water. Bathymetric surveys in combination with the currently available DEM could be used to generate estimates of volume based on water depths in wetland and MSU areas of the Refuges.

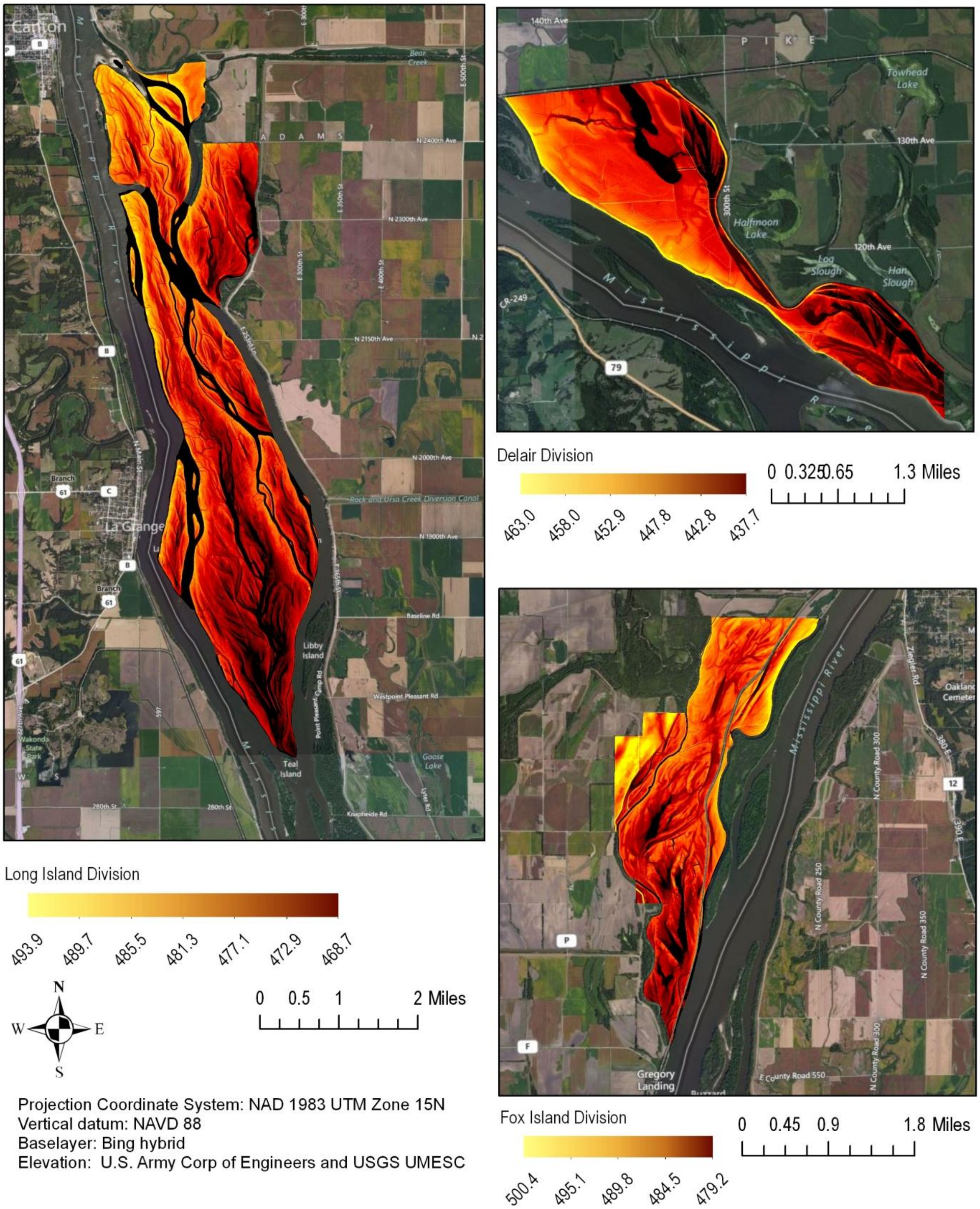


Figure 2 LiDAR elevation information for Great River NWR: Delair, Fox Island and Long Island Divisions

4.2 Geology

The underlying geology is typically covered by quaternary (recent) alluvium (river-derived mixture of clays, gravel and cobble). The rock underneath the alluvium is sedimentary, deposited as part of a series of inundation events by seas and oceans. Generally, the underlying bedrock in this region is from 365-505 million years old. Clarence Cannon geology is late Ordovician Period (505 to 441 million year old rocks) on the western portion and primarily rock from the Silurian/Devonian Period (441 to 362 million-year-old rocks) on the eastern portion. The Delair division is also composed of rocks and layers from the Silurian/Devonian Period. These layers are thin crystalline to fossiliferous limestone, and shales with a few dolomites. Fox Island and Long Island Division are underlain by rock from the Lower Mississippian period (362 million 345 million year old rocks), which followed the Devonian period. These rocks are also limestone rocks, often from sea life that existed during this period.

During pre-glacial times about 1 million years before the present, the Mississippi River flowed to the east of its current location. During this period, the Iowa River occupied the current Mississippi River floodplain from about Muscatine, Iowa to Grafton, Illinois. During the Pleistocene Epoch or Ice Age, beginning about 1,000,000 years ago, great continental ice sheets moved into the mid-latitudes of the United States, and the Midwest was overrun by the Nebraskan, Kansan, Illinoian, and Wisconsinian glaciers. These glaciers deposited drift on the uplands and filled the alluvial valleys with outwash. Following the Kansan glaciation (130,000 years B.P), the Mississippi River established in the current channel and the glaciers did not advance this far south. The Illinois River currently flows in portions of the historical Mississippi River channel. During glacial melting periods, the Mississippi River carried a significant larger amount of water, which created the multiple terraces that are visible today. In the alluvial valleys, some of the valley fill has been scoured away and subsequent river changes and flooding have created the present day floodplain morphology and alluvial soils.

4.3 Soils

Because the units are located within the glacial floodplain, existing soils were formed through alluvial processes and are a combination of clay or mud often extending to depth. Soil drainage based on soil types indicates that most of the soils are poorly drained to very poorly drained (Figure 3). Clarence Cannon NWR, Fox Island Division and Delair Division are located within Mississippi River meander belts, which are areas the Mississippi River used to flow through during the waning of the last glaciation; a period with greater discharge, regular river avulsions (rapid abandonment of a river channel and the formation of a new river channel) and aggradation as a result of glacial outwash. These areas are typically poorly drained and formed greater than 10,000-12,500 years before the present, at the beginning of the Holocene period. A variety of soil types are present across the Refuges with rich, organic soils dominating. All of these soils are classified as being either occasionally or frequently flooded (NRCS web soil survey). The official soil description for each of the soil types is available from the NRCS (Link). Most of the soils are appropriate for tree or prairies species. Some examples of the information for the mapped soil types are provided below. Many of the listed soil types are "competing" series, which means they are similar with slight variations in flood plain location, inundation and sand content.

Some of the soils present in the Delair Division include Beaucoup, Darwin, and Titus silty clay loam. Beaucoup soils are haplaquolls that formed under bottomland forest and marsh grass vegetation in seasonally saturated areas. Titus soils are found on flood plains of large streams. They occupy micro-highs, shallow depressions, and backswamps. In addition, there were Coffeen, Haymond, and Petrolia silt loams. Some of the well-drained areas are Sparta loamy fine sand, and Sarpy loamy fine sand.

The Long Island Division also contains some of the same soil types as the Delair Division, including Beaucoup and Titus silty clay loam, as well others such as Blake-Slacwater, Raveenwash, and Wakeland silt loams. A small section has also been delineated as Riverwash, which is a sand and gravel mix.

Soils within the Fox Island Division are silt loams and silty clay loams, with some fine sandy loam and sandy loam. These include Klum, Hunsville, Zook and Beaucoup, among others, which are often suitable for forested areas.

Clarence Cannon NWR includes similar soils types to the Fox Island and several additional types, which include: Chequest, Dockery, and Carlow. These soils extend to significant depths, nearly level, somewhat poorly drained and poorly drained soils formed in alluvium on flood plains.

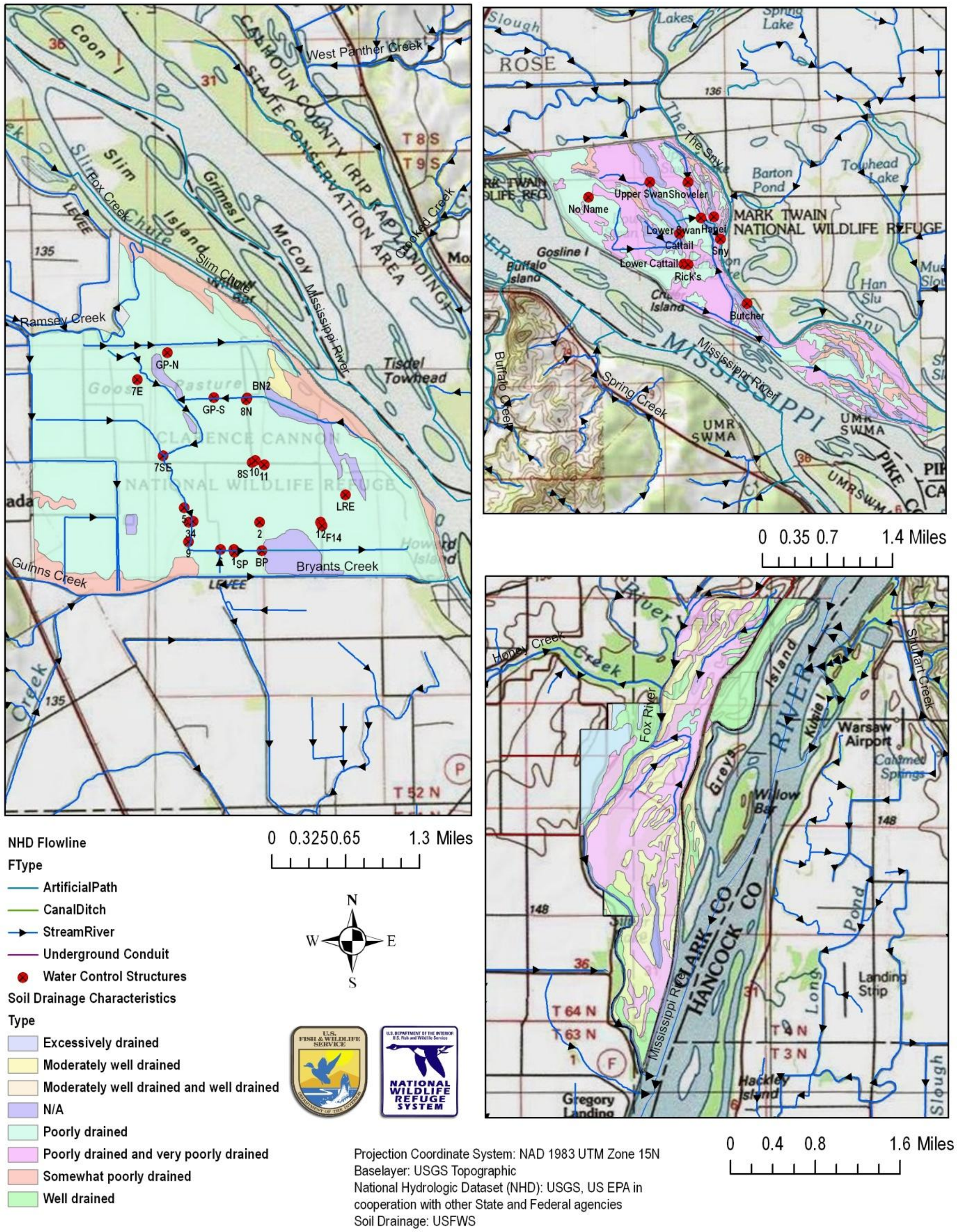


Figure 3 Derived soils drainage with national hydrologic dataset and water control structures

4.4 Long Term Climate Trends

Climate is defined within the WRIA: as the typical precipitation and temperature conditions over years or decades. Climate trends and patterns will affect groundwater levels, river runoff, flooding regularity and flooding magnitude. The WRIA and the HMP provide a broad overview and analysis of trends and patterns in precipitation and temperature for the region of the Refuge. There are a number of models and studies that have evaluated current and anticipated trends in this part of the Midwest, which provide supplementary information and a more comprehensive analysis (e.g. Hayhoe et al. 2010, UCS 2009).

Compared to historical records, annual stream hydrographs are changing due to a number of factors including changes in precipitation and temperature. There has been a roughly 27% increase in days with heavy precipitation for this region from 1958-2007 (Groisman et al. 2005). Going forward, for these heavy precipitation events, a greater percent of precipitation will likely be rain, versus snow. These heavy precipitation events lead to flash flooding and increased erosion. The expectation is for earlier and higher peak runoff from the larger snow-driven rivers (e.g. Mississippi River) in the area and large variability in expected runoff from smaller rivers. However, despite long-term increases in precipitation and runoff in this area over the last century, climate projections do not anticipate continued large increases in runoff (Lettenmaier et al. 2008; Hayhoe et al. 2010).

There is not currently a pattern of increasing drought, but increasing average summer day and evening temperatures may lead to reductions in soil moisture. Increasing evaporation rates and evapotranspiration by plants may lead to less runoff from precipitation events and regular drought conditions.

Weather information was collected for two stations that fulfill the period of record and data accuracy requirements for the U.S. Historical Climatology Network (USHCN; Menne et al. 2012). The USHCN is a network of sites listed by the National Weather Service, which fulfill standards in quality and continuity of data collection. Information was collected for USHCN stations located at Steffenville, MO (NOAA station ID: 238051) and Bowling Green, MO (230856; Figure 4-5). Additionally, monthly statistics were collected for weather stations located at Elsberry (1S), MO (232591) and Lock and Dam No. 20 near Canton, MO (231275) for general comparison (Appendix A). The Elsberry and Canton weather stations are located within the Mississippi River floodplain bluffs area. These Elsberry and Canton weather stations have a lower mean maximum temperature, a higher mean minimum temperature and were less likely to report snow at measurable depth during the winter months versus the Bowling Green or Steffenville, MO stations. The typical historical climate patterns and predicted future trends found for the WRIA were:

1. The Refuges will typically have hot and humid summers and cold winters, with temperatures cold enough to freeze shallow wetlands solid. Currently, it is not unusual for parts of Missouri to experience drought because of low precipitation and high temperatures leading to rapid soil moisture depletion. The frequency of these events is likely to increase, based on existing climate forecast models and current trends.

2. The USHCN weather station located at Bowling Green showed a mean annual precipitation of 36.5 inches, with the highest rainfall typically in May. For all of the stations precipitation was usually 3-4 inches per month, from March thru October.

3. Long-term precipitation records show that 1950-1957, 1960-1961 and 1971-1972 were particularly dry. Wetter than normal years included: 1970, 1980-1985, 1993, 2009 and 2011. No obvious trends in increasing and decreasing precipitation were identified for the weather stations. Although, climate scenarios suggest that floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns may change. Heavy precipitation events have increased in this region and rainfall is more concentrated into heavy events, with longer, hotter dry periods in between (Kunkel et al. 2003).

4. Mean temperature is typically highest in July or August and coolest in January or December (Figure 4). Long-term temperature records indicate that the last 10 years were particularly warm and 1960-1970 were particularly cold. There is some evidence for an increase in mean temperature values across the period of record. One climate projection scenario suggests a 13-15° F increase may happen by the end of this century (UCS 2009). Another scenario suggests an increase of only 0.018 ° F/year or approximately 1.6 ° F by 2100 (Magness et al. 2011).

5. The typical agricultural growing season is approximately 165-200 days, starting the last week of April and ending the first week of October.

6. A comparison of the Pacific Decadal Oscillation (PDO) index to the October to March precipitation (% of average) and October to March mean temperature at Bowling Green, suggests that during “cool phase” years (negative for the index), this region will actually be warmer and drier than typical, which is in agreement with other analysis (e.g. Nigam et al. 1999). The PDO is often described as a long-lived El Niño-like pattern of Pacific climate variability (Zhang et al. 1997). The PDO often has a longer periodicity (15-20 years) and has been negative throughout 2012 (current data Link)

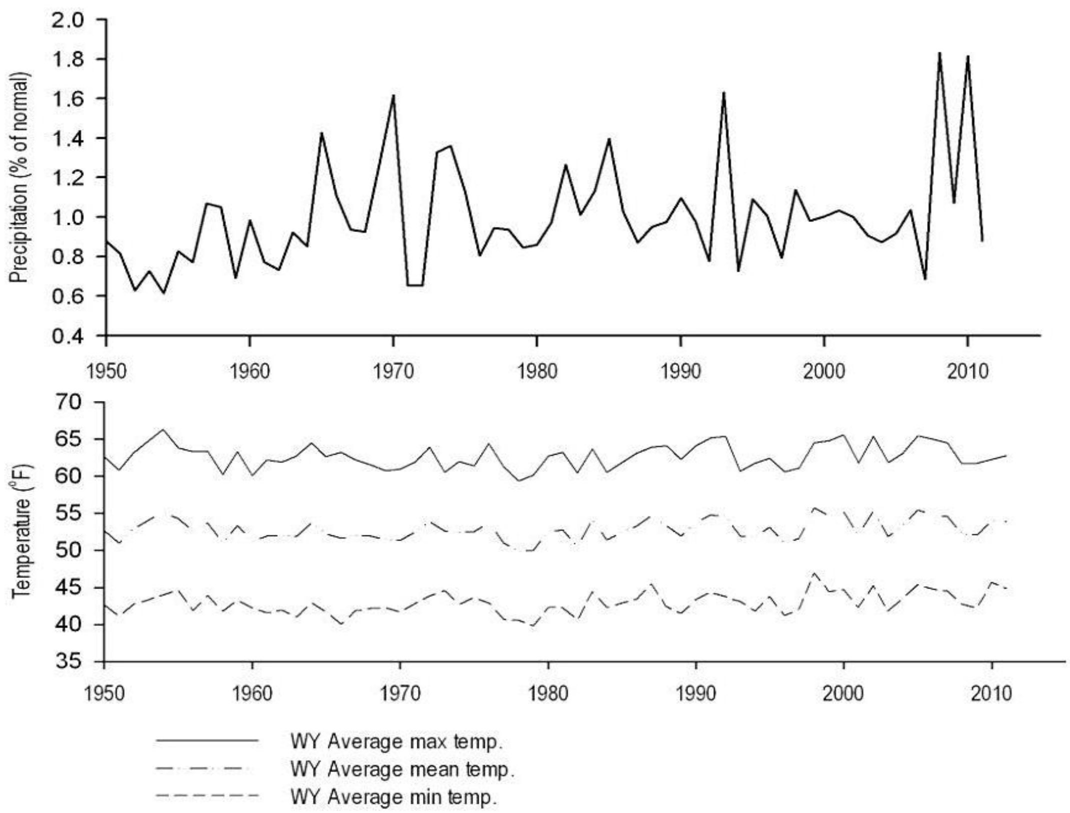


Figure 4 (top) Water year (WY; Oct. 1 to Sep. 31) fractional percentage that precipitation deviates from normal (1= typical and 2= 200% of normal) and (bottom) temperature trends from 1950 to 2011 at Bowling Green, MO (Station ID: 230856)

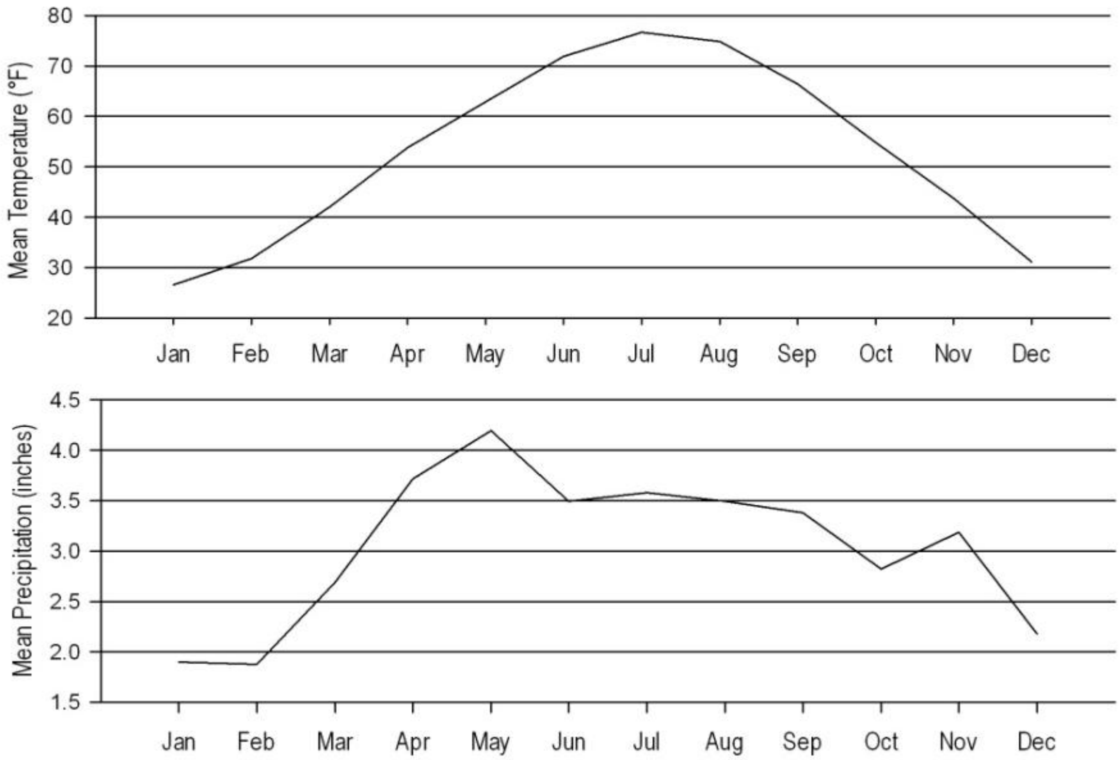


Figure 5 Monthly mean precipitation and temperature from 1950-2011 at Bowling Green, MO (Station ID: 230856)

5. Water Resource Features

Multiple water management plans created for the two Refuges are available through the USFWS ServCat document storage database (reference codes 4804, 4832, 4810, 4809 and 4814). Most of the water management plans were created from 1984-1995, which exist as source documentation of the creation of moist soil units, ditches and levee modifications. Additionally, water management efforts and were documented within annual narratives for subsequent years. Typically, water impoundments are lowered from March to July, and water levels were increased in August to September and maintained through the winter months. Appendices B and C contain figures illustrating wetland, HMP land classifications and National Hydrologic Dataset (NHD) flowpaths for each of the Refuges.

5.1 Wetlands and Bottomland Prairies

The National Wetland Inventory for the Divisions was completed using color Infrared images (1:58k) from 1985 and 1986 (Cowardin et al 1979). Data collected at the Bowling Green NE 2 weather station (NOAA Station ID: 230856) indicate these two years were respectively 119% and 121% of the typical mean annual precipitation (36.5 in) from 1950 to 2010. This suggests that wetlands in this region were likely to holding more water and may have been delineated with a larger extent and a potentially inappropriate wetland status (i.e. permanent or temporary).

For Clarence Cannon NWR, the NWI classified roughly 63% of the acquired area as wetland, primarily as permanent emergent managed impounded wetlands. A reclassification of the habitat types was done for the HMP based on Nelson 2005, which reclassified the majority of habitat as marsh riverine/moist soil units, floodplain forest, wet bottomland prairie and a small percentage of shrub swamp. Additionally, the HMP identified the primary water regime as seasonal/temporary. Only a small percentage of the units are considered semi-permanent or permanent.

For the Delair Division, the NWI classified roughly 58% of the acquired area as wetland, primarily as temporary freshwater-forested shrub, forested wetland, emergent wetland and lake. A reclassification of the habitat types was done for the HMP based on Nelson 2005, which reclassified the majority of habitat as wet-mesic bottomland prairie, floodplain forest and marsh riverine. Essentially, the areas not included in the NWI were classified as bottomland prairie and the areas of freshwater emergent wetland were re-classified as marsh riverine. The majority of these units are considered seasonally or temporarily flooded.

For the Long Island Division, the NWI classified roughly 90% of the acquired area as wetland, primarily as freshwater forested/shrub or lake. A reclassification of the habitat types was done for the HMP based on Nelson 2005, which reclassified the majority of habitat as seasonal/temporarily floodplain forest or permanent large riverine.

For the Fox Island Division, the NWI classified roughly 39% of the acquired area as wetland, primarily as temporary or seasonally flooded forested shrub, forested wetland and emergent wetland. A reclassification of the habit types was done for the HMP based on Nelson 2005, which reclassified the majority of habitat as wet-mesic bottomland prairie, floodplain forest, shrub swamp and marsh riverine. Essentially, the areas not included in the NWI were classified as bottomland prairie and the areas of freshwater forest and shrub were classified as floodplain forest or shrub swamp. The majority of these units are considered seasonally or temporarily flooded. The HREP includes enhancing wetlands in and around Logsdon Slough, Coin Pond, Slim Slough, and Old Lake by installation of two groundwater wells, improving channels and installing new water control structures.

5.2 NHD Flowlines (streams, creeks and ditches)

NHD flowlines were clipped to a ¼ mile buffer of the Refuges acquisition boundary and summarized based on named features and feature types (i.e. USGS FCodes) (Appendix C). Furthermore, ditches and flow direction was modified to reflect current conditions. Each Division had roughly 20-40 miles of NHD flowpaths within or adjacent to the acquisition boundary. The most prominent named features include the Mississippi River (≈27 miles), Fox River (≈5.6 miles), The Sny (≈5.45 miles) and Bryants Creek (≈3.86 miles). Additionally, Ramsey Creek, Guinns Creek and Slim Chute located and identified within the Geographic Names Information System (GNIS). The majority of the flowpaths were considered artificial paths or stream/river features.

Additionally, the NHD point data identified a location just upstream of Clarence Cannon NWR at which Bryant Creek reportedly disappears underground or reappears at the surface (labeled 'Sink/Rise' a phenomenon typically found in karst areas). The location and functional implications of this point has not been evaluated at this point.

5.3 Water Control Structures (WCS)

Currently, ten water control structures are identified in the Delair Division and 21 water control structures are identified for Clarence Cannon NWR (Figure 3). However, the 2000 Annual narrative identified 12 water control structures in the Delair Division and 28 water control structures at Clarence Cannon NWR (USFWS 2000, ServCat reference 5508). However, multiple structures have been moved to different locations or removed entirely to combine units since 2000. A majority of the structures use boards or stop logs to manipulate water levels in wetlands and moist soil units. These structures currently have survey quality GPS coordinates and elevation information from structure cross bars.

Additionally, several structures are being constructed on the Fox Island Division as part of the Habitat Rehabilitation and Enhancement Project (HREP).

The Long Island Division has multiple structures at unknown locations. Six small moist soil units were constructed in the early 1970's in the south-central portion of Long Island, adjacent to Long Island Lake. The units are contained by low-level dikes and natural ridges, are not actively manage and comprise approximately 40 acres. At one time water levels were actively managed and controlled by screwgates and/or flashboard riser structures measuring from 14" to 24" in diameter. It is not known if these structures still exist.

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Currently, the WCS have not been correlated to the real property inventory (RPI) numbers available from the USFWS. In addition to these structures, levees, Refuge road and ditches are controlling and directing water, limiting sheet flow or fragmenting units. Evaluating the removal of some of these structures was suggested within the HMP (USFWS 2011).

Table 1 Water control structures

Clarence Cannon WCS	Type (unconfirmed)	Delair Division WCS	Type (unconfirmed)
7SE	Concrete WCS	Lower Swan	Metal rectangular box with grate
BN2	Metal half round WCS	Cattail	Concrete WCS
1	Metal half round WCS	Butcher	Metal half round WCS
2	Metal half round WCS	Hanei	Metal half round WCS
3	Metal half round WCS	Lower Cattail	Metal half round WCS
4	Metal half round WCS	No Name	Metal half round WCS
5	Metal half round WCS	Rick's	Metal half round WCS
6	Metal half round WCS	Shoveler	Metal half round WCS
7E	Screwgate	Sny	Metal half round WCS
8N	Metal half round WCS	Upper Swan	Metal half round WCS
8S	Metal half round WCS		
9	Metal half round WCS		
10	Metal half round WCS		
11	Metal half round WCS		
12	Metal half round WCS		
F14	Metal half round WCS		
LRE	Metal half round WCS		
BP	Metal half round WCS		
SP	Metal half round WCS		
GP-N	Metal half round WCS		
GP-S	Metal half round WCS		

6. Water Resource Monitoring

The WRIA identified historical and ongoing water resource related monitoring on or near the Refuges. Water resource monitoring can be divided broadly into quality and/or quantity monitoring on surface water or groundwater.

Water quantity monitoring typically includes a stage and/or discharge measurement in a stream or aquifer. The staff gages installed at multiple locations on the Refuges to monitor water levels in the units are typically a way to estimate water level or volume within the units. For the purposes of the WRIA, water quantity information was briefly evaluated for applicability, period of record and trends. Monitoring locations that are directly

Water quality can include laboratory chemical analysis, deployed sensors or biotic sampling such as fish assemblages or invertebrate sampling. Biotic sampling is often used as an indicator of biological integrity, which is a measure of stream purpose attainment by State natural resources management organizations. The Mississippi River has a number of these datasets and has been sampled as part of the EPA Great Rivers assessment (Link) and through the efforts of multiple State environmental protection agencies. For example, the USGS long-term research and monitoring program (Link) has both regular monitoring sites within the pools and sites that are occasionally monitored as part of a longer period more intensive sampling program.

The data for historical sampling locations that are not considered active can be retrieved through EPA STORET (STOrage and RETrieval; Link) database based on ID No. (Appendix D). The data warehouse is a repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others.

6.1 Water Monitoring Stations and Sampling Sites

Fifty-three active monitoring locations are considered applicable to the Refuges' water resources. Recently, 41 staff gauges, corrected to mean sea level, were installed at Clarence Cannon NWR and Delair Division to track water levels (Appendix C). Six active surface water-monitoring sites and two groundwater sites were determined to be directly applicable to the Refuges. Surface water sites are applicable if located on a waterway that passes through the Refuge and groundwater wells were only considered applicable if they were located in the Mississippi River alluvial flood plain. Four weather-monitoring stations (2 from USHCN) were identified and discussed in Section 4.4.

A list of sites that are relevant but not necessarily directly applicable to the resources of concern or that are currently inactive was also created (Appendix D). Data was also collected from the EPA STORET database, which houses monitoring data collected by the states under the Clean Water Act. Surface water stations were considered applicable if they were located within the HUCs of interest and/or drainage areas adjacent to Refuge property. Seventy-six sites were identified, primarily completed by the U.S. EPA, Illinois EPA or Missouri DNR (Appendix D).

Table 2 Active applicable monitoring locations

Description	ID and Link	Location	Depth/Flood stage	Elevation	Notes	Owner
Groundwater well in Pike County, Missouri, Hydrologic Unit 07110009	Site Number: 392147090541901 - Clarksville USGS site	Latitude 39°21'47", Longitude 90°54'19" NAD83	Well depth: 650 feet	Land surface altitude: 490.00 feet above MSL NAVD88.	Well completed in "Cambrian-Ordovician aquifer system" (S300CAMORD) national aquifer. Well completed in "Champlainian Series" (365CMPL) local aquifer. This well is affected by groundwater pumping locally.	The record for this site is maintained by the USGS Missouri Water Science Center.
Groundwater well in Marion County, Missouri Hydrologic Unit 07110004	Site number: 395043091262601- Hannibal USGS site	Latitude 39°50'43", Longitude 91°26' 26" NAD 27	Well depth: 85 feet	Land surface altitude 480 feet above MSL NGVD 1929	Well completed in the Mississippi River Valley alluvial aquifer. This site is located between the Delair Division and Long Island Division. This site has water levels from 1958-2012	The record for this site is maintained by the USGS Missouri Water Science Center.
Fox River at Wayland, MO	USGS 05495000	Latitude 40°23'32.7", Longitude 91°35'52.4" NAD83	Flood stage: 15 ft. Record high stage: 23.07 ft. on 06/15/2011	Drainage area 400 square miles; Gage zero datum 501.52 NGVD 1929	This site has a comprehensive water chemistry (1960-1972; 2000-2012), This site has a precipitation accumulator	The record for this site is maintained by the USGS Missouri Water Science Center.
Mississippi River at Keokuk, IA	USGS 05474500	Latitude 40°23' 27", Longitude 91°22' 27" NAD27	Flood stage: 16 ft. Record high stage 27.58 ft.	Drainage area approx. 119,000 square miles; Gage zero datum 471.41 NGVD 1929	Applicable to Fox Island Division, but prior to the confluence with the Des Moines River. This site has a comprehensive WQ sample set.	This is a USGS Iowa Water Science Center gage which is operated in cooperation in Ameren, which is a power company
Mississippi River at Louisiana, MO	Link to St. Louis District Corp. of Engineers site	Longitude: -91.04663962, Latitude: 39.45259563 River Mile: 282.9 miles above the mouth of the Ohio River	Flood stage: 15 ft. Record high stage 28.40 ft.	Gage Zero: 437.33 Ft. NGVD29	The primary gage of concern for anticipating water levels and when the levee is exceeded at Clarence Cannon NWR	This gage is owned, operated, and maintained by the St. Louis District, Corps of Engineers.

Gregory Landing	Link to St. Louis District, Corp of Engineers site	Longitude: -91.4959, Latitude: 40.2792, River Mile: 352.9 miles above the mouth of the Ohio River	Flood stage: 16 ft. Record high stage 27.58 ft.	Gage Zero: 472.71 NGVD 1929	Applicable to Fox Island Division	This gage is owned, operated, and maintained by the St. Louis District, Corps of Engineers.
L&D 24 Tail-waters	Link to St. Louis District, Corp of Engineers site	Latitude: 39.37472200, Longitude: -90.90694400. River Mile: 273.2 miles above the mouth of the Ohio River	Flood Stage: 25 ft. Record High Stage: 37.69 Ft.	Gage Zero: 421.81 Ft. NGVD29	Gage applicable to Clarence Cannon NWR (upstream)	This gage is owned, operated, and maintained by the St. Louis District, Corps of Engineers.
Mosier Landing on Mississippi	Link to St. Louis District, Corp of Engineers site	Latitude: 39.25729670 Longitude: -90.72721281 River Mile: 260.3 miles above the mouth of the Ohio River	Record High Stage: 54.3	Gage Zero: 400.00 Ft. NGVD29 Flood Stage:41 Ft.	Most applicable gage for determining flood elevations at Clarence Cannon NWR	This gage is owned, operated, and maintained by the St. Louis District, Corps of Engineers.

6.2 Surface Water Quantity

Hydro-Climatic Data Network (HCDN)

The Hydro-Climatic Data Network (HCDN) is a network of stream gages located within relatively undisturbed watersheds, which are appropriate for evaluating trends in hydrology and climate, which are affecting flow conditions. This network attempts to provide a look at hydrologic conditions without the confounding factors of direct water manipulation and land use changes. The closest site from this network is the North River at Palmyra, MO (USGS 05501000). This site suggests, based on annual mean discharge that overall conditions were drier in the 1950s, 1960s and early 2000, while the 1980s and the last 4 years were wetter than normal based on mean annual discharge (Figure 6). Typically, there is a drought year once every ten years and the data does suggest a long-term trend of increasing discharge and slight increase in typical peak discharge.

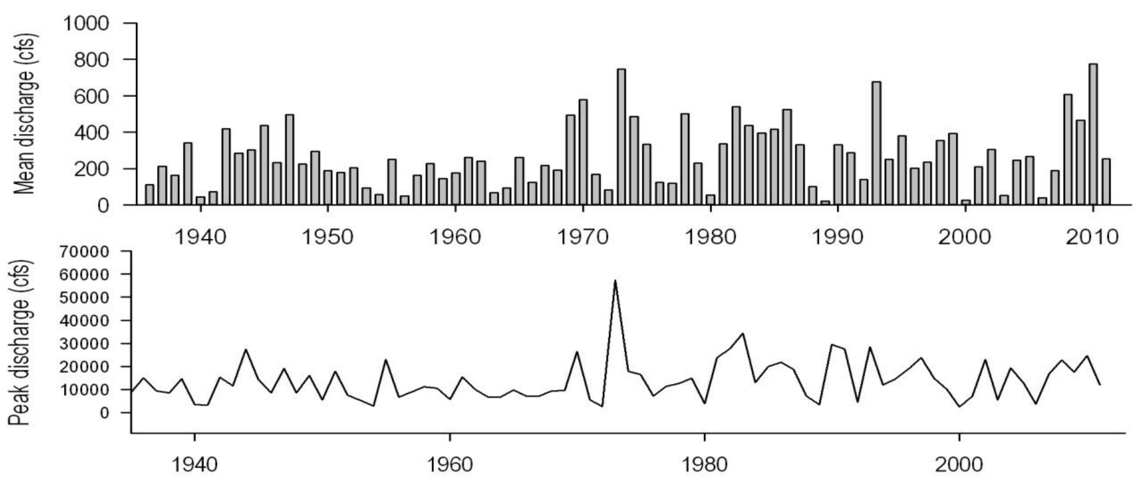

Figure 6 Mean annual and peak discharge for the North River at Palmyra, MO (USGS 05501000)

Fox Island Division-Fox River

The Missouri Department of Conservation (MDC) conducted an inventory and assessment of the Fox River, which evaluated the watershed and provided recommendations (Hrabik 1992). The USGS gaging station on the Fox River is useful for the Fox Island Division and a potentially relevant indicator for patterns in the other local streams and rivers. The Fox River did not have any apparent long-term trends in peak discharge. Although, mean monthly discharge is higher in many months relative to the period of record at the Fox River. When compared to the HCDN site on the North River (USGS 05501000), the Fox River has a smaller discharge, but displays similar intra-annual patterns in peak discharge.

The Fox Island Division Habitat Rehabilitation and Enhancement Project (HREP; USACE 2006) evaluated water quality and completed a hydrologic analysis of both the Fox River and Mississippi River. Generally, overbank flooding from the Mississippi River and the Fox River has a return interval of roughly every 2 years, meaning overbank flooding will occur 50% of the time, primarily as backwater flooding because of elevated stage on the Mississippi River.

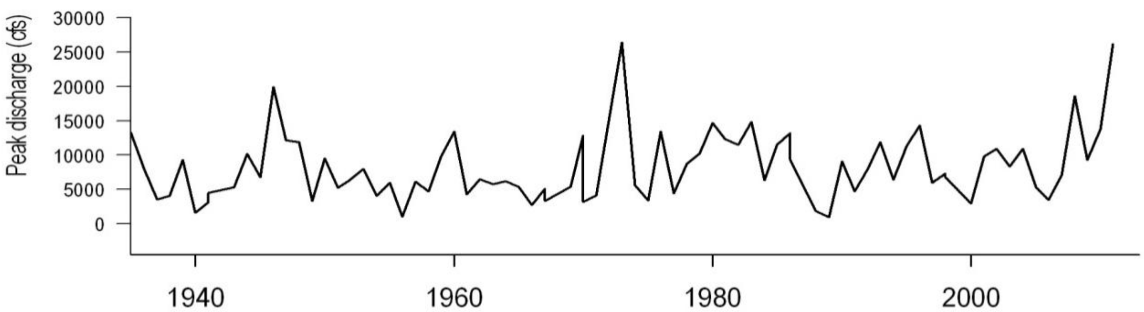

Figure 7 Peak discharge for the Fox River at Wayland, MO (1935-2010)

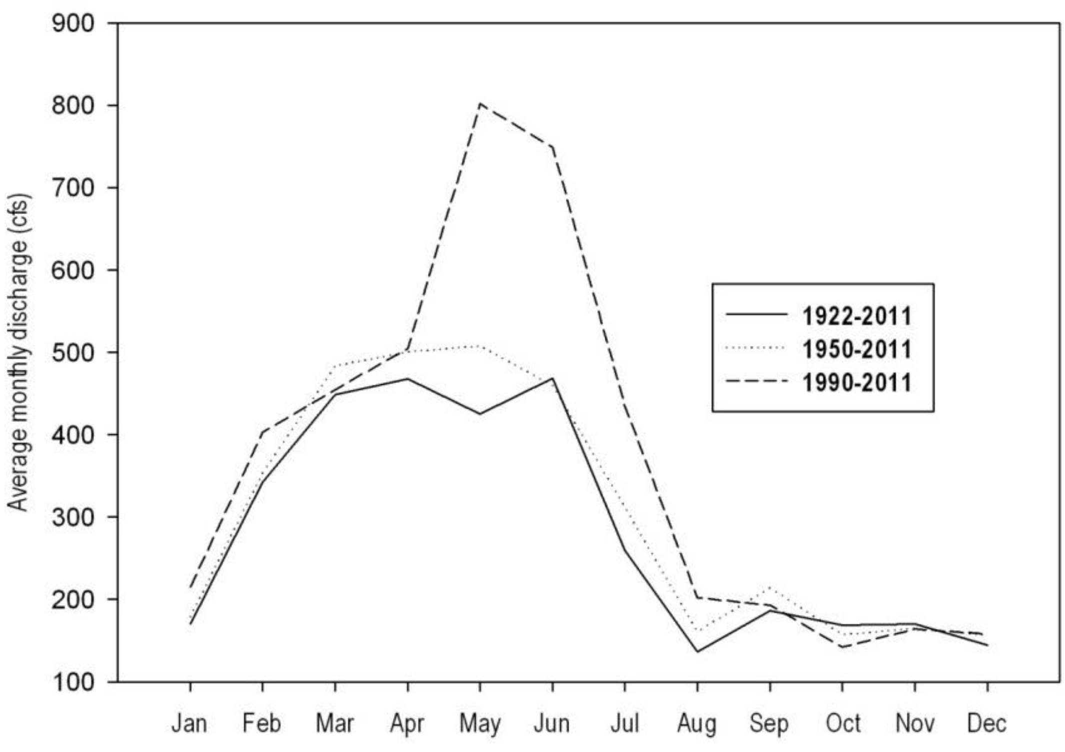

Figure 8 Mean monthly discharge for Fox River at Wayland, MO

Delair Division

The Delair Division is within a leveed area that is part of the Sny Island Levee Drainage District, which during high water runoff events uses a variety of methods and locations to control runoff, retain sediment and pump water. Olson et al (2011) summarized some of the historical management activities and suggests that this District has been a pioneer in the reduction of sediment and the creation of settling basins for nutrient and sediment retention. Water quantity analysis was not completed for this Division, because of the extent and complexity of the management on The Sny runoff and the Mississippi River levee, which effectively separates the Division from large flood events.

Mississippi River models (Clarence Cannon NWR, Long Island Division and Fox Island Division)

The most recent modeling of Mississippi River discharge and elevation are interpolated by Mississippi River mile from an online tool developed by The U.S. Army Corp of Engineer-St Louis district (USACE 2004; Figure 9). These values were developed using an unsteady flow hydrologic model in combination with the Bulletin 17B method (IACWD 1982) to derive flood elevations for a 2 to 200 year event. The revised models suggest an increase of 0.8 ft. (to 463.2 ft. MSL) for a 100-year event at the Louisiana, MO U.S. Army Corp of Engineers gage (USACE 2004). Additional analysis for Pool 25 discharge was completed as part of the USGS Long Term Resource Monitoring Program. The return interval (often referred to as 'flood frequency') is a statistical estimate of the time between specific water discharges. This is the likelihood of reaching a particular maximum discharge for a given location on the River. For example, the 5-year return interval has a 1 out of 5 (20%) likelihood of occurring in a given year and a 100-year return interval has a 1% chance of occurring in a given year. These calculated return intervals can be an underestimate, due to changing underlying flood pressures, which will invalidate the typical methods of utilizing the entire period of record as a basis of flood elevations calculations (USACE 2004). Olsen and Stakhiv (1999) suggest that particularly at locations south of Hannibal, Missouri, using the entire period of record for evaluating flood frequency will underestimate the likelihood of large events. The limitations of the methods in Bulletin 17B, Federal Guidelines for Determining Flood Flow Frequency (IACWD 1982), are discussed within the most recent modeling effort. Once stream-flow exceeds the carrying capacity of the lock and dam structures on the Mississippi River (e.g. L&D 24 at 155,000 cfs) flow can no longer be controlled through that particular section of river.

Return Interval	Discharge (cfs)	Elevation (NGVD 1929)
2	210,000	442.6
5	269,000	445.8
10	310,000	447.5
25	370,000	449.8
50	404,000	450.7
100	443,000	451.7
200	489,000	452.7

Peak elevation and discharge for the Mississippi River (Mile 262) near Clarence Cannon NWR.

Return Interval	Discharge (cfs)	Elevation (NGVD 1929)
2	200,000	488.0
5	245,000	490.9
10	282,000	492.6
25	317,000	494.3
50	353,000	495.8
100	396,000	497.4
200	442,000	498.8

Peak elevation and discharge for the Mississippi River (Mile 356) near Fox Island Division.

Return Interval	Discharge (cfs) Mile 340	Elevation (NGVD 1929)-Mile 340	Discharge (cfs) Mile 333	Elevation (NGVD 1929)-Mile 333
2	203,000	481.2	204,000	477.5
5	255,000	484.1	255,000	480.3
10	286,000	485.5	288,000	482.2
25	326,000	487.5	333,000	484.8
50	364,000	489	375,000	486.7
100	408,000	490.5	419,000	488.4
200	454,000	491.9	463,000	489.8

Peak elevation and discharge for the Mississippi River (Mile 340 and 333) at the upstream and downstream ends of Long Island Division

Figure 9 (left) Interpolation of return intervals (e.g. 100 means a 1% likelihood) for Mississippi River flows and water surface elevation for river miles adjacent to Clarence Cannon NWR, Fox Island Division and Long Island Division. Discharge in cubic feet per second

6.3 Clarence Cannon NWR Mississippi Water Levels

HMP Objective 5.B is to:

> *"Manage refuge lands for wildlife first, while considering upper Mississippi River floodplain functions and contributing to improving those values by…. continuing to study River hydrology to evaluate the feasibility of improving connectivity at refuge units with some level of levee protection while monitoring high-quality wetland or other habitats. Use 1- to 10-year flood level spillways at locations such as Clarence Cannon NWR or some newly acquired areas. "*

Following the 1993 flood, an 800-foot spillway was cut into the Mississippi River levee on the southeast side of the refuge. The construction of the spillway allows floodwaters to enter, providing connectivity to the river at high water levels and repurposing the Refuge as a location for temporary floodwater storage. However, floodwaters that quickly enter the Refuge through the spillway are often impounded for prolonged periods, due to the lack of adequate drainage pathways.

The most relevant water level gage for determining if water levels are exceeding the levee or to determine the regularity of inundation is the St. Louis District Corp of Engineers gage located at Mosier Landing (river mile 260.3; Link). Alternatively, the discharge tailwater at Lock & Dam 24 (river mile 273.2; Link) can be used to gain a rough estimate of water surface elevations adjacent to the Refuge. Due to the elevation drop in the river, the elevation at this gage will typically indicate a higher elevation then observed at the Refuge.

From 1996 until 2003 the spillway was exceeded when the gage for the Lock & Dam 24 tail water (L&D24 TW; at Louisiana, MO) exceeded approximately 452.21 feet above Mean Sea Level (MSL). This value was raised to approximately 453.31 ft. in 2004, when the elevation of the spillway was increased to 449.1 ft. This spillway elevation has an approximate return interval of 20 years. This value was exceeded most recently in 2001, 2008 and briefly in 2011. Water has entered the refuge multiple times in the last five years, which is statistically unlikely. There is no evidence of a statistical trend of increasing flood frequency beyond the slight increase already discussed. This suggests that recent water levels are just part of wetter period and not necessarily indicative of future water levels.

The main levee was raised from 450.2 ft. to 452.2 ft. in 1991, which will equal approximately a 150-year flood event based on the calculated return intervals. The return intervals suggest that this levee has a statistically low likelihood of being exceeded (Figure 9).

One recommendation from the HMP specific to Clarence Cannon NWR is the lowering and/or removing portions of the levee to allow for the eastern section of the Refuge (800-1000 acres) to be directly influenced by Mississippi River water level fluctuations, thereby replicating hydrologic functions which occurred naturally prior to construction of the levee. This recommendation suggests that natural scours and sloughs, which have been filled and/or disconnected from the River, would be enhanced and reconnected to the natural water regime.

Lowering the grade at portions of the existing levee's southeast corner and/or other areas would allow for a more consistent connection with the River during a wider range of flood events. This would allow the river to backflow into the area, which would minimize the negative impacts associated with a direct river connection, such as sediment and contaminant deposition. The length of time during which receding high water levels form isolated pools behind the levee would be reduced, resulting in less stagnant water and higher oxygen levels. However, without additional drainage options, the Refuge would still retain water longer than desirable.

6.4 Groundwater elevation

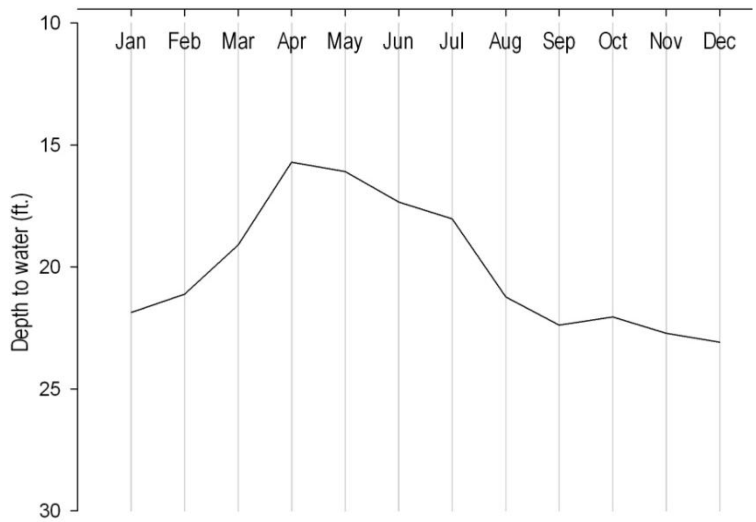

Figure 10 Mean monthly feet below the surface of groundwater from 1957-2011 in Marion County near Hannibal, Missouri (USGS 395043091262601)

The monitoring well at Hannibal, Missouri is located within the Mississippi River alluvial flood plain and therefore the most likely to be representative of relative groundwater levels within the region (Figure 10). Water levels at this site typically oscillate at 15-23 ft. below ground level, and are highest in April or May and are typically lowest in September through December. It is not clear if groundwater pumping for agricultural purposes is taking place and influencing these data.

Additionally, there was a groundwater well located upstream of Fox Island Division in Wayland, Missouri which is near a surface water monitoring gage. This site maintained records from 1975-2010, but appears to be discontinued. This site did not indicate any trend increasing nor decreasing in depth to water for the period of record. However, where data was available, the groundwater levels do appear to correspond roughly to surface water fluctuations, based on a comparison to the Fox River surface water station located nearby. This implies surface and ground water interaction facilitated by porous soils.

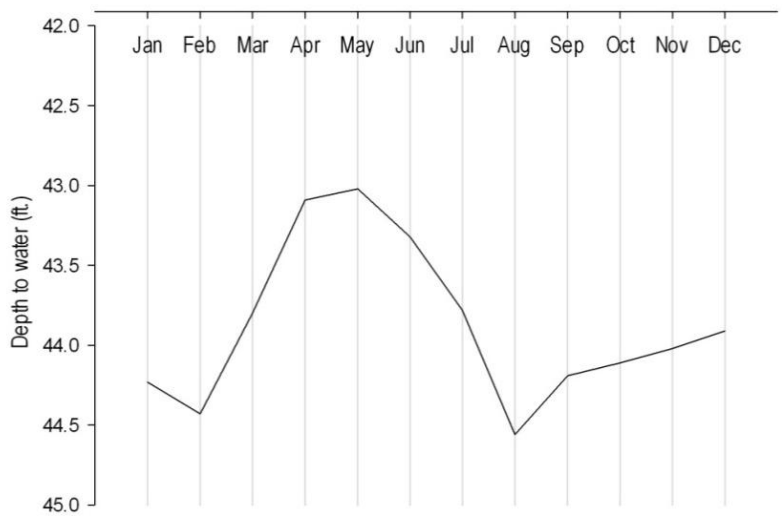

Figure 11 Mean groundwater levels from 1983-2010 at Wayland, MO near the Fox River

The Mississippi River and the saturated vadose zone (shallow zone extending from the ground surface to the water table) surrounding it; is likely acting as a hydraulic dam to groundwater flow causing water to rise up to the surface as seeps and springs. According to the *Principal Aquifers of the 48 Conterminous United States (Miller and Appel 1997*), the eastern half of Clarence Cannon NWR is within the Silurian-Devonian aquifer, which is carbonate based rock, which is generally fairly porous rock with high levels of transmissivity. The western half of Clarence Cannon NWR and the other Divisions were not classified into a primary aquifer, as the alluvium extends to depth and wells of sufficient depth with characterizations are not available. The water elevation for the northern portion of Clarence Cannon is at approximately 425 feet above mean sea level (or approximately 15 feet below ground surface) in 2006 according to driller's logs received by the state of Missouri.

6.5 Surface Water Quality

Water chemistry information was downloaded from the EPA STORET database, using the EPA "Surf your Watershed" (http://cfpub.epa.gov/surf/locate/index.cfm) and the USGS NWIS database (http://qwwebservices.usgs.gov/). Additionally, information was obtained from the USGS Long Term Research Monitoring Program and a number of peer reviewed journal articles that evaluated water chemistry and completed additional types of sampling, which are not commonly available within the databases. Available water chemistry information was primarily for sample sites along the Mississippi River and did not include sample locations within the Divisions nor on the tributary source water locations directly upstream of the Divisions.

Patricia Herman (USFWS) completed the contaminants assessment process (CAP) in 2010 for the Great Rivers/Clarence Cannon NWR. This process included the identification of contaminant sources that are on and off the Refuge units, delineation of transport pathways for contaminants, potentially contaminated areas, and natural resources at risk. The major hydrologically relevant conclusions within the CAP were (Herman 2010):

1. The Upper Mississippi River basin is considered a major source of nutrients (especially nitrate) that contribute the Gulf dead zone or hypoxia problem (Rabalais, Turner & Scavia 2002). The water sources for the Mississippi River include the tributary rivers, drainage ditches, tile drainage systems, and groundwater, which load the backwaters of the Mississippi River with nutrients.
2. Aquatic life in Refuge backwaters may be exposed to a complex mixture of metals, organic chemicals used for pesticide manufacturing, and emerging contaminants. Long-term exposure to these kinds of contaminants may cause organism abnormalities or may adversely affect growth, development, reproduction, and survival of sensitive species.
3. Flooding is the most prevalent mechanism for the deposition of contaminants in the refuge. In 1989, staff from the Rock Island Ecological Services Office conducted contaminant studies along the Illinois and Mississippi Rivers to determine if pollutants were present in aquatic sediments. Refuge sites tested included Fox Island, Long Island, Delair and Clarence Cannon NWR. No organic pollution from chemicals such as DDT, chlordane or PCB was detected in refuge divisions. Heavy metal concentrations were between normal and slightly elevated.

The previous contaminant survey was completed subsequent to a period with fewer floods and prior to multiple large flood events. This suggests that the potential for contaminants should be reevaluated, particularly focusing on heavy metals.

Water chemistry was also reviewed as part of the Fox Island Habitat Rehabilitation and Enhancement Project (HREP) for the Mississippi River and the Fox River. The evaluation of the water chemistry data in the area was limited to a couple of locations, based on a few sampling events and did not include the collection of recent information. The primary concern is elevated levels of metals (e.g. manganese and iron) that have been detected in the Fox River, Mississippi River and groundwater at levels above Federal and state water quality criteria. They suggest that aeration from pumping will help to remove the metals, leading to precipitation at pump site locations.

Sedimentation is a major concern on the Long Island Division, where it has reduced depths and limited boat travel in chutes and channels. Much of the sedimentation is due to the combination of increased upstream erosion and the subsequent deposition due to reduced velocities on the Mississippi River following the construction of the Locks and Dams (USFWS 2012). To address these issues restoration projects have been initiated to enhanced deeper waters for fish habitat through dredging and closing side chutes to reduce sedimentation. Despite the sedimentation concerns, the Division is located immediately downstream of Lock and Dam 20, which suggests that upstream areas of the Division may actually be subject to erosion and stream bed down-cutting as a result of reduced sediment from upstream entrainment in Pool 20.

303(b) Reporting and 303(d) assessments

Section 303(d) of the Clean Water Act requires that each state identify water bodies where water quality standards are not met, based on designated usage.

The northern boundary of CCNWR is bounded by Ramsey Creek to the north and Bryants Creek forms the southern boundary. These Creeks drain primarily agricultural lands from the west and are subject to backwater from the Mississippi River. Through pumping, Bryants Creek is the primary source water to Refuge units. These Creeks have been assessed as "good" for a designated use of "protection of aquatic life (general warm-water fishery)" which falls under a more general category of "fish, shellfish, and wildlife protection and propagation" (MDNR 2010). Although, the Missouri Department of Natural Resources

(MDNR) did suggest that there may be impairment potential because of habitat degradation on the two streams, a designation that does not currently meet the criteria for 303(d) listing under the current rules.

As of 2006, at the Delair Division, the Sny River was assessed adjacent to the Division as "good" for fish consumption, but has not been assessed for the support of aquatic life, which is separate designated use. Bay Creek, an adjacent flow path was determined to be impaired for dissolved oxygen, fecal coliform, total phosphorous, sedimentation/siltation and total suspended solids. It is likely that the Sny River may have similar impairments, but has not been evaluated for these impairments. The Mississippi River adjacent to the Delair Division supports primary contact and aquatic life, but is impaired for fish consumption, due to mercury in fish tissue.

The Mississippi River adjacent to the Long Island and Fox River Division is impaired for fecal coliform, manganese, polychlorinated biphenyls (PCBs) and fish consumption and currently requires the development of a total max daily load TMDL plan. A segment of the Fox River that runs through the Fox River Division has been assessed and determined "good" for the designated uses of: drinking water supply, protection of aquatic life and whole body recreation. Honey Creek, which joins the Fox River at the Division, was determined to be good, for the protection of aquatic life. Upstream of Fox Island on the Mississippi, the lower Des Moines River at its confluence with the Mississippi is impaired for whole body contact due to pathogens.

7. Water Law

Given that the Refuge units are in both Missouri and Illinois, subtle differences in applicable water law do exist, despite a common basis in riparian right doctrine. In states that apply the riparian rights doctrine, landowners of property with naturally flowing surface water running through or adjacent to their property have rights to reasonable use of the surface water associated with the property itself. The "reasonable use" standard protects downstream users by ensuring that one landowner's use does not unreasonably impair the equal riparian rights of others along the same watercourse. Additionally, the law limits riparian rights to those rights "intimately associated" with the water; uses falling outside of this definition are usually considered unreasonable uses.[1]

An important corollary to the riparian rights doctrine is that, generally, states classify their navigable[2] surface waters as public, whether through statute or through the common law public trust doctrine.[3] This is important because on public waters, the riparian landowners' rights are subject to public rights of, at a minimum, navigation. For this reason, states regulate waters for the purpose of putting the water to "beneficial use," a term defined differently amongst the states.

7.1 Missouri

Missouri's judicially defined reasonable-use rule provides that riparian owners have the "right to the flow of the stream in its natural course and natural condition in respect to both volume and purity, except as affected by reasonable use by other proprietors."[4] Landowners' riparian rights include "the limited right to use the water to irrigate [their] land," so long as the "natural wants" of other riparian owners are met.[5] These "natural wants," consisting of "drinking water for family and livestock," take priority over other water uses.[6] Courts determine what constitutes reasonable use on a case-by-case basis, looking at, among

[1] John W. Johnson, United States Water Law: An Introduction 38 (CRC Press, 2009).

[2] "Navigable," in this context, is a legal term of art that varies from state to state, separating public waters from those that are private. As a general notion, "navigable" means navigable in fact, which, historically, has been tested by whether or not a log or canoe could float on the water. *See, e.g.,* Paul G. Kent & Tamara A. Dudiak, *Wisconsin Water Law: A Guide to Water Rights and Regulations* 4 (University of Wisconsin-Extension, 2d ed., 2001).

[3] The public trust doctrine, in most states, refers to the concept that state, as trustee to the public, preserves navigable waters "for public use in navigation, fishing and recreation." Black's Law Dictionary 1232 (6th ed. 1990). This prohibits the state from selling the beds to private parties.

[4] *Bollinger v. Henry*, 375 S.W.2d 161, 166 (Mo. 1964).

[5] Id.

[6] Id.

other things, “the volume of water in the stream, the seasons and climatic conditions, and the needs of other riparian proprietors.”[7]

The state of Missouri does not have a sophisticated water permitting system like some of the other Region 3 states. However, it has taken some measures to, at a minimum, inventory and plan for long-term water resource use. The state tasked the Missouri Department of Natural Resources (DNR) to develop a State Water Resources Plan in order to assess the existing and future needs of surface and ground water for “drinking water supplies, agriculture, industry, recreation, environmental protection and related needs.”[8] As part of the state water resources program, the DNR also has the duty of creating a plan for water resource emergencies.[9] The water inventory examines: (1) existing surface and groundwater uses, (2) quantities available for future uses, and (3) water extraction and use patterns, including both regulated and unregulated users.[10] Based on the collected data, DNR can then make recommendations annually to the general assembly about potential statutory revisions that should be made related to the state’s water laws.[11]

DNR uses a registration program to facilitate its water resource inventory. The program requires “major water users,” or those users with a “water source and equipment necessary” to withdraw or divert at least 100,000 gallons-per-day from any surface or ground water source,[12] to register with the Missouri Division of Geology and Land Survey by providing information regarding the water source, the installation, the purpose used, the time of year withdrawals will be made, and the daily and annual amounts withdrawn.[13]
Missouri has implemented a smattering of either permit programs or regulations for other activities on public waters. As an example, the state requires permits for dam construction on public waters,[14] which includes a requirement to construct a chute for fish.[15] Failure to construct a chute to the statutorily defined parameters constitutes a public nuisance.[16] Also, the state, through its Well Installation Board, regulates well drilling to a limited extent.[17]

At the local level, the state has authorized communities to establish water supply districts, water conservancy districts, drainage districts, and levee districts. Community public water supply districts may determine the scope of the district and have powers delegated by the state, such as eminent domain and taxation, to administer the construction and maintenance of a water supply.[18] Similarly, community members can establish water conservancy districts that focus on protection of a primary water source in their region.[19] These districts have the delegated power to take actions such as imposing fees on irrigation wells.[20] Since excessive water seems to pose more of a threat to Missouri citizens than water shortages, community-administered drainage and levee districts exist to construct projects for the purpose of reclaiming swampland for either sanitary or agricultural reasons, so long as the drainage or levee activities do not negatively impact the public.[21] The state places much emphasis on the role of local communities to control water resources.

[7] Id.
[8] Missouri Rev. Stat. § 640.415.
[9] Missouri Rev. Stat. §256.440–443.
[10] Missouri Rev. Stat. § 640.412
[11] Missouri Rev. Stat. § 640.415.
[12] Missouri Rev. Stat. § 256.400(4).
[13] Missouri Rev. Stat. § 256.410.
[14] Missouri Rev. Stat. § 236.435.
[15] Missouri Rev. Stat. § 236.230.
[16] Id.
[17] Missouri Rev. Stat. §§ 256.600-256.660.
[18] Missouri Rev. Stat. §§ 247.010–247.673.
[19] Missouri Rev. Stat. §§ 256.030–256.070.
[20] Missouri Rev. Stat. § 256.655.
[21] Missouri Rev. Stat. § 242.563; *see, also*, Missouri Rev. Stat. §§ 242.010–242.750, 245.010–244.205.

7.2 Illinois

Illinois does not have a sophisticated means for claiming rights to water, especially for instream water rights. As a state that generally follows the traditional riparian rights doctrine,[22] all landowners adjacent to a body of water have a right to reasonable use of the water, so long as it does not impact the same rights as other similarly situated landowners.[23] The legislature codified surface and ground water into one system under the Water Use Act of 1983, which extended the common law reasonable-use rule to groundwater withdrawals.[24]

The statute specifically defined "reasonable use," in keeping with the common law, as "the use of water to meet natural wants and a fair share for artificial wants. It does not include water used wastefully or maliciously."[25] In Illinois, "natural wants" refer to uses necessary to the land, mainly domestic uses.[26] "Artificial wants," on the other hand, refer to uses that would increase "comfort and prosperity."[27] In times of shortage, the state will prioritize natural wants over artificial wants, and once natural wants are satisfied, water users may consume their "just proportion" of artificial wants.[28] Courts ultimately determine on a case-by-case basis whether a water user has consumed beyond his "just proportion," looking at the relative needs of the water users and the water availability.[29]

With the reasonable-use rule as a foundation, Illinois allows communities to regulate groundwater consumption through the establishment of water authorities, in order to give communities the power to take control of their local resource. The Water Authority Act (WAA) sets out a detailed and extensive procedure for citizens to create a water authority, but once established, the local authority has broad powers.[30]

At least thirteen water authorities have been established since the law was enacted, mostly in the eastern-central part of the state.[31] However, the WAA specifically excludes water used for agricultural purposes, irrigation, and small domestic wells for less than four families from the Authorities jurisdiction.[32] The law does not provide any specific authority for water authorities to ensure minimum flows or instream uses, but at least provides a broad catchall, allowing authorities to "make such regulations as it deems necessary to protect public health, welfare and safety and to prevent pollution of its water supply."[33] This may be the only provision FWS could rely upon to protect instream flows within a local water authority region.

In addition to the local water authorities, the Illinois Department of Natural Resources (DNR) has jurisdiction over public waters, and the agency has a duty to document all navigable waters and "jealously guard the true and natural conditions" of state waters.[34] Under this policy, DNR's Office of Water Resources manages a permit system for construction projects in public water ways, i.e. navigable waters, and for public water developments that may impact public rights to use the water.[35]

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[22] *Evans* v. *Merriweather*, 4 Ill. 491 (1842); *Knaus v. Dennler*, 525 N.E.2d 207, 209 (Ill. App. Ct. 1988).
[23] Gary R. Clark, *Illinois Groundwater Law: The Rule of Reasonable Use* 14–15 (State of Illinois, Department of Transportation and Division of Water Resources 1985).
[24] Water Use Act of 1983, 525 Ill. Comp. Stat. 45/6 (2011).
[25] 525 Ill. Comp. Stat. 45/4.
[26] *Evans* v. *Merriweather*, 4 Ill. 491, 495 (1842).
[27] Id.
[28] *Bliss v. Kennedy*, 43 Ill. 67, 74 (1867).
[29] *Id.* at 76–77.
[30] 70 Ill. Comp. Stat. 3715/1 *et seq.* (2011).
[31] *See* http://www.isws.illinois.edu/docs/wsfaq/wsmore.asp?id=q6; http://www.agr.state.il.us/marketing/IALD/organizations/IALDDirectory%2058.pdf.
[32] 70 Ill. Comp. Stat. 3715/8 (2011).
[33] 70 Ill. Comp. Stat. 3715/24 (2011).
[34] 615 Ill. Comp. Stat. 5/5 (2011).
[35] Ill. Admin. Code tit. 17 §§ 3700, 3704, 3708 (2010).

In Illinois, FWS has a right to the reasonable use of surface and ground water associated with the boundaries of the refuges. While FWS cannot affirmatively assert its right to instream use, it may have a claim against other water users if a shortage occurs, even if that right consists of a just proportion of its natural wants.[36] However, these issues have yet to be explored by the courts.

[36] Illinois courts have not spoken on whether instream uses for fish and wildlife purposes would constitute a natural want.

8. Geospatial Data Sources

1. HUC polygons are available from the EPA as part of the Watershed Boundary Dataset (WBD). These boundaries were delineated in cooperation with the USGS using methodology adapted from Seaber et al (1987)

2. High-resolution LiDAR data (1 m cell size) is currently available from The Upper Midwest Environmental Sciences Center (UMESC) for all of the Great River NWR; Clarence Cannon NWR will be available in the fall 2012. Notably, this most recent elevation data is available in the North American Vertical Datum (NAVD 1988), which will demonstrate a slight difference from the datum's (1912 and NAD 1929) used to calculate the elevations for the river gages, levee heights and Corp management of the river.

3. Multiple types of geospatial layers are available from the Missouri Spatial Data Information Services website (http://www.msdis.missouri.edu/data/newdata.html).

4. The National Wetland Inventory- U. S. Fish and Wildlife Service. 1985-1986. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. http://www.fws.gov/wetlands/

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11. Appendix A Monthly weather summaries

STEFFENVILLE, MISSOURI (238051)
Period of Record Monthly Climate Summary
Period of Record : 1/ 1/1893 to 4/30/2012

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	36.3	40.5	52.8	65.1	75.1	83.7	89.1	87.5	80.1	68.8	53.3	39.7	64.4
Average Min. Temperature (F)	17.5	20.9	31.1	41.9	52.4	61.6	65.7	63.8	55.8	44.8	32.6	22.0	42.5
Average Total Precipitation (in.)	1.68	1.58	2.79	3.56	4.50	4.35	3.94	3.73	4.02	2.93	2.43	1.79	37.30
Average Total SnowFall (in.)	6.4	5.7	3.8	0.8	0.0	0.0	0.0	0.0	0.0	0.1	1.3	5.0	23.

BOWLING GREEN 2 NE, MISSOURI (230856)
Period of Record Monthly Climate Summary
Period of Record : 2/1/1931 to 4/30/2012

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	35.4	41.6	52.4	65.3	73.9	83.0	87.8	85.7	78.9	68.1	53.3	39.6	63.8
Average Min. Temperature (F)	16.2	19.9	30.1	41.8	50.3	59.6	64.7	62.2	53.7	42.4	32.2	20.8	41.2
Average Total Precipitation (in.)	1.72	1.71	2.80	3.88	4.28	3.97	3.59	3.43	3.36	2.89	2.92	2.08	36.63
Average Total SnowFall (in.)	3.5	4.3	2.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	14.5
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

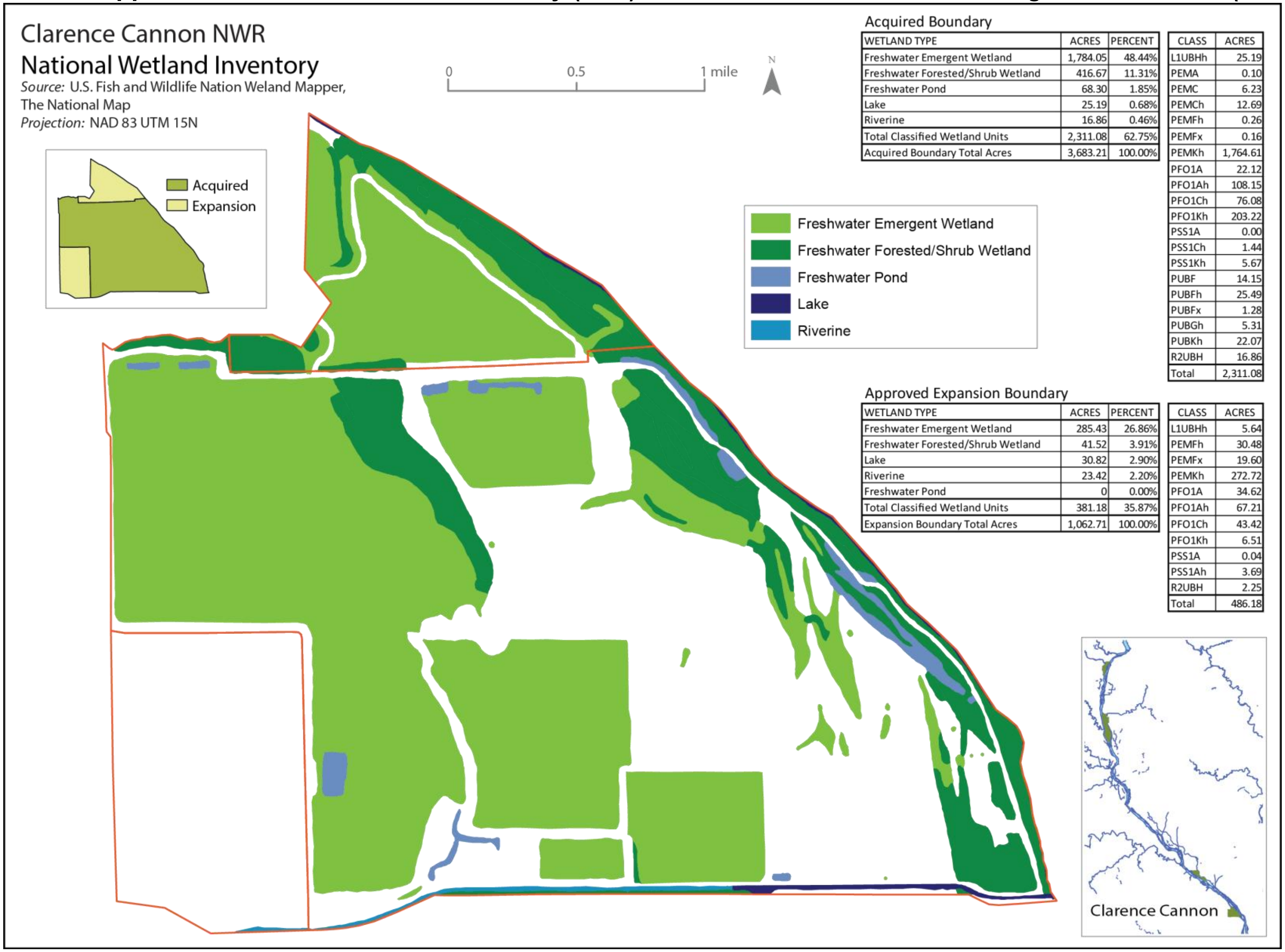
CANTON L AND D 20, MISSOURI (231275)
Period of Record Monthly Climate Summary
Period of Record : 1/ 1/1893 to 4/30/2012

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	35.0	39.6	51.0	64.0	73.9	83.0	87.6	85.7	78.6	67.9	52.5	39.3	63.2
Average Min. Temperature (F)	16.8	20.7	30.6	42.5	53.2	62.9	66.8	64.8	56.1	44.7	32.8	21.9	42.8
Average Total Precipitation (in.)	1.66	1.53	2.65	3.68	4.51	4.24	3.92	3.70	3.74	2.87	2.48	1.88	36.86
Average Total SnowFall (in.)	3.8	4.1	2.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	3.3	14.6
Average Snow Depth (in.)	1	1	0	0	0	0	0	0	0	0	0	1	0

ELSBERRY 1 S, MISSOURI (232591)
Period of Record Monthly Climate Summary
Period of Record : 1/ 1/1931 to 4/30/2012

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	39.1	43.9	55.2	67.7	77.0	85.8	89.9	88.0	80.9	70.1	55.2	42.3	66.3
Average Min. Temperature (F)	19.0	22.7	32.0	42.8	52.1	61.6	65.6	63.7	55.1	43.8	33.1	23.4	42.9
Average Total Precipitation (in.)	1.96	1.97	3.16	3.67	4.17	3.82	3.66	3.40	3.42	3.08	2.93	2.48	37.72
Average Total SnowFall (in.)	3.9	3.9	2.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.6	15.4
Average Snow Depth (in.)	1	0	0	0	0	0	0	0	0	0	0	0	0

12. Appendix B National Wetland Inventory (NWI) and desired habitat and water regimes from HMP (USFWS 2011)



Acquired Boundary

WETLAND TYPE	ACRES	PERCENT
Freshwater Emergent Wetland	1,784.05	48.44%
Freshwater Forested/Shrub Wetland	416.67	11.31%
Freshwater Pond	68.30	1.85%
Lake	25.19	0.68%
Riverine	16.86	0.46%
Total Classified Wetland Units	2,311.08	62.75%
Acquired Boundary Total Acres	3,683.21	100.00%

CLASS	ACRES
L1UBHh	25.19
PEMA	0.10
PEMC	6.23
PEMCh	12.69
PEMFh	0.26
PEMFx	0.16
PEMKh	1,764.61
PFO1A	22.12
PFO1Ah	108.15
PFO1Ch	76.08
PFO1Kh	203.22
PSS1A	0.00
PSS1Ch	1.44
PSS1Kh	5.67
PUBF	14.15
PUBFh	25.49
PUBFx	1.28
PUBGh	5.31
PUBKh	22.07
R2UBH	16.86
Total	2,311.08

Approved Expansion Boundary

WETLAND TYPE	ACRES	PERCENT
Freshwater Emergent Wetland	285.43	26.86%
Freshwater Forested/Shrub Wetland	41.52	3.91%
Lake	30.82	2.90%
Riverine	23.42	2.20%
Freshwater Pond	0	0.00%
Total Classified Wetland Units	381.18	35.87%
Expansion Boundary Total Acres	1,062.71	100.00%

CLASS	ACRES
L1UBHh	5.64
PEMFh	30.48
PEMFx	19.60
PEMKh	272.72
PFO1A	34.62
PFO1Ah	67.21
PFO1Ch	43.42
PFO1Kh	6.51
PSS1A	0.04
PSS1Ah	3.69
R2UBH	2.25
Total	486.18

Great River NWR; Long Island
National Wetland Inventory

Source: U.S. Fish and Wildlife Service National Wetland Mapper, The National Map
Projection: NAD 83 UTM 15N

Acquired Boundary

WETLAND TYPE	ACRES	PERCENT
Freshwater Forested/Shrub Wetland	4,747.92	71.04%
Lake	1,015.04	15.19%
Freshwater Emergent Wetland	146.93	2.20%
Freshwater Pond	83.31	1.25%
Riverine	0	0.00%
Total Classified Wetland Units	5,993.20	89.67%
Acquired Boundary Total Acres	6,683.34	100.00%

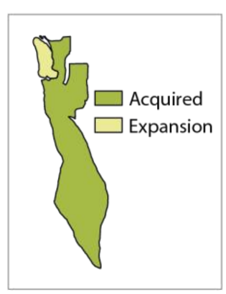
CLASS	ACRES
L1UBHh	1,015.04
PEM/SS1Ah	35.10
PEM/SS1Ch	3.57
PEMAf	1.31
PEMAfh	31.01
PEMCh	75.94
PFO1A	15.90
PFO1Ah	2,840.48
PFO1Ch	1,810.49
PSS1/EMAh	26.75
PSS1Ah	29.00
PSS1Ch	21.75
PSS1Fh	3.55
PUBFh	9.37
PUBG	13.47
PUBGh	36.86
PUBHh	23.62
Total	5,993.20

Approved Expansion Boundary

WETLAND TYPE	ACRES	PERCENT
Freshwater Forested/Shrub Wetland	312.88	59.06%
Freshwater Emergent Wetland	58.21	10.99%
Freshwater Pond	16.40	3.10%
Lake	6.79	1.28%
Riverine	0	0.00%
Total Classified Wetland Units	394.28	74.42%
Expansion Boundary Total Acres	529.80	100.00%

CLASS	ACRES
L1UBHh	6.79
PEM/SS1Ah	8.31
PEM/SS1Ch	32.46
PEMAh	7.70
PEMCh	8.09
PEMFh	1.65
PFO1Ah	229.40
PFO1Ch	66.20
PSS1Ah	17.28
PUBGh	16.40
Total	394.28

Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Lake
Riverine

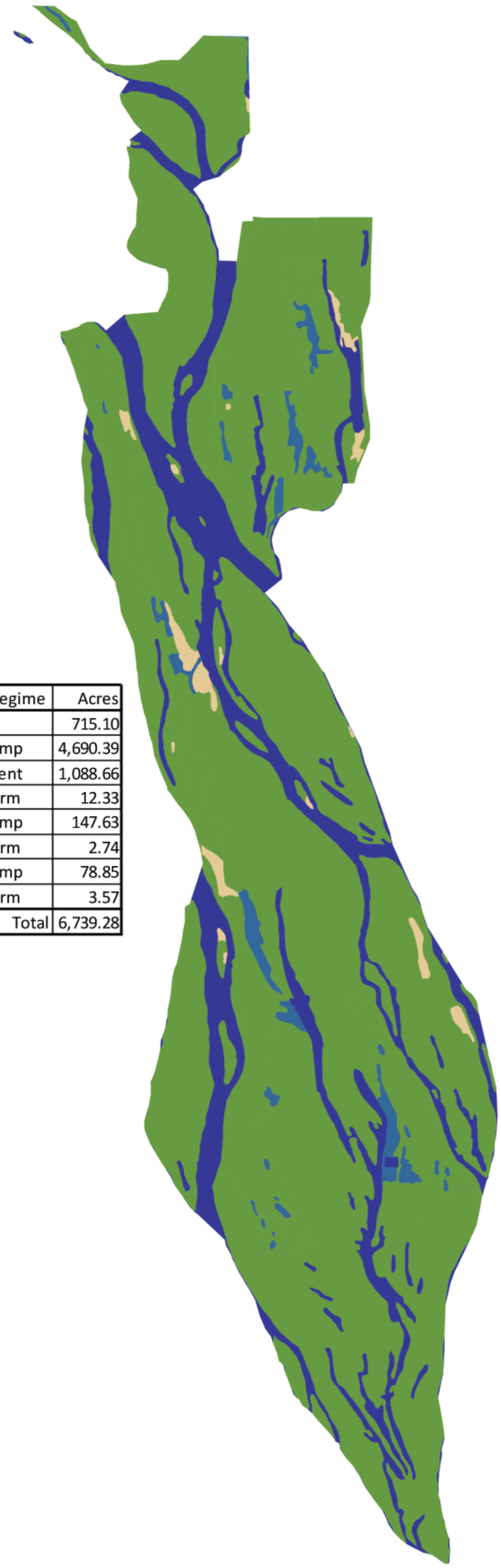


Great River NWR; Long Island
Desired Habitat Types

Source: U.S. Fish and Wildlife Service Habitat Management Plan
Projection: NAD 83 UTM 15N

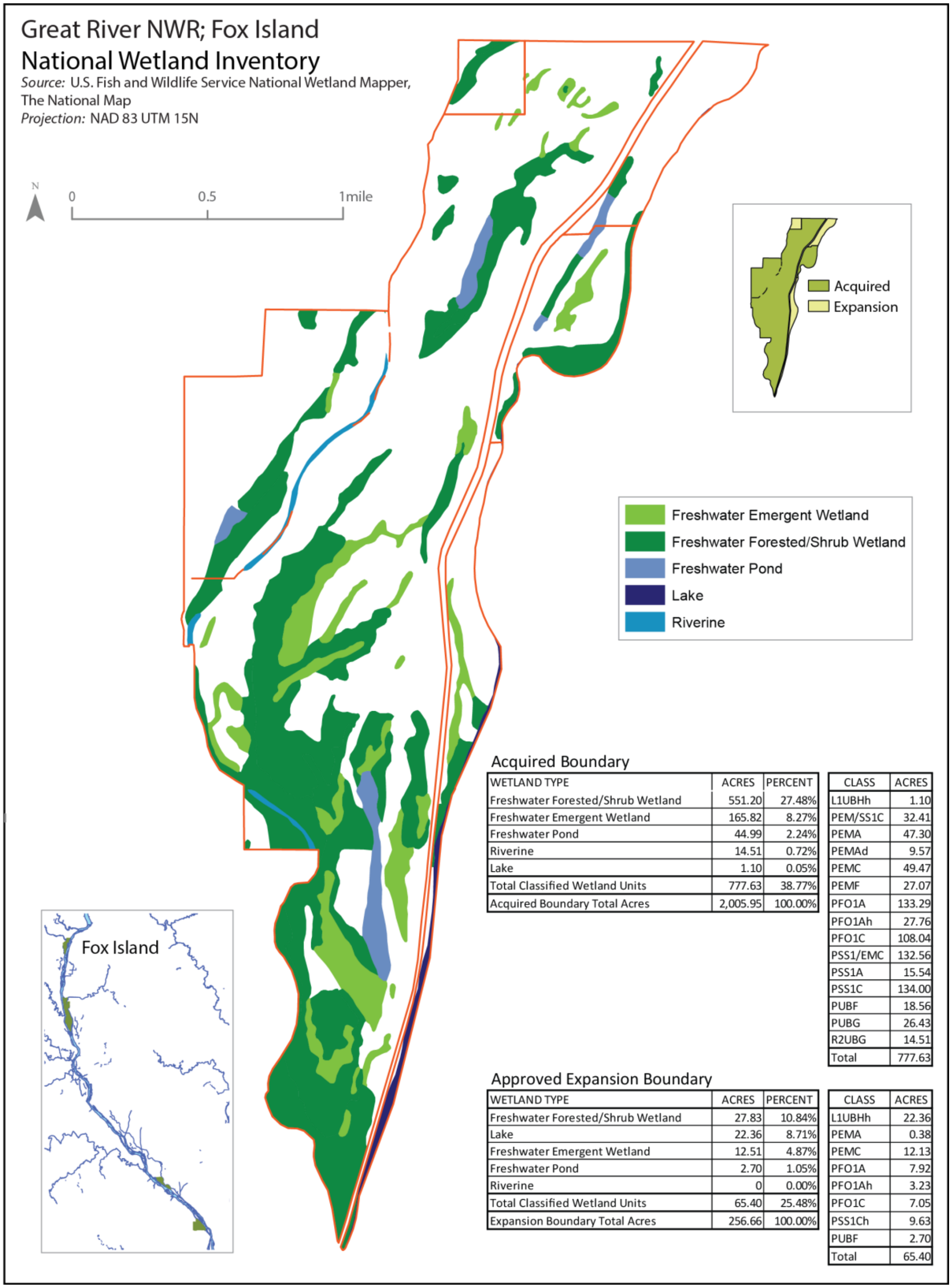
Developed
Floodplain Forest
Large Riverine
Marsh Riverine
Marsh Riverine/MSU
Scrub/Shrub
Shrub Swamp
Wet Bottomland Prairie
Wet-Mesic Bottomland Prairie
Wet/Wet Mesic Bottomland Prairie

N
0 0.5 1 mile



Natural Communities	Acres	Percent
Floodplain Forest	5,405.50	80.21%
Large Riverine	1,100.99	16.34%
Marsh Riverine	150.37	2.23%
Shrub Swamp	82.42	1.22%
Developed	0.00	0.00%
Marsh Riverine/MSU	0.00	0.00%
Scrub/Shrub	0.00	0.00%
Wet Bottomland Prairie	0.00	0.00%
Wet/Wet Mesic Bottomland Prairie	0.00	0.00%
Wet-Mesic Bottomland Prairie	0.00	0.00%
Total	6,739.28	100.00%

Natural Communities	Water Regime	Acres
Floodplain Forest	NA	715.10
Floodplain Forest	Seas/Temp	4,690.39
Large Riverine	Permanent	1,088.66
Large Riverine	Semi Perm	12.33
Marsh Riverine	Seas/Temp	147.63
Marsh Riverine	Semi Perm	2.74
Shrub Swamp	Seas/Temp	78.85
Shrub Swamp	Semi Perm	3.57
	Total	6,739.28



Acquired Boundary

WETLAND TYPE	ACRES	PERCENT
Freshwater Forested/Shrub Wetland	551.20	27.48%
Freshwater Emergent Wetland	165.82	8.27%
Freshwater Pond	44.99	2.24%
Riverine	14.51	0.72%
Lake	1.10	0.05%
Total Classified Wetland Units	777.63	38.77%
Acquired Boundary Total Acres	2,005.95	100.00%

CLASS	ACRES
L1UBHh	1.10
PEM/SS1C	32.41
PEMA	47.30
PEMAd	9.57
PEMC	49.47
PEMF	27.07
PFO1A	133.29
PFO1Ah	27.76
PFO1C	108.04
PSS1/EMC	132.56
PSS1A	15.54
PSS1C	134.00
PUBF	18.56
PUBG	26.43
R2UBG	14.51
Total	777.63

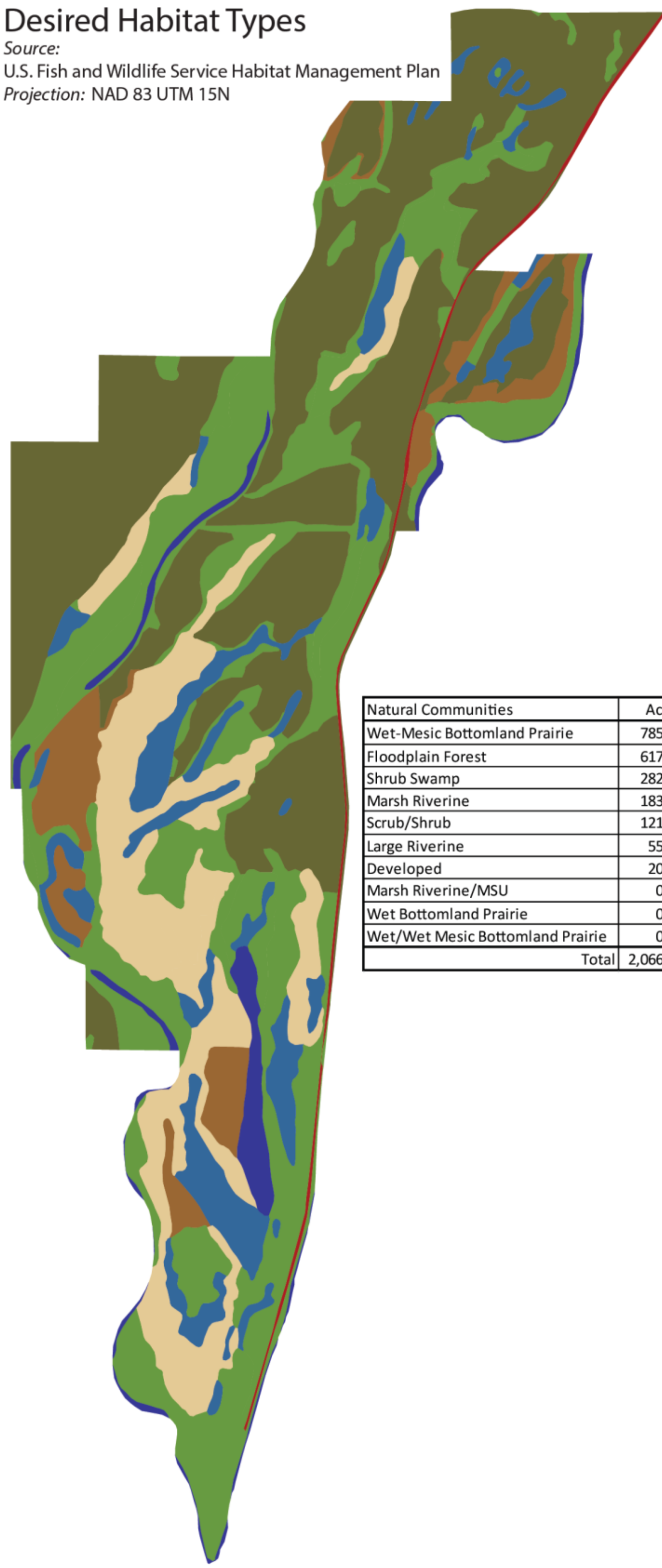
Approved Expansion Boundary

WETLAND TYPE	ACRES	PERCENT
Freshwater Forested/Shrub Wetland	27.83	10.84%
Lake	22.36	8.71%
Freshwater Emergent Wetland	12.51	4.87%
Freshwater Pond	2.70	1.05%
Riverine	0	0.00%
Total Classified Wetland Units	65.40	25.48%
Expansion Boundary Total Acres	256.66	100.00%

CLASS	ACRES
L1UBHh	22.36
PEMA	0.38
PEMC	12.13
PFO1A	7.92
PFO1Ah	3.23
PFO1C	7.05
PSS1Ch	9.63
PUBF	2.70
Total	65.40

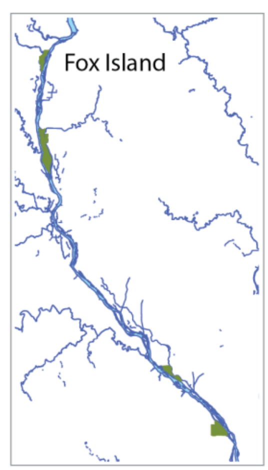
Great River NWR; Fox Island
Desired Habitat Types

Source:
U.S. Fish and Wildlife Service Habitat Management Plan
Projection: NAD 83 UTM 15N



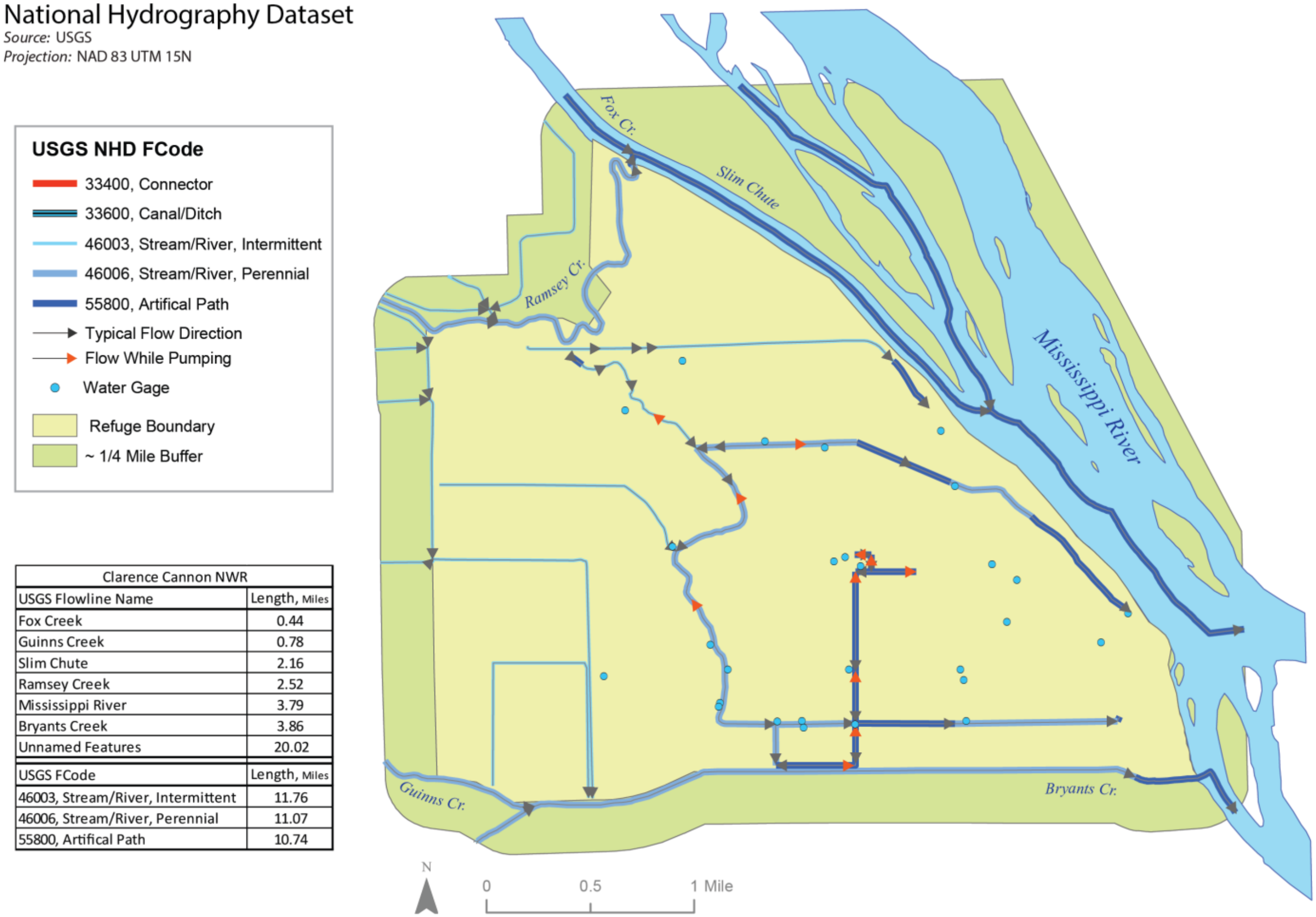
Natural Communities	Acres	Percent
Wet-Mesic Bottomland Prairie	785.95	38.03%
Floodplain Forest	617.50	29.88%
Shrub Swamp	282.26	13.66%
Marsh Riverine	183.11	8.86%
Scrub/Shrub	121.89	5.90%
Large Riverine	55.43	2.68%
Developed	20.42	0.99%
Marsh Riverine/MSU	0.00	0.00%
Wet Bottomland Prairie	0.00	0.00%
Wet/Wet Mesic Bottomland Prairie	0.00	0.00%
Total	2,066.54	100.00%

Natural Communities	Water Regime	Acres
Developed	NA	20.42
Floodplain Forest	NA	338.70
Floodplain Forest	Seas/Temp	278.79
Large Riverine	Permanent	55.43
Marsh Riverine	Seas/Temp	138.54
Marsh Riverine	Semi Perm	44.57
Scrub/Shrub	NA	121.89
Shrub Swamp	NA	0.00
Shrub Swamp	Seas/Temp	282.26
Wet-Mesic Bottomland Prairie	NA	785.95
Total		2,066.54



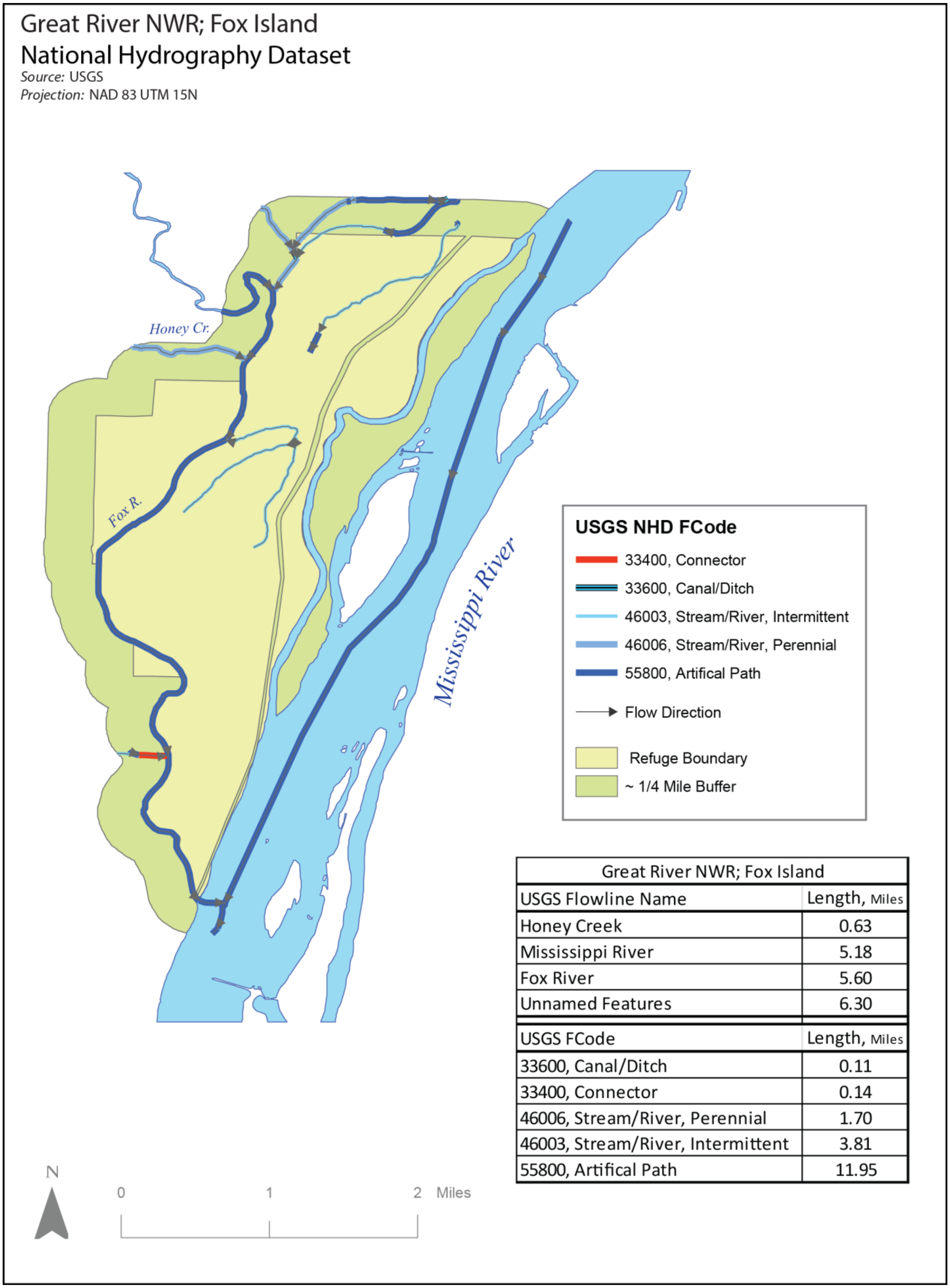
13. Appendix C Refuge Division flowpaths

Clarence Cannon NWR
National Hydrography Dataset
Source: USGS
Projection: NAD 83 UTM 15N



Clarence Cannon NWR	
USGS Flowline Name	Length, Miles
Fox Creek	0.44
Guinns Creek	0.78
Slim Chute	2.16
Ramsey Creek	2.52
Mississippi River	3.79
Bryants Creek	3.86
Unnamed Features	20.02
USGS FCode	Length, Miles
46003, Stream/River, Intermittent	11.76
46006, Stream/River, Perennial	11.07
55800, Artifical Path	10.74

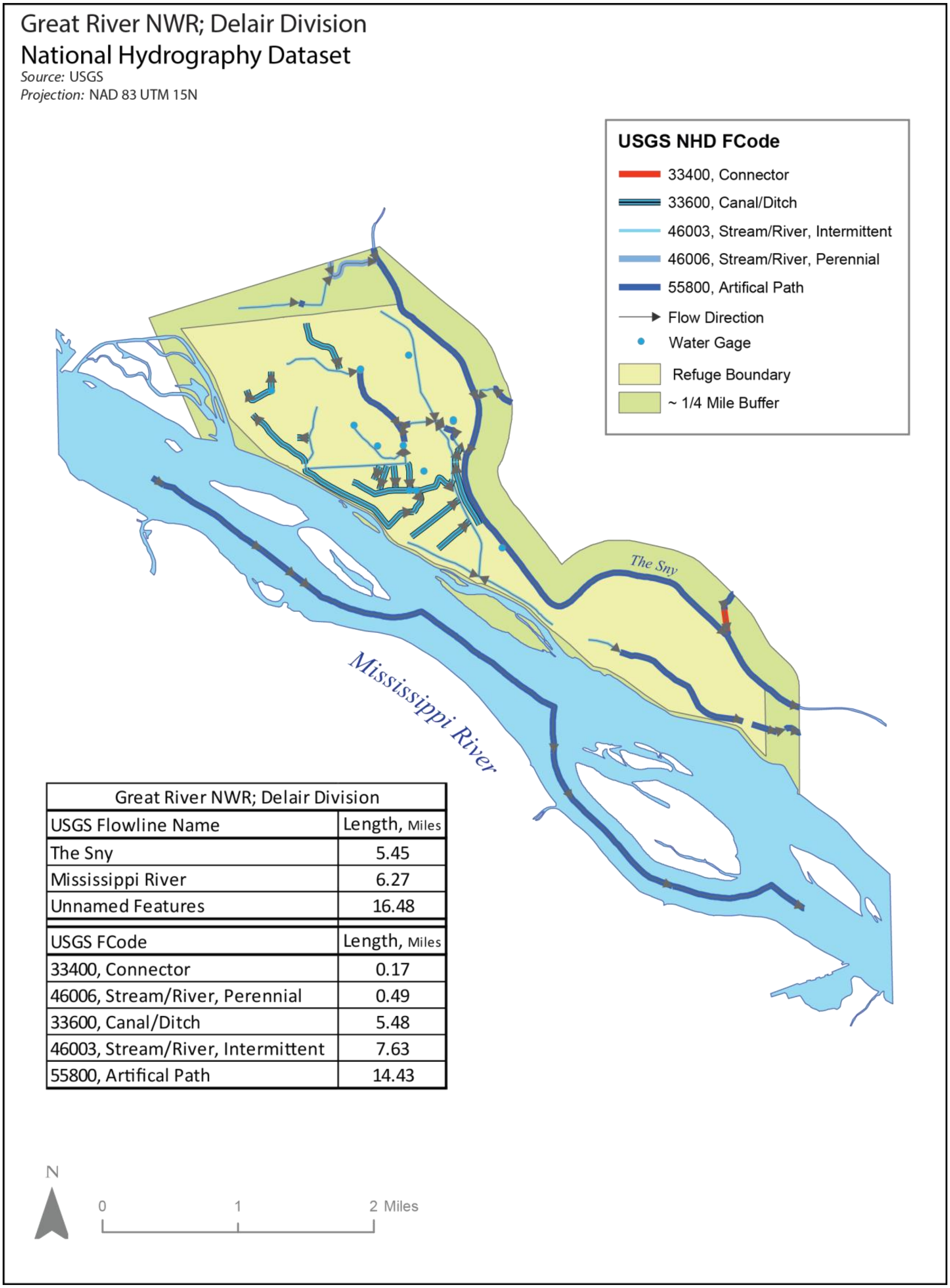
Figure 12 Clarence Cannon NWR NHD (modified)



Great River NWR; Fox Island	
USGS Flowline Name	Length, Miles
Honey Creek	0.63
Mississippi River	5.18
Fox River	5.60
Unnamed Features	6.30

USGS FCode	Length, Miles
33600, Canal/Ditch	0.11
33400, Connector	0.14
46006, Stream/River, Perennial	1.70
46003, Stream/River, Intermittent	3.81
55800, Artifical Path	11.95

Figure 13 Fox Island Division NHD

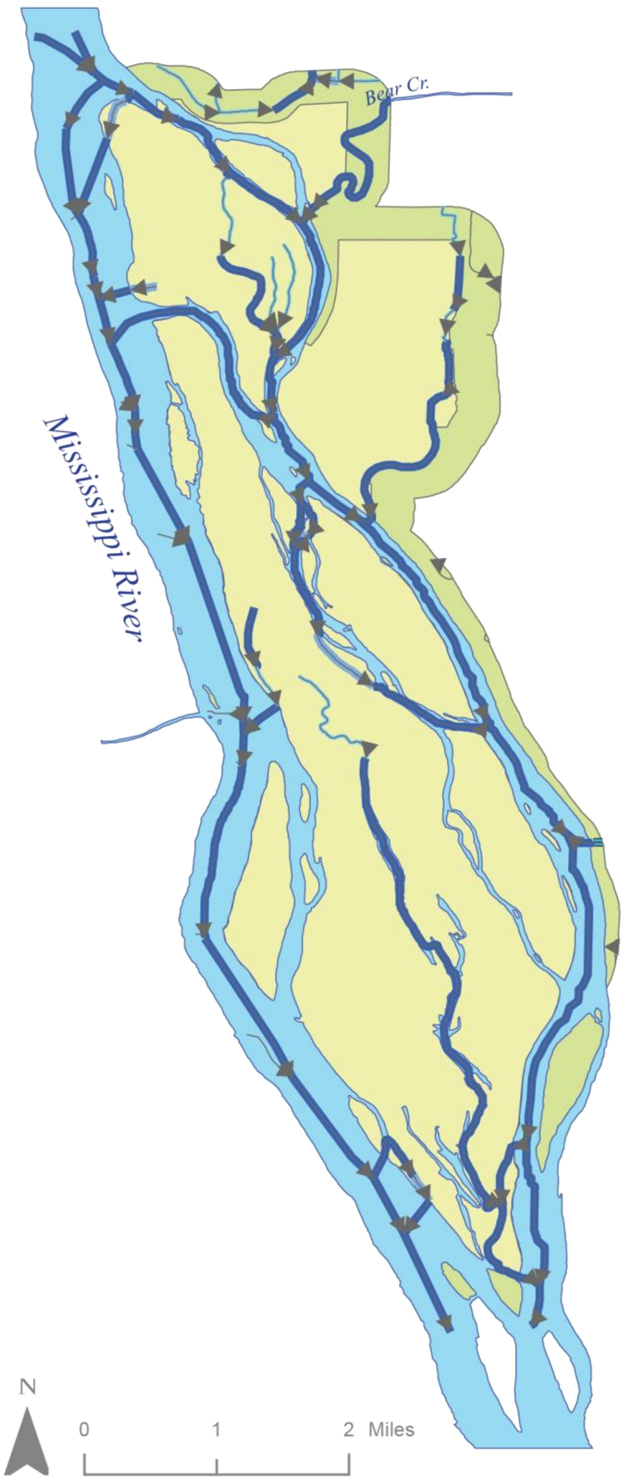


Great River NWR; Delair Division	
USGS Flowline Name	Length, Miles
The Sny	5.45
Mississippi River	6.27
Unnamed Features	16.48

USGS FCode	Length, Miles
33400, Connector	0.17
46006, Stream/River, Perennial	0.49
33600, Canal/Ditch	5.48
46003, Stream/River, Intermittent	7.63
55800, Artifical Path	14.43

Figure 14 Delair Division NHD w/ ditches and staff gages

Great River NWR; Long Island
National Hydrography Dataset
Source: USGS
Projection: NAD 83 UTM 15N



USGS NHD FCode
33400, Connector
33600, Canal/Ditch
46003, Stream/River, Intermittent
46006, Stream/River, Perennial
55800, Artifical Path
Flow Direction
Refuge Boundary
~ 1/4 Mile Buffer

Great River NWR; Long Island	
USGS Flowline Name	Length, Miles
Bear Creek	1.64
Mississippi River	10.47
Unnamed Features	33.66
USGS FCode	Length, Miles
33600, Canal/Ditch	0.05
46006, Stream/River, Perennial	5.29
46003, Stream/River, Intermittent	1.36
55800, Artifical Path	39.07

Figure 15 Long Island Division NHD

14. Appendix D Water monitoring sites (STORET)

Table 3 USGS and USACE potentially applicable historical monitoring sites

Surface water-Site number	Site name	Agency	Data	Notes
92321090565601	Pharrs Island	USGS	Access Data	Water Qaulity (WQ) Samples 1991
5512000	The Sny at Atlas, IL	USGS	Access Data	Discharge 1939-1942
5502100	Hadley Creek near New Canton, IL	USGS	Access Data	Discharge 1941-1942
5502080	Hadley Creek near Shinn, IL	USGS	Access Data	Discharge 1941-1947
5501600	Mississippi River at Hannibal, MO	USGS	Access Data	Gage height 2009-2012, WQ 1981-1990
5495150	Mississippi River at Canton, MO	USGS	Access Data	WQ 1969-1975
Groundwater-Site number			-	
402356091344001	Wayland, MO	USGS	Access Data	Data from 1975-2010
400026091242401	1S 9W-11.5h1 - E. Southern tip Long Island	USGS	Access Data	WQ data from 1984-1992
Climate-Site number			-	
393810091145600	Rain gage at Miss R at L & D 22 nr Saverton, MO	USCE	Access Data	Data from 04/2012-
395600091245600	Rain gage at memorial bridge at Quincy, IL	USCE	Access Data	Data from 04/2012-

Table 4 Historical and inactive monitoring sites

Organization ID	Organization Name	Station ID	Station Name	Type	Latitude	Longitude
1117MBR	US EPA Region 7	1117MBR-002769	MISS RIVER AT CLARKSVILLE MO	River/Stream	39.3833333	-90.916667
1117MBR	US EPA Region 7	1117MBR-007306	MISSISSIPPI RIVER DOWNSTREAM OF LOUISIANA, MO.	River/Stream	39.4325	-91.019167
1117MBR	US EPA Region 7	1117MBR-009510	WYACONDA RIVER	River/Stream	40.0788889	-91.544167
EMAP_GRE	EMAP-Great Rivers Ecosystems	EMAP_GRE-GRE06604-1015	Mississippi: Lower Impounded	River/Stream	40.16893	-91.51139
EMAP_GRE	EMAP-Great Rivers Ecosystems	EMAP_GRE-GRE06604-1031	Mississippi: Lower Impounded	River/Stream	40.21992	-91.49775
EMAP_GRE	EMAP-Great Rivers Ecosystems	EMAP_GRE-GRW04449-341	Mississippi: Lower Impounded	River/Stream	40.149156	-91.510705
EMAP_GRE	EMAP-Great Rivers Ecosystems	EMAP_GRE-GRW04449-327	Mississippi: Lower Impounded	River/Stream	39.4317	-91.009177
EPA_R7	US EPA Region 7	EPA_R7-007306	MISSISSIPPI RIVER DOWNSTREAM OF LOUISIANA, MO.	River/Stream	39.4325	-91.019167
IL_EPA	Illinois EPA	IL_EPA-KCA-01	BAY CREEK	River/Stream	39.44311	-90.79549
IL_EPA	Illinois EPA	IL_EPA-KCA-10	BAY CREEK	River/Stream	39.447872	-90.795361
IL_EPA	Illinois EPA	IL_EPA-KI-04	BEAR CREEK	River/Stream	40.12685	-91.41717
IL_EPA	Illinois EPA	IL_EPA-KI-07	BEAR CREEK	River/Stream	40.1186111	-91.478888
IL_EPA	Illinois EPA	IL_EPA-KCAA-01	BELLEVIEW HOLLOW	River/Stream	39.349853	90.775514
IL_EPA	Illinois EPA	IL_EPA-KCK-01	FOX CREEK	River/Stream	39.281586	-90.737472
IL_EPA	Illinois EPA	IL_EPA-RLC	GOOSE	Lake	39.99954	-91.42876
IL_EPA	Illinois EPA	IL_EPA-K-07	MISSISSIPPI RIVER CEN	River/Stream	39.96472	-91.44791
IL_EPA	Illinois EPA	IL_EPA-K-08	MISSISSIPPI RIVER CEN	River/Stream	40.11389	-91.48375
IL_EPA	Illinois EPA	IL_EPA-K-10	MISSISSIPPI RIVER CEN	River/Stream	40.1449	-91.50749
IL_EPA	Illinois EPA	IL_EPA-K-18	MISSISSIPPI RIVER CEN	River/Stream	40.04357	-91.45437

Organization ID	Organization Name	Station ID	Station Name	Type	Latitude	Longitude
IL_EPA	Illinois EPA	IL_EPA-K-19	MISSISSIPPI RIVER CEN	River/Stream	40.2216667	-91.490277
IL_EPA	Illinois EPA	IL_EPA-K-55	MISSISSIPPI RIVER CEN	River/Stream	40.1441111	-91.511055
IL_EPA	Illinois EPA	IL_EPA-K-81	MISSISSIPPI RIVER CEN	River/Stream	40.14573	-91.5144
IL_EPA	Illinois EPA	IL_EPA-K-05	MISSISSIPPI RIVER CEN	River/Stream	39.45757	-91.0469
IL_EPA	Illinois EPA	IL_EPA-K-12	MISSISSIPPI RIVER CEN	River/Stream	39.45717	-91.0377
IL_EPA	Illinois EPA	IL_EPA-K-20	MISSISSIPPI RIVER CEN	River/Stream	39.3827778	90.900833
IL_EPA	Illinois EPA	IL_EPA-K-21	MISSISSIPPI RIVER CEN	River/Stream	39.3736111	90.905833
IL_EPA	Illinois EPA	IL_EPA-KCB-01	SIX MILE CREEK	River/Stream	39.3922222	-90.885555
IL_EPA	Illinois EPA	IL_EPA-KC-04	SNY RIVER	River/Stream	39.39984	-90.90971
IL_EPA	Illinois EPA	IL_EPA-KC-06	SNY RIVER	River/Stream	39.3580556	-90.840277
IL_EPA	Illinois EPA	IL_EPA-KC-08	SNY RIVER	River/Stream	39.273914	-90.740883
IL_EPA	Illinois EPA	IL_EPA-KCAE-01	SPRING CREEK	River/Stream	39.4383333	-90.756666
IL_EPA	Illinois EPA	IL_EPA-KCAZB-01	U-TRIB BAY CREEK	River/Stream	39.443758	-90.794822
IL_EPA	Illinois EPA	IL_EPA-KCL-01	WEST PANTHER CREEK	River/Stream	39.318486	-90.752906
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCA-01	BAY CREEK	River/Stream	39.44311	-90.79549
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCA-10	BAY CREEK	River/Stream	39.447872	-90.795361
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KI-04	BEAR CREEK	River/Stream	40.12685	-91.41717
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KI-07	BEAR CREEK	River/Stream	40.1186111	-91.478889
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCAA-01	BELLEVIEW HOLLOW	River/Stream	39.349853	-90.775514
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCK-01	FOX CREEK	River/Stream	39.281586	-90.737472
IL_EPA_WQX	illinois epa	IL_EPA_WQX-RLC	GOOSE	Lake	39.99954	-91.42876
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-07	MISSISSIPPI RIVER	River/Stream	39.96472	-91.44791
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-08	MISSISSIPPI RIVER	River/Stream	40.11389	-91.48375
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-10	MISSISSIPPI RIVER	River/Stream	40.1449	-91.50749
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-18	MISSISSIPPI RIVER	River/Stream	40.04357	-91.45437
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-19	MISSISSIPPI RIVER	River/Stream	40.2216667	-91.490278
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-55	MISSISSIPPI RIVER	River/Stream	40.1441111	-91.511056
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-81	MISSISSIPPI RIVER	River/Stream	40.14573	-91.5144
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-05	MISSISSIPPI RIVER	River/Stream	39.45757	-91.0469
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-12	MISSISSIPPI RIVER	River/Stream	39.45717	-91.0377
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-20	MISSISSIPPI RIVER	River/Stream	39.3827778	-90.900833
IL_EPA_WQX	illinois epa	IL_EPA_WQX-K-21	MISSISSIPPI RIVER	River/Stream	39.3736111	-90.905833
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCB-01	SIX MILE CREEK	River/Stream	39.3922222	-90.885556
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KC-04	SNY RIVER	River/Stream	39.39984	-90.90971
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KC-06	SNY RIVER	River/Stream	39.3580556	-90.840278
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KC-08	SNY RIVER	River/Stream	39.273914	-90.740883
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCAE-01	SPRING CREEK	River/Stream	39.4383333	-90.756667
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCAZB-01	U-TRIB BAY CREEK	River/Stream	39.443758	-90.794822
IL_EPA_WQX	illinois epa	IL_EPA_WQX-KCL-01	WEST PANTHER CREEK	River/Stream	39.318486	-90.752906
MDNR	Missouri Dept. of Natural Resources	MDNR-7416/0.1	Agate Lake left of fishing dock near canoe stand	Reservoir	40.0069332	-91.510739
MDNR	Missouri Dept. of Natural Resources	MDNR-7416/0.6	Agate Lake throughout lake	Reservoir	40.007424	-91.499967
MDNR	Missouri Dept. of Natural Resources	MDNR-14/0.25	Buffalo Cr. @ Hercules Inc. Outfall 001	Facility Industrial	39.4319772	-91.018813
MDNR	Missouri Dept. of Natural Resources	MDNR-14/0.7	Buffalo Cr. @ Hercules Inc. Outfall 003	Facility Industrial	39.4238382	-91.021676
MDNR	Missouri Dept. of Natural Resources	MDNR-14/0.4/0.1	Dyno Nobel, LOMO Plant Outfall 001	Facility Industrial	39.4304274	-91.022605
MDNR	Missouri Dept. of Natural Resources	MDNR-14/0.8/0.25	Hercules Inc. Outfall 006	Facility Industrial	39.425003	-91.027815
MDNR	Missouri Dept. of Natural Resources	MDNR-7432	Jasper Lake off of boat dock	Reservoir	40.012078	-91.511114

Organization ID	Organization Name	Station ID	Station Name	Type	Latitude	Longitude
MDNR	Missouri Dept. of Natural Resources	MDNR-7432/0.1	Jasper Lake off of boat dock	Reservoir	40.012078	-91.511114
MDNR	Missouri Dept. of Natural Resources	MDNR-7432/0.3	Jasper Lake, main body	Reservoir	40.0156958	-91.507454
MDNR	Missouri Dept. of Natural Resources	MDNR-3699/45.9	Mississippi R. @ Hercules Inc. Outfall 002	Facility Industrial	39.4361151	-91.028629
MDNR	Missouri Dept. of Natural Resources	MDNR-3699/47.2	Mississippi R. @ Louisiana	River/Stream	39.4527017	-91.043003
MDNR	Missouri Dept. of Natural Resources	MDNR-3699/44.2	Mississippi R. bl. Louisana	River/Stream	39.4227416	-91.000988
MDNR	Missouri Dept. of Natural Resources	MDNR-7002/1.2	Wakonda Lake nr. boat ramp	Reservoir	40.0000611	-91.519987
MDNR	Missouri Dept. of Natural Resources	MDNR-7002/1.0	Wakonda Lake throughout lake	Reservoir	39.9971194	-91.521852
MDNR	Missouri Dept. of Natural Resources	MDNR-7002/1.4	Wakonda Lake, Wakonda S.P., Public Beach	Reservoir	40.0036936	-91.522214
NARS_WQX	EPA National Aquatic Resources Survey	NARS_WQX-NLA06608-3280	MISSING	Lake	40.0160859	-91.508022
NARS_WQX	EPA National Aquatic Resources Survey	NARS_WQX-NLA06608-1232	MISSING	Lake	39.2972164	-91.001522
UMC	Univ. of Missouri, Columbia	UMC-7002/1.2	Wakonda Lake nr. boat ramp	Reservoir	40.0000611	-91.519987

15. Appendix E Flood profiles for Mississippi River pools and Mississippi River stage at Gregory Landing

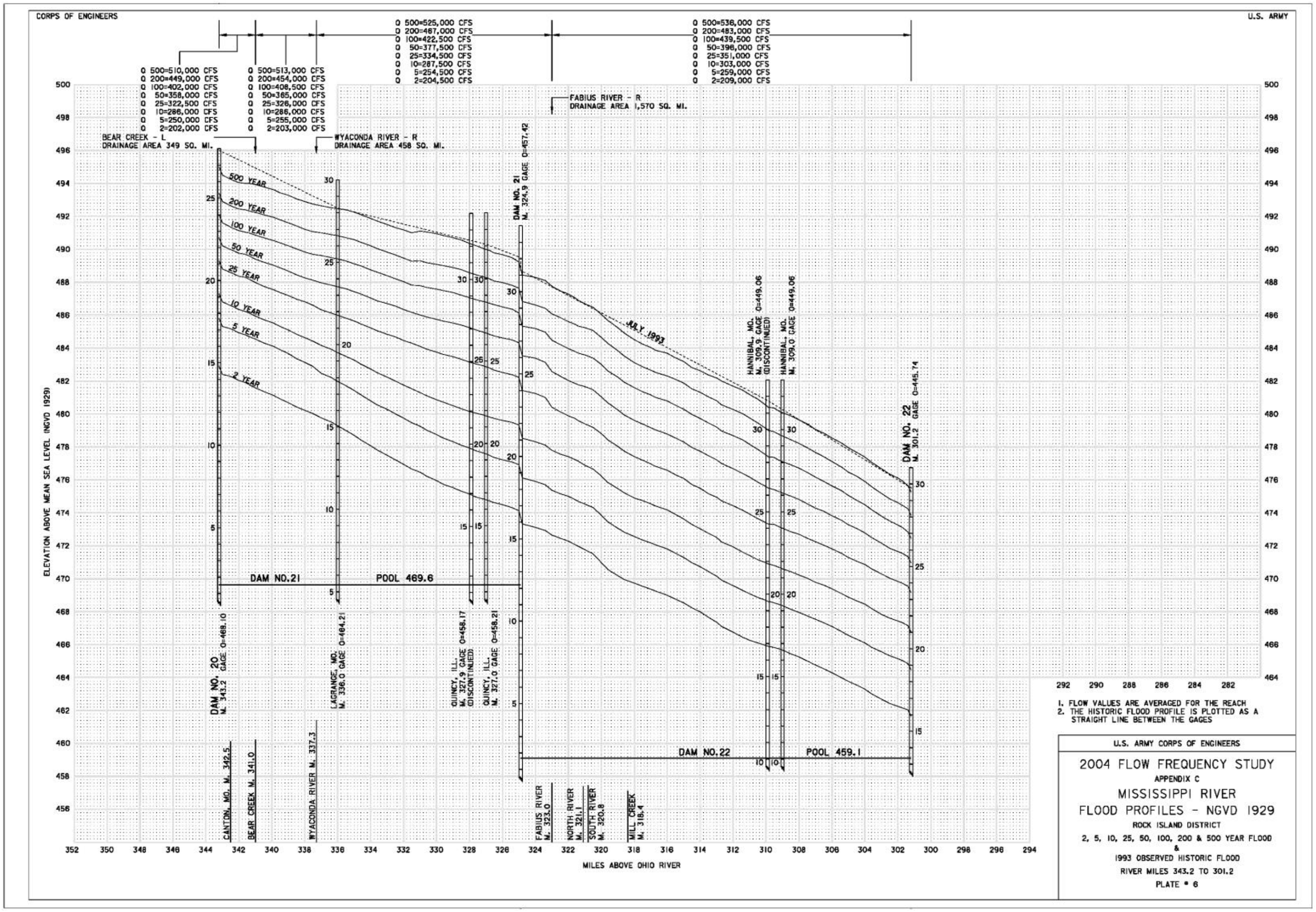


Figure 16 Flood profiles for Pool 20 and 21

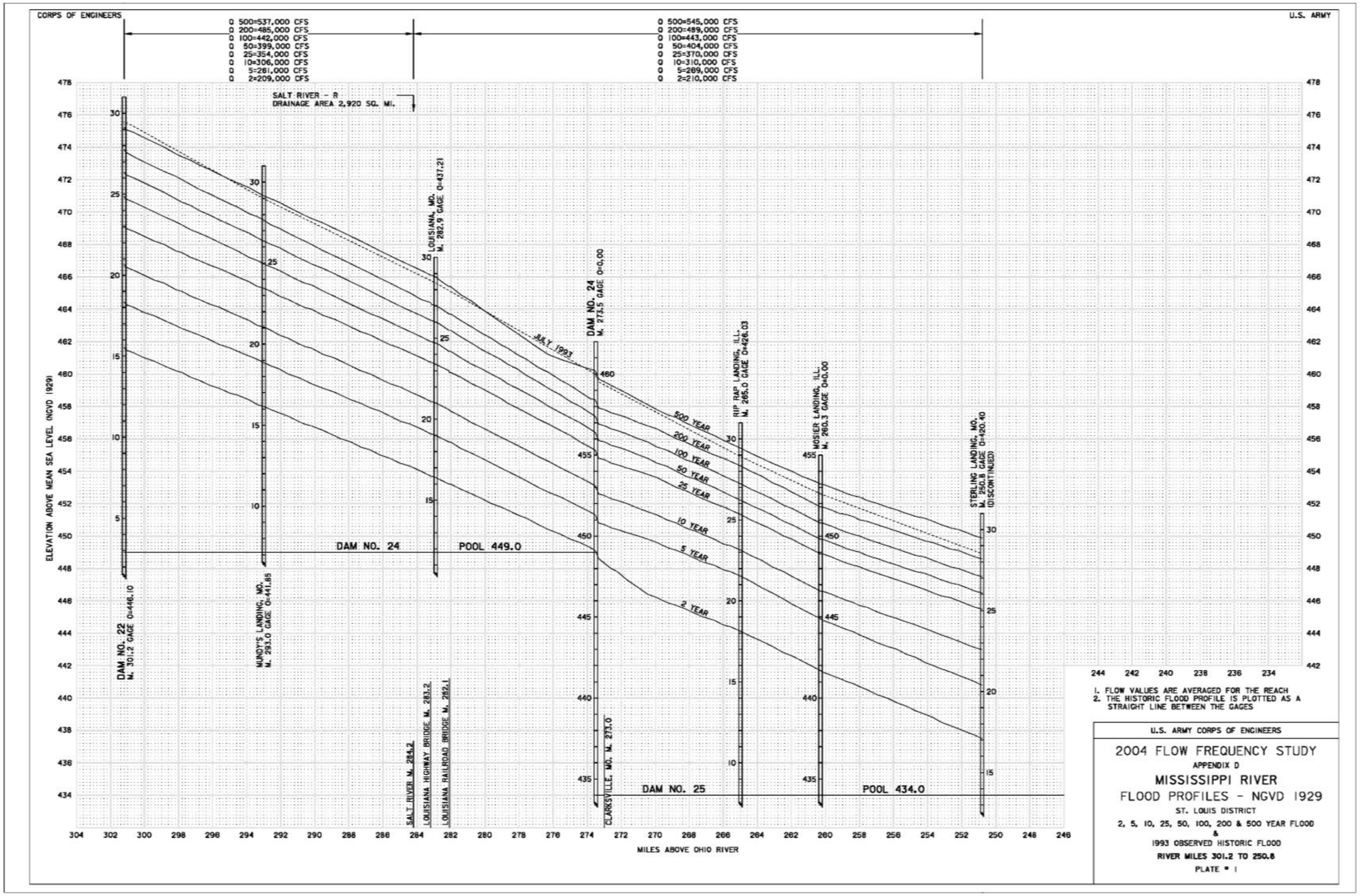


Figure 17 Flood profiles for pool 24 and 25

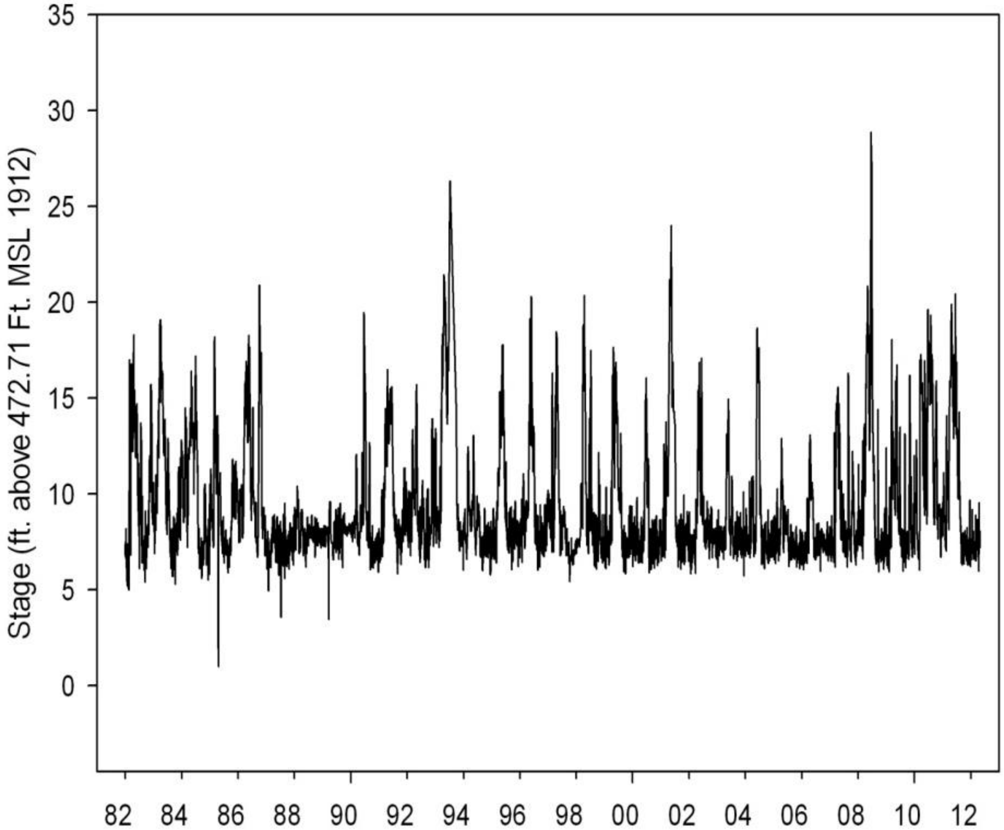


Figure 18 Stage of Mississippi River at Gregory Landing, MO