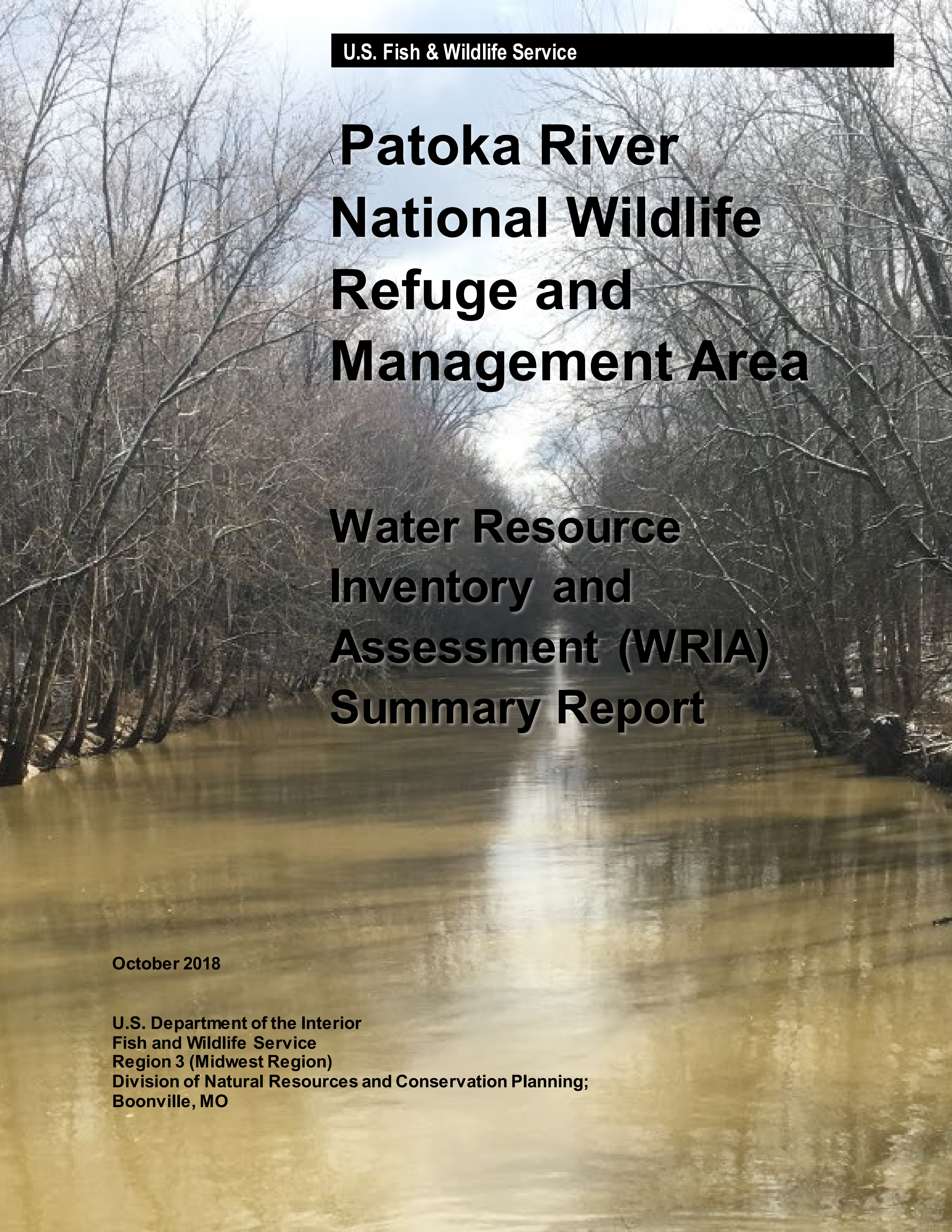

U.S. Fish & Wildlife Service

Patoka River National Wildlife Refuge and Management Area

Water Resource Inventory and Assessment (WRIA) Summary Report

October 2018

U.S. Department of the Interior
Fish and Wildlife Service
Region 3 (Midwest Region)
Division of Natural Resources and Conservation Planning;
Boonville, MO

The mission of the U.S. Fish & Wildlife Service is working with others to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people.

The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

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Author's Note:

There are embedded links throughout this document within the table of contents and indicated by underlined text. A database of the presented data, additional data, documents and the referenced studies will be available as part of a digital document library housed on the Environmental Conservation Online System (ECOS). Geospatial data layers were obtained from Patoka River NWR, The National Map, NWIS, STORET, and The Indiana Map.

Disclaimer:

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Chapter 1: Executive Summary

The Water Resource Inventory and Assessment (WRIA) is a reconnaissance-level effort, which provides:

- Descriptions of landscape, topography, and natural setting information
- Historic, current, and projected climate information, including hydroclimate trends
- An inventory of surface water and groundwater resource features
- An inventory of relevant infrastructure and water control structures
- Summaries of historical and current water resource monitoring, including descriptions of datasets for applicable monitoring sites
- Brief water quality assessments for relevant water resources
- A summary of state water laws
- A compilation of main findings and recommendations for the future

The WRIA provides inventories and assessments of 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.

WRIAs have been recognized as an important part of the NWRS Inventory and Monitoring (I&M) and are identified as a need by the Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change. Inventory and Monitoring 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. 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 summary narrative supplements existing and scheduled planning documents, by describing current hydrologic related information and providing an assessment of water resource needs and issues of concern. The WRIA will be a useful planning tool for Refuge management in conjunction with the Comprehensive Conservation Plan (CCP), Habitat Management Plan (HMP) and Inventory & Monitoring Plan (IMP). The CCP (USFWS 2008a), HMP (USFWS 2017a), and IMP (USFWS 2017b) are already complete for Patoka River National Wildlife Refuge (PRNWR). Much of the information within these plans relate to water resources and are reiterated in the WRIA summary narrative.

This Water Resource Inventory and Assessment (WRIA) Summary Report for this Refuge describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations regarding Refuge water resources. As part of the WRIA effort for this Refuge, water resources staff in the Division of Natural Resources and Conservation Planning (DNRCP) received review comments and edits from Heath Hamilton.

This Summary Report synthesizes a compilation of water resource data contained in the national interactive online WRIA database (https://ecos.fws.gov/wria/). 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 PRNWR.

The following two sections describe in detail the key findings and recommendations from this assessment. These findings and recommendations were related to the online WRIA database as threats and needs for the Refuge that will be included in regional and national summaries. Those threats and needs are compiled in Appendix A: Threats and Needs Tables.

1.1 Findings

1. The Patoka River has been highly physically altered due to the dredging of Houchin's Ditch in the 1920's. The activity disconnected the River's historic channel and meanders from flow, created sidecast spoil levees which isolated portions of the floodplain, and has caused the River itself to incise and downcut. Many of the Patoka's tributaries within PRNWR have had similar alterations and face the same issues. As a result, there is decreased floodplain connectivity and in-channel habitat.
2. The hydrology of the Lower Patoka River has be also dramatically altered as well by the construction of the Patoka Lake Dam in 1978. This reservoir has altered the natural hydrograph of the Patoka, leading to lower, prolonged flood peaks in the spring, and higher baseflows in the summer and fall. This effect is seen most on the upstream portions of the Refuge and least on the downstream portions due to the increased contributions of unimpounded tributaries further downstream.
3. The Refuge, and southern Indiana as a whole, has already seen a dramatic increase in the total amount of annual precipitation, the frequency of large-rainfall events, and the frequency of hazardous weather such as tornados. These effects have led to increased runoff and flooding. These trends are only expected to increase as climate change continues. In addition to precipitation changes, the Refuge can expect to see hotter summers, milder winters, longer growing seasons, and a shift in the plant hardiness zone.
4. Water quality throughout the Lower Patoka River is highly degraded due to effluent from oil, coal, and gas extraction and associated activates, acid mine drainage, agricultural runoff, municipal waste water treatment plants, and failing septic systems. While many water quality parameters have shown some sign of improvement in recent years, there are still 142.9 miles of impaired river and streams within a quarter mile of the Refuge's boundaries. Additionally, there are 67 active or recently active NPDES permits within five miles of the Refuge and its associated Wildlife Management Areas, and it is shown in this document that at least one permit has exceeded its limits 20 times in the past 10 years. Water quality is perhaps the biggest factor affecting in-stream fish and wildlife populations within the Refuge.
5. There is a large amount of water quality sampling that has been done in the region in order to better understand effects and trends over time. The result of sampling in the area has led to hundreds of thousands of individual samples over a period spanning decades. Understanding what this data can tell us is an important factor for the Refuge in understanding how water quality is affecting Refuge resources over time.
6. Understanding water quality on the Refuge is further complicated by the number of tributaries and channels contained within the Refuge itself. The NHD database indicates that there are roughly 542 miles of rivers and streams within the Refuge's Approved Acquisition Boundary. Improving water quality and in-stream habitat quality on the numerous tributaries of the Patoka is very important in sustaining overall ecosystem health of the Refuge.
7. The PRNWR is spread out linearly along the Patoka River Floodplain. This configuration allows it to maximize the amount of floodplain habitat conserved in the Lower Patoka Basin. However, it also leads to some situations that many other Refuges might not face.

There are 38 state and county maintained bridge crossings within 0.25 miles of the Refuge as well as an Interstate Highway bridge on the I-69. There is the potential for negative effects from the bridges, especially since the design, construction, and maintenance is beyond Service control. They could potentially constrict flow on the Patoka or its tributaries, cause excessive scour or debris jams, present a barrier to fish passage, or serve as potential points for accidental spills or releases into the River.

8. There are five state inventoried dams within a quarter mile of the Refuge. These dams could present a barrier to fish passage, alter hydrology, or pose a liability if they are located on Refuge lands.
9. In addition to the bridges and dams, there are several major oil and gas pipelines, and two active railroad lines crossing Refuge lands. All of these pipelines and railroads pose the potential for accidental spills and releases of contaminants.

1.2 Recommendations

1. Degradation of water quality in the Patoka River watershed has negatively impacted fish and wildlife populations, and as such, the improvement of water quality on the Refuge is a task of utmost importance. This is a task that is beyond the Service's abilities to address alone. Improvement of water quality on the Refuge could come through a combination of stricter environmental compliance enforcement, best management practices for mining and agricultural areas, remediation of existing contaminated lands, and the continued acquisition and restoration of lands in the Patoka River floodplain. Partnering with other state and federal agencies, Universities or other research organizations, and non-profit groups could help bring about the changes needed.
2. An important part of improving water quality is documenting where, when, and how much it is being degraded. Using monitoring to assess trends in water quality over time, and target specific hotspots contributing most to contamination in the watershed, could point to areas on which partners should focus the most attention. For example, sampling from a 2015 USFWS report indicated that Indian Hill Lake should be monitored closely due to elevated conductivity and a reported fish kill. Designing monitoring protocols that correspond with Indiana State Water Quality Standards will ensure that samples are comparable to existing water quality datasets.
3. Analysis and interpretation of existing water quality data in relation to the Refuge is another important component of water quality improvement. There are several studies that have been done examining water quality and biotic communities in the Patoka. Now with the understanding of these relationships, an overall study of the spatiotemporal trends in water quality in the Lower Patoka for various chemical constituents could help the Refuge better understand which areas have historically been most contaminated, to what extent, and how this has changed and might continue to change over time. Partnering with local universities or state agencies might help provide the funding and research design to implement such a project.
4. Another important aspect of improving water quality is understanding where water quality standards are currently being exceeded by NPDES permit holders. Actively monitoring NPDES permitting information for facilities directly impacting the Refuge and documenting if damages are occurring could help regulatory agencies responsible for enforcing compliance.
5. Increasing floodplain connectivity on the Patoka, especially in the Houchin's Ditch portions is an important item for improving habitat and restoring natural hydrology to the Patoka. Sidecast spoil levees should be breached, pinchpoints in floodplain sheet flow

eliminated, and where possible, the historic meanders of the Patoka and South Fork of the Patoka should be considered for reconnection to active flow. Many of these practices are already being implemented on the Refuge.

6. Better understanding of water levels on the Refuge could improve knowledge of current floodplain function and the relation of specific Refuge units to reported river stages. Installing staff plates on all Refuge units and surveying to a common datum would be a first step in understanding water levels across the Refuge.
7. A second step in better understanding water levels would be some form of automated water level monitoring. In-situ monitoring could help develop relationships and patterns in flooding on Refuge units to relate to USGS continuously operating gages.
8. Bathymetric data on particular units could help to further refine this knowledge of floodplain water levels and dynamics. Bathymetric data could be combined with monitoring data and related to USGS gages to understand how often portions of the floodplain go underwater. This knowledge could serve to better inform restoration or management activities.

Chapter 2: Introduction

The Patoka River National Wildlife Refuge and Management Area is located in Pike and Gibson counties in southwestern Indiana. The Refuge headquarters are located in Oakland City, Indiana. The Refuge was established in 1994 under the authority of the Emergency Wetlands Resource Act and includes up to 22,472 acres within the current acquisition boundary, of which 9,466 acres have been formally purchased and included as Refuge property through October 2018. The remaining acreage within the acquisition boundary is held by private landowners or private companies and will be acquired by the Refuge as it becomes available from willing sellers, and when funds allow.

The Refuge protects one of the few remaining expanses of bottomland forested wetlands in the Midwestern United States, and one of two intact floodplain forest systems within Indiana. Refuge staff and partners work to protect, restore, and enhance a myriad of different habitats including upland and bottomland forests, scrub-shrub and emergent wetlands, open water, prairies and old-fields, managed moist-soil units, and agricultural land.

The area has historically faced many anthropogenic disturbances. Portions of the Patoka River were ditched, diked, and channelized starting in the early 1900's. Historic and current energy production (coal mining, natural gas, and oil well development), intensive agriculture, uncontrolled timber operations, and community effluent have added to the land disturbances in the area of the Refuge and also contribute to diminished water quality of the Patoka River.

In addition to the Refuge, staff manage two satellite units within the vicinity of the Refuge. The Cane Ridge Wildlife Management Area (WMA) is 24 miles west of the Refuge headquarters located on the southwest side of the 3,000 acre Gibson Lake, which is a manmade cooling pond for Duke Energy's Gibson Station Power Plant. Cane Ridge was formerly row crop agriculture but was converted into a federally endangered Interior least tern nesting area along with 193 acres of moist-soil management. Nine miles north of the Refuge headquarters is the 219-acre White River Bottoms WMA. This WMA was restored from agricultural fields and planted to bottomland hardwood trees.

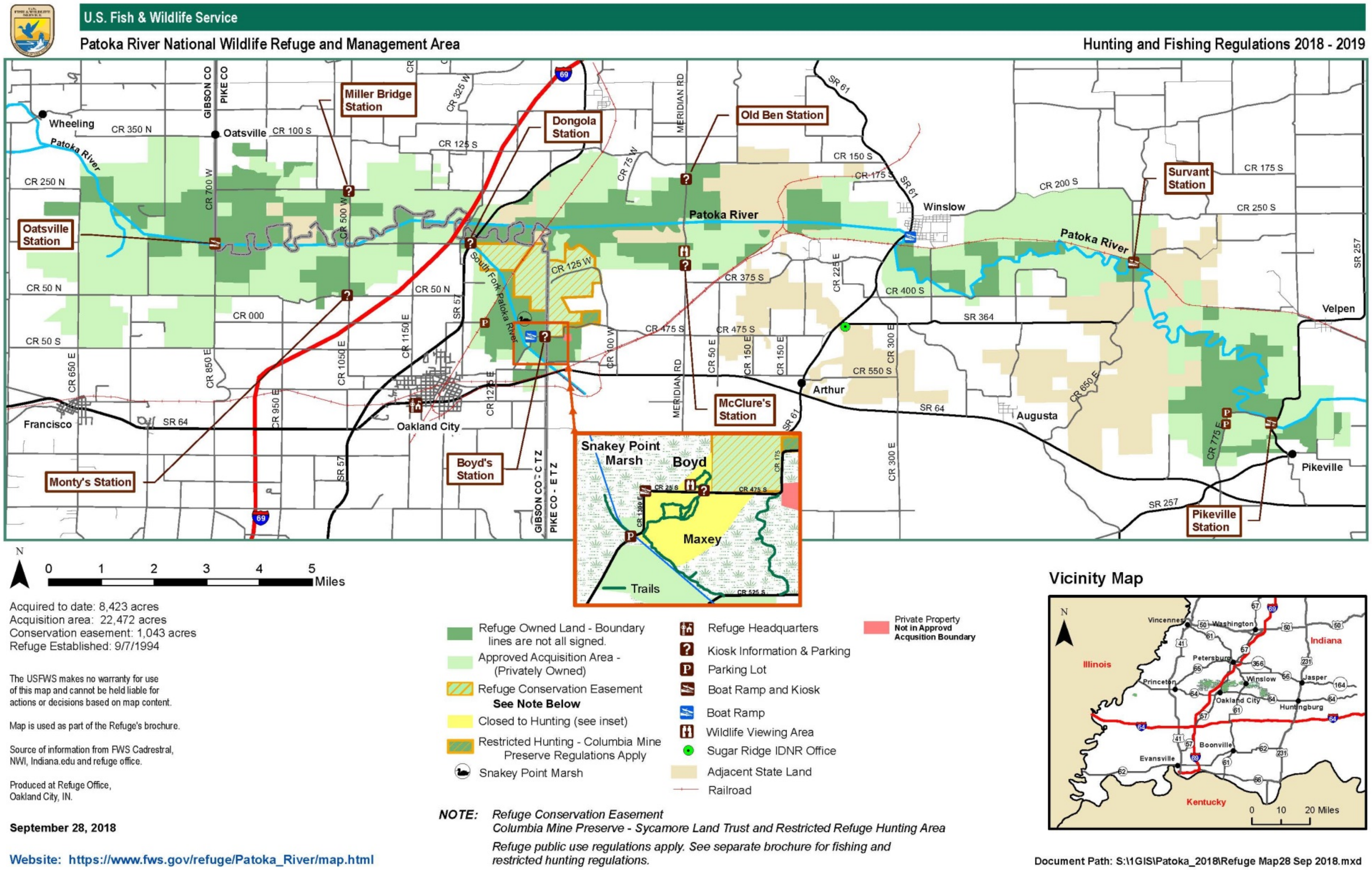


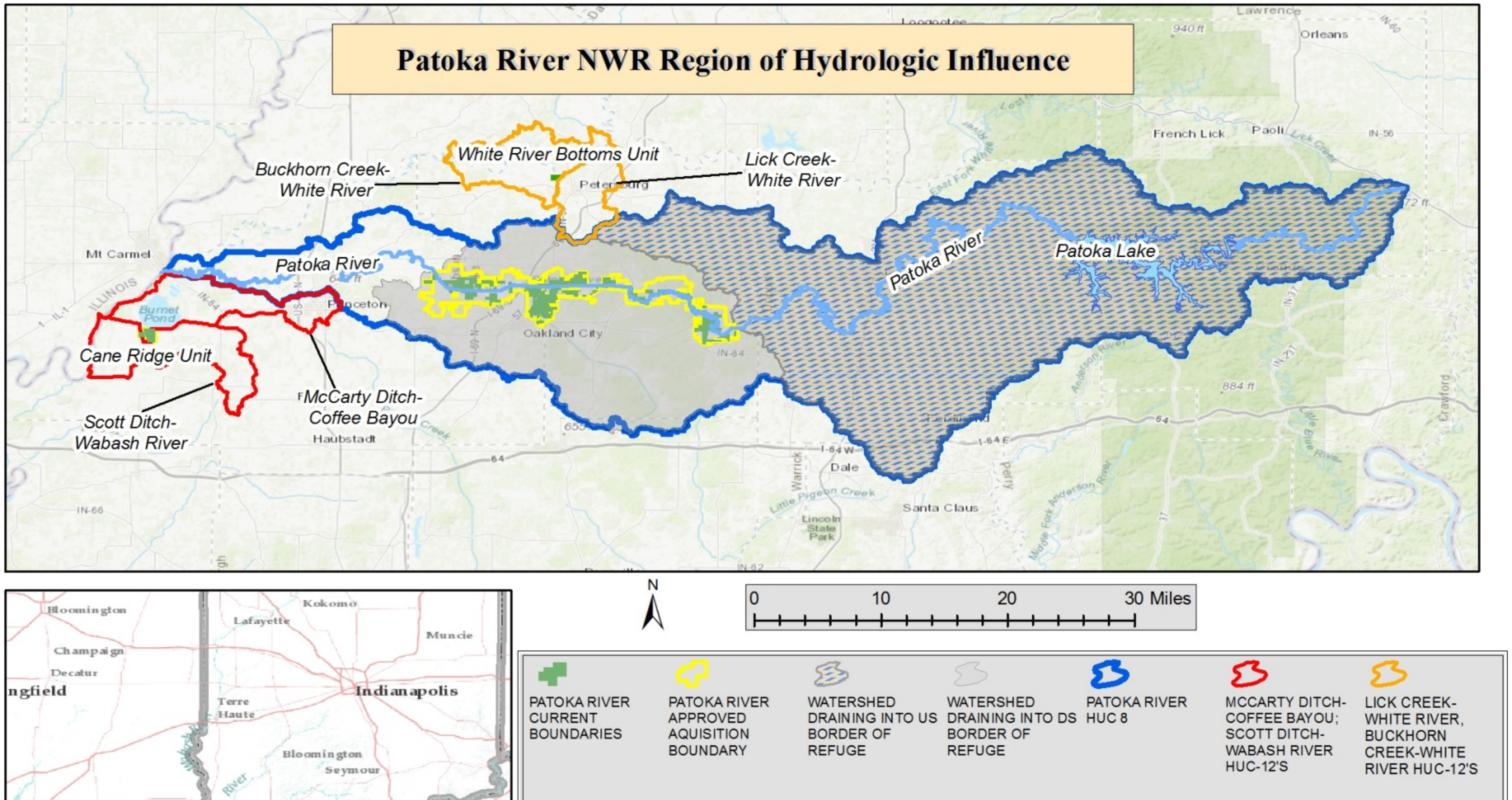
Figure 2.1.1: Map of Patoka River National Wildlife Refuge and Management area as of 2018.

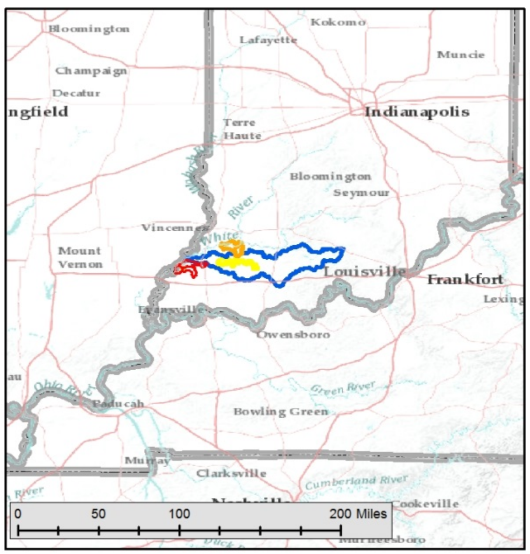
Chapter 3: Natural Setting

The natural setting section describes the abiotic resources associated with the Refuge, including relevant watershed boundaries, topography, and climate. These underlying, non-living components of an ecosystem provide the context on which water resources are constructed and managed. Many of these elements are also described in Patoka NWR's Comprehensive Conservation Plan (CCP) (USFWS 2008a), Habitat Management Plan (USFWS 2017a), and Inventory and Monitoring Plan (IMP) (USFWS 2017b).

3.1 Region of Hydrologic Influence (RHI)

Hydrologic information can be described in the context of Patoka River NWR's designated Region of Hydrologic Influence (RHI), which is the relevant region for the collection of water quality and quantity information. Hydrologic Unit Codes (HUCs) designate watersheds of various sizes and often represent the initial aggregate level of water quality and quantity information available from a variety of agencies. HUC boundary datasets can be obtained from the USGS National Watershed Boundary dataset, which can be accessed from The National Map portal (https://nhd.usgs.gov/data.html). PRNWR's RHI was chosen as the Patoka River HUC 8 which drains a total area of 856.9 square miles and runs from east to west towards Illinois and the Wabash River. The Refuge lies relatively low in the watershed with 543.7 square miles of the watershed draining into it at its upstream boundary. By the downstream boundary however, it is 790.7 square miles, a 45% increase in the drainage area. The reaches of the Patoka downstream of the Refuge can influence the Refuge as well due to the relationship the Patoka has with the Wabash, which can create a hydraulic dam effect on the Patoka during high water (USFWS 2008a). The Cane Ridge Unit is located in the Lower Wabash River HUC-8 and it's RHI is contained by the McCarty Ditch-Coffee Bayou and Scott Ditch-Wabash River HUC-12's, which combined drain an area of 80.6 square miles. However, Cane Ridge receives most of its water through pumping from the Wabash River (Refuge staff, personal communication 2018), so the Wabash could be considered part of this unit's RHI as well. The White River Bottoms Unit is located in the White River HUC-8 and it's RHI is contained by the Lick Creek-White River and Buckhorn Creek-White River HUC-12's for a combined drainage area of 53.0 square miles.





Watershed Name	Area (sq. mi.)
Patoka River HUC-8	856.9
Patoka River Drainage Upstream End of Refuge	543.7
Patoka River Drainage Downstream End of Refuge	790.7
Patoka River Drainage Downstream of Refuge	66.2
McCarty Ditch- Coffee Bayou HUC-12	34.8
Scott Ditch- Wabash River HUC-12	35.8
Lick Creek - White River HUC-12	22.5
Buckhorn Creek - White River HUC-12	30.5

Figure 3.1.1: Map of Patoka River NWR's Region of hydrologic influence and associated drainage area

3.2 Topography

High resolution (1-meter) bare-earth LiDAR data (NAVD88) is currently available for Patoka River NWR & MA. It was obtained from the State of Indiana and LAS files were processed by USFWS staff. Data was collected in 2013 by Woolpert Consultants Inc. Topographic maps are shown below (Figure 3.2.1). As can be seen, Patoka River NWR & MA lies almost exclusively in the Patoka River floodplain. The floodplain becomes much wider in the reach downstream (west) of Winslow, IN. The eastern end of the Refuge lies in a much steeper, narrower portion of the Patoka River floodplain, dropping at a rate of 12 feet per mile. The western end of the Refuge lies in the flats created by Glacial Lake Patoka. Here the floodplain is much wider (as much as 2 miles across), and the river drops at a much slower rate of about 1 foot per mile (USFWS 2008a)

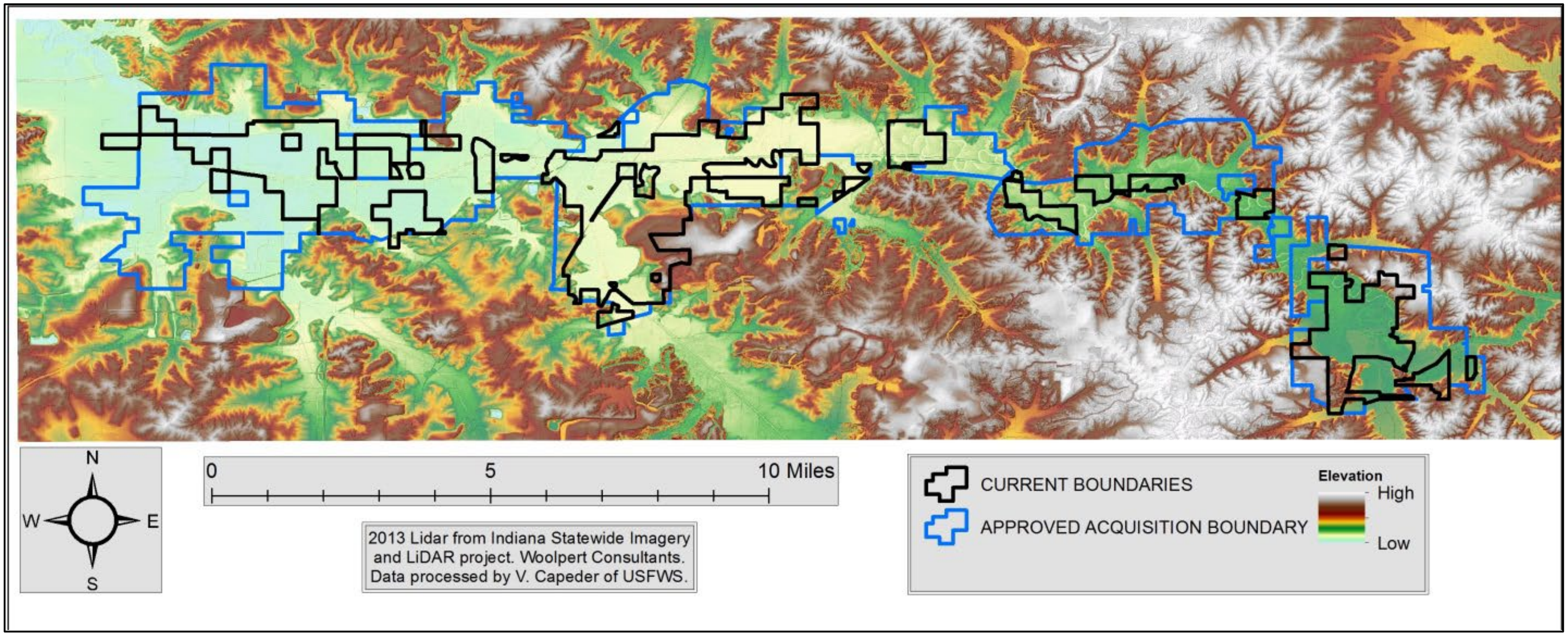


Figure 3.2.1: Available Lidar topography for Patoka River NWR (Woolpert Consultants 2013)

3.3 Long Term Climate Trends

The WRIA provides a preliminary broad-based analysis of trends and patterns in precipitation and temperature. Climate is defined here as the typical precipitation and temperature conditions for a given location over years or decades. These types of trends and patterns affect groundwater levels, river runoff, and flooding regularity and extent. This section evaluates Patoka River NWR's current and historical climate patterns by:

- Discussing the current climate and changes already experienced in the region
- Briefly summarizing projections for the future from selected models
- Analyzing a U.S. Historical Climatology Network (USHCN) dataset

Historical Climate Conditions

The climate of the Patoka River is fairly typical for that of the Lower Ohio River Valley, with a Cfa Koppen-Geiger classification, meaning it experiences a mild, fully humid climate with hot summers (max temperature greater than 97.2F) (Chen 2013). Although, much seasonal variation can occur depending on the influence of polar or tropical air masses. Cloudiness is typically least in autumn and greatest in winter (Indiana State Climate Office 2002). Total evaporation can be as high as 38.9 inches from May-October in the region around Evansville (NWS 1982). The PRNWR CCP (USFWS 2008a) cites NOAA (1991), describing the local climate as below:

> *"The Refuge lies in the path of moisture-bearing low pressure formations that move from the western Gulf region, northeastward over the Mississippi and Ohio Valleys to the Great Lakes and northern Atlantic Coast. Much of the area's precipitation results from these storm systems, especially in the cooler part of the year. The average annual precipitation totals 44.2 inches. Of this total, about 23 inches, or nearly 52 percent, falls during the growing season of April to September. The highest and lowest annual precipitation totals for the period of record are 64.8 inches in 1945 and 28.0 inches in 1887, respectively. Maximum monthly precipitation is 15.1 inches while the minimum is 0.05 inches. The average seasonal snowfall is about 13.5 inches. On the average, 3 days out of the year have at least 1 inch of snow on the ground (NOAA, 1991)."*

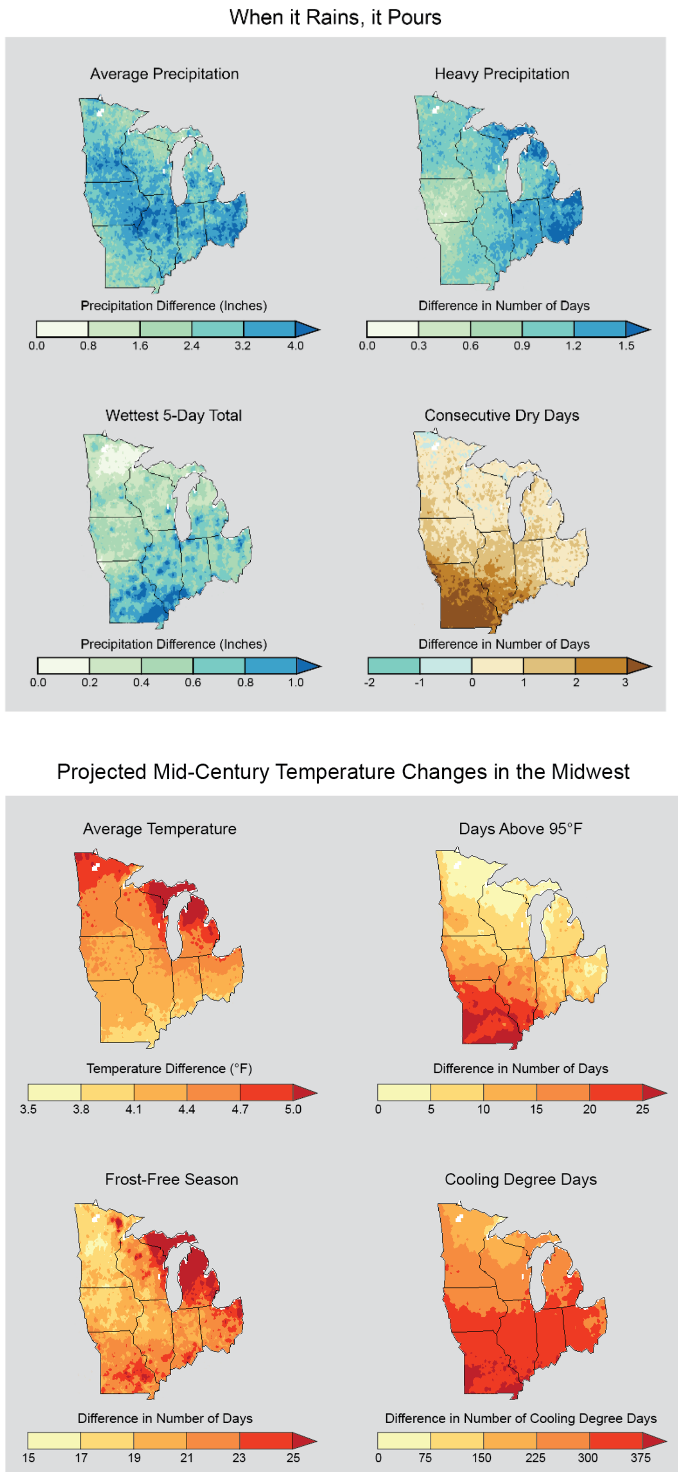


Figure 3.3.1: Projected changes in climate across the Midwest by mid-century (NOAA NCDC / CICS-NC, 2014)

Projected Climate Changes

Atmospheric carbon dioxide levels are predicted to double by 2060 from 20th century levels (Davis et al. 2000). This doubling will lead to disruption in global cycles such as precipitation, diurnal temperature extremes, cloudiness, hydrology, and sea levels (Griffith et al 2008). The nation as a whole has experienced a 1.3-1.9 degree Fahrenheit increase in average temperatures since 1895, and can expect a 2-4 degree increase over the next century (Melilo et al. 2014), although this change is not uniform over all regions of the country or over time (Winkler et al. 2012, Melilo et al. 2014, Rupp et al. 2016). A 2004 study showed that areas in the central United States (including parts of Indiana) are experiencing a local minimum of warming compared to the rest of the nation, due to the interaction between increased precipitation, soil moisture, and evapotranspiration (Pan et al. 2004, Pryor et al. 2013). However, in the future, Indiana's summers could be up to 13 degrees Fahrenheit warmer on average by the end of the century (UCS 2009) and 5 to 6 degrees warmer by mid-century (Widhalm et al. 2018), with every single summer of the future being hotter than the hottest summers of the past (UCS 2009). Indianapolis is expected to experience up to 28 days per year over 100 degrees Fahrenheit by the end of the century under high-emissions scenarios (USCS 2009), and with the Patoka River lying some 100 miles south, this number could be higher for the Refuge.

In addition to the increase in hot days, the extreme coldest temperatures of the year are expected to get warmer as well. Growing season in southern Indiana is expected to rise from its historic average of 185 days to 216 days by 2050 (Widhalm et al. 2018), much more than the Midwest average of a 14 day increase (Pryor et al. 2013). The plant hardiness zone is expected to change from 6B to 7B, the same as modern day northern Alabama (Widhalm et al. 2018). Along with the lengthening growing season, studies point towards there being 2 or less days with 2” of snow by the end of the century (Widhalm et al. 2018).

Several reports indicate that the Midwest is currently experiencing much more frequent and intense precipiatation events in the region than it was a century ago (Kunkel et al. 2003, Winkler et al. 2012, Kunkel et al. 2013). There are also estimates that intense precipitation events will increase, with both the 24-hour and 7-day rainfall events doubling by the end of the century (Wuebbles and Hayhoe 2015). In addition to rainfall, it has been found that the number of autumnal tornado days in southern Indiana has increased between 4 and 8 per year as a result of climate change, and the lower Ohio River Valley is an area that can expect to see the largest increases in the future (Agee et al. 2016).

The Midwest has experienced an increase in runoff and suspended sediment loads (Johnson et al. 2013). Flooding in Indiana is predicted to get much worse (EPA 2009), and most of this will be due to increases in winter, spring, and fall precipitation as well as heavier rain events (UCS 2009, Hayhoe et al. 2010, Liu et al. 2015). Although, some increases are an indirect result of land use changes in response to climate change (Cibin et al. 2017). These changes in hydrologic processes can lead to variability in observed daily minimum and maximum temperatures (Scherer and Diffenbaugh 2013). Pike County in particular was noted by one study to be at particular risk out of all counties in Indiana to hazards from flooding (Liu et al. 2015). Basic inventorying and monitoring of hydrologic processes on the Refuge is crucial because effects from climate change cannot be established without robust baselines (Griffith et al. 2008).

USHCN Dataset

The USHCN is a network of sites listed by the National Weather Service, which maintains standards in quality and continuity of data collection (http://cdiac.ess-dive.lbl.gov/epubs/ndp/ushcn/ushcn.html). An analysis of the historical climate data from USHCN Station 128036, Shoals, IN was performed to better understand what kinds of climate-related trends have been observed in the local area. The Shoals, IN station has data from 1908 to present with a 94% coverage of monthly data during this time period. However, only data from 1913 to present was used in the analysis because from 1908 to 1912 there was too much missing data. The site is located approximately 27 miles northeast of Patoka River NWR, and is situated at an elevation of 477 NAVD88 feet, whereas most of the Refuge sits in between 410 and 550 feet. This was the closest site of adequate period and completeness of records, so was chosen for analysis in the report. The results of the analysis are as follows.

- Annual average precipitation was found to have a statistically significant increasing trend from 1913 to 2017 (Figure 3.3.3, p-value < 0.001, median = 43.7”, mean 44.2”). This increasing trend was significant for all four seasons as well.
- The number of rain events 2” or larger per year was found to have a statistically significant increasing trend from 1913 to 2017 (Figure 3.3.5, p-value < 0.001, median = 1.0 day/year). Also, a more in depth look at the exceedance of rainfall in a day ranging from 0.01” to 4.00” showed an increase for all types of rainfall amounts in recent years. The largest differences were seen with the 2”, 3”, and 4” rainfalls. For instance, the average number of 3” rains went from 0.418 days per year (on average once every 2.4 years) to 0.719 days per year (on average once every 1.4 years) (Table 3.3.2).
- While the average precipitation and large storm events have shown marked increases, the average temperature for this region has shown a decrease from 1913 to 2017.

Annual average temperature showed a statistically significant decrease for the period analyzed (Figure 3.3.4, p-value < 0.001, median = 54.4 F)

- The growing season length however, did show an increasing trend from 1913 to 2017, showing a longer period between the last frost of spring and first frost of autumn each year. However this trend was not statistically significant (Figure 3.3.6, p-value = 0.11, median = 171.5

Kendall's Tau Non-Parametric Monotonic Trend Test

Dependent Variable	p-value	slope	median
Annual Average Precipitation	< 0.001	(+)	43.7
Cool-season Precipitation	< 0.001	(+)	19.6
Spring Precipitation	< 0.001	(+)	12.6
Fall Precipitation	< 0.001	(+)	9.6
Annual Average Temperature	< 0.001	(-)	54.4
Summer Precipitation	0.016	(+)	11.6
Winter Precipitation	0.011	(+)	8.1
Linear Regression Analysis			
Annual # Days With Precipitation > 2”	< 0.001	(+)	1.0
Length of Growing Season	0.11	(+)	171.5

Table 3.3.1: Statistically significant climate trends for 1913-2017, Station No. 128036, Shoals, IN

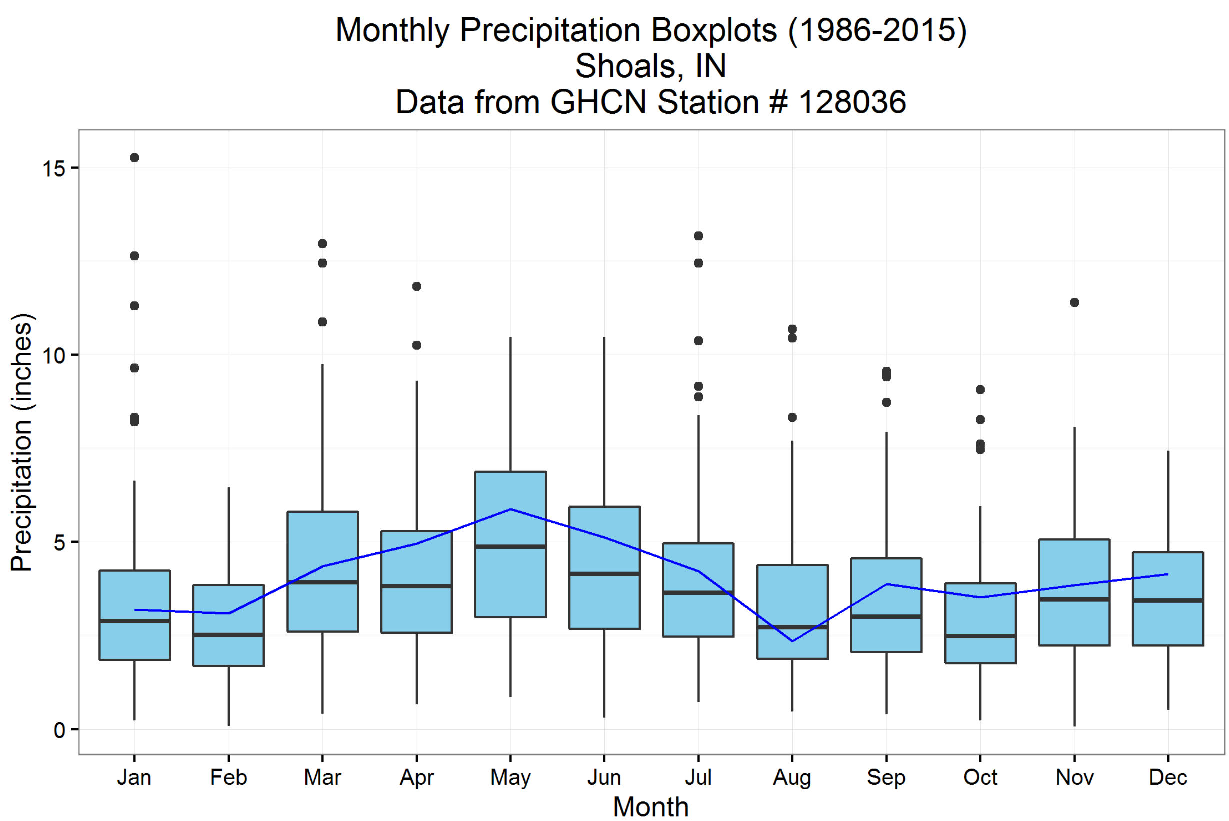


Figure 3.3.1: Monthly average precipitation for USC00128036 Shoals 8 S, IN US.

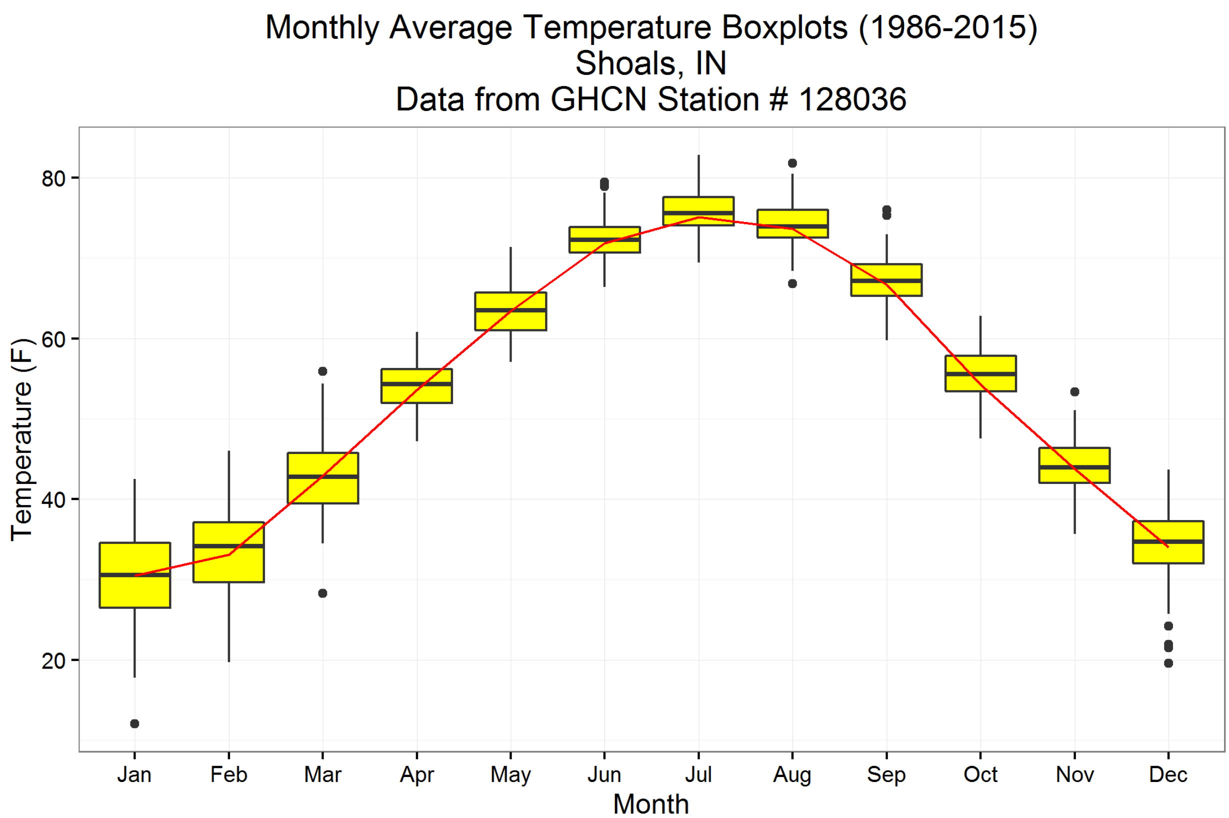


Figure 3.3.2: Monthly average temperature for USC00128036 Shoals 8 S, IN US.

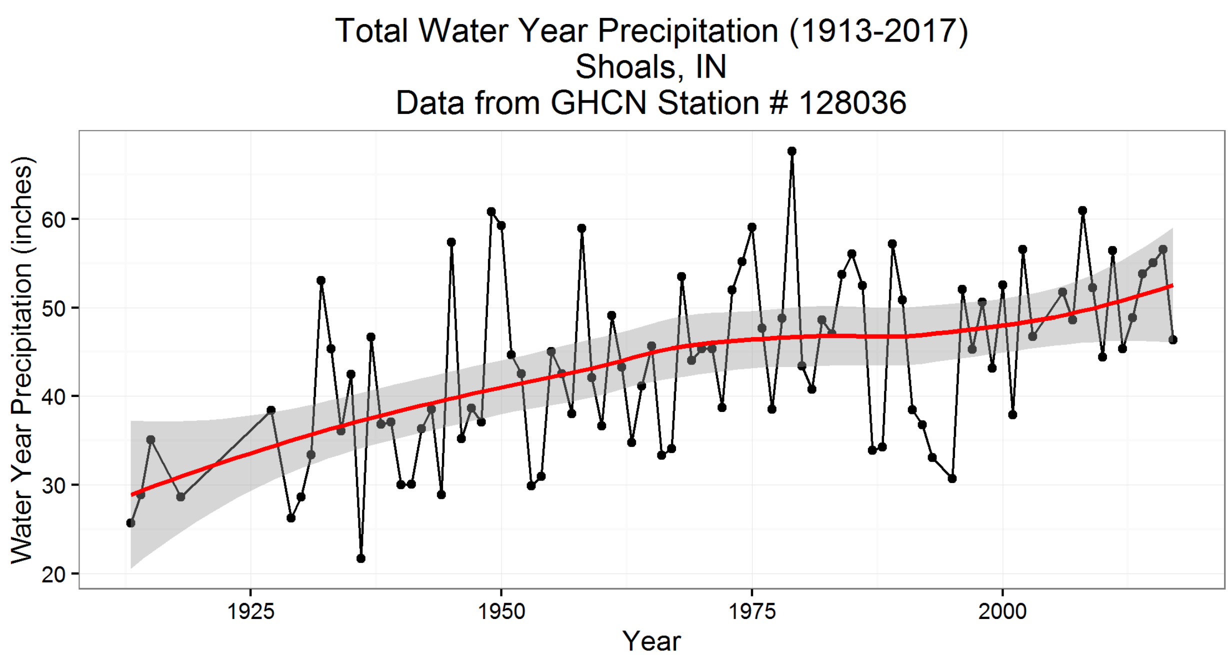


Figure 3.3.3: Water year precipitation for USC00128036 Shoals 8 S, IN US (1913-2017). Red line is a loess regression trend line.

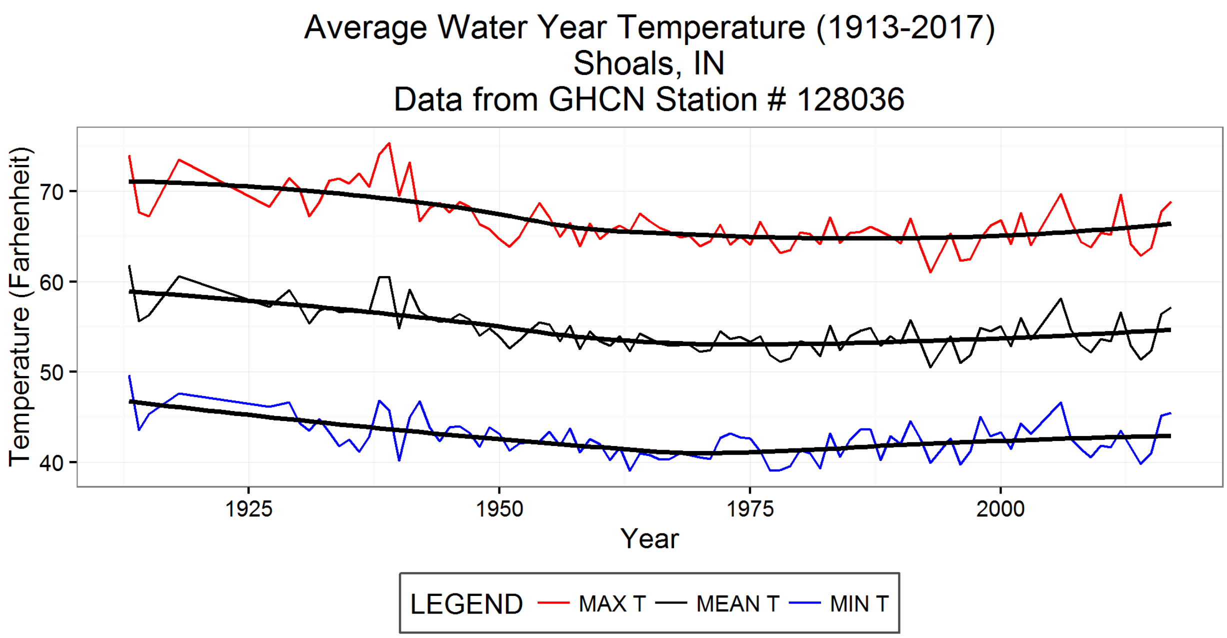


Figure 3.3.4: Water year average maximum, minimum, and mean for USC00128036 Shoals 8 S, IN US (1913-2017). Black lines are loess regression trend lines.

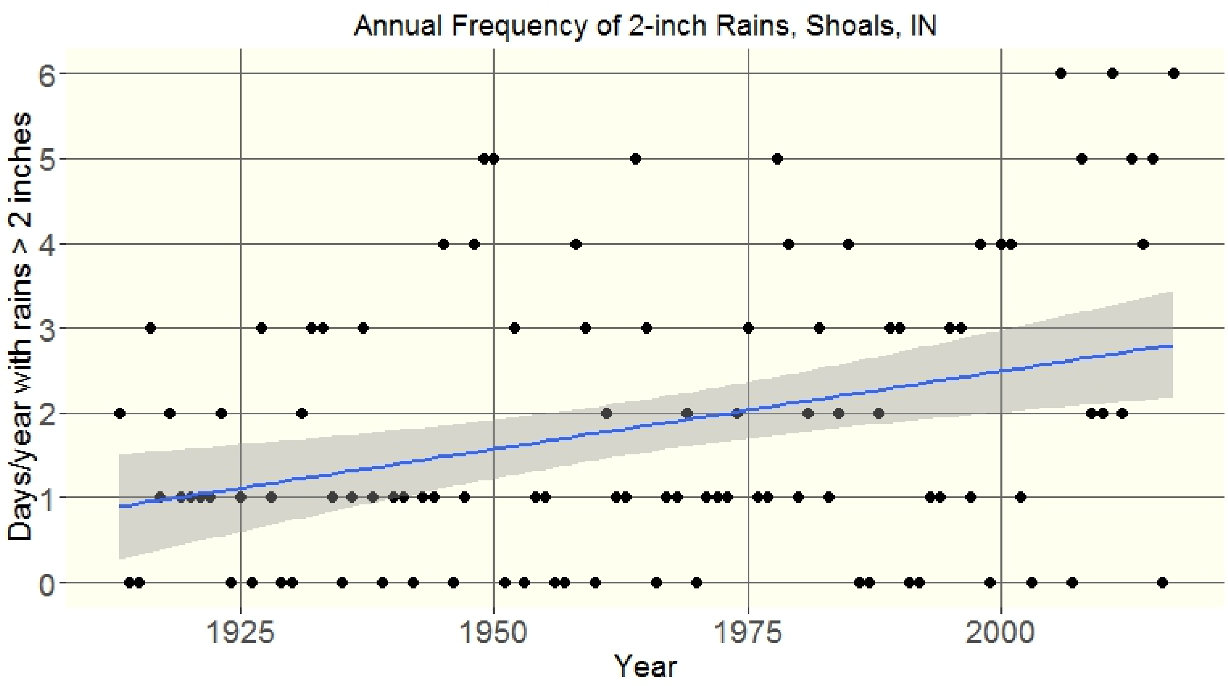


Figure 3.3.5: Number of days per year with 2" of rain or more. USC00128036 Shoals 8 S, IN US (1913-2017). Blue line is a linear regression trend line.

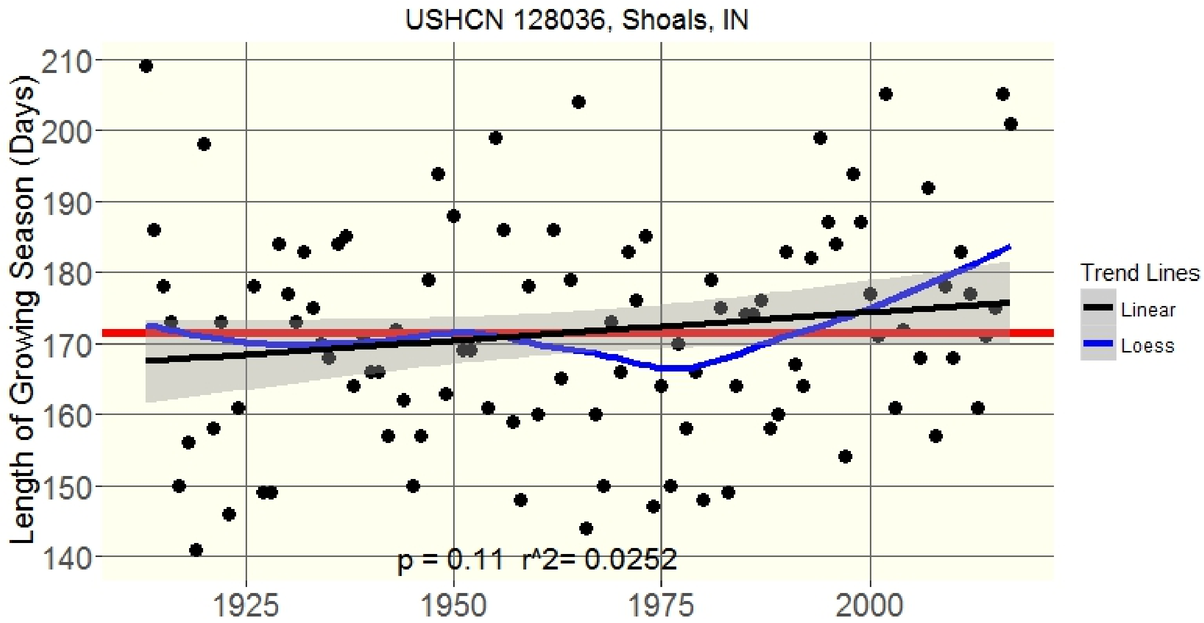


Figure 3.3.6: Length of growing seasons (daily minimum > 32F). USC00128036 Shoals 8 S, IN US (1913-2017). Blue line is a loess regression trend line, black line is a linear regression trend line, red line is the median (171.5).

Inches of rain in a day equaled or exceeded	Avg. Number of days/year (1913-1992)	Avg. Number of days/year (1993-2017)	Percent Change
4.00	0.076	0.125	**+ 64%**
3.00	0.418	0.791	**+ 89%**
2.00	1.57	2.17	**+ 72%**
1.00	10.3	13.8	**+ 33%**
0.50	29.5	32.9	**+ 12%**
0.25	50.6	54.6	**+ 8.0%**
0.10	74.4	77.8	**+ 4.5%**
0.05	88.7	91.3	**+ 3.0%**
0.01	110	112	**+ 1.5%**

Table 3.3.2: Cumulative frequency of daily rains for Shoals. IN. Comparison of past conditions (1913-1992) to contemporary conditions (1993-2017.)

Chapter 4: Water Resource Features

4.1 Management Units

The Patoka River NWR consists of a variety of individual units spread out across the Patoka River floodplain. Refuge units are acquired over time from willing landowners in the Acquisition Boundary. The Acquisition Boundary encompasses up to 22,472 acres, however the total Refuge owned lands at the time of this report was 9,466 acres (Refuge staff, personal communication 2018). The main part of PRNWR can be split up into eastern and western halves, with the eastern half covering the portion of the Patoka with a higher gradient, narrower floodplain and an unditched, meandering channel. The western half covers the wide, lower gradient portion of the River, and in this half much of the River was dredged into the modern day Houchin's Ditch. Most of the Refuge is passively managed floodplain habitat where management activity typically consists of planting trees, creating scrapes on the floodplain, or putting breaches in spoil levees, where possible (Refuge staff, personal communication 2018). There are a few more distinct hydrologic units on the Refuge worth pointing out. Starting from east to west, there is Dillin Bottoms Moist Soil Unit (MSU), east of Winslow. This is composed of two MSU's covering 60 acres managed via stop log structures. Moving further west, there is a large floodplain lake named Gray Woods Swamp, this is a natural, passively managed floodplain wetland (Refuge staff, personal communication 2018). West of Gray Woods Swamp, there are several lakes on the recently acquired Columbia Mine Preserve. Four of the lakes are regularly inundated by the Patoka including Indian Hill, Massey, Loveless, and Peacock Lakes. In addition, there are three lakes that are not inundated by the Patoka on a regular basis, including Laura Hare, Sprigtail, and Stonehenge Lakes (USFWS 2015). Near the Columbia Mine Preserve, there is the Snakey Point Marsh and Bucks Marsh areas, which are unmanaged floodplain wetlands that receive water when the South Fork Patoka River floods. Further west along the Patoka there are Monty's, Oatsville, and Wheeling units. These are three larger (653 acres combined) temporary wetland bottomland tracts that are important areas for migratory waterfowl (USFWS 2017a). In addition to the main Refuge area, there are two outlying property holdings; Cane Ridge (488 acres) and White River Bottoms (219 acres) Wildlife Management Areas (WMA). West of the Refuge, Cane Ridge WMA is a site adjacent to the Duke Energy Power Plant facility and consists of several small MSU's that draw water from the Wabash River. These units serve as important habitat for Least Tern and Whooping Crane (USFWS 2017a). To the north of the Refuge, White River Bottoms WMA is an unmanaged inholding of Patoka NWR that receives seasonal flooding from the White River.

When the Patoka River was ditched in the 1920's, it left behind many disconnected reaches of the Patoka River channel that are now separated. These historic channels are the original meanders and morphology of the River prior to its channelization. Many of these still provide habitat as floodplain oxbow lakes, but the ideal situation would be to reconnect these historic channels back to the River. Refuge staff have investigated this matter and have found that this would be a very difficult task to accomplish at this time. Since the river was ditched two things have happened: First, Houchin's Ditch has incised significantly, so now the river bottom is much lower than that of the historic channels. Secondly, the historic channels have begun filling in with sediment, thus raising their elevation. There may exist portions of cut off channels on the South Fork of the Patoka River that would have a higher chance of success of reconnection (Refuge staff, personal communication 2018).

Infrastructure

There are seven total impoundments on the Refuge, two at Dillon Bottoms and five at Cane Ridge WMA. There are five water control structures (stop logs) at Dillon Bottoms and ten at Cane Ridge. The only permanent pump on the Refuge is at Cane Ridge. This pump takes in water from the Wabash River and delivers it to the MSU's at Cane Ridge. It is housed with the pumps that Duke Energy uses for their power plant. This pump is important because it is used to flood the Cane Ridge wetland units which are used by Whooping Cranes and Least Terns (Refuge staff, personal communication 2018). There is also one portable pump that the Refuge uses to flood their other MSU's in the fall if needed. There are staff plates installed in every MSU, but they are not all surveyed into a common datum at this time (Refuge staff, personal communication 2018).

In addition to these wetland management infrastructure items, there are a number of public infrastructure assets that fall within the Refuge Acquisition Boundary. There are 10 state maintained bridges and 28 county maintained bridges within 0.25 miles of the Refuge Acquisition Boundary that cross either the Patoka or its tributaries (Figure 4.1.2). While these bridges do not belong to FWS and are not the responsibility of the Refuge, the way in which these bridges are maintained or reconstructed could impact Refuge resource features. They could cause excessive scour and erosion, cause debris jams, and present a barrier to fish passage. In addition, they could be vulnerable locations for hazardous substance spills from vehicle transport.

There are five state listed dams within 0.25 miles of the Refuge Acquisition Boundary (Figure 4.1.2) that are of concern due to potential dam failure, barriers to fish passage, and alteration of natural hydrologic regimes. One of these is on the main stem of the Patoka in the town of Winslow, while the other four are located on tributaries. An additional infrastructure item of interest is the historic Wabash and Erie Canal. There are 5.7 miles of the Wabash and Erie Canal within a 0.25 mile buffer of the Refuge Acquisition Boundary. The canal was completed in 1843 and connected the water of the Ohio River to the ports of Lake Erie in Toledo, OH. It only operated for about 10 years (wabashanderiecanal.org). The historic nature of the canal could influence the extent of work done on Refuge lands that intersect with the canal.

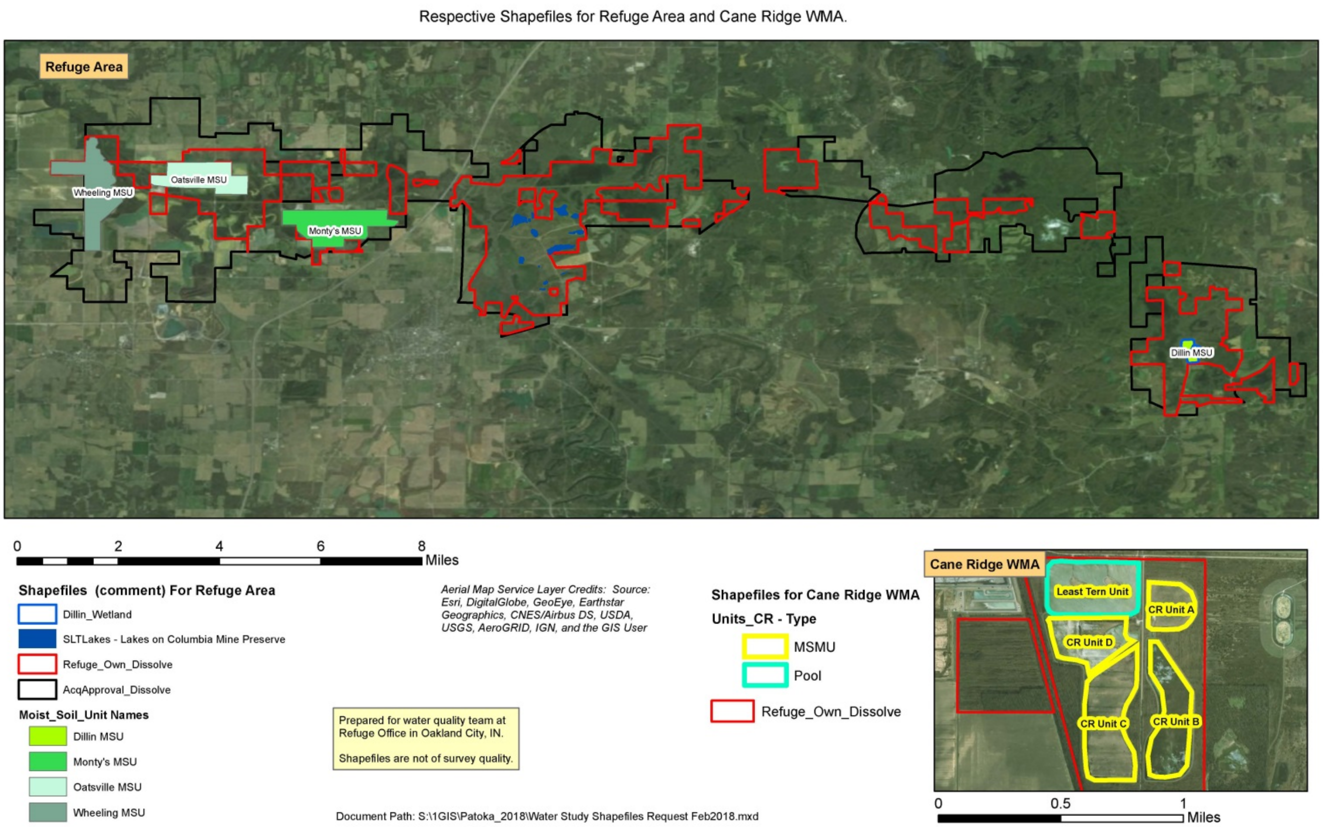


Figure 4.1.1: Management units of Patoka River NWR and Cane Ridge WMA.

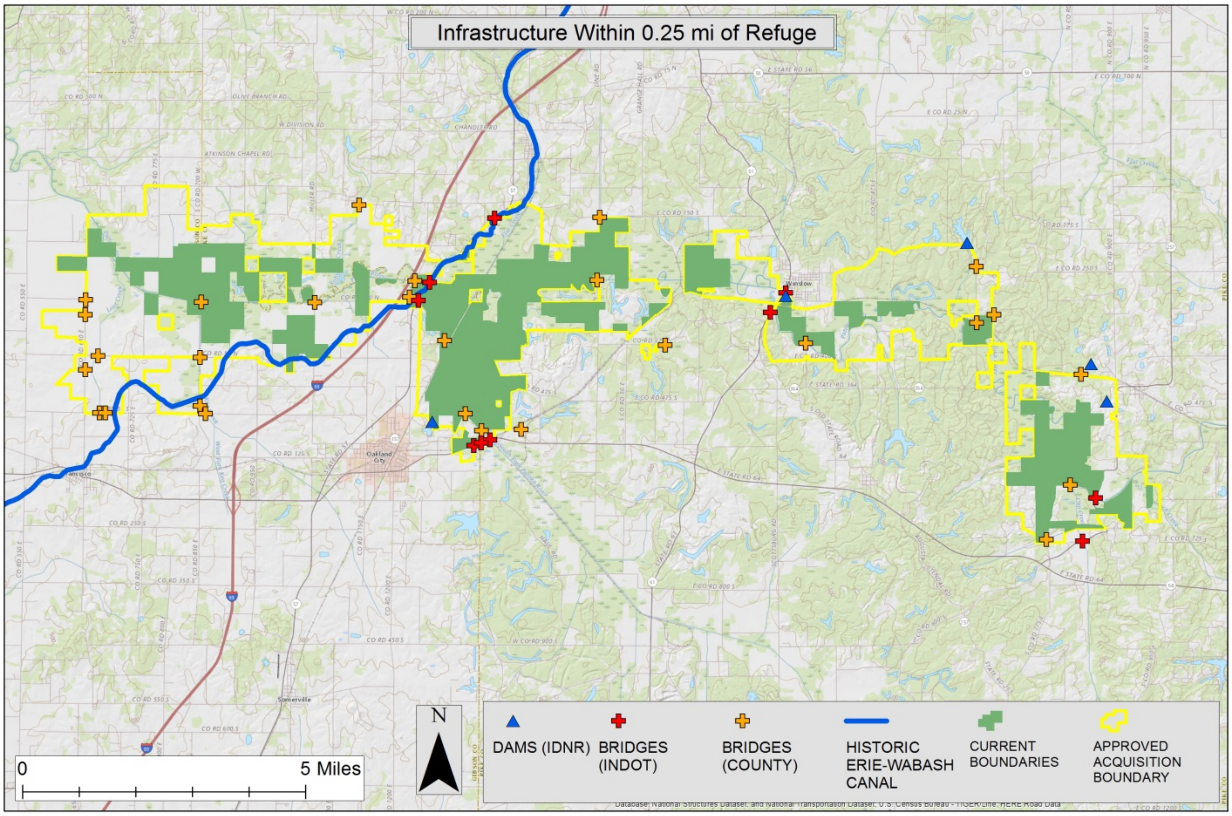


Figure 4.1.2: Public and historic infrastructure within a 0.25 mile buffer of the Refuge.

4.2 National Wetlands Inventory

The National Wetland Inventory (NWI) is an extensive, ongoing survey by the USFWS, of aquatic habitats across the United States. The NWI is based on interpretation of aerial photographs, not ground surveys, and its criteria differ somewhat from those used in jurisdictional wetland delineations for permitting by the United States Army Corps of Engineers under Section 404 of the Clean Water Act. Classifications may also be somewhat outdated. Wetlands data for Patoka River NWR can be accessed using the NWI Wetlands Mapper found at this website: https://www.fws.gov/wetlands/Data/Mapper.html.

4.3 National Hydrography Dataset

The National Hydrography Dataset (NHD) is a vector geospatial dataset including information about the nation's lakes, ponds, rivers, streams, and other water features that are part of the USGS's National Map (data is obtained from here: https://viewer.nationalmap.gov/basic/). Within the unit boundaries, the flowpaths identified by the NHD can be broken down based on type. Maps and a table of relevant NHD information for Patoka River NWR are provided below.

The NHD provides an approximate representation of streams, tributaries, and other waterbodies and does not necessarily reflect actual conditions. Further, the NHD's inventory of "named features" is not necessarily all-inclusive, and some of the flowlines may be mis-categorized. The general direction of flow in the Patoka River Basin is from east to west.

As Figure 4.3.1 shows, PRNWR not only includes portions of the Patoka River, Houchin's Ditch, and its oxbows, but also a large number of tributaries. A staggering 541.96 miles of river and stream channels (mostly unnamed) are contained within a 0.25 mile buffer of the Acquisition Boundary of the Refuge (Table 4.3.1). This is of importance for the Refuge because the varying water quality of these tributaries can directly affect water quality of the Patoka River itself. Many of the tributaries listed either face water quality issues or are ditched and channelized (Refuge staff, personal communication 2018). In addition to the numbers presented below, the Refuge contains 19 miles of former river channel that were cut-off when Houchin's Ditch was dredged in the 1920's and the South Fork was dredged in 1912 (USFWS 2008a, Refuge staff, personal communication 2018). NHD Feature Codes (Fcode) indicate that the majority of stream lines within the 0.25 mile buffer are classified as a canal or ditch, with the second most common type being perennial stream or river (Table 4.3.2). In addition to the NHD stream layer, there are approximately 1,700 acres of perennial lakes or ponds and 1,989 acres of swamp or marsh as classified by the NHD waterbody layer.

Description	Total Miles (within Acq. Bounary +0.25 mi buffer)	Percent
Turkey Creek	1.08	0.2%
Sugar Creek	1.72	0.3%
Stone Coe Creek	1.17	0.2%
South Fork Patoka River	4.12	0.8%
Rock Creek	2.16	0.4%
Robinson Creek	2.14	0.4%
Patoka River	29.11	5.4%
Morrow Lateral	1.60	0.3%
Mill Creek	1.22	0.2%
Lost Creek	3.44	0.6%
Lick Creek	1.92	0.4%
Keg Creek	2.22	0.4%
Hurricane Creek	1.36	0.3%
Hog Branch	1.15	0.2%
Flat Creek	2.03	0.4%
Cup Creek	1.11	0.2%
Buck Creek	1.85	0.3%
Bruster Branch	1.39	0.3%
Big Creek	2.17	0.4%
Beadens Creek	1.03	0.2%
Barren Ditch	1.56	0.3%
Unnamed	476.41	87.9%
Total	**541.96**	**100.0%**

Table 4.3.1: NHD flowlines found at PRNWR

NHD Fcode Description	Total Miles (within Acq. Boundary +0.25 mi buffer)	Percent
33400, Connector	0.81	0.2%
55800, Artificial Path	137.56	6.7%
33600, Canal/Ditch	36.40	48.3%
46000, Stream/River	261.85	14.1%
46003, Stream/River Intermittent	76.49	5.3%
46006, Stream/River Perennial	28.84	25.3%
Total	**541.96**	**100%**

Table 4.3.2: NHD flowline types found at PRNWR

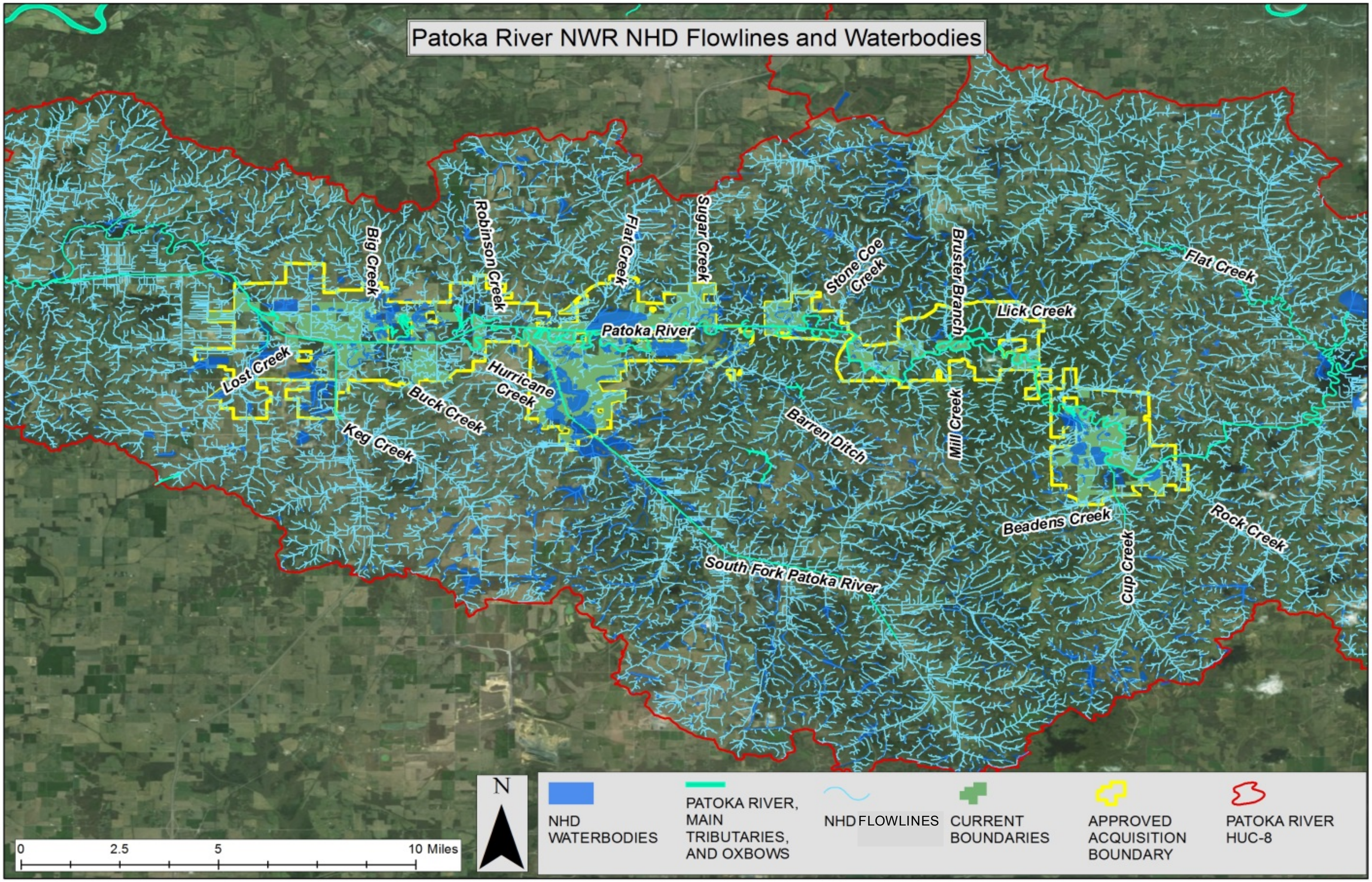


Figure 4.3.1: Flowlines and waterbodies contained in the USGS NHD dataset within the Refuge and local vicinity.

Chapter 5: Water Resource Monitoring

The WRIA identified historical and ongoing water resource related monitoring on or near Patoka River NWR. Water resource datasets that were collected can be categorized as water quantity or water quality monitoring of surface or groundwater. Water quantity monitoring typically involves measurements of water level and/or volume in a surficial water body or subsurface aquifer. 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 resource management organizations. There were three surface water quantity sites analyzed on the Patoka River, one groundwater site, and three water quality sites. The water quality sites chosen were a select few from the many available for the area. Relevant sites were evaluated for applicability based on location, period of record, extensiveness of data, sampling parameters, trends, and dates of monitoring.

5.1 Water Monitoring Stations and Sampling Sites

Several resources offer water quality and quantity datasets relevant to Patoka River NWR and were utilized in the creation of the Refuge's water monitoring site inventory:

- Data for historical sampling locations can be retrieved through the EPA STORET (STOrage and RETrieval; http://www.epa.gov/storet) database. This data warehouse is a repository for water quality, biological, and physical data used by state environmental agencies, EPA and other federal agencies, universities, and private citizens.
- Water quantity and quality data for active and inactive monitoring sites can also be accessed from the USGS National Water Information System (NWIS) database (http://www.waterqualitydata.us).
- NPDES Permit Sampling data was accessed for this assessment through personal communication with the FWS Indiana Ecological Services Office and the Indiana Department of Environmental Management (IDEM), as well as querying the EPA Enforcement and Compliance History Online (ECHO) website.

The WRIA identified seven monitoring sites that are considered applicable to PRNWR's water resources, including six surface water monitoring sites (three water quantity/three water quality), and one groundwater monitoring station. See Table 5.1.1 below for more info on these sites.

Site Name	ID and Link	Location	Elevation	Notes	Record maintained by:
Water Quantity					
Patoka River at Princeton, IN	USGS 03376500	Latitude 38°23'25" Longitude 87°32'56" NAD27	388.56 feet above NAVD88	Discharge (1934-present), peak streamflow (1935-present)	USGS Indiana Water Science Center

Patoka River at Winslow, IN	USGS 03376300	Latitude 38°22'49" Longitude 87°13'00"NAD 27	400.00 feet above NAVD88	Discharge (1968-present), peak streamflow (1937-present), some water quality data (2006-present)	USGS Indiana Water Science Center
Patoka River at Jasper, IN	USGS 03375500	Latitude 38°24'49" Longitude 86°52'36" NAD83	445.22 feet above NAVD88	Discharge (1948-present), peak streamflow (1913-present), water quality data (1963-1975)	USGS Indiana Water Science Center
Knox, (KN 7), (well site)	USGS 383247087361001	Latitude 38°32'47" Longitude 87°36'10" NAD27	403.25 feet above NAVD88	Depth to water level (Groundwater)	USGS Indiana Water Science Center
Water Quality					
Patoka River at CR-300 W Bridge	WQX-2362	Latitude 38.3825 N Longitude 87.3333 W NAD83	Unknown	Ambient stream water quality monitoring (1991-present)	Indiana Department of Environmental Management
South Fork Patoka River at CR 24 S Bridge	WQX-15331	Latitude 38.3478 N Longitude 87.3200 W NAD83	Unknown	Ambient stream water quality monitoring (2012)	Indiana Department of Environmental Management
CR 850 E N of SR 64 Francisco, IN 47649	ING40037	Latitude 38.3411 N Longitude 87.4144 W NAD83	Unknown	NPDES Permit (2014-2020). Formerly Permit # IN0057428 (1994-2014).	US EPA

Table 5.1.1: Water monitoring sites used for analysis.

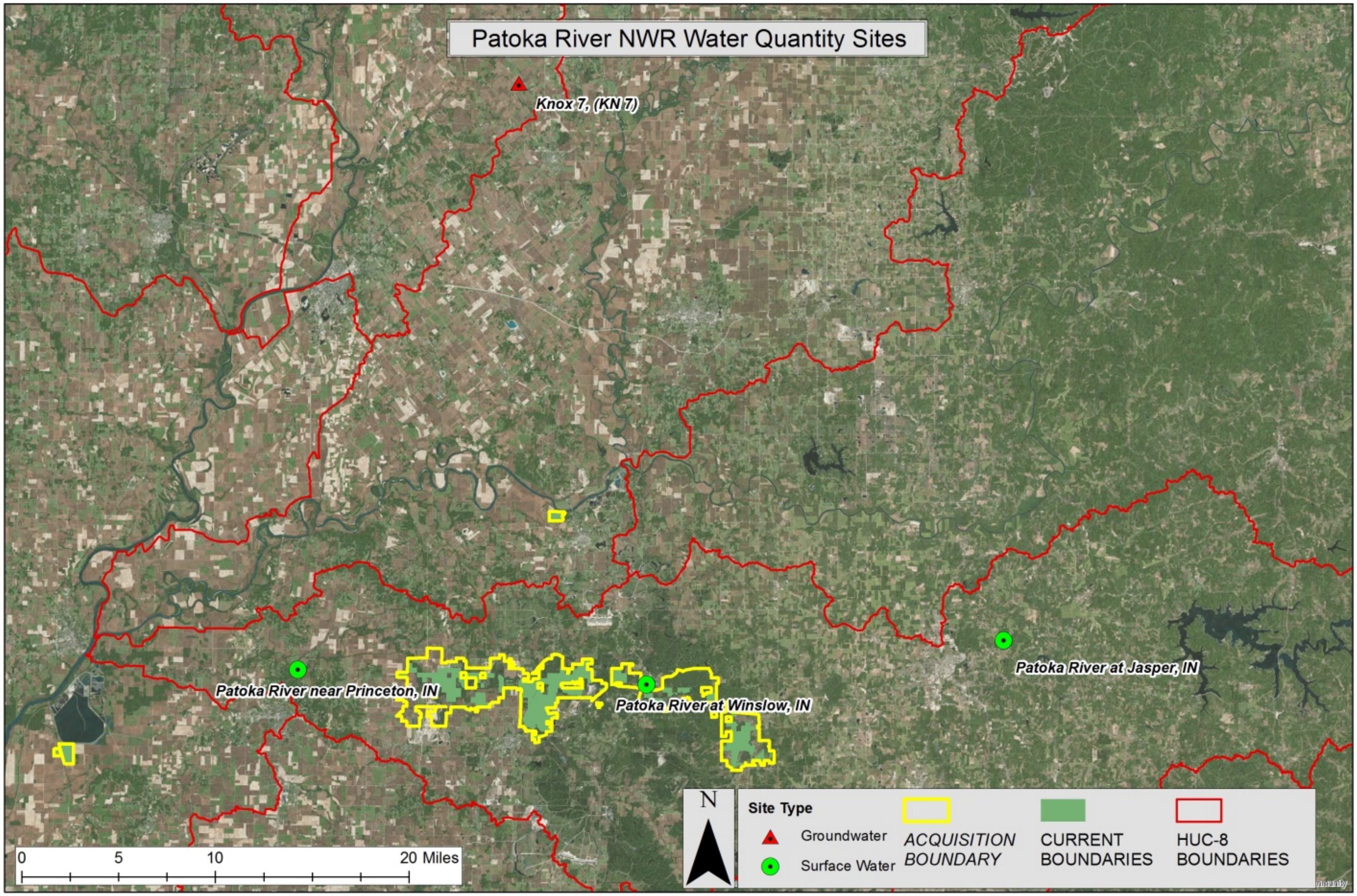


Figure 5.1.1: Map of water quantity monitoring sites analyzed in WRIA.

5.2 Surface Water Quantity

The Patoka River watershed covers 856.9 square miles, and drains an eight county area. Major tributaries include the South Fork Patoka River (76.3 sq. mi) and Flat Creek (58.9 sq. mi.) (USFWS 1996). Landuse within the upper portions of the watershed is primarily forest, while in the lower Patoka, it is primarily agriculture (AIRW 2007). As is mentioned in the Refuge CCP and HMP, perhaps the two largest alterations to the Patoka occurred in the 1920's with the dredging of Houchin's Ditch, and in 1978 with the construction of the Patoka Lake Dam (USFWS 2007 ,USFWS 2017a). Patoka Lake is the third largest body of water in Indiana at 8,800 acres, and provides drinking water to over 65,000 residents in a nine-county area (AIRW 2007). However the dam and lake have altered the natural flooding regime downstream where the Refuge lies, so that spring peaks are not as high on average due to the storage capacity of the lake, and summer lows are not as pronounced due to a prolonged release of spring floodwaters over the summer and fall (Figure 5.2.2).

Data from three water quantity monitoring gages were analyzed. One is at Jasper, IN (USGS-0337550) which is upstream of the Refuge and has a drainage area of approximately 262 square miles. This site is located approximately 28 miles downstream of Patoka Lake and 27 miles upstream of the Refuge, so is most indicative of hydrologic conditions above the Refuge. The next site is located at Winslow, IN (USGS-03376300), in the middle of the Refuge, and as such is likely the best indicator of hydrologic condition on the Refuge's upstream half. This site has a drainage area of approximately 603 square miles. The last surface water quantity site is located at Princeton, IN (USGS-03376500). The river gage is located downstream of the Refuge, so is most indicative of hydrologic conditions on the downstream portions of the Refuge. The drainage area at this site is approximately 822 square miles. See Table 5.1.1 for more details on each site.

As mentioned above, one of the largest alterations to the Patoka River hydrograph was the construction of Patoka Lake, which was completed in 1978 (USGS 1988). Figure 5.2.2 shows the difference between the average monthly annual hydrograph from before and after the dam's construction. Prior to the dam, the spring flood peaks were higher and did not last as long. The summer and fall saw times of much lower flow than current conditions. The annual monthly hydrograph from after the dam's construction shows that the Jasper, IN gage displays little if any peak in the spring, with an almost constant discharge from January to March. Further downstream at Winslow and Princeton there is more of a pronounced spring flood peak, due to the larger proportion of unimpounded watersheds contributing to those locations. The Princeton, IN gage has the longest period of record of the three (1934 to present). The Winslow gage has the shortest period of record (1968-present) and includes a five-year gap shortly after the Patoka Lake Dam was constructed. Figure 5.2.4 shows the median annual hydrogaph at Princeton since the dam's construction. High flows in the spring are seen from March to early May, followed by low flow from approximately July through mid-November. Examining the average annual flows for all three sites (Figure 5.2.3) reveals that they all show an increasing trend over time. This trend is statistically significant for all three gages and is likely the result of both an increasing trend of annual precipitation in the area as well as anthropogenic alterations to the landscape. Table 5.2.2 shows that the Patoka River experiences a large range in flows with the highest daily average flow on record at the Princeton gage of 13,800 cfs, and a low of only 17 cfs. Refuge Staff utilize stage values from these gages on the Patoka to relate to flooding on various wetland units. Table 5.2.3 shows the current summary of flooding at the Oatsville Bottoms unit relative to the Princeton and Winslow gages. In addition, the Princeton gage had flood stages listed for it on the NWS water.weather.gov site. These flood levels can help better understand flooding in relation to local infrastructure in the area.

In addition to the gages on the main stem of the Patoka, there are nearby USGS gage stations worth noting. There are two USGS gages at the Patoka Lake dam.USGS-03374498 measures lake stage upstream of the dam and USGS-03374500 measures Patoka River streamflow downstream of the dam. There is a gage at Mt. Carmel, IL (USGS-03377500) on the Wabash River, which is of interest, because the Wabash can cause backwater on the Patoka when it is at a very high stage. There is also historic gauging data on the South Fork of the Patoka near Spurgeon, IN (USGS-03376350) from 1964 to 2005.

Highest Flow Date	Mean Flow (CFS)	Lowest Flow Date	Mean Flow (CFS)
05/04/1996	*13,800*	*07/01/2012*	*17*
03/16/2006	*12,700*	*09/07/2010*	*22*
03/24/2008	*12,200*	*09/09/1999*	*31*
05/06/1983	*12,000*	*10/11/1978*	*32*
05/04/2011	*11,800*	*10/04/2001*	*34*

Table 5.2.2: Highest and lowest mean daily flows for (USGS-03376500**), Patoka River at Princeton, IN**

Flood Category	Stage (ft.) – Princeton gage	Stage (ft.) – Winslow gage
Initial Flood- Oatsville Bottoms	10.5	15.5
Full Flood- Oatsville Bottoms	12.8	18.7
NWS Action Stage	16	No info
NWS Flood Stage	18	No info
NWS Moderate Flood Stage	20	No info
NWS Major Flood Stage	23	No info

Table 5.2.3: Table of stage and flooding relationship for Patoka River NWR (Refuge staff, personal communication 2018, water.weather.gov).

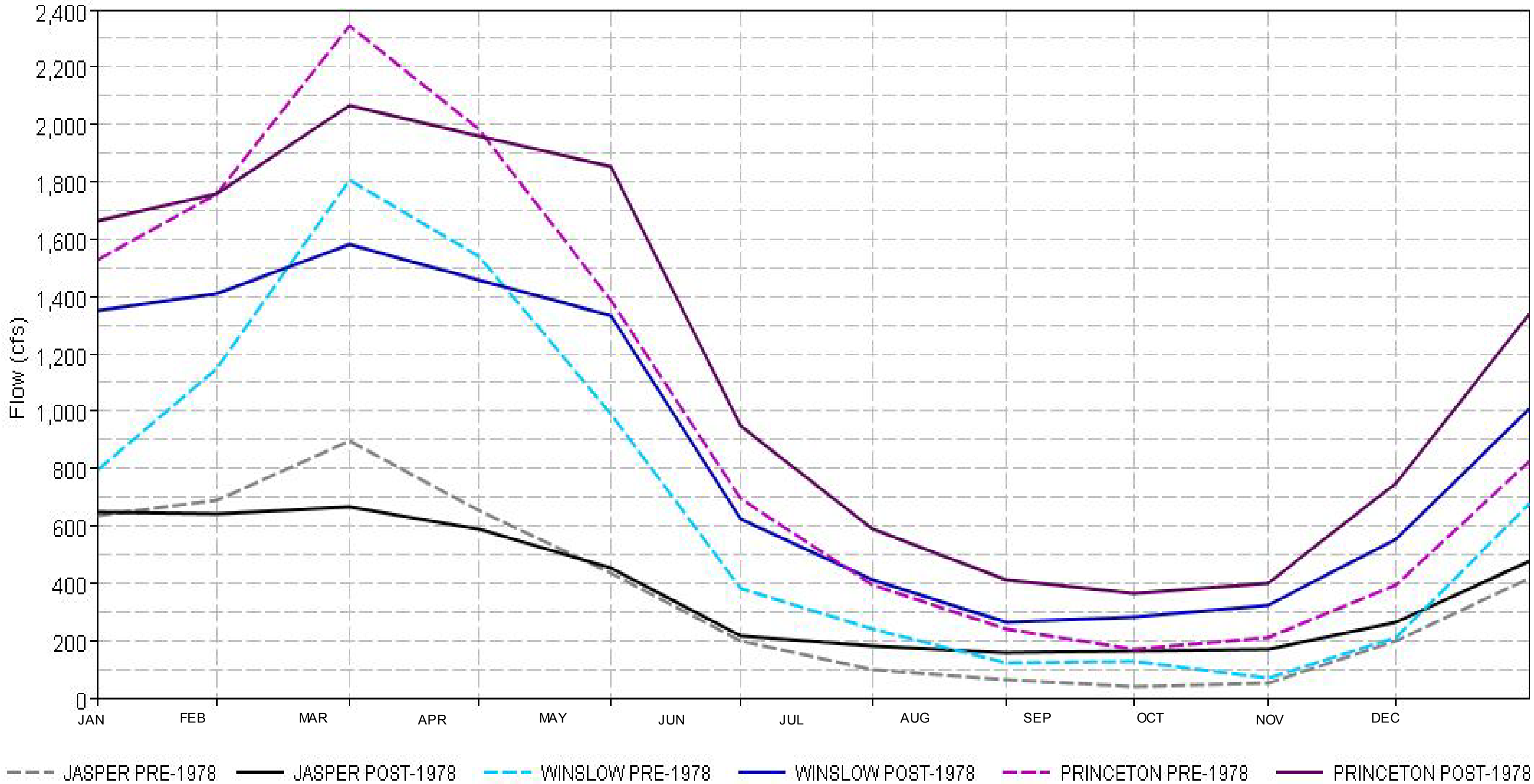


Figure 5.2.2: Average monthly discharge for pre and post Patoka Lake Dam.

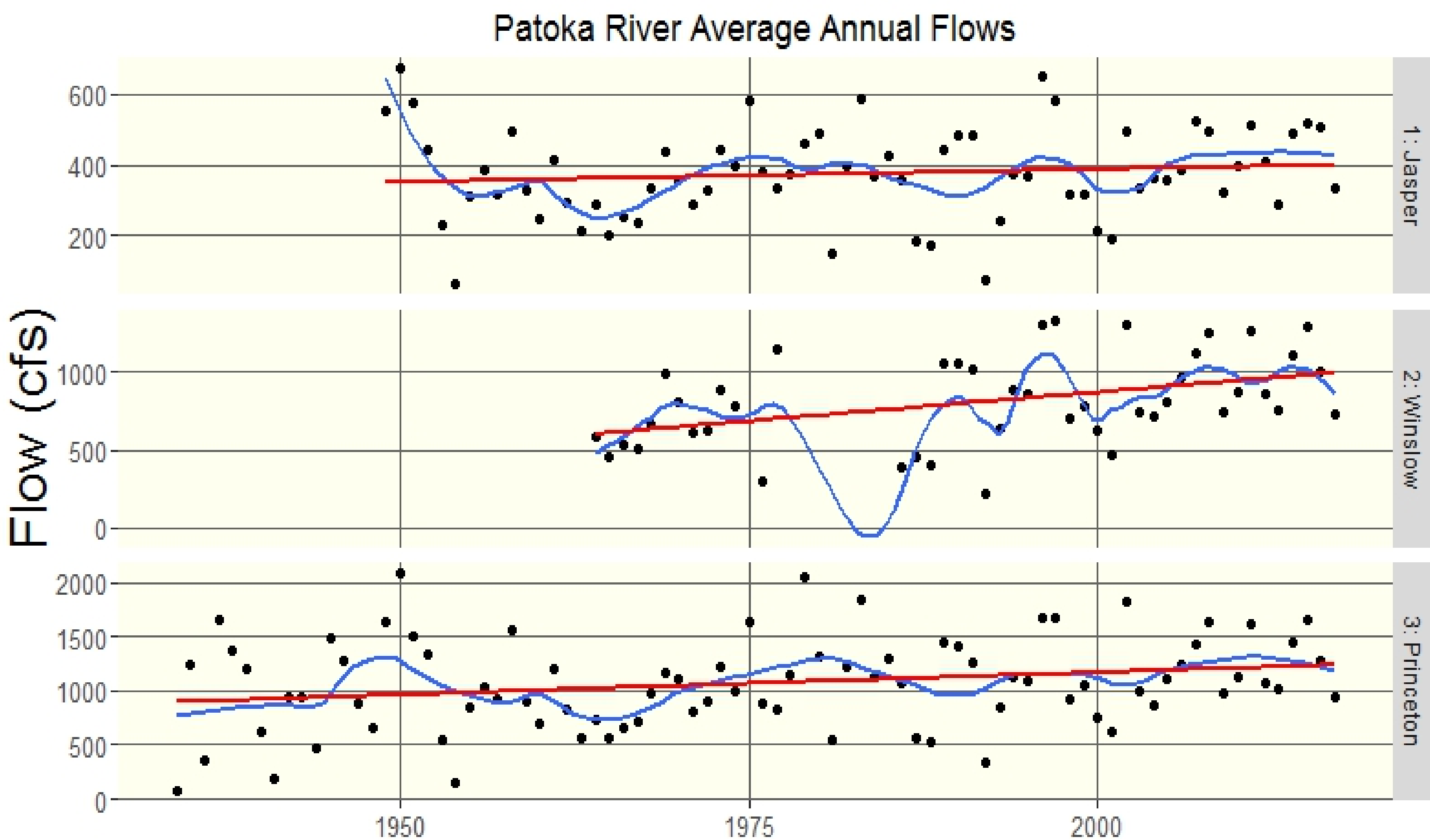


Figure 5.2.3: Average annual discharge and trends for the Patoka River. Red line is a linear regression, blue line is a Loess Regression

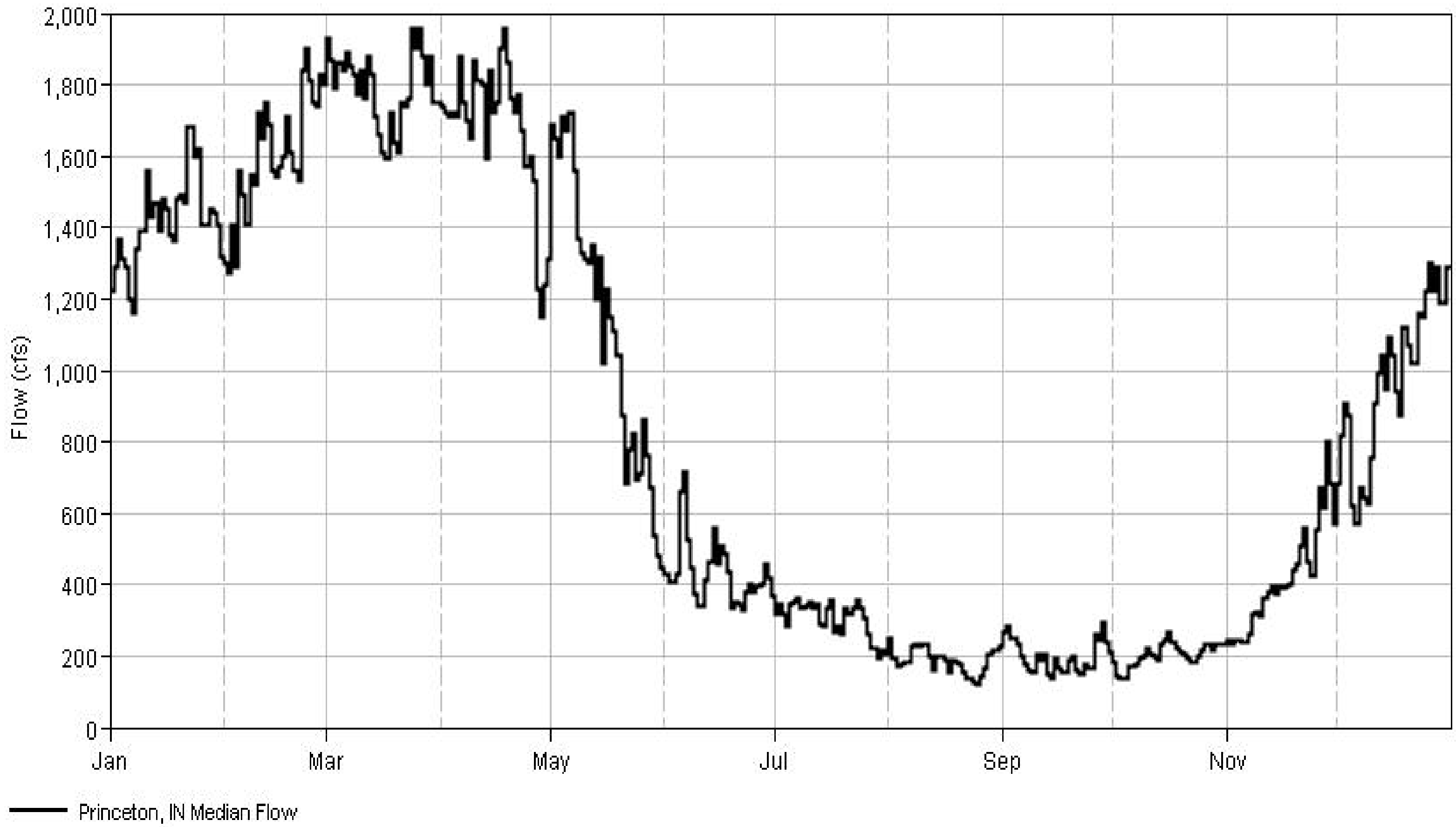


Figure 5.2.4: Median annual hydrograph of daily average flow for (*USGS-03376500*), Patoka River at Princeton, IN.

5.3 Hydroclimatic Data Network (HCDN)

Reference hydrographs obtained from the Hydro-Climatic Data Network (HCDN) provide additional context for the assessment of surface water quantity patterns. The HCDN is a network of USGS stream gages located within relatively undisturbed watersheds, which are appropriate for evaluating trends in hydrology and climate that are affecting flow conditions (Slack et al., 1992, Lins 2009). This network attempts to provide a look at hydrologic conditions without the confounding factors of direct water manipulation and land use changes. Annual peak discharge and average annual discharge trends were compared for this analysis. The nearest HCDN site was chosen to represent the regional hydroclimate in the area surrounding Patoka River NWR. The nearest station that met the HCDN requirements was the North Fork Embarras River near Oblong, IL, USGS-0334600, with a period of record from 1940 to present. This USGS station is approximately 53 miles from the Refuge's westernmost boundary. Both peak and average annual discharge show statistically significant increases in flow over time with p-values of 0.016 and 0.019 respectively. Based on the results of the USGS HCDN site analysis, the area is experiencing an increase in peak runoff and total runoff, independent of anthropogenic alterations to the landscape and watershed system. This matches the findings in section 3.3 'Long-Term Climate trends'. Over the past 100 years, there have been dramatic increases in total annual precipitation, and the frequency of heavy precipitation events (2 inches or greater of rainfall in a day) (Section 3.3).

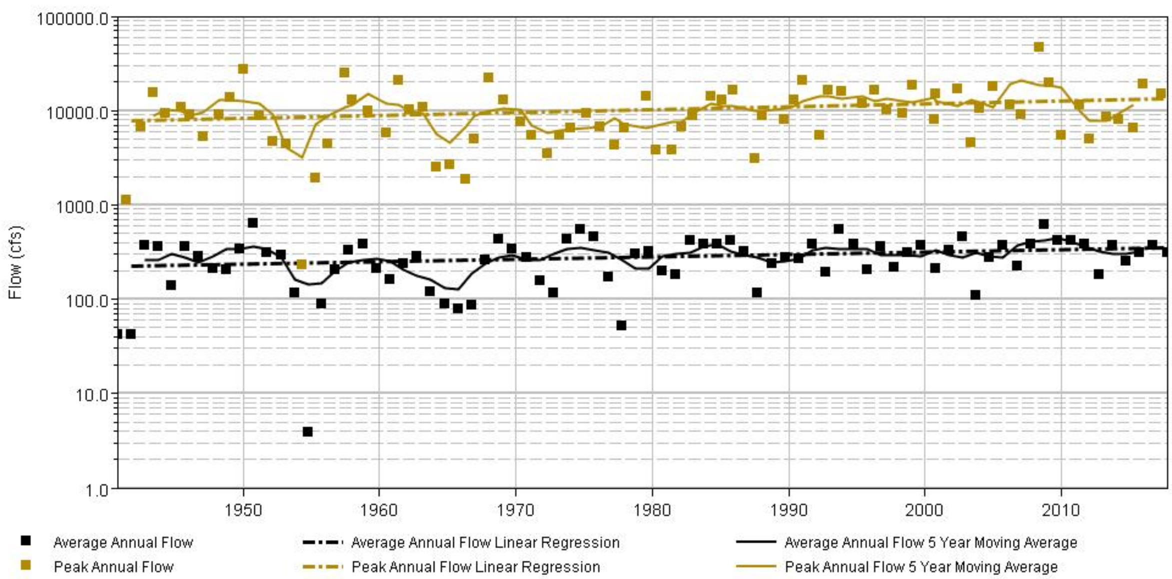


Figure 5.3.1: Peak and average annual flow trends for HCDN station USGS-0334600, North Fork Embarras River near Oblong, IL

5.4 Groundwater Quantity

Groundwater in the Patoka River NWR area likely varies greatly depending on location. As Figure 5.4.1 shows the unconsolidated groundwater aquifer type varies depending on whether it is located in a river valley or in uplands. Most of PRNWR falls within an alluvial groundwater aquifer system, with some of the more upland portions falling within dissected till. Alluvial till is described as “fine sand and gravel”, producing “generally less than 5 (gpm)”according to the Indiana DNR. More detailed maps of subsurface aquifers in Pike and Gibson counties can be found at https://www.in.gov/dnr/water/4302.htm.

The only groundwater well currently recording and with an acceptable period of record was Knox 7 (KN7), USGS- 383247087361001. This well is located approximately 27 miles from the Refuge, so is not indicative of conditions on site, but can help understand groundwater dynamics in the region. The ground surface at this well is 403.25 feet NAVD88, and it is drilled into what is described as “Sand and gravel aquifers (glaciated regions)” and “Holocene Alluvium” according to the USGS description. Not too much can be related to the Refuge from this gage, but it can be seen in Figure 5.4.2 that the groundwater table is typically highest in May and lowest in September and on average is 8-10 below the ground surface. The period of record in Figure 5.4.3 shows that on an annual basis the groundwater level can range from less than 3 to over 11 feet below the ground surface. There is also an apparent upward trend in the groundwater table (it is closer to the ground surface on average). This phenomenon is likely explained by the fact that there is more precipitation (and more infiltration as a result) and more runoff as was shown in sections 3.3 and 5.3. The groundwater table in this area is part of an alluvial aquifer which gets is maintained in part by the Wabash River.

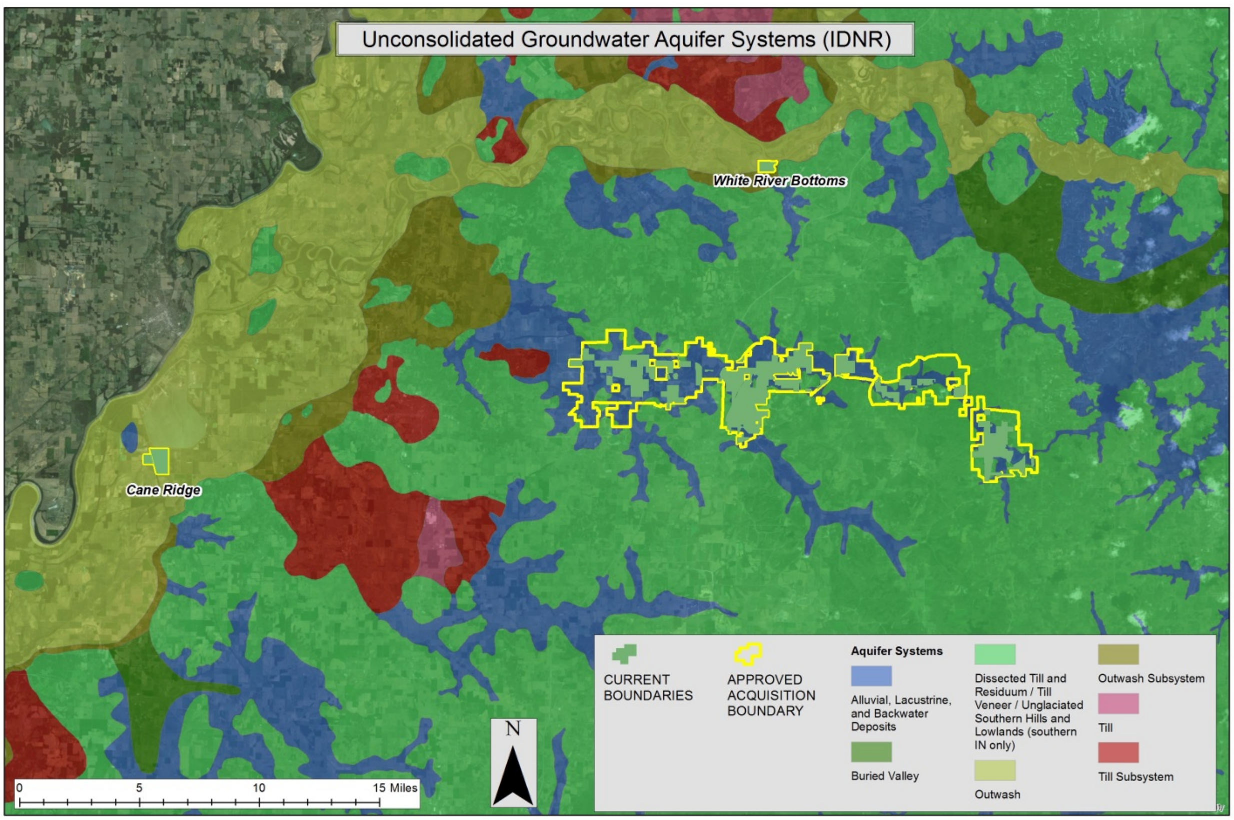


Figure 5.4.1: Unconsolidated groundwater aquifer systems for Patoka River NWR and vicinity (Indiana DNR 2018)

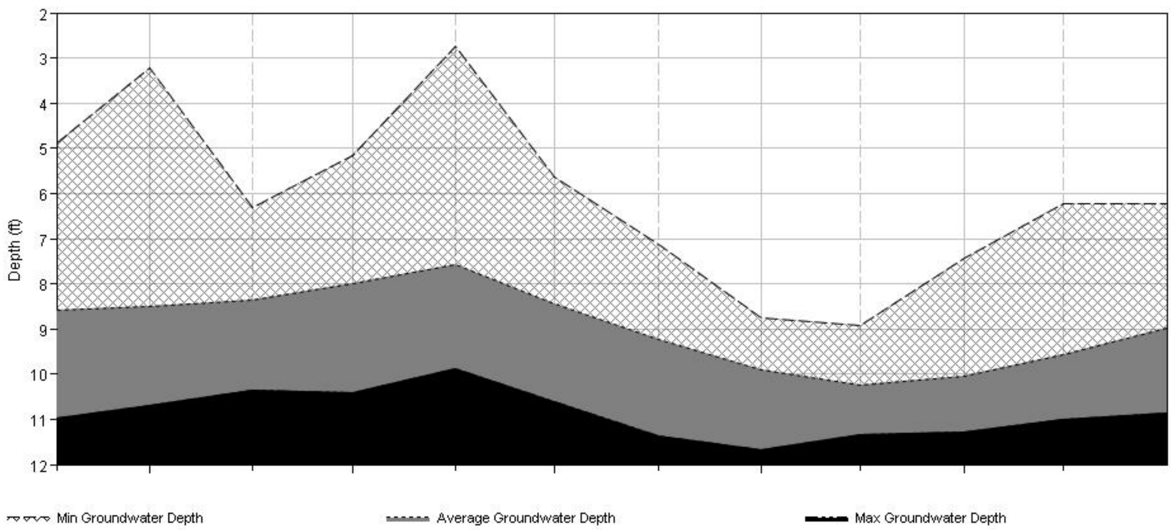
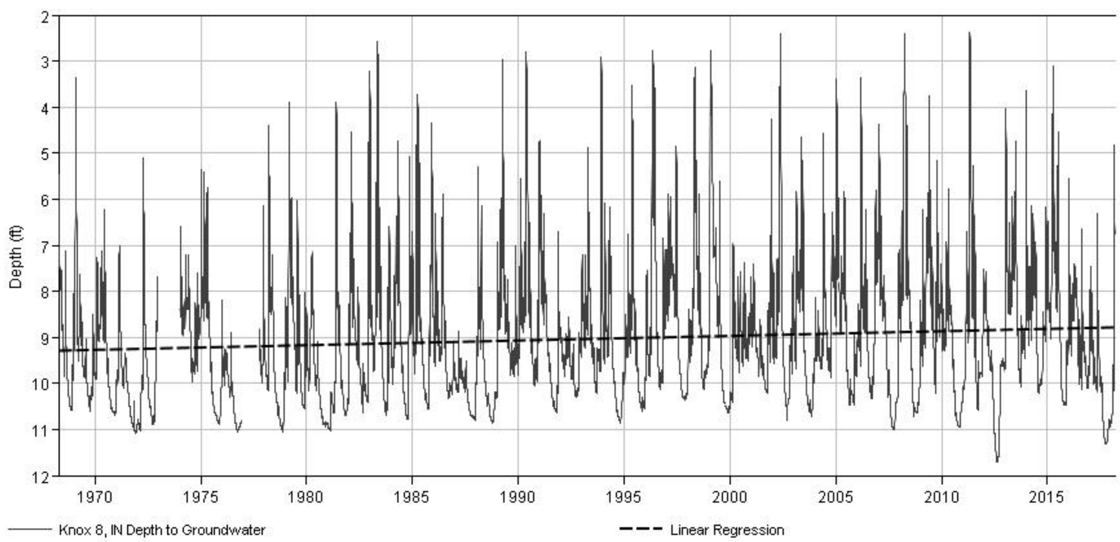


Figure 5.4.2: Monthly minimum, maximum, and average groundwater depth at USGS-383247087361001, Knox 7 (KN7)



5.4.3: Mean daily depth to groundwater for USGS-383247087361001, Knox 7 (KN7)

5.5 Water Quality Criteria

The Environmental Protection Agency (EPA) developed technical guidance manuals and nutrient criteria for the protection of aquatic life in various types of waters specific to different ecoregions. Those developed for rivers/streams and lakes/reservoirs for ecoregion IX (Southeastern Temperate Forested Plain and Hills) are summarized below (USEPA 2000; Table 5.5.1). These criteria are relevant to individual streams and lakes within Patoka NWR's RHI.

Additional information related to the application of federal water quality standards and regulations to wetlands is provided by the EPA's Water Quality Standards Handbook (http://water.epa.gov/lawsregs/guidance/wetlands/quality.cfm). Procedures outlined in this handbook are used when specific criteria for wetlands are developed.

Parameter	Ecoregion IX	
	Rivers and Streams	Lakes and Reservoirs
TP (ug/L)	36.56	20
TN (mg/L)	0.69	0.36
Chl *a* (ug/L)	0.93 (Spectrophotometric)	5.18 (Spectrophotometric)
Turb (FTU)	5.7	-
Secchi (m)	-	1.53

Table 5.5.1: Nutrient criteria for rivers/streams and lakes/reseroirs established for EcoRegion IX: Southeastern Temperate Forested Plain and Hills (EPA 2000)

State of Indiana Water Quality Standards (WQS) are available and updated online at (https://in.gov/idem/cleanwater/2329.htm). Here, specific criteria are set for a wide variety of water quality parameters. They are listed based on designated uses for aquatic life (4-day average), human health outside of mixing zone (30-day average), and human health point of water intake (30-day average). Many WQS vary based on other measured parameters, for instance, sulfate standards vary based on measured water hardness; ammonia varies based on pH and water temperature; and maximum water temperatures vary based on time of year. Any water quality sampling protocols undertaken should be set up so that they can be reliably compared to state standards. For example, sampling to see if ammonia is exceeding levels for aquatic life would need to cover a 4-day period, and at the same time would need to sample for pH and water temperature.

5.6 Surface Water Quality

The EPA has compiled national recommended water quality criteria for roughly 150 pollutants (http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm) to provide guidance in developing state-specific standards. The development of state and federal water quality standards requires consideration of the existing and potential uses of water bodies. Different uses often require different levels of protection for specific pollutants. Water bodies may have several different uses associated with them, such as aquatic life and recreation, in which case criteria for each pollutant are determined based on the most vulnerable designated use (http://water.epa.gov/drink/contaminants/#List). Impairment listings for assessed waterbodies relevant to PRNWR are discussed below.

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. Section 303d data from the State of Indiana (2016) were utilized to identify any impaired streams, rivers, or lakes on or in close proximity to Patoka River NWR. Table 5.6.1 lists the water bodies with known designated use(s) impaired along with the cause(s) of those impairment(s). It is worth noting that the impairments attributed to a specific stream or river include many of its smaller tributaries as well. As can be seen in Figure 5.6.1, many of the streams in the Patoka River and White River watersheds are designated as impaired, and most of the tributaries that flow directly into the Refuge are listed as impaired, including the main stem of the Patoka itself. Many of these impairments are for impaired biotic communities, which compromises the mission statement of the Refuge itself (Table 5.6.1). The delisting of these waters throughout the Refuge is crucial for the fulfillment of its establishing purpose and objectives.

Creek Name (Including Adjacent Tributaries)	***Impairment***	***Stream Miles of Impairment Within 0.25 Miles of Refuge***
BIG CREEK	IMPAIRED BIOTIC COMMUNITIES/NUTRIENTS	5.29
BRUSTER BRANCH	IMPAIRED BIOTIC COMMUNITIES	7.25
CUP CREEK	E. COLI/IMPAIRED BIOTIC COMMUNITIES	1.55
HURRICANE CREEK	IMPAIRED BIOTIC COMMUNITIES/NUTRIENTS	1.29
KEG CREEK, EAST FORK	E. COLI/IMPAIRED BIOTIC COMMUNITIES/NUTRIENTS	11.53
KEG CREEK, WEST FORK	AMMONIA/IMPAIRED BIOTIC COMMUNITIES/NUTRIENTS	3.85
LICK CREEK	IMPAIRED BIOTIC COMMUNITIES	3.96
MILL CREEK	IMPAIRED BIOTIC COMMUNITIES	2.81
PATOKA RIVER	PCBS (FISH TISSUE)	55.61
PATOKA RIVER	IMPAIRED BIOTIC COMMUNITIES/PCBS (FISH TISSUE)/TOTAL MERCURY (FISH TISSUE)	13.32
PATOKA RIVER	IMPAIRED BIOTIC COMMUNITIES/PCBS (FISH TISSE)	16.25
PATOKA RIVER, SOUTH FORK	E. COLI/IMPAIRED BIOTIC COMMUNITIES	10.24
ROCK CREEK	DISSOLVED OXYGEN/ E. COLI/IMPAIRED BIOTIC COMMUNITIES	4.30
SUGAR CREEK	DISSOLVED OXYGEN	2.96
TURKEY CREEK	IMPAIRED BIOTIC COMMUNITIES	1.83
WHITE RIVER	E. COLI	0.87

Table 5.6.1:List of impairments for 303(d) listed streams within 0.25 miles of PRNWR

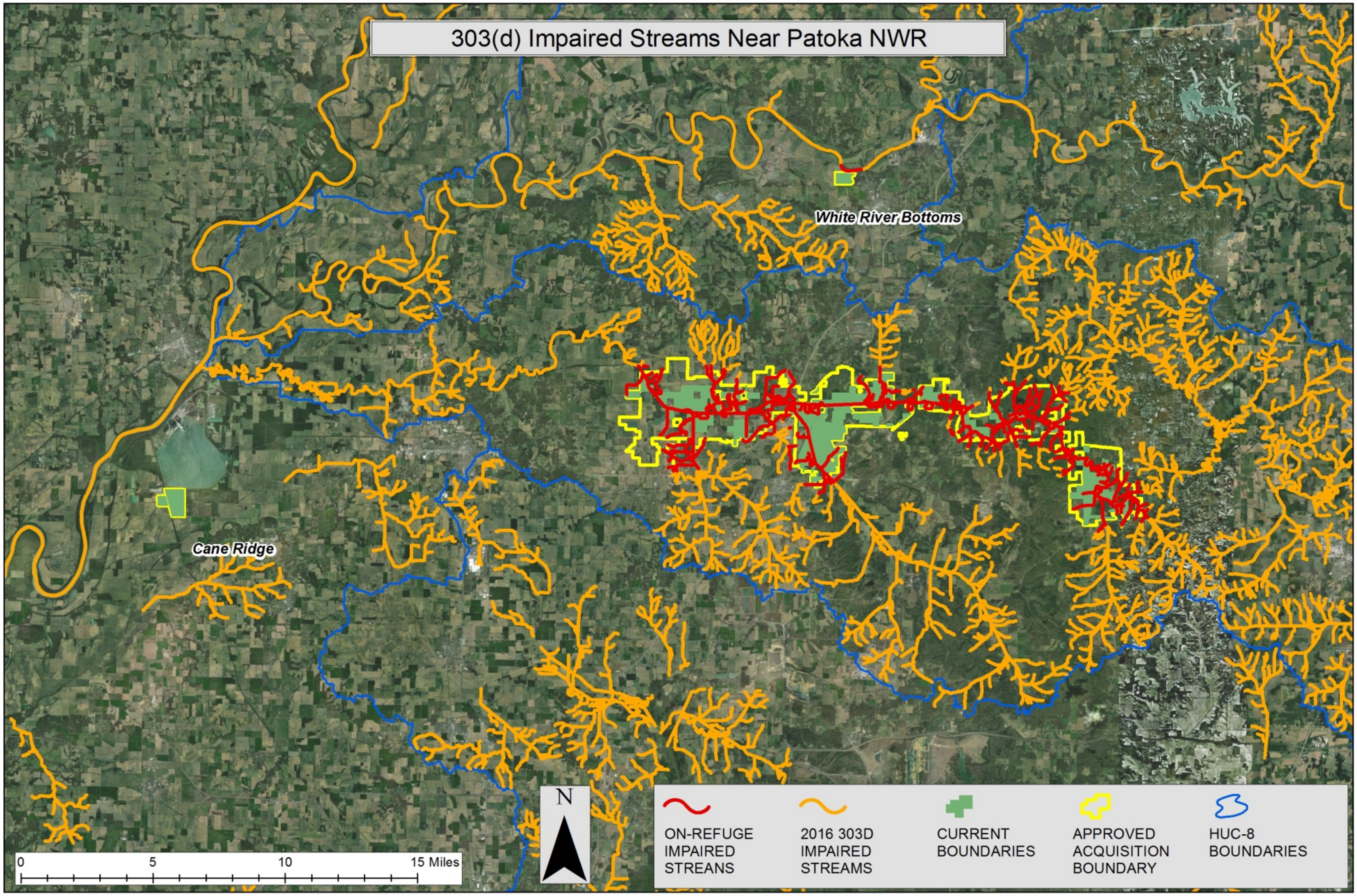


Figure 5.6.1: 303(d) listed streams on PRNWR and nearby vicinity.

NPDES Permits

Locations of nearby active or recently active NPDES permits (as of 2017) is shown in Figure 5.6.2. There are 37 permits within 5 miles of the main portion of the Patoka River NWR Approved Acquisition Boundary, 10 within 5 miles of the Cane Ridge Unit, and 20 within 5 miles of the White River Bottoms Units. While NPDES permits are in place to ensure the legality of all industrial and point source discharges, it has been shown that even discharges under the legal threshold could impair biotic communities long-term through accumulation in sediments (USFWS 2008b). There is also the chance that the permit specifications may be accidentally exceeded which could lead to harm of biotic communities. Of particular concern to PRNWR is the NPDES permitting for the Peabody Coal operation on Keg Creek. NPDES permit information for this site indicates it has exceeded its permit criteria 20 times in the past 10 years (see Patoka River NWR Water Quality section for more details). If additional data is needed to protect Refuge wildlife and species, a monitoring plan should be implemented to capture water quality samples during periods where contaminant releases may potentially exceed permit criteria.

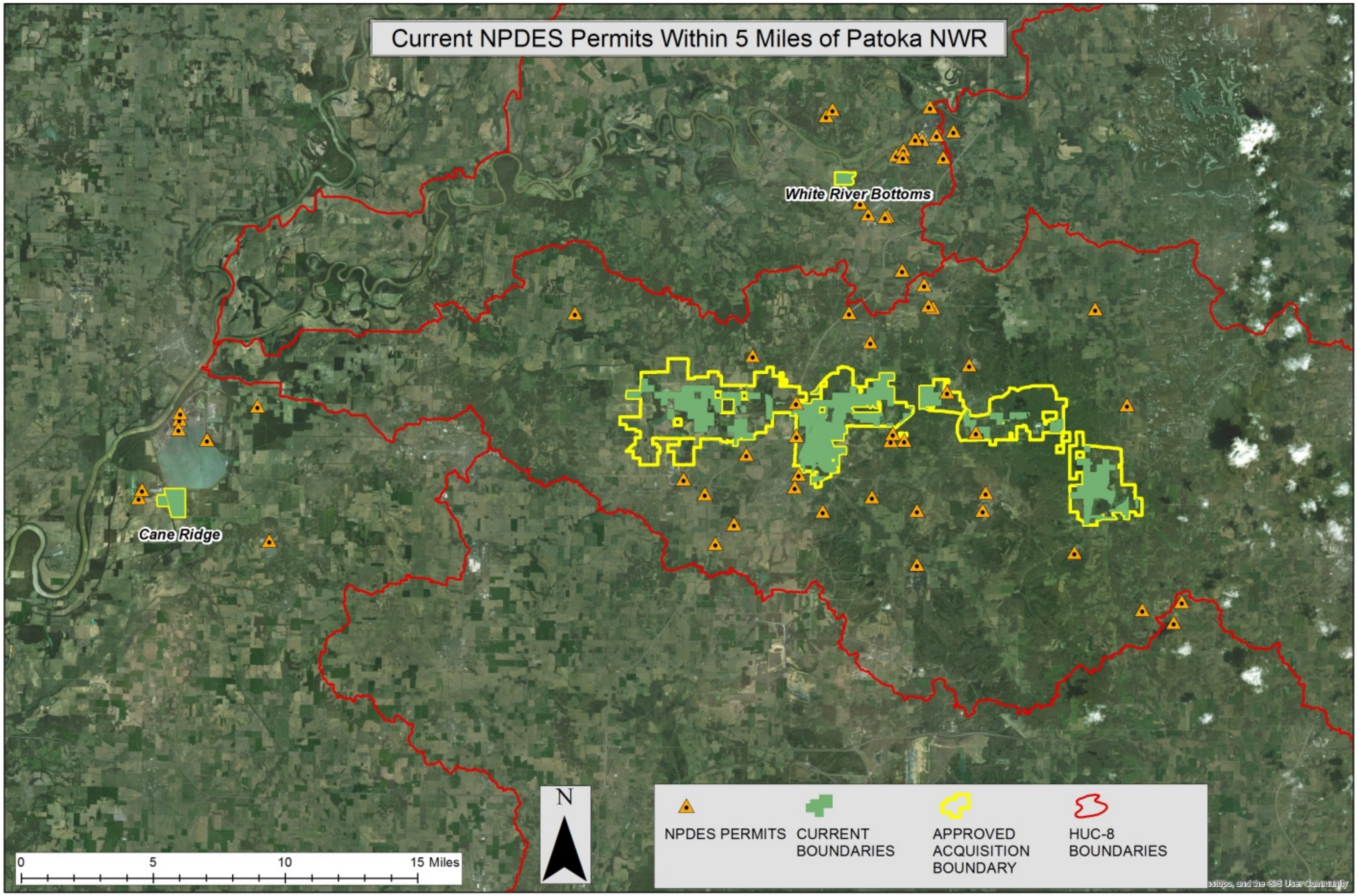


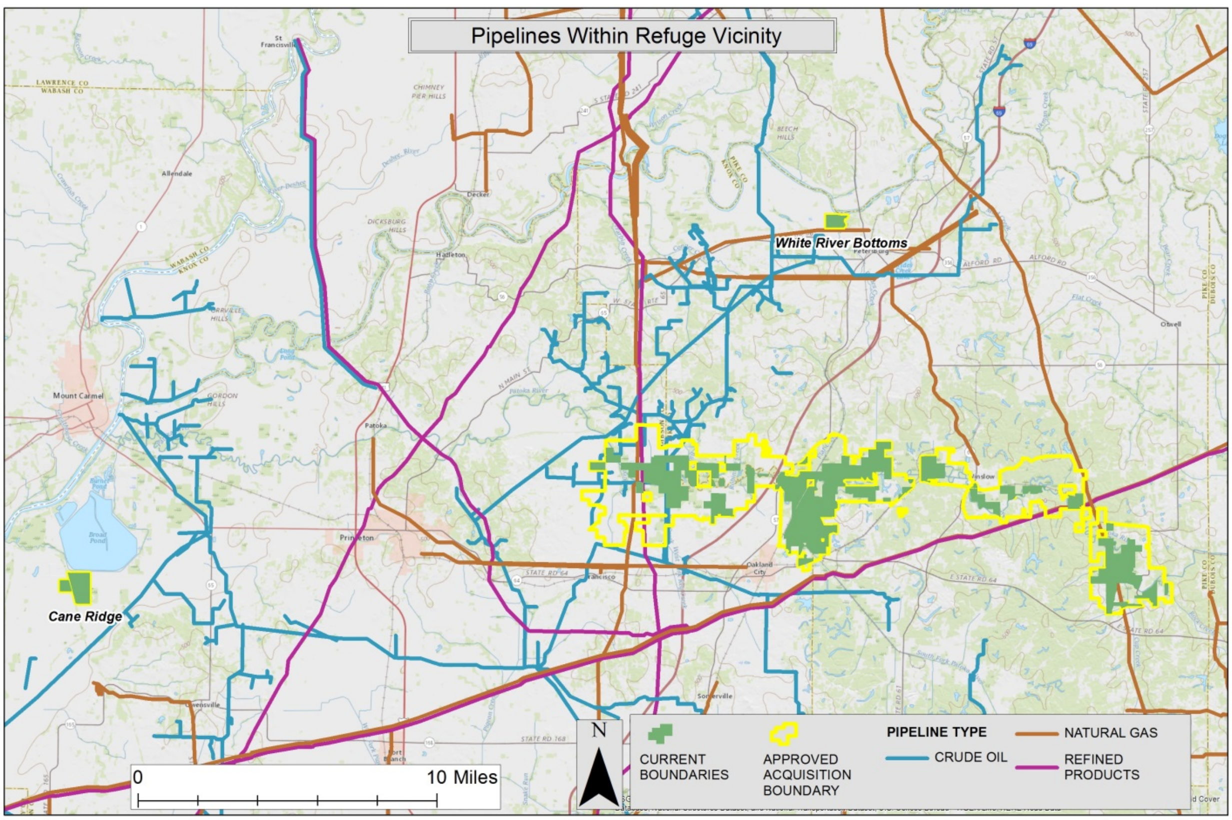
Figure 5.6.2: Recently active and active NPDES permits within 5 miles of PRNWR

Other Water Quality Threats

In addition to 303(d) impairments and proximity of NPDES permit locations, Patoka River NWR faces potential water quality risks from other sources. Figure 5.6.4 shows the location of surface coal mines and oil and gas wells in the Patoka River HUC-8. The extensive oil and gas production in the watershed has led to much of the water quality degradation, as well as the resulting amount of water quality data that has been collected.

Associated with oil and gas development, are the pipelines used to transport the extracted and refined products. Figure 5.6.3 shows all oil and gas pipelines passing throughout the area surrounding the Refuge. Numerous crude oil, refined products and natural gas pipelines pass under the Patoka River and its tributaries. If a leak were to occur in any of these lines it would lead to contamination and possible harm to biotic communities.

Additional potential sources of contamination include the I-69 interstate corridor, which passes directly through the center of the Refuge. Also, the two railroads that pass through the Refuge pose a spill and contamination threat. This includes the Norfolk Railroad and the Indiana Southern Railroad. There have already been two recorded train derailments since the time of the Refuge's establishment (Refuge staff, personal communication 2018).



Figre 5.6.3: Map of oil and gas pipelines passing through Patoka River NWR and vicinity (Indiana DNR 2018)

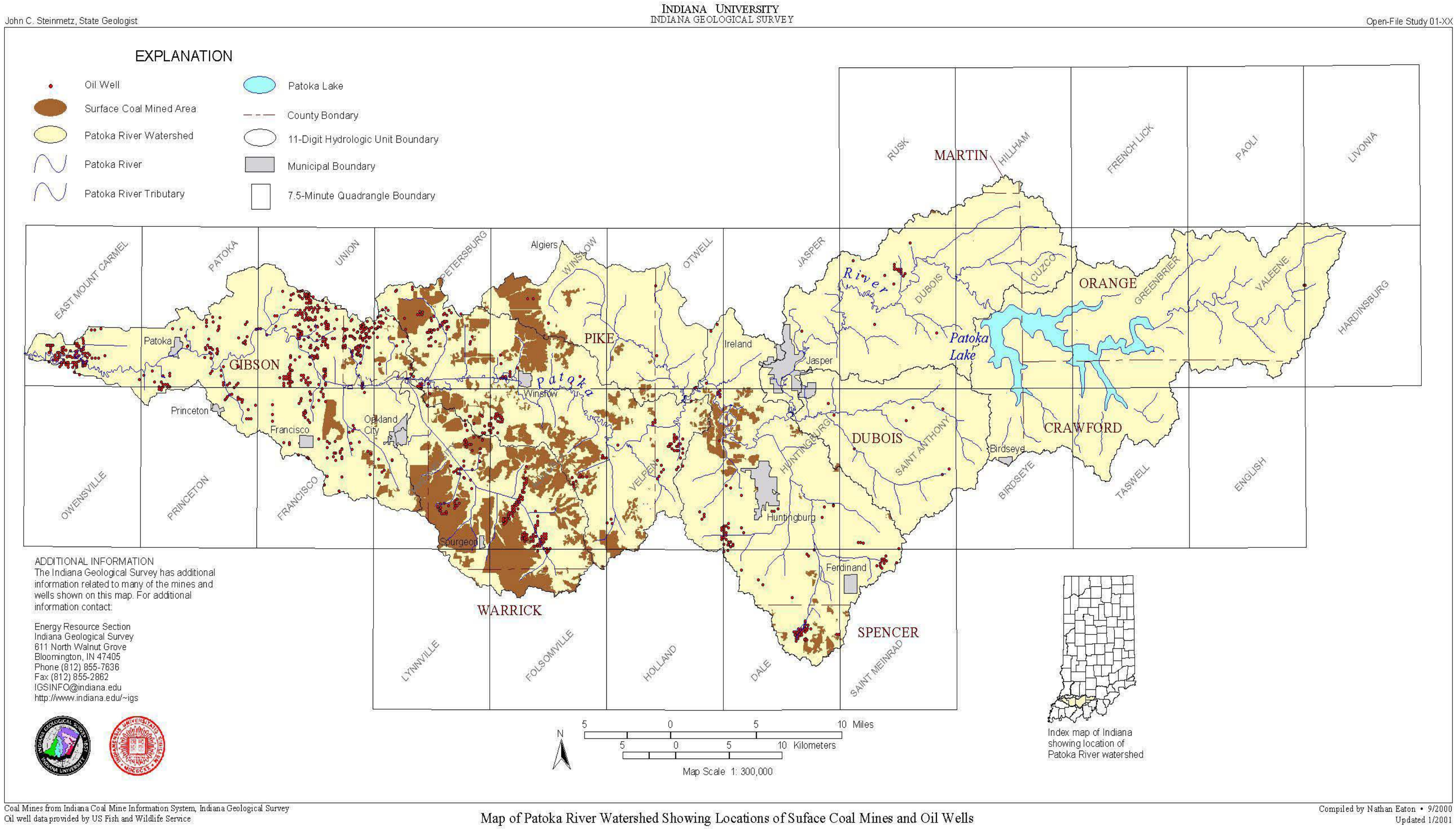


Figure 5.6.4: Map of surface coal mining and oil wells in the Patoka River Watershed (Eaton 2000)

Patoka River NWR Water Quality

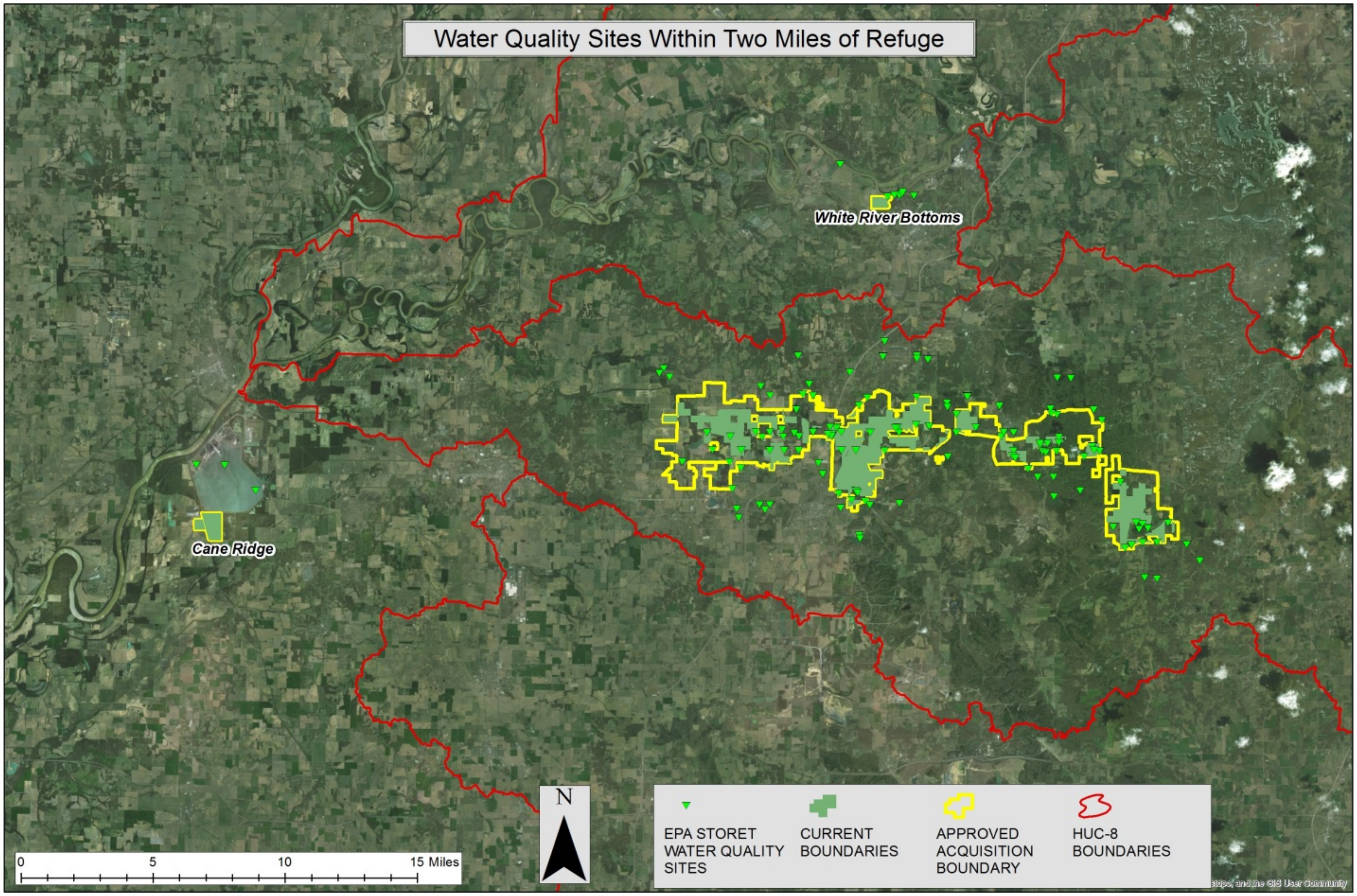


Figure 5.6.5: Water quality sampling sites from EPA STORET that fall within a two-mile buffer of PRNWR.

Water quality in the Patoka River is highly degraded from historic, pre-mining conditions (USFWS 1996, USFWS 2008b). As such, there has been much water quality monitoring tracking various contaminant levels, reporting on permitting compliance, and evaluating the success of various restoration activities. These monitoring efforts have led to copious amounts of publicly available water quality data. Within just a two-mile buffer of the Refuge Approved Acquisition Boundaries, there are 205 sample sites with 46,310 sampling results available from the USEPA STORET database. Sampling done for all NPDES permit compliance is available online from the USEPA Enforcement and Compliance History Online (ECHO) website. Many NPDES permits require monthly or bi-monthly monitoring, and as such, there are over 200,000 sampling results for NPDES permits, over the past ten years, for the area around the Refuge. There was a comprehensive sampling effort performed at PRNWR in 2006 as part of a USFWS study (USFWS 2008a). In addition, there are 2,502 sampling results from 198 unique trips in the Patoka River HUC-8 Basin available from Hoosier Riverwatch, a volunteer-based stream monitoring program through the IDEM. For the purposes of this report, it is not feasible to condense and synthesize all of the water quality sampling data available, though this is a task that would be beneficial to the Refuge. This could be a task performed by a researcher, summer intern, or dedicated volunteer, who could work in conjunction with Refuge staff and Region 3 Water Resources staff to systematically catalog, synthesize, and relate this data to the Refuge itself.

Three water quality monitoring sites were chosen for analysis: one on the Patoka River, one on the South Fork Patoka River, and sampling information associated with NPDES permit ING40037 (formerly IN0057428), discharging into Keg Creek on the west side of the Refuge. The main stem Patoka River was represented by IDEM site # WQX-2362 located at the CR-300 W Bridge, North of Oakland City. This site has samples dating from 1973 to present, though most relevant data in this dataset comes from 1991 and later. Over this site's period of record, 314 different parameters have been sampled, ranging from common water quality indicators such as dissolved oxygen and pH, to more specific contaminants such as Triadimefon or 2,6-Dinitrotoluene (pesticide and mining by-product). Several more common water quality indicators that were included for summary in this report include Chloride (mg/L), Specific Conductance (µmho/cm2), Dissolved Oxygen Saturation (%), Sulfate (mg/L), Total Phosphorus (mg/L), Total Nitrogen- Kjeldahl (mg/L), and pH. Based on this sampling station and the time period available, the Patoka River has shown small improvements in water quality over time (Figure 5.6.6, 5.6.7). Chloride, Specific Conductance, Total Nitrogen, and Sulfate have shown overall decreasing trends, while Dissolved Oxygen Saturation has shown an increasing trend. Total Phosphorus, however, has not shown much of a trend in either direction since the early 90's, and pH seems to have remained in a fairly neutral range (between 7.0 and 8.0) in this timeframe, but is showing a slightly increasing trend (more alkaline). However, trends and averages are not the only issues of concern, as spikes and high concentration events can be detrimental. Specifically, there have been more high concentration spikes in Total Nitrogen in recent years despite the overall decreasing trend. Evaluating trends in water quality concentrations/parameters is largely dependent on when they are sampled. The sampling strategy can influence the detection or appearance of trends (ie, scheduled sampling versus event sampling). Any interpretation of the data available for this site should take sample timing and study design into account.

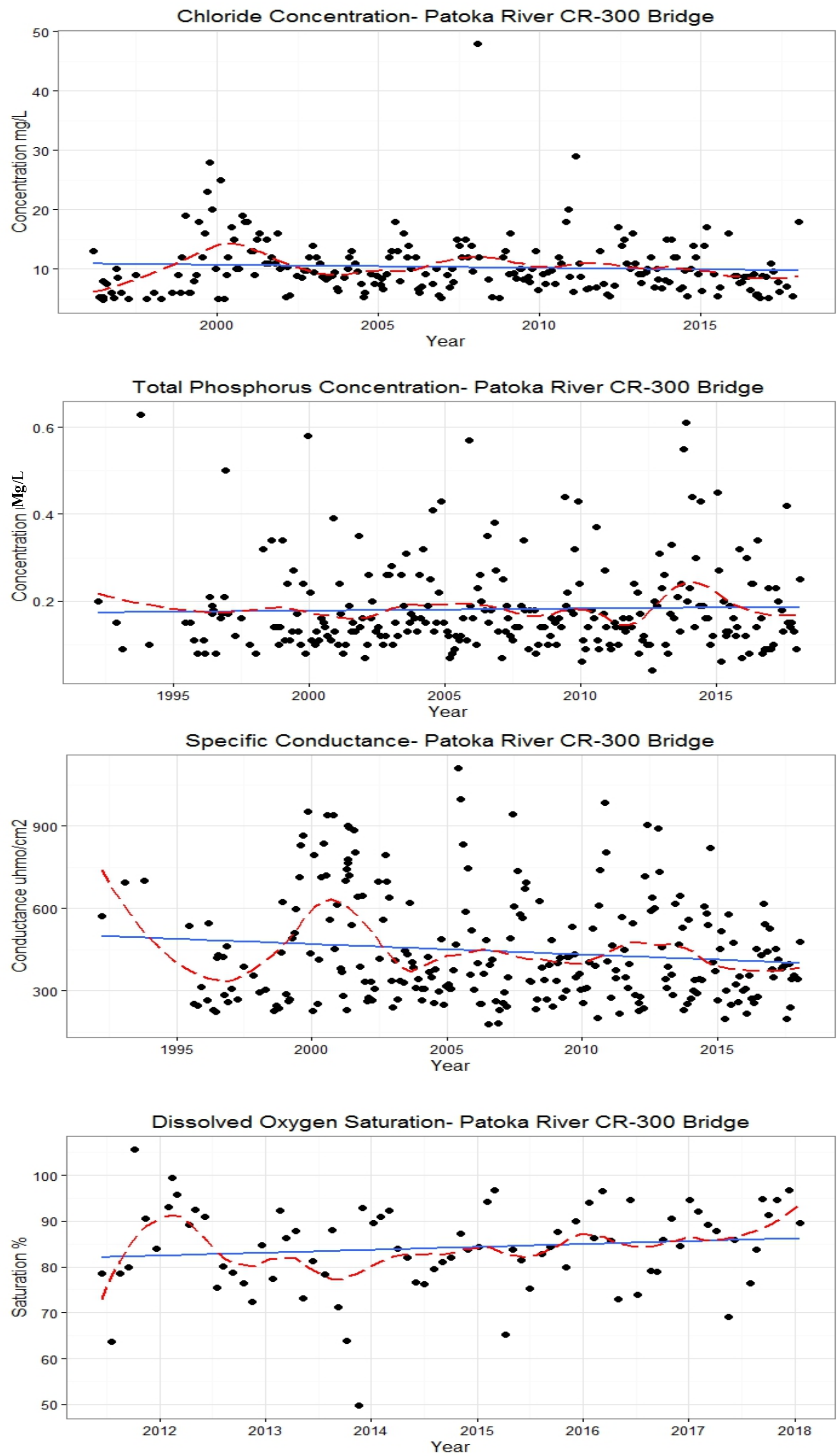


Figure 5.6.6: Selected water quality parameters for WQX-2362; chloride, total phosphorus, specific conductance, and dissolved oxygen

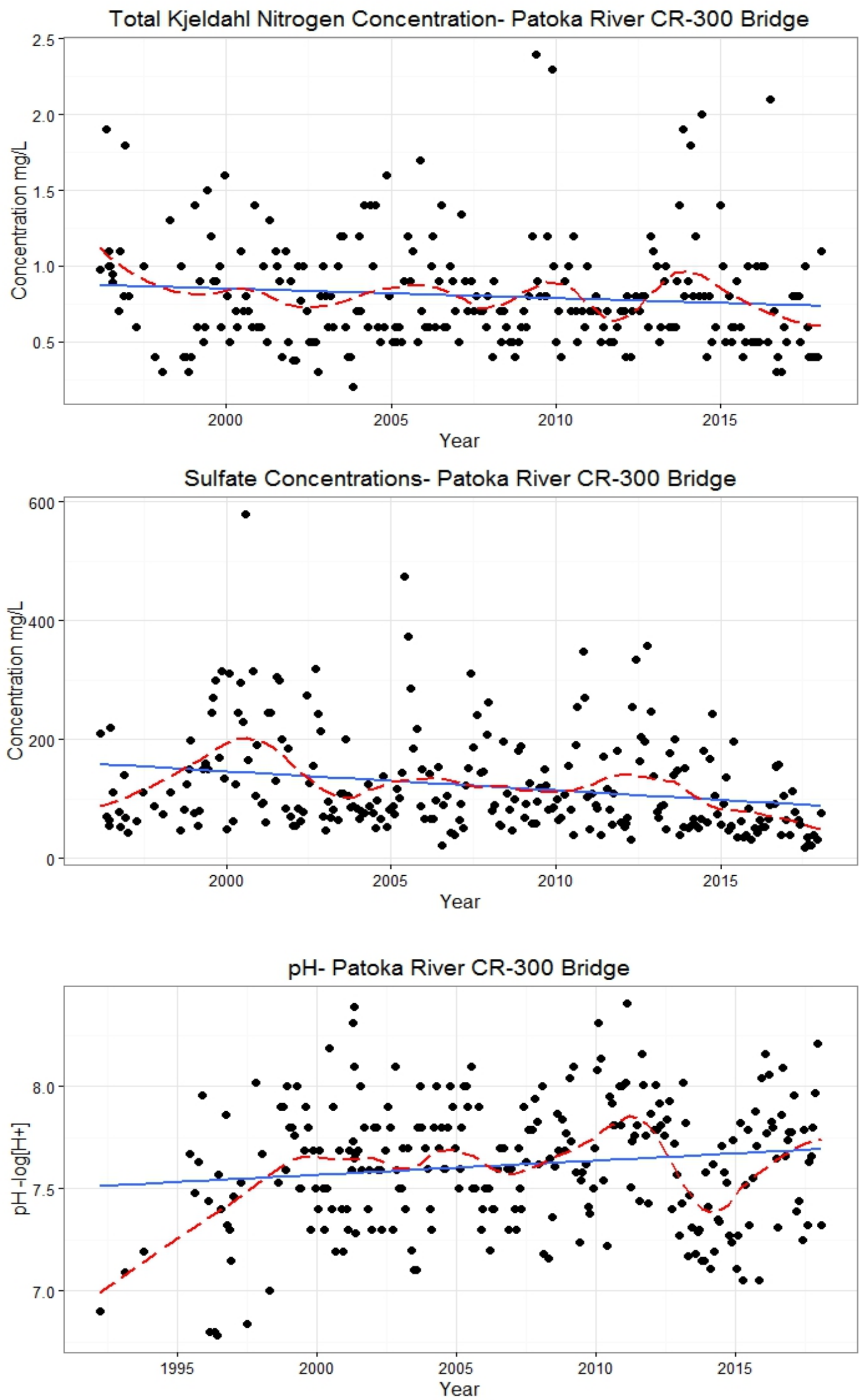


Figure 5.6.7: Selected water quality parameters for WQX-2362; total nitrogen, pH, sulfate.

The South Fork Patoka River was a location of specific interest to Refuge staff because this tributary historically has suffered some of the worst water quality due to the large amount of acid mine drainage in its watershed to the south. Sampling data on the South Fork was a little more limited in the vicinity of the Refuge; there weren't any long term datasets available. But there was some sampling data from CR 24 South bridge (WQX-15331), located on the Refuge, just upstream of the Snakey Point Marsh area. Sampling at this site consisted of 10 total visits during 2012. The more common water quality indicators are summarized in Table 5.6.2. Future sampling at this site would help establish whether the tributary is improving or degrading in water quality over time.

Parameter	*Number of Samples*	*Mean*	*Median*	*Std Dev.*	*Units*	*Notes*
Choride	3	7.50	8.20	1.06	mg/L	
Chlorophyll-a (Phytoplankton)	1	1.87	---	---	ug/L	Only 1 sample
Dissolved Oxygen Saturation	10	85.73	81.85	8.62	%	
Total Kjeldahl Nitrogen	3	0.40	0.41	0.02	mg/L	
pH	10	7.76	7.78	0.11		
Total Phosphorus	3	0.02	0.00	0.02	mg/L	Two of three samples below detection limits
Specific Conductance	10	3340.10	3420.00	259.24	umho/cm	
Sulfate	3	1766.67	1800.00	286.74	mg/L	

Table 5.6.2: Summary of water quality parameters from site WQX-15331, South Fork Patoka River at Country Rd. 25 South.

One other item of specific interest to the Refuge was NPDES permit sampling associated with permit ING40037. This permit is for a large coal cleaning and processing facility that discharges effluent to Keg Creek, which flows directly onto Refuge lands and into the Patoka River. This NPDES permit is valid from 2014 to 2019, and previously was filed under IN0057428 from 1994 to 2014. This permit covers 11 different outfalls at the facility, and sets limits for:

- pH
- Total suspended solids
- Settleable solids
- Iron
- Intermittent Discharge Duration
- Flow, in conduit or thru treatment plant
- Precipitation volume
- Duration of discharge
- Copper
- Manganese
- Nickel
- Zinc
- Aluminum

In publicly available data online (echo.epa.gov) there are records from 2009 to 2018. In this 10-year period there were 20 recorded exceedances (non-compliance), occurring on 20 days, within 10 separate months. Thirteen of these exceedances were for total suspended solids (Daily Average), five were for Total Suspended Solids (Daily Max), and two were for Iron. These exceedances were recorded for seven different outfalls. More details from this site are recorded in the table in Appendix C. In the permit requirements, it states that monthly sampling is a requirement, and this monthly sampling data is also available online at echo.epa.gov . There is concern from FWS staff about this particular NPDES site because of the potential of discharges exceeding limits in between times of routine sampling, limits potentially being set too high, and the potential cumulative toxic effects of these contaminants in riparian sediments (USFWS 2008b).

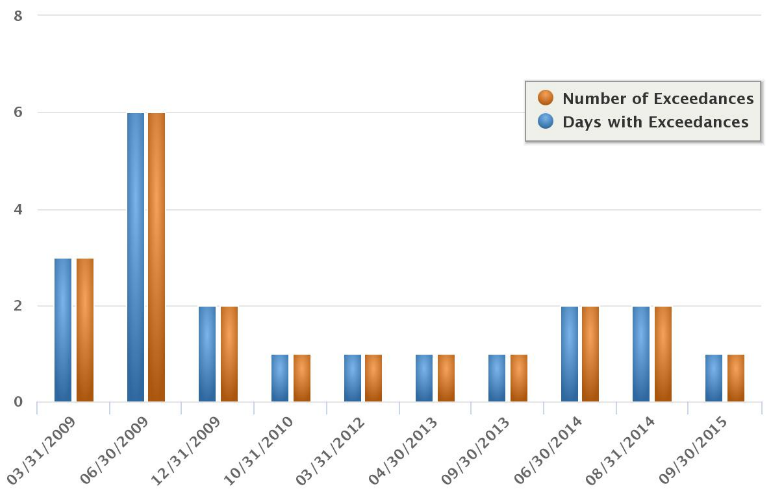


Figure 5.6.8: Reported exceedances for NPDES permit ING40037

5.7 Previous Water Quality and Contaminants Studies

There are various reports and studies that go into more depth on water quality related issues than this WRIA. There sources are all available on the USFWS internal cataloging database ServCat (ecos.fws.gov/ServCat) as well as publicly at data.gov. A brief summary of these studies is discussed below.

Two USFWS Contaminant Assessment Process (CAP) reports have been completed for Patoka River NWR, on in 1997, and one in 2004. The 1997 report can be found at this following link, and the 2004 report can be found at this link (note: requires DOI network access to view). The findings of the CAP's will not be discussed in detail in this report.

Pre-dating the Refuge, an investigative report from the USGS, *Streamflow and Stream Quality in the Coal-Mining Region, Patoka River Basin, Southwestern Indiana, 1983-1985*, was published in 1988 by Danny E. Renn. This study examined 29 sites across the Patoka River basin, and found that the main stem of the Patoka River generally had lower values for chemical constituents than its tributaries, and attributed the higher concentrations in the tributaries to acid-mine drainage. For eight of the tributary sites, the sampling found average pH levels as low as 3.8. An early investigation of water quality and contaminants in the Refuge was conducted and published in the *Baseline Contaminants Investigation of the Patoka River Watershed, Southwest Indiana* (USFWS 1996). This report looked at fish tissue, sediment, and water quality samples across the Patoka River basin, and found that sediments contained elevated levels of inorganic and polycyclic aromatic hydrocarbons (PAH) contaminants. The inorganic contaminants were believed to indicate runoff laden with heavy metals from mining areas, while the PAH contaminants were attributed to previous oil spill and extraction activities. Another important piece of water quality literature in the area includes *Biological Response of Oil Brine Threats, Sediment Contaminants, and Crayfish Assemblages in an Indiana Watershed, USA* (Simon and Morris 2007). This study assess 62 total samples from 2002 that examined water chemistry, sediments, crayfish, and stream habitat. The results indicated that crayfish were found to have elevated levels of arsenic, cadmium, chromium, manganese, nickel, and zinc. Also, that elevated PAH concentrations were associated with a decline in the diversity of crayfish assemblages. A 2008 report from the USFWS entitled *Preliminary Diagnosis of Contaminant Patterns in Streams and Rivers of National Wildlife Refuges in Indiana* (USFWS 2008b) looked at water quality and associated biotic communities across three Refuges in southern Indiana, including PRNWR. This study concentrated on dissolved metals and nutrients, as well as aquatic macroinvertebrate, crayfish, and fish assemblages. This study examined 50 sampling sites on PRNWR and upstream. It found that the lowest biotic integrity and species richness were associated with the highest levels of contaminants. Crayfish in particular showed highest sensitivity to conductivity, while fish assemblages were correlated most highly with chloride and zinc. Macroinvertebrate assemblage structure was tied to several metals, ammonia, pH, and alkalinity. A more recent water quality survey of the lakes on the Columbia Mine Preserve was included in the *Survey of Patoka River National Wildlife Refuge and Management Area, Columbia Mine Unit Water Bodies* (USFWS 2015). The study was performed by the USFWS fisheries office in Carterville, IL. They found that dissolved oxygen and pH levels in the lakes were acceptable for fish and aquatic life. Conductivity in the lakes ranged from 0.041 to 0.65 ms/cm, with the exception of Indian Hill lake, which was recorded at 1.5 ms/cm. Indian Hill Lake also has had a reported fish kill (USFWS 2015, Refuge staff, personal communication 2018), and lower pH readings (more acidic) have been recorded. The report recommended that monthly water quality samples be taken at the ponds to develop baseline levels, and that Indian Hill Lake should have the highest priority of monitoring due to the elevated conductivity levels and reported fish kill. A report from the Indiana DNR identifies potential groundwater contamination sites in the Patoka, White, and West Fork White River Basins. Nitrates were identified as the most common contaminant (IDNR 1998). A 2000 report from the IDEM identifies potential contaminant sources as agricultural activities, storage and treatment activities, disposal activities, hazardous waste sites, industrial facilities, mining/mine drainage, among others (IDEM 2000). Many of these activities are present in the Patoka River basin, so the possibility of groundwater contamination is present.

Chapter 6: Water Law

Indiana draws a line between surface water and groundwater: surface water[1] is public, whereas groundwater is private.[2] Through the state's permitting system, however, state agencies regulate both water systems. The following two sections detail the pertinent laws regarding surface and ground water systems.

[1] Surface water in Indiana consists of lakes and streams. 14-25-1-2. "Diffused water" that falls on or pools on private land is wholly within the ownership of the landowner. *Id.*

[2] Ind. Code § 14-25-1-2 (2011); *New Albany & Salem R.R. v. Peterson*, 14 Ind. 112, 114 (1860) (Indiana follows doctrine of absolute use for groundwater.). Other distinctions may be drawn as well. For example, if underground channels or streams were at issue, courts would likely apply the riparian rights doctrine, as they do for surface water. *Gagnon v. French Lick Springs Hotel Co.*, 72 N.E. 849, 851–52 (1904).

Surface Water

Indiana applies traditional riparian rights doctrine to its surface waters, conforming to other states' standard of reasonable use. Specifically, the state legislature statutorily defined a landowner's riparian right as an "equal right to the flow of the water through his land," so long as that use does not materially injure the rights of those below him.[3] The courts have found at least four rights that exist within the a riparian right, which include rights to: access to the public waterway, build a pier, accretions, reasonable use for general purposes such as boating and domestic use.[4] In Indiana, "public waters," include naturally flowing surface waters, and they should be "put to beneficial uses to the fullest extent," and non-beneficial uses should, in fact, "be prevented."[5] Helpfully, "beneficial use" means "the use of water for any useful and productive purpose" and, most importantly, includes "fish and wildlife" within its definition.[6]

Indiana has taken several legislative steps to protect its resources. In order to facilitate planning, the Natural Resources Commission (NRC) maintains an inventory of all state waters, which includes an assessment of whether streams are capable of supporting "instream and withdrawal uses."[7] "Instream use," in Indiana, means the "use of water that uses surface water in place," and the statute specifically identifies fish and wildlife habitat as an instream use, among others.[8]

In addition to the inventory, state law gives the NRC power to establish minimum flows and groundwater levels, "taking into account the varying low flow characteristics of the streams of Indiana and *the importance of instream* and withdrawal uses."[9] The NRC also has the power to coordinate with federal agencies on "water resource development, conservation, and use."[10]

With this authority, the NRC established procedures to govern contracting with persons requesting withdrawals or releases from reservoirs.[11] If a FWS-managed Refuge in Indiana relies upon impounded upstream water, FWS may apply for a contract with NRC for a release like any other water user.[12] While releases for instream use for fish and wildlife may be an uncommon contract request, nothing in NRC's regulations precludes FWS from applying. Further, a contract for a release of water would be consistent with the state's water conservation initiatives.

In the case of freshwater lakes, the NRC may declare an emergency and issue a temporary or permanent order to stop withdrawals if the "lowering of the lake level is likely to result in significant environmental harm to the freshwater lake or to adjacent property."[13] Also, while the state allows riparian landowners to dam and impound lakes and streams, it requires an analysis by the NRC to ensure that the level of the lake or the flow of the stream "exceeds reasonable

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[3] *Dilling v. Murray*, 6 Ind. 260, 262 (1855).
[4] *Parkison v. McCue*, 831 N.E.2d 118, 128 (Ind. App. 2006).
[5] Ind. Code §§ 14-25-1-1 , 14-25-1-2, 14-25-1-10 (2011).
[6] Ind. Code § 14-25-7-2 (2011) (emphasis added).
[7] Ind. Code §§ 14-25-7-13, 14-8-2-48 (2011).
[8] Ind. Code § 14-25-7-4 (2011).
[9] Ind. Code § 14-25-7-14 (2011) (emphasis added).
[10] Ind. Code § 14-25-7-12(7) (2011).
[11] 312 Ind. Admin. Code 6.3 *et seq*. (2011).
[12] 312 Ind. Admin. Code 6.3-3-1 (2011). When reservoir operators create increased flows, however, downstream riparian-right holders do not have rights to the increased flow. Ind. Code § 14-25-1-5 (2011).
[13] Ind. Code §§ 14-25-5-7, 14-25-5-14 (2011).

use at the time of impoundment," and that the dam or impoundment retains an outlet for stream flows.[14]

Should disputes arise over surface water use, the NRC conducts mandatory mediation between the parties, which entails a hearing and a non-binding recommendation.[15]

Groundwater

Indiana treats groundwater as a private property right of the landowner, as opposed to its treatment of surface water, which is publicly owned.[16] A landowner cannot bring an action against another groundwater user for withdrawing water to the landowner's detriment unless the withdrawal was "deliberate or gratuitous."[17]

Although the state recognizes groundwater as a private resource, the state still authorized the Indiana Department of Natural Resources (DNR), a separate government body from NRC, to regulate when it "has reason to believe it is necessary and in the public interest" to restrict groundwater use for the "economy, health, and welfare" of the state and its citizens.[18] To achieve this goal, the state established a program that creates "restricted use areas," based on necessity. Groundwater users located in a designated "restricted use area" may continue to withdraw water out at the same rate, but may not exceed 100,000 gallons-per-day beyond current use at the time the property becomes "a restricted use area."[19] Withdrawals in excess of that amount require a permit, which the DNR permits or denies based on a series of criteria.[20] The same cap applies to new users after the DNR has designated the region a "restricted use area," with the additional requirement that new users must report when they drill new wells.[21]

Regardless of whether a water user is located within a "restricted use area," any facility capable of withdrawing more than 100,000 gallons per day must report to the DNR.[22] The DNR may also declare a groundwater emergency when evidence indicates that continued ground water withdrawals from a significant groundwater withdrawal facility will exceed the recharge capability of the groundwater resource in that area.[23] Once the DNR declares such an emergency, it can restrict the amount of water a facility withdraws upon a reasonable belief that: (1) the facility caused the emergency, (2) the remaining water is necessary to supply potable water uses, or (3) continued withdrawals will exceed recharge capability of the groundwater resource.[24]

Additionally, like surface water, the NRC still retains authority to establish minimum groundwater levels in aquifers to determine at which point "withdrawals would be significantly harmful to the water resource of the area."[25] To date, however, NRC has only exercised its authority to

[14] Ind. Code § 14-25-1-4 (2011).
[15] Ind. Code § 14-25-1-8 (2011).
[16] *New Albany & Salem R.R. v. Peterson*, 14 Ind. 112, 114 (1860).
[17] *Wiggins v. Brazil Coal & Clay Corp.*, 452 N.E.2d 958 (Ind. 1983).
[18] Ind. Code § 14-25-3-3, 14-25-3-4 (2011).
[19] Ind. Code § 14-25-3-6 (2011).
[20] *Id.*
[21] *Id.*
[22] Ind. Code § 14-25-7-15 (2011).
[23] Ind. Code § 14-25-4-10 (2011).
[24] Ind. Code § 14-25-4-12 (2011).
[25] Ind. Code § 14-25-7-14 (2011).

establish a contract system for reservoir impoundment (discussed above), and no action has been taken to permit groundwater withdrawals.[26]

The contract system established in Indiana may provide FWS with an affirmative means of securing instream rights to water. Further, the state has enabled itself to take control of its water resources when shortages occur, halting withdrawals if need be.

Summary

The above legal summary of Indiana water law designates several key points that may be relevant to Patoka River NWR's interests:

- "Fish and wildlife" is considered a beneficial use of a body of water. The Refuge's use of the Patoka River and tributaries as fish and wildlife habitat has established a precedent of beneficial use. This could give the Refuge some credence if a legal dispute were ever to arise over degradation of habitat on the Refuge.
- The Patoka River relies on upstream impounded water from Patoka Lake. If it were ever needed, the FWS could contract with the Indiana NRC for release of water from the lake to support its beneficial uses. Although, the amount of release may not cause environmental harm to the lake or adjacent properties.
- Any facility capable of pumping more than 100,000 gallons per day of groundwater must report to the DNR. If the Refuge were to ever acquire or maintain infrastructure of this size, it would be expected to fulfill permitting requirements to the state.
- The Indiana NRC has the authority to enforce groundwater contracts if withdrawals are "significantly harmful to the water resource". This could serve as a means for the Refuge securing instream rights to water in streams (so they can maintain enough baseflow), if it were ever found that groundwater withdrawals were impacting Refuge resources.

[26] 312 Ind. Admin. Code 6.3 *et seq*. (2011).

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Appendix A: Threats and Needs Tables

The following data will be uploaded into the National WRIA Database.

Threats

Title	Threat Type	Threat Cause	Threat Status	Severity	Feasibility	Quality
Houchin's Ditch	Loss/Alteration of Stream Channel Habitat	Channelization	Current	Moderate	Existing	High
Houchin's Ditch	Loss/Alteration of Floodplain Habitat	Channelization	Current	High	Existing	High
Houchin's Ditch	Altered Flow Regimes	Channelization	Current	Moderate	Existing	High
Patoka Lake Dam	Altered Flow Regimes	Dams	Current	Moderate	Existing	High
Increasing precipitation	Excess Surface Water	Extreme Precipitation Events	Current	Moderate	Existing	High
Increasing precipitation	Excess Surface Water	Change in Precipitation Patterns (Non-Extreme)	Current	Moderate	Medium-term	High
Increasing precipitation	Habitat Shifting/Alteration	Climate Warming	Future	Moderate	Medium-term	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Salinity/TDS/Chlorides/Sulfates	Oil and Gas Development	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Salinity/TDS/Chlorides/Sulfates	Industiral Effluent	Current	Moderate	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Salinity/TDS/Chlorides/Sulfates	Wastewater Treatment Facilities	Current	Moderate	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Pesticides	Agricultural Runoff	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Metals (other than Mercury)	Oil and Gas Development	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Hydrocarbons	Oil and Gas Development	Current	Moderate	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Nutrient Pollution	Wastewater Treatment Facilities	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Nutrient Pollution	Agricultural Runoff	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Pathogens	Failing Septic	Current	Moderate	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Altered pH	Oil and Gas Development	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Other Contaminants/Altered Water Chemisty	Oil and Gas Development	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Altered pH	Mining/Quarrying	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Metals (other than Mercury)	Mining/Quarrying	Current	High	Existing	High
Poor water quality. Patoka River Mainstem and Tributaries. See WRIA report for more details	Salinity/TDS/Chlorides/Sulfates	Mining/Quarrying	Current	High	Existing	High
Numerous Bridges	Loss/Alteration of Stream Channel Habitat	Roads/Culverts	Future	High	Medium-term	Moderate
Numerous Bridges	Bank	Roads/Culverts	Future	Low/Unkown	Medium-term	Moderate

	Erosion/Channel Incision Sedimentation					
Small State Inventory Dams	Impaired Stream Connectivity	Dams	Current	Moderate	Existing	Moderate
Numerous Pipelines and the potential for spills.	Hydrocarbons	Pipelines and utility corridors	Future	High	Medium-term	Moderate

Needs

Title	Level 1 Type	Level 2 Type	Status	Priority	Effort Required	Immediacy	Feasibility	Quality
Water quality improvement	Water Quality Mitigation/Habitat Improvement	Reduce non-point source pollution	Current	High	Major	Short-term	No	High
Water quality improvement	Water Quality Mitigation/Habitat Improvement	Reduce point-source pollution	Current	High	Major	Short-term	No	High
Water quality improvement	Coordination/Support	Build/Strengthen/Expand Watershed Partnerships	Current	High	Minor	Short-term	No	High
Water quality monitoring	Monitoring/Measurement	Water quality baseline monitoring	Current	Moderate	Minor	Short-term	Yes	High
Water quality monitoring	Monitoring/Measurement	Targeting water quality monitoring	Current	High	Minor	Short-term	Yes	High
Water quality monitoring	Monitoring/Measurement	Create/Update Water Monitoring Plan	Current	Moderate	Minor	Short-term	Yes	High
Water quality studies	Modeling/Research/Assessment	Water Quality Concentration/Loading Assessment	Current	Moderate	Minor	Medium	Yes	Medium
Water quality studies	Modeling/Research/Assessment	Data gap analysis/water monitoring network design	Current	High	Minor	Medium	Yes	Medium
Water quality studies	Mapping and Geospatial Data/Analysis	Water Systems Mapping	Current	Moderate	Minor	Medium	Yes	Medium
NPDES permit exceedance compliance	Monitoring/Measurement	Water Rights/Entitlements Litigation	Future	Moderate	Major	Short-term	No	Medium
Floodplain connectivity/restoration	Water Quality Mitigation/Habitat Improvement	Restore Floodplain Function	Initiated	High	Major	Medium	No	High
Floodplain connectivity/restoration	Water Quality Mitigation/Habitat Improvement	Restore habitat	Current	Moderate	Major	Medium	No	High
Water level monitoring	Monitoring/Measurement	Water level monitoring	Current	Moderate	Minor	Short-term	Yes	High
Bathymetry	Mapping and Geospatial Data/Analysis	Bathymetry/storage	Future	Moderate	Minor	Medium	Yes	High

Appendix B: NPDES Permit Information

NPDES ID	Facility Name	Address	Permit Issue Date	Permit Expiration Date	SIC Code
INR10H408	DENU TURKEY HOUSE	CR 860 W & OLD HOLLAND RD .5 MI NHOLLAND, IN 47541	OCT-16-2013	OCT-15-2018	
INR10K111	6960 OAKLAND CITY SUBSTATION TO RUMBLETOWN JUNCTION REBUILD PROJECT	CR 300 W & PATOKA RIVERPETERSBURG, IN 47567	MAY-21-2015	MAY-19-2020	
ING340023	ENTERPRISE PRINCETON TERMINAL	SR 64 & CR 950 EOAKLAND CITY, IN 47660	AUG-16-2016	OCT-31-2020	4613 = Refined Petroleum Pipelines
IN0061506	FRANCISCO WWTP	CR 125 S 2.3 MI E FRANCISCOFRANCISCO, IN 47649	JAN-27-2017	MAY-31-2022	4952 = Sewerage Systems

INR10D135	I-69 DESIGN BUILD FROM RP 33+44 TO 37+80 (CONTRACT #IR-33038	I 69 & PATOKA RIVERPETERSBURG, IN 47567	FEB-19-2016	FEB-17-2021	
INR10L951	MORNING STAR FARMS NORTH	CR 300 S & SR 57OAKLAND CITY, IN 47660	MAY-13-2016	MAY-12-2021	
INR10J605	NEW LAKE DAM	CR 1350 E & CR 200 SOAKLAND CITY, IN 47660	FEB-07-2015	FEB-06-2020	
IN0064581	OAKLAND CITY WATER TREATMENT PLANT	12596 E CR 100 SOAKLAND CITY, IN 47660	NOV-13-2017	NOV-30-2022	4941 = Water Supply
IN0021687	OAKLAND CITY WWTP	US 64 E & HARRIS ST S OFOAKLAND CITY, IN 47660	SEP-23-2014	FEB-29-2020	4952 = Sewerage Systems
ING040037	PEABODY MIDWEST MINING LLC - FRANCISCO M	CR 850 E N OF SR 64FRANCISCO, IN 47649	MAR-14-2014	APR-30-2019	1221 = Bituminous Coal And Lignite - Surface
INR10M364	SR 65 BRIDGE REPLACEMENT (DES #0800578)	SR 65 & GOOSE CREEKPATOKA, IN 47666	JUL-21-2016	JUL-20-2021	
ING040189	TRIAD MINING LLC HURRICANE CREEK MINE	SR 57 & CR 50 NOAKLAND CITY, IN 47660	AUG-15-2017	SEP-30-2022	1221 = Bituminous Coal And Lignite - Surface
ING040188	TRIAD MINING LLC AUGUSTA MINE	SECS 8 16 17 20 21 T2S R7WAUGUSTA, IN 47598	JAN-19-2018	JAN-31-2023	1221 = Bituminous Coal And Lignite - Surface
IN0058866	BLACKFOOT RECYCLING & DISPOSAL FACILITY	3726 E SR 64WINSLOW, IN 47598	NOV-10-2016	APR-30-2022	5093 = Scrap And Waste Materials
ING040220	SUN ENERGY GROUP LLC HILSMEYER MINE	8750 W OLD SR 64HOLLAND, IN 47541	AUG-01-2016	JUL-31-2021	1221 = Bituminous Coal And Lignite - Surface
IN0040789	WINSLOW MUNICIPAL WWTP	201 S WALNUT STWINSLOW, IN 47598	JUL-08-2016	MAR-31-2022	4952 = Sewerage Systems 9511 = Air, Water, & Solid Waste Management
ING040217	TRIAD MINING LLC LOG CREEK & ROUGH CREEK MINES	1216 E CR 900 SOAKLAND CITY, IN 476609055	JUN-15-2016	AUG-31-2021	1221 = Bituminous Coal And Lignite - Surface
INR10D201	INDOT DES #0500411 & 0902201, I-69 CONTRACT IR-33040 FROM RP 38+63 TO RP 46+64	I 69 MM 38-46PETERSBURG, IN 47567	MAR-15-2016	MAR-14-2021	
INRM01951	TRI COUNTY ASPHALT INC.	882 N CR 800 EOTWELL, IN 47564	FEB-24-2016	FEB-23-2021	2951 = Asphalt Paving Mixtures And Blocks
ING040282	AML SITE 146, DAVIS CEMETERY (AIGNER CONSTRUCTION)	180 COUNTY ROAD 600 WMARYSVILLE, IN 47660	FEB-01-2016	JAN-31-2021	1221 = Bituminous Coal And Lignite - Surface 1241 = Coal Mining Services
ING040281	AML SITE 2083, SUGAR RIDGE AREA 2 (KERNS EXCAVATION LLC)	499 E CR 375 SMUREN, IN 47598	FEB-01-2016	JAN-31-2021	1221 = Bituminous Coal And Lignite - Surface 1241 = Coal Mining Services
ING040129	SOLAR SOURCES UNDERGROUND LLC CHARGER MINE	1592 N SR 61PETERSBURG, IN 47567	JAN-15-2016	FEB-28-2021	
INR10L243	STELLA-JONES YARD EXPANSION 2015	3818 S CR 50 EWINSLOW, IN 47598	DEC-11-2015	DEC-09-2020	
IN0031704	PIKE CENTRAL MIDDLE & HIGH SCHOOL	1810 E SR56PETERSBURG, IN 47567	JUL-31-2015	NOV-30-2020	8211 = Elementary And Secondary Schools
INR10K483	MERCANTILE STORE IN PETERSBURG, IN	1032 N SR 61PETERSBURG, IN 47567	JUL-23-2015	JUL-21-2020	
ING670091	TEXAS EASTERN TRANSMISSION OAKLAND CITY SITE 1	S CR 900 E & E CR 250 SVELPEN, IN 47590	JUL-16-2015	JUL-31-2020	4922 = Natural Gas Transmission

ING040107	TRIAD MINING LLC PATOKA RIVER MINE	4251 W 125 SPETERSBURG, IN 47567	JUL-16-2015	AUG-31-2020	1221 = Bituminous Coal And Lignite - Surface
INR10K028	TEXAS EASTERN TRANSMISSION OAKLAND CITY SITE 1	S CR 900 E & E CR 250 SVELPEN, IN 47590	MAY-03-2015	MAY-01-2020	
ING040250	SUN ENERGY GROUP LLC HILSMEYER 2 MINE	SR 64 N & CR 950 ESTENDAL, IN 47585	APR-15-2015	JUL-31-2020	1221 = Bituminous Coal And Lignite - Surface
ING040206	PEABODY MIDWEST MINING LLC SOMERVILLE EAST	SR 61 S & CR 100 EWINSLOW, IN 47598	FEB-13-2015	MAR-31-2020	1221 = Bituminous Coal And Lignite - Surface
INR10I905	FARBEST FARMS INC - PIKE COUNTY BROODER HUB	42 S CR 50 WPETERSBURG, IN 47567	AUG-19-2014	AUG-18-2019	
INRM01774	TANGENT RAIL PRODUCTS, INC.	3818 S CR 50 EWINSLOW, IN 47598-8866	JUL-30-2014	JUL-29-2019	2491 = Wood Preserving
IN0042536	WINSLOW MUNICIPAL WWTP	201 S WALNUT STWINSLOW, IN 47598	JUL-25-2014	JUL-31-2019	4941 = Water Supply 9511 = Air, Water, & Solid Waste Management
INR10H881	BRIDGE REPLACEMENT FOR COUNTY BRIDGE #147 ON S CR 350 E OVER PATOKA RIVER	CR 350 E & PATOKA RIVERWINSLOW, IN 47598	FEB-19-2014	FEB-18-2019	
ING040236	SUN ENERGY GROUP LLC BLACKFOOT 5 GRAY 1 MINE	1650 S SR 61WINSLOW, IN 47598	DEC-13-2013	MAR-31-2019	1221 = Bituminous Coal And Lignite - Surface
ING040274	VIGO SUNNA LLC - VIGO SUNNA MINE	E CR 900 S & AUGUSTA STENDAL RDSTENDAL, IN 47585	DEC-13-2013	DEC-31-2018	1221 = Bituminous Coal And Lignite - Surface
IN0063045	TANGENT RAIL PRODUCTS, INC.	3818 S CR 50 EWINSLOW, IN 47598-8866	JAN-17-2013	MAR-31-2018	2491 = Wood Preserving

Table B.1: NPDES permits near Patoka NWR main Refuge area.

NPDES ID	Facility Name	Address	Permit Issue Date	Permit Expiration Date	SIC Code
INR10P993	DUKE ENERGY GIBSON STATION PERIMETER DITCH	1097 N CR 950 WOWENSVILLE, IN 47665	NOV-07-2017	NOV-06-2022	
INRM00341	DUKE ENERGY INDIANA LLC - GIBSON GENERA	1097 N CR 950 WOWENSVILLE, IN 47665	AUG-10-2014	AUG-09-2019	4953 = Refuse Systems
INR10P297	DUKE GIBSON RWS TYPE II LANDFILL FINAL COVER GRADING PLAN	1097 N CR 950 WOWENSVILLE, IN 47665	JUL-21-2017	JUL-20-2022	
IN0064157	GIBSON COUNTY COAL, LLC - GIBSON SOUTH M	RR 1, CR 300 SOWENSVILLE, IN 47665	AUG-30-2013	SEP-30-2018	1222 = Bituminous Coal - Underground 1241 = Coal Mining Services
ING040253	GIBSON COUNTY COAL, LLC - GIBSON SOUTH M	RR 1, CR 300 SOWENSVILLE, IN 47665	DEC-15-2015	JAN-31-2021	1222 = Bituminous Coal - Underground
INR10P546	GIBSON COUNTY LOGISTICS	SR 64 & CR 800 WPRINCETON, IN 47670	AUG-25-2017	AUG-24-2022	
INR10I574	GIBSON GENERATING STATION BORROW AREAS PROJECT	1097 N CR 950 WOWENSVILLE, IN 47665	JUN-20-2014	JUN-19-2019	
INR10K753	GIBSON GENERATING STATION IMPOUNDMENTS IMPROVEMENT PROJECTS	1097 N CR 950 WOWENSVILLE, IN 47665	SEP-04-2015	SEP-02-2020	
INR10L701	GIBSON GENERATING STATION TYPE I LANDFILL LONG TERM BORROW	1097 N CR 950 WOWENSVILLE, IN 47665	MAR-31-2016	MAR-30-2021	

	AREA				
INR10M111	GIBSON GENERATING STATION TYPE I LANDFILL LONG TERM BORROW AREA	1097 N CR 950 WOWENSVILLE, IN 47665	JUN-08-2016	JUN-07-2021	

Table B.2: NPDES permits near Cane Ridge area.

NPDES ID	Facility Name	Address	Permit Issue Date	Permit Expiration Date	SIC Code
INR10N115	ALTHOFF PORK FARMS LLC	S DUTCH HINKLE RD & CR 1250 SMONROE CITY, IN 47557	DEC-08-2016	DEC-07-2021	
INR10J092	JASON ALTHOFF - TURKEY HOUSES	S DUTCH HINKLE RD & CR 1250 SMONROE CITY, IN 47557	SEP-20-2014	SEP-19-2019	
INR10I687	WHITE RIVER PIPE EXPOSURE AND BANK STABILIZATION	WHITE RIVER & SR 57 .5 MI WPETERSBURG, IN 47567	JUL-16-2014	JUL-15-2019	
IN0002887	IPL PETERSBURG GENERATING STATION	6925 N STATE ROAD 57PETERSBURG, IN 47567	SEP-29-2017	SEP-30-2022	4911 = Electric Services
IN0004391	FRANK E RATTS GENERATING STAT ION	6825 BLACKBURN RDPETERSBURG, IN 47567-8760	AUG-31-2017	SEP-30-2022	4911 = Electric Services
ING080252	FORMER TOBACCO ROAD 151	211 W MAIN STPETERSBURG, IN 475679401	MAY-16-2017	OCT-31-2020	5541 = Gasoline Service Stations
INR10N609	ARNOLD BORROW AREA	7625 N SR 57PETERSBURG, IN 47567	APR-04-2017	APR-03-2022	
INR10N028	PETERSBURG GENERATING STATION LANDFILL CAP PROJECT	6925 N SR 57PETERSBURG, IN 47567	NOV-18-2016	NOV-17-2021	
INR10M671	1004 ILLINOIS STREET EXISTING DEVELOPMENT DEMOLITION	1004 E ILLINOIS STPETERSBURG, IN 47567	SEP-10-2016	SEP-09-2021	
INR10M667	FRANK E. RATTS STATION DEVELOPMENT	6825 BLACKBURN RDPETERSBURG, IN 47567	SEP-08-2016	SEP-07-2021	
INR10M161	RATTS GENERATING STATION STREAM RESTORATION	6825 BLACKBURN RDPETERSBURG, IN 47567	JUN-14-2016	JUN-13-2021	
IN0024325	PETERSBURG MUNICIPAL WWTP	307 W SPRUCE RDPETERSBURG, IN 47567	MAR-04-2016	JUN-30-2021	4952 = Sewerage Systems
INR10K852	PETERSBURG TO BREED THERMAL UPRATE PROJECT	STATEWIDEPETERSBURG , IN 47567	SEP-18-2015	SEP-16-2020	
INR10K409	PETERSBURG STATION WWTP CONSTRUCTION PROJECT	6925 N SR 57PETERSBURG, IN 47567	JUL-10-2015	JUL-08-2020	
INR10K414	PETERSBURG STATION WWTP CONSTRUCTION PROJECT	6925 N SR 57PETERSBURG, IN 47567	JUL-10-2015	JUL-08-2020	
INR10K415	PETERSBURG STATION WWTP CONSTRUCTION PROJECT	6925 N SR 57PETERSBURG, IN 47567	JUL-10-2015	JUL-08-2020	
INR10K226	IPL PETERBURG GENERATIND STATION GUARDHOUSE	6925 N SR 57PETERSBURG, IN 47567	JUN-07-2015	JUN-05-2020	
ING040022	SOLAR SOURCES INC CARBONDALE MINE	BLACKBURN ROAD & HWY 57 3 MI WESTPETERSBURG, IN 47567	OCT-16-2014	OCT-31-2019	1221 = Bituminous Coal And Lignite - Surface
ING040023	SOLAR SOURCES INC PRIDES CREEK MINE	2519 N 75 EPETERSBURG, IN 47567	AUG-15-2014	AUG-31-2019	1221 = Bituminous Coal And Lignite - Surface
INR10H224	AMBER MANOR	801 E ILLINOIS STPETERSBURG, IN 47567	SEP-11-2013	SEP-10-2018	

Table B.3: NPDES permits near White River Bottoms area.

Appendix C: NPDES Permit ING040037 Exceedance Information

Monitoring Period Date	Outfall	Parameter Code	parameter	Average Daily Flow (MGD)	Limit Type	DMR Value	dmr_value_unit	Limit	limit_value_unit	% Exceedance	Load Over Limit (lb/period)	Number of Days	Days with Exceedances
3/31/2009	1	530	Solids, total suspended	0.013	DAILY AV	107	mg/L	35	mg/L	206	242.1653598	31	1
3/31/2009	1	530	Solids, total suspended		DAILY MX	107	mg/L	70	mg/L	53		31	1
3/31/2009	74	530	Solids, total suspended	0.006	DAILY AV	54	mg/L	35	mg/L	54	29.49449895	31	1
6/30/2009	1	530	Solids, total suspended		DAILY MX	204	mg/L	70	mg/L	191		30	1
6/30/2009	1	530	Solids, total suspended	0.01	DAILY AV	204	mg/L	35	mg/L	483	423.1383975	30	1
6/30/2009	1	1045	Iron, total (as Fe)	0.01	DAILY AV	3.52	mg/L	3	mg/L	17	1.3019643	30	1
6/30/2009	28	530	Solids, total suspended	0.01	DAILY AV	58	mg/L	35	mg/L	66	57.5868825	30	1
6/30/2009	75	530	Solids, total suspended	0.005	DAILY AV	84	mg/L	35	mg/L	140	61.34254875	30	1
6/30/2009	75	530	Solids, total suspended		DAILY MX	84	mg/L	70	mg/L	20		30	1
12/31/2009	50	530	Solids, total suspended		DAILY MX	141	mg/L	70	mg/L	101		31	1
12/31/2009	50	530	Solids, total suspended	0.005	DAILY AV	95.5	mg/L	35	mg/L	173	78.26391169	31	1
10/31/2010	1	530	Solids, total suspended	0.3	DAILY AV	63	mg/L	35	mg/L	80	2173.27887	31	1
3/31/2012	62	530	Solids, total suspended	0.23	DAILY AV	41	mg/L	35	mg/L	17	357.0386715	31	1
4/30/2013	75	530	Solids, total suspended	0.2	DAILY AV	70	mg/L	35	mg/L	100	1752.64425	30	1
9/30/2013	75	530	Solids, total suspended	0.12	DAILY AV	43	mg/L	35	mg/L	23	240.36264	30	1
6/30/2014	75	530	Solids, total suspended	0.25	DAILY AV	47	mg/L	35	mg/L	34	751.13325	30	1
6/30/2014	75	1045	Iron, total (as Fe)	0.25	DAILY AV	3.89	mg/L	3	mg/L	30	55.70904938	30	1
8/31/2014	75	530	Solids, total suspended	0.07	DAILY AV	49.37	mg/L	35	mg/L	41	260.2501447	31	1
8/31/2014	75	530	Solids, total suspended		DAILY MX	87	mg/L	70	mg/L	24		31	1
9/30/2015	14	530	Solids, total suspended	0.194	DAILY AV	54	mg/L	35	mg/L	54	922.8923865	30	1

Table C.1: Detailed NPDES exceedance information for permit ING040037

Division of Natural Resources and Conservation Planning, Region 3
18500 Brady Ln.
Boonville, MO 65233

U.S. Fish and Wildlife Service
http://www.fws.gov

Region 3, U.S. Fish and Wildlife Service
http://www.fws.gov/midwest