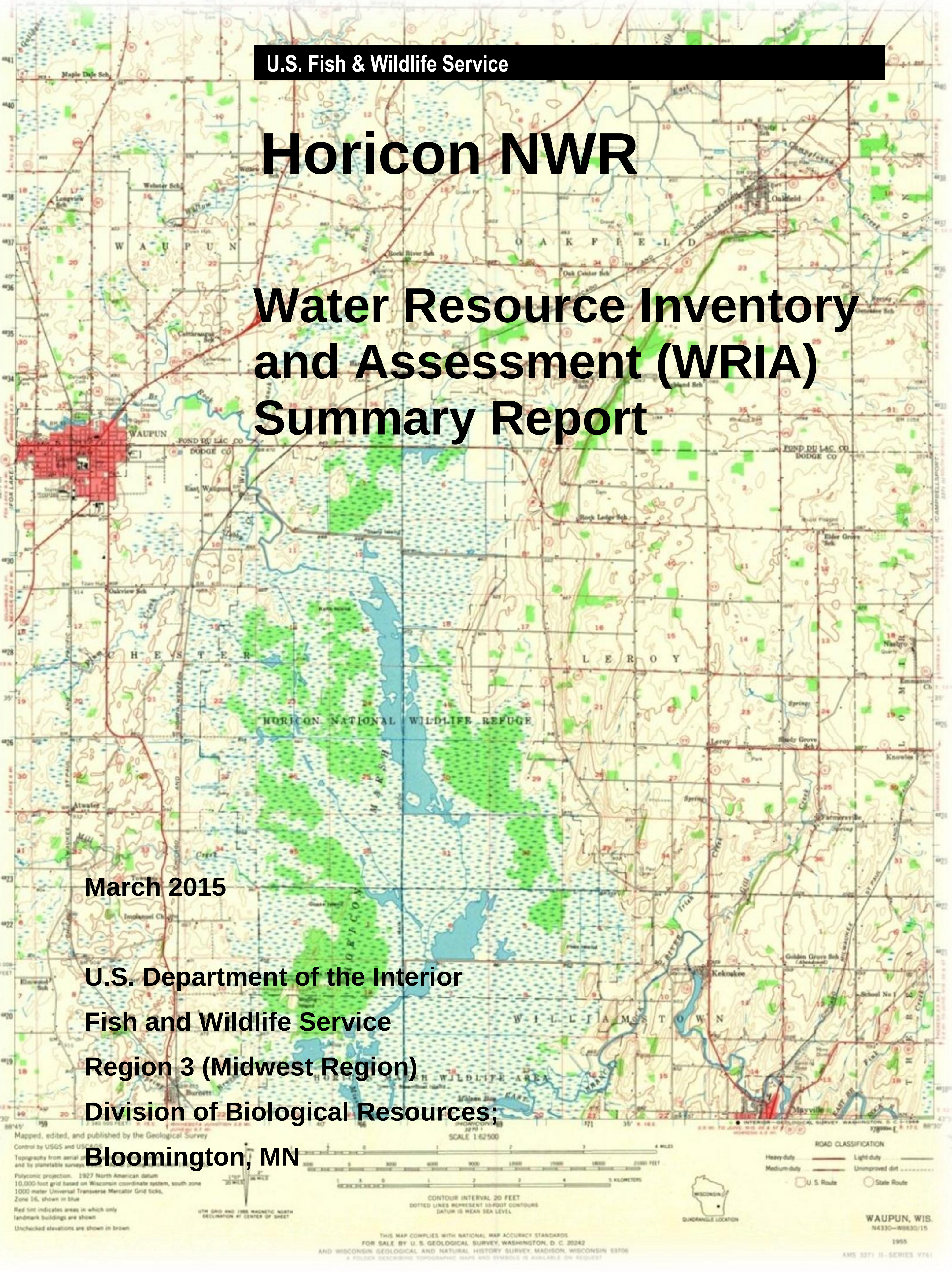

U.S. Fish & Wildlife Service

Horicon NWR

Water Resource Inventory and Assessment (WRIA) Summary Report

March 2015

U.S. Department of the Interior
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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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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 the U.S. Fish and Wildlife Service, USGS seamless server, the Environmental Protection Agency, and the Missouri Spatial Data Information Services website.

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Executive Summary

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

- An inventory of water resource infrastructure
- Assessments of Refuge water resource issues
- Summaries of historical and current water resource monitoring
- 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 is identified as a need by the *Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change* (USFWS 2010a, b). I&M is one element of the USFWS's climate change strategic plan to address the potential changes and challenges associated with conserving fish, wildlife and their habitats (USFWS 2011). WRIAs have been developed by a national team comprised of USFWS 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 tool for Refuge management and future assessments, such as a hydro-geomorphic analysis (HGM), and can be utilized as a planning tool for the Comprehensive Conservation Plan (CCP), Habitat Management Plan (HMP) and Inventory & Monitoring Plan (IMP). The Contaminants Assessment Process (CAP) is complete for the Refuge (Warner et al., 2012). Many of the findings and recommendations within the CAP are applicable to water resources and are reiterated in the WRIA summary narrative.

This WRIA Summary Report for Horicon NWR (HNWR) describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations regarding Refuge water resources.

This Summary Report synthesizes a compilation of water resource data contained in the national interactive online WRIA database (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 HNWR.

Findings

The primary issues threatening Refuge water resources are outlined below. In general, the most threatening water resource related concerns for the Refuge are invasive carp and cattail expansion, sediment and nutrient loading, and potential changes in flooding patterns. Actions to mitigate these issues are strongly tied to water level management, an action which is often constrained by downstream management of Lake Sinissippi and, for the Refuge, Wisconsin Department of Natural Resources (WDNR) waters in Horicon Marsh State Wildlife Area (HMSWA). Limitations to the degree Refuge waters may be fluctuated creates challenges for ecosystem management, especially since cattails and carp thrive under stable water levels, while also creating ideal conditions for sediment deposition. These factors in combination with a changing climate create problematic circumstances for the sustainability of waterfowl habitat and other ecosystem functions.

- Invasive carp populations
  - Carp remove aquatic vegetation and mix substrates throughout the water column.
  - Increased turbidity degrades water quality and alters the ecosystem.
  - Past mitigation measures have had little effect, and carp re-invade areas where they had previously been eradicated because of flood pathways.

- Non-native cattail
  - Aggressive non-native cattails have already overtaken much of the Marsh and now threaten to choke out remaining habitats.
  - Invasive cattails thrive under higher sedimentation and stable impoundment conditions found at the Marsh.
  - Control options are limited because of downstream activities at Lake Sinissippi, which at times cause backflow conditions at the Main Water Control Structure (WCS) and limit the Refuge's drawdown ability.

- Sedimentation
  - Sediment storage is a natural function of the Marsh, but sedimentation has increased exponentially because of land use conversion to row crop agriculture over the past century and increased infrastructure impounding Marsh water.
  - While the USFWS has been working to increase buffer strips and other best management practices (BMPs) in the upper watershed since 2006, sedimentation has not been offset entirely and continues to threaten Refuge water quality.

- Nutrient loading
  - The primary inputs to Horicon Marsh, the West and South Branch Rock Rivers, suffer impacts from high phosphorus loading (Heim 2013). The South Branch Rock River consistently demonstrates higher concentrations than other parts of the Rock River Basin.
  - Plum and Mill Creeks suffer from nutrient loading, but pose lower threats to the Marsh compared to larger tributaries of the West and South Branches of the Rock River. These are relatively small tributaries, and contamination bound to sediments of these subwatersheds likely settle out before reaching the Marsh. Their impacts are most likely localized to the western portion of the Refuge.
  - Ladoga Creek, which feeds the West Branch Rock River, consistently meets phosphorus standards (0.075 mg/L), has little siltation, good habitat, and cool water temperatures (Heim 2013).
  - Legacy sediments and nutrients that have settled out within and upstream of the Marsh may be at risk of future transport downstream for many more decades. The volume of sediments and nutrients which have accumulated in streambeds and Marsh substrates over many decades are currently unknown, which may mean that concentrations could remain high for many years after the implementation of water quality BMPs.

- Other contaminants
    - The CAP identifies Highway 49 as a likely source of contaminants.
    - High levels of atrazine were discovered at the Refuge in the late 1990s, but the issue has not been evaluated since and may continue to threaten surface and groundwater.
    - Parts of the Rock River Watershed were designated by the WDNR as “Atrazine Prohibited Areas” because levels exceeding water quality standards were detected, but it may still be used in other upstream areas.

- Flooding
    - The West Branch Rock River is currently discharging more water than it once did, and gage data on the South Branch Rock River suggest conditions are now flashier than they once were. A statistically significant increase in average annual discharge was found at a downstream gage near Afton, WI, and the increase has been greatest in the months of May-July. A gage near Horicon, WI representing overall Marsh outflows also demonstrates this general positive trend, though the data is not statistically significant.
    - Flooding risks continue to worsen due to higher volumes of water and sediment moving through the Refuge, which has cascading effects downstream because of rising bed elevations and diminishing water holding capacities.
    - Flooding and sediment deposition issues may worsen if Lake Sinissippi water level management causes more frequent backflow conditions at the Main Water Control Structure. The degree to which these processes threaten Refuge water management is dependent in part on future climate change impacts.
    - Higher flood risks are largely the result of climate change impacts and a shorter frozen season in the region, since less snowmelt infiltrates in a gradual manner during spring. The precipitation-fed surface waters have also responded to climate-related increases in average annual rainfall.
    - “Bounces” in the Marsh water level have occurred in the wake of extreme flooding, sometimes up to three feet in magnitude, and disrupt nesting patterns for several waterfowl species (USFWS 2007). Such events should be expected to increase in frequency because general sedimentation issues within the watershed will diminish buffering functions of water retention basins, creating a flashier system overall.
    - Because of higher discharges and flashier conditions of the Rock River, water level management for the purpose of waterfowl habitat has become much more challenging, particularly for shorebirds that require exposed mudflats in the summer months when the increase in discharge has been the greatest to date.

- Climate change
    - Daily maximum and average temperatures have decreased in summer and autumn and increased in winter and spring in Dodge and Fond du Lac Counties, while the average minimum temperatures have increased in all seasons (Kucharik et al. 2010). However, no trend in historic temperature data for fall is apparent in the interpolated PRISM dataset, based on fall averages from 1950-2011. Extremely cold nights in winter have decreased in frequency, a trend that is predicted to continue (WICCI 2011). General warming is evident by a later first freeze and earlier spring thaw, as well as a larger fraction of precipitation falling as rain rather than snow.
    - There has been a statistically significant increase in average annual precipitation since the 1950s based on USHCN data in this area of Wisconsin, and total precipitation has increased most dramatically in the fall (Kucharik et. al. 2010). Since maximum and average daily temperatures have decreased in fall and summer while precipitation has increased, larger volumes of water are likely present on the surface and/or subsurface during these seasons than there historically have been.
    - The changing climate and hydrology in the region will complicate water level management, particularly for the purpose of migratory bird habitat.

- Possible implications of climate change or continued trends
    - In the immediate future, daily maximum and average temperatures in winter and spring, as well as average minimum temperatures in all seasons, could either continue to increase or maintain current elevated levels from past conditions. Erratic surface water behavior will persist and will likely worsen, and while future runoff within the Basin is not expected to increase, higher than historic conditions will at least be maintained. However, the longer growing season combined with higher temperatures, higher atmospheric moisture holding capacity, and a likely increase in water availability could cause an increase in evaporative loss in the Rock River Basin.
    - If increased occurrences of flood conditions and higher-magnitude precipitation events are either maintained or continue upward trends as predicted by some models (WICCI 2011), WCSs may have a shorter lifespan than expected in their design if there are more frequent high-magnitude events.
    - Legacy sediments may become a bigger threat to Marsh resources if intense storms and extremely high flows occur more frequently as some climate change models predict.
    - Besides higher sediment loading, potential increases in discharge will also increase nutrient and contaminant loadings to Horicon Marsh, which would result in decreases in dissolved oxygen, more turbid waters, and reduced light attenuation. Such changes would disturb the natural ecology of the system by altering aquatic vegetation utilized by waterfowl and other aquatic life.
    - The year-round impacts of widespread animal agriculture in the area are not well understood. Specifically, potential winter manure spreading activities may threaten the Upper Rock River Basin’s water quality (Heim 2013), and this issue could be exacerbated by projected increases in winter temperatures and precipitation.
    - Land and water use in the region will adapt to any changes in climate, which could indirectly influence Refuge waters. For example, an earlier spring thaw could result in earlier field preparation time and longer cultivation periods before a later first freeze. This presents more potential for erosion, nutrient pollution, and pesticide/herbicide inputs to threaten local water quality, especially considering more frequent high-magnitude storms are expected during the growing season. Pesticide and herbicide use may also increase because of changes in weed growth and insect populations as a result of a changing climate.
    - To account for drier conditions that may occur between extreme storm events, irrigation patterns may change. More irrigation equipment may be installed, a larger irrigated area, and higher water withdrawal rates may be necessary during dry spells in the summer from an aquifer with subsurface water quantity already impacted to some degree by industrial use (USGS 1992). Similarly, extreme precipitation events and total annual precipitation increases will probably increase the area of land that is artificially drained, which will exacerbate already-existing nutrient loading problems, especially if the growing season also continues to lengthen since agricultural activities would persist for a longer portion of the year.
    - The effects of higher water levels in general in Wisconsin have recently caused reduced shorebird habitat in managed areas, however localized flooding has created additional habitat in other areas, particularly over agricultural lands, which birds make use of (WDNR, 2014). However, the utilization of such areas likely exposes migratory birds to harmful pollutants more directly, and could result in fewer numbers directly using HNWR managed habitat.

Recommendations

The WRIA provides a collection of recommendations related to the primary findings from existing water quality and quantity information, as well as identified gaps in the water resource inventory. These recommendations are suggestions to help improve understanding of water resource quality, quantity, and limitations for Refuges, however alternative opportunities to act on current or future threats may exist. Each water resource concern and recommendation should be thoroughly assessed prior to the implementation of management actions, and when appropriate should be incorporated into the planning process with consideration for Refuges' overall goals and priorities.

Several recommendations are associated with water resource threats and needs common to most Refuges in the Midwest Region, and their implementation at all of the Region's management locations would improve the collection, understanding, and application of water resources. These generalized recommendations include:

- ❖ Monitor water levels across the Refuge in mean sea level datum.
- ❖ Develop water level management plans and monitor changes over time.
- ❖ Use available Light Detection and Ranging (LiDAR) data to evaluate how higher water levels could impact surrounding lands, and conduct more detailed surveys where necessary.
- ❖ Collect bathymetric surveys for the Refuges' most valuable water features, and use this information to compute overall water storage capacities and distribution so water resources may be managed effectively.
- ❖ Evaluations of the Refuges' sediment budgets, with focus on sedimentation rates coupled with elevation information, should be conducted to better-understand the dynamics between water storage, water basin depths, and flood frequencies, and to help anticipate future changes to these processes.

Recommendations specific to HNWR are listed below, and additional water resource management suggestions have been detailed in the CCP (USFWS 2007; ServCat Reference 5985).

- ❖ An assessment of the sediment budget for the entire Rock River Watershed, with a focus on sedimentation rates of the West Branch Rock River and coupled with elevation information, would provide insight on the impacts higher sediment loading may have on Marsh depths and flood frequencies.
- ❖ Better strategies for coordinating water levels between Refuge, WDNR, and Lake Sinissippi waters would help reduce the impacts of flooding and manage sediment movement within the watershed, thereby maintaining the basins' capacities to buffer high discharges. Overall, the various impoundments along the upper Rock River should be managed as a system through increased coordination and collaboration among the various water managers. For example, coordinated management that allowed high, sediment laden flows to pass through the system as efficiently as possible would benefit all users.
- ❖ Several water quality monitoring recommendations were made by Gruetzman (2011). Water quality monitoring data from relevant tributaries should be evaluated to improve understanding of the Marsh's phosphorus, sediment, and water budgets, and the marshland's role as either a primary sink or source for sediments and nutrients should be determined.
- ❖ Gruetzman (2011) additionally recommends a detailed evaluation of monitoring data for dissolved and total phosphorus to determine if phosphorus is primarily transported through the Marsh

bound to sediment or in dissolved form. Since some monitoring data suggests that a larger proportion of total phosphorus enters the Marsh bound to sediments in the summer months, a watershed-scale evaluation to determine current probable areas of sediment sources would help target areas for additional BMP implementation.

- Sediment and nutrient loads were monitored for Horicon Marsh by the USGS from 1997-2000, and again in 2009-2012, however the published results from the two study periods have not yet been compared in detail. The changes between these two datasets should be statistically evaluated with particular consideration for differences in hydrologic parameters, to determine how effective BMPs have been in the area and how total phosphorus, dissolved phosphorus, and total suspended sediment loadings have changed. This will help guide future water quality improvement plans.

- Since flooding issues within the Refuge may worsen in the future and offset attempts to eliminate carp populations, invasive carp control may not be an especially high restoration priority. If carp persistence could somehow be focused to certain areas there may even be some benefits to the ecosystem, since rooting behaviors could help undermine established cattail stands (Beule 1979).

- Invasive cattail management is necessary for sustaining quality waterfowl habitat within the Refuge, and attempts to control spread may become more challenging if the Marsh bed elevation rises due to continued sedimentation. The Refuge will need the ability to perform more effective drawdowns and, in coordination with downstream partners, potentially ‘flush’ the Marsh periodically. Such actions should occur in late summer or early fall at a time that prevents reseeding. Results from controlled experiments at Horicon Marsh by Beule (1979) provide management guidelines to follow on this topic, but waters must simultaneously be managed to meet habitat requirements for waterfowl, which may change with the climate.

- Based on the findings from the Horicon Marsh Watershed Improvement Project (Heim 2013), the South Branch Rock River should be prioritized for water quality improvement measures since it contributes overall higher levels of phosphorus than the West Branch drainage, and mitigation efforts focused in this basin may be more effective than in the West Branch Rock River. Both Rivers are, however, important to continue sampling for phosphorus and sediment, and both should continue to be targeted for restoration and water quality improvements. Continuous, year round monitoring is necessary to effectively assess runoff issues, since the extensive agricultural activities in the Basin create the potential for runoff contamination caused by winter spreading activities. Animal feedlots and drain tile discharges contributing excessive nitrogen and phosphorus should also be targeted, BMP activities should continue to be monitored, and if possible nutrient management plans should be implemented at every farm in the basin (Heim 2013).

- A detailed assessment of Ladoga Creek may reveal how this basin is meeting water quality standards, and such information could help guide management practices for the rest of the watershed (Heim 2013).

- Conduct a field-based infrastructure evaluation to ensure WCSs and monitoring equipment would withstand current elevated flows, as well as the potential for more frequent intense discharges and longer seasons of flowing water. A breach or failure of one of the Refuge WCSs could have lasting effects on both upstream and downstream ecosystems. Likewise, infrastructure owned by other entities, such as the dam impounding the Rock River near Waupun, should be assessed to determine if any outside threats to the Marsh exist, especially upstream.

- HNWR’s management practices must adapt to the changing amounts of water, sediment, and nutrient inputs to the Marsh, with some consideration for future climate trends, to sustain the Marsh’s current ecosystem functions in the long term.

Climate change adaptation recommendations

Several management recommendations included in the WRIA summary are related to current and anticipated climate changes, and are detailed below.

- Because of likely changes in climate conditions, investigations related to flood control, low flow water level management, and higher runoff volumes in the region should be initiated. An additional analysis focused on predicted climate-driven changes in land use in the region, especially in the context of agricultural activities, should be conducted. Findings from these evaluations should be factored into future management plans.

- Because HNWR is such an essential part of the migration corridors for many bird species, and because nearby development and infrastructure prohibits the Marsh habitat to migrate as it naturally may have with climate forcing, there should be a focus on preserving the ecosystem functions that HNWR currently provides.

- A longer season of managed stable, high water levels, beginning earlier than May and possibly longer than mid-July, might be necessary to account for potential earlier migration and nesting activities of some species, an activity which could be impacted by increased flooding and facilitate greater sedimentation. Dramatic fluctuations in water levels caused by high flows after large storm events should be prevented by continuing the expansion of buffer controls and other BMPs in upstream reaches of the Rock River.

- Assuming current wetter conditions persist, management must account for the extra water, prepare for potential increases in sediment volumes and alter drawdown and flood timing to account for waterfowl behavior changes. The consequences of milder falls, later winter freezes, earlier spring thaws, and other weather pattern alterations on bird migration are already being felt in some areas of the Midwest (Yardley 2007), and may continue in the form of migration shifts north and earlier breeding seasons.

- Temperature and wetland habitat changes will likely continuously affect waterfowl nesting timing, migration extent and timing, and available food sources. However, effects may be felt across the entire flyway, so implications of climate change at HNWR in the context of migratory birds are difficult to isolate. Refuge water management will need to adapt while taking into consideration the fact that changes in observed bird populations utilizing Horicon Marsh may be confounded by climate effects on a much broader scales. A metric should be developed to help monitor waterfowl populations at the Refuge in a way that isolates Refuge variables from these factors.

- The possible sedimentation and Marsh infilling that may continue with more extreme weather events could facilitate rapid cattail expansion, which would reduce the amount of habitat available for migrating waterfowl. Drawdowns conducted to facilitate prescribed burns that reduce cattail expansion, increase emergent plant diversity, and promote resources to sustain bird populations should be coordinated with our state and local partners, and planned with anticipation for more frequent extreme events, particularly in the fall when changes in precipitation and temperature patterns have been most dramatic. If climatic conditions continue to change, managers may need to consider a wider range of infrastructure, management, and disturbance measure options to help facilitate drawdowns and control cattail expansion.

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1. Introduction and Refuge Information

Horicon National Wildlife Refuge (HNWR) is located in eastern Wisconsin, south of Lake Winnebago in Dodge and Fond du Lac counties. Wildlife, habitat, and recreational opportunities are managed at HNWR as part of a complex of areas, including the Fox River National Wildlife Refuge, Green Bay National Wildlife Refuge, Gravel Island National Wildlife Refuge, and the Leopold Wetland Management District. WRIAs for these other Refuges will be completed separately. Conservation goals and objectives for HNWR and Fox River NWR are summarized jointly in a Comprehensive Conservation Plan (USFWS, 2007).

HNWR was established on July 16, 1941 "for use as an inviolate sanctuary, or for any other management purpose, for migratory birds…" by the authority of the Federal Migratory Bird Conservation Act of 1929. The Refuge is less than 30 miles downstream of the Rock River's headwaters (USFWS 2007). Significant opportunities and responsibilities for Refuge managers accompany such a position in the watershed, since activities in the river's beginnings have implications for its use and health as it journeys downstream.

The Rock River Basin is shaped by nearly 3,900 river miles meandering through it and covers approximately 3,750 square miles of land (Kirsch et al., 2002), roughly 1,890 square miles of which belong to the upper division of the watershed where the 22,000-acre HNWR is located. Approximately 11,000 acres of the southern portion of Horicon Marsh are managed by WDNR for hunting, fishing, and other recreational activities as part of HMSWA.

Horicon Marsh is part of the Upper Midwest and Great Lakes Land Conservation Cooperative (LCC) and the Southeastern Wisconsin Savannah and Till Plain Level IV Ecoregion (53c; Omernik et al., 2004). Land use in this area primarily consists of cropland used to grow forage and feed grains to sustain the region's dairy industry, and much of the natural vegetation has been cleared for this purpose. However, some forested areas remain on steeper end moraines and depressions (Natural Resources Conservation Service [NRCS] 2008). The natural vegetation that does exist shows a transition from hardwood forests and oak savannahs in the west to tall grass prairies found in the south.

Refuge lands consist of approximately 15,500 acres of Marsh, 2,000 acres of woodlands, and 3,600 acres of grasslands. More specifically, land use within Refuge boundaries is primarily perennial Marsh habitat with some wet meadow areas, especially in the west. Fragmented upland forest and grasslands surround the wetland portions of the Refuge and provide some degree of protection from runoff and nutrient loading contributed by the agricultural lands that surround portions of Horicon Marsh (Figure 1, Table 1). According to an 1800's vegetation survey, the majority of the Refuge's historic land cover included Marsh and sedge meadow, wet prairie, and lowland shrubs. West of the Marsh there was bur oak, white oak, and black oak, while land to the east supported communities of sugar maple, basswood, red oak, white oak, and black oak (USFWS 2007).

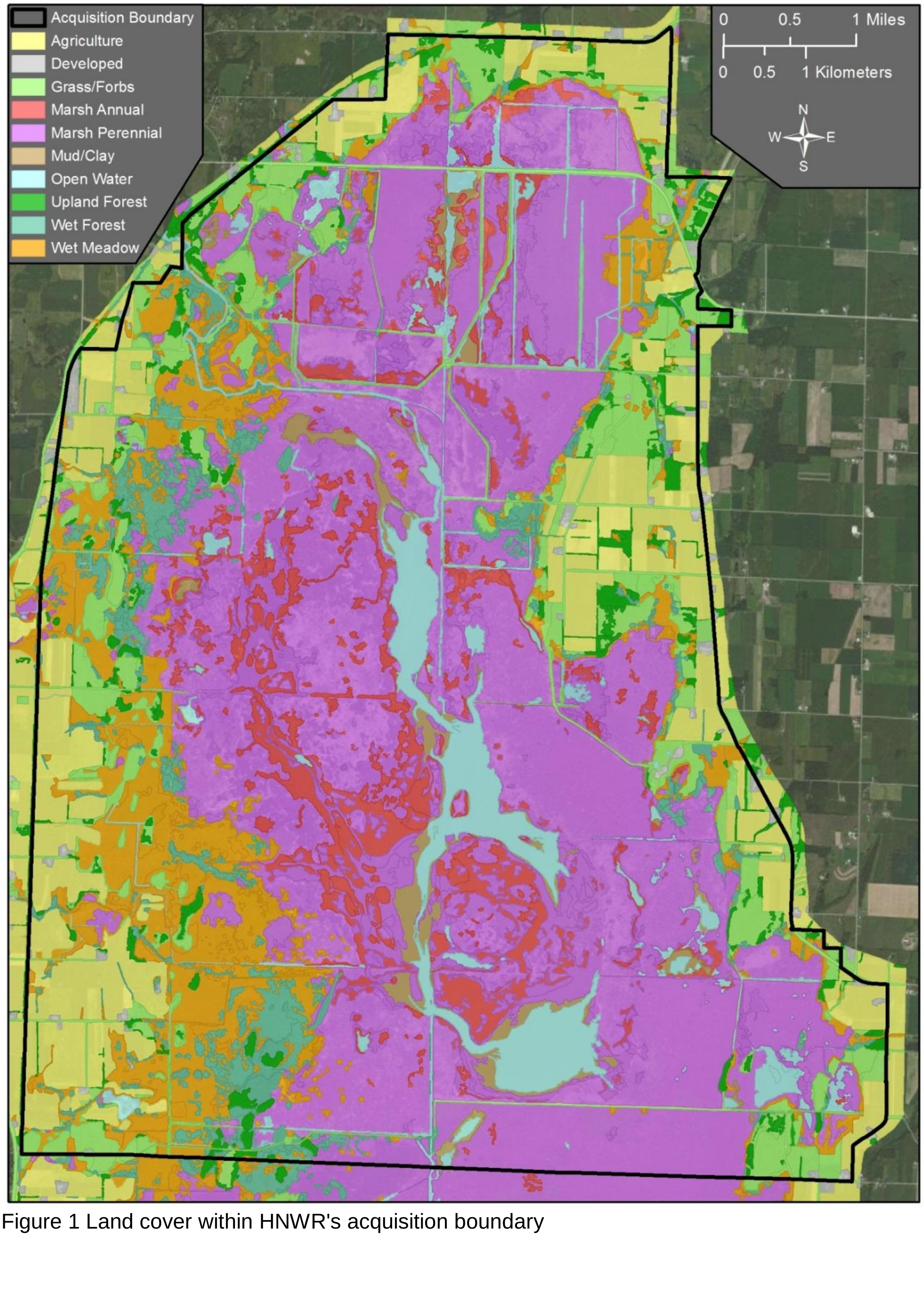


Figure 1 Land cover within HNWR's acquisition boundary

Description	Total Acres (acquisition boundary)	Percent
Agriculture	3,106.33	11.55%
Developed	171.44	0.64%
Grass/Forbs	2,483.89	9.24%
Marsh Annual	1,793.65	6.67%
Marsh Perennial	11,938.11	44.40%
Mud/Clay	581.04	2.16%
Open Water	1,661.14	6.18%
Upland Forest	673.73	2.51%
Wet Forest	1,344.74	5.00%
Wet Meadow	3,134.38	11.66%
Total	26,888.46	100%

Table 1 Land cover acreage and percentage within HNWR's acquisition boundary

Horicon Marsh, was designated a "Wetland of International Importance" by the Ramsar Convention on December 4, 1991. It was also recognized as a Globally Important Bird Area in the American Bird Conservancy's United States Important Bird Areas program in 1997 and as a State Important Bird Area in 2004 because it provides valuable migration habitat for Canada geese, ducks, and other migratory birds. Over 50% of the Mississippi Flyway Canada Geese migrate through the Marsh during the fall, as does 2% of the biogeographic population of Mallards (USFWS 2007).

Though the Marsh provides important wetland habitat and other ecosystem functions, it also represents a severely-altered environment. Land clearing upstream related to agriculture and development has increased nutrient and sediment loads to the Refuge. In the late 1800's, the Main Channel of Horicon Marsh was dredged in an attempt to use the land for agriculture, but after these efforts failed it was converted back to hunting land. Today, silage, grain, winter wheat, sweet corn, peas, soybeans, milk production, cattle, and hog industries are central to the local economy (UW Cooperative Extension, 2011), but critically jeopardize the integrity of the region's water resources. This became evident after flow and water quality monitoring activities in the late 1990s by the USGS revealed high sediment and nutrient loading received by the Marsh, which sparked a series of restoration initiatives.

In response to adverse effects of these activities, HNWR has adopted an active restoration approach, which involves an intricate network of impoundments that are managed with consideration for nesting and migration patterns of waterfowl (USFWS 2007). A more comprehensive history of these management practices, as well as the establishment of the Refuge facility is available within the CCP (USFWS 2007).

Additional watershed-scale restoration measures, such as buffer strip development, no-till farming, and other BMP developments in the upper portions of the Watershed have been underway since 2006. As of 2012, over 46,300 acres of approximately 90,000 cropped acres in the portion of the Rock River Watershed in Fond du Lac and Dodge counties had an associated nutrient management or conservation plan, and approximately 25 miles of riparian buffer had been developed (Heim 2013; Figure 2). Additional information about BMP practices installed in the Upper Rock River Watershed between August of 2006 and December of 2010 are provided in the Project Year 1 Final Report (Rock River & Horicon Marsh Volunteer Initiative [RRHMVI] 2012).

The Project Year 1 Final Report for the Rock River & Horicon Marsh Volunteer Initiative offers a preliminary comparison between sampling in the 1990s and flow, dissolved phosphorus, total phosphorus, and total suspended solids collected from October 2009 through September 2010 (RRHMVI 2012). The report provides a list of annual phosphorus loads delivered by the top point source phosphorus contributors of the South/West Branch Rock River Watersheds (Table 3) and the East Branch Rock River Watershed, which is less-relevant to the Refuge portion of the Marsh. The data shows that BMP programs implemented in the region have already shown effectiveness, evident by decreased phosphorus discharges at the largest point source contributors by 85% or more from 1999-2009. The report also discusses reductions in peak total phosphorus and peak total suspended sediment in the more-recent monitoring (Table 4).

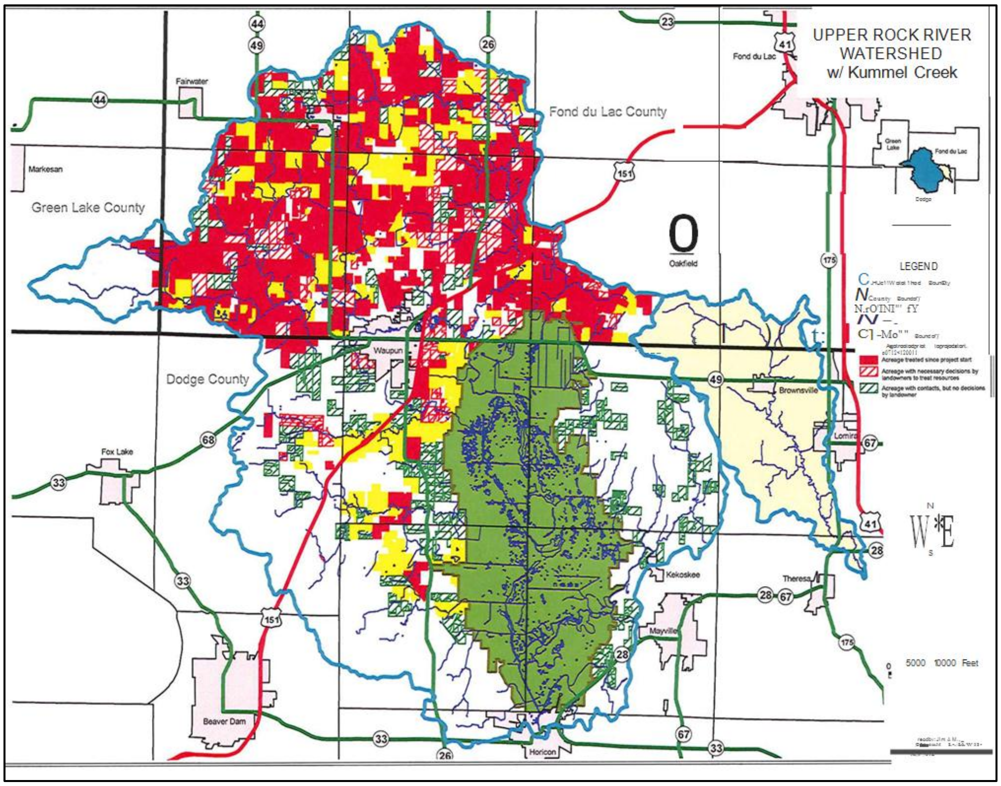


Figure 2 2012 status map of buffer strip and BMP development in the Rock River Watershed (Heim 2013)

Practice	Fond du Lac County	Dodge County	Total
Buffers	16.1 miles		16.1 miles
Nutrient Management Plans	24,275 acres	2,816 acres	27,091 acres
Conservation Plans and Revisions	34,636 acres	3,051 acres	37,687 acres
Shallow Water Areas	28	1	29
Upland Wildlife Nesting Cover	410 acres		410 acres

Table 2 Inventory of installed conservation practices in the Upper Rock River Watershed from 2006-2010 (RRHMVI 2012)

Year	Saputo Cheese Annual Phosphorus (lbs)	City of Waupun Annual Phosphorus (lbs)
1999	53,064	30,801
2000	53,027	17,119
2001	48,687	28,495
2002	31,175	37,842
2003	18,878	22,002
2004	10,749	3,955
2005	6,475	2,066
2006	4,508	2.872
2007	4,661	3,432
2008	5,263	3,327
2009	6,656	4,554

Table 3 Annual phosphorus discharge from top point source contributors of the Upper Rock River Watershed (RRHMVI 2012)

Parameter	Peak from sampling in the late '90's (mg/L)	Peak from 2009-2010 monitoring (mg/L)
Total suspended sediment	302	98
Total phosphorus	3.1	0.6

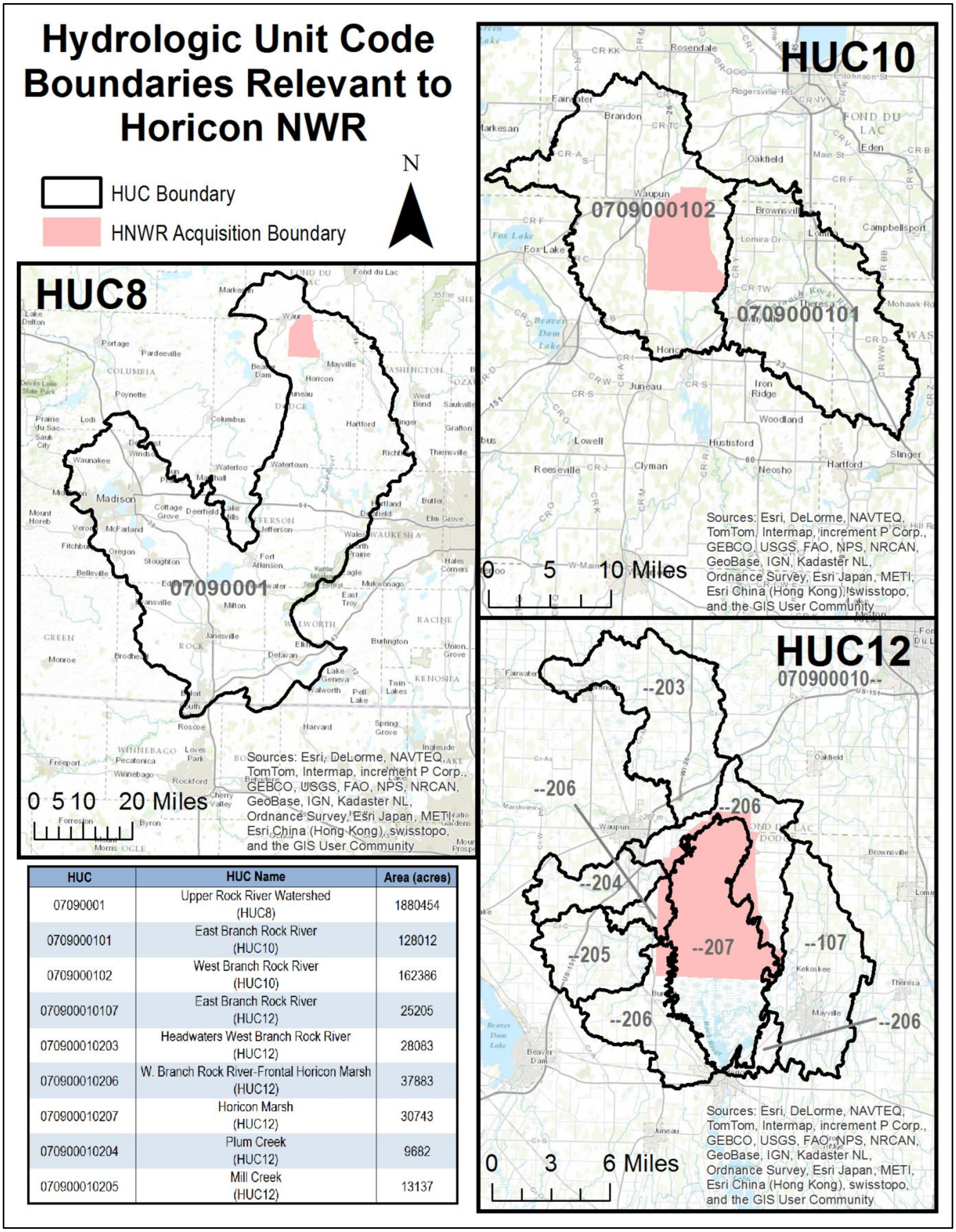
Table 4 Total suspended sediment and total phosphorus peak concentrations for monitoring conducted in the late 1990's and 2009-2010 (RRHMVI 2012)

2. Natural Setting

The natural setting section describes the abiotic resources associated with the refuge, including relevant watershed boundaries, topography, geology, climate, and soils. 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 the CCP (USFWS 2007).

Hydrologic Unit Codes (HUCs)

Hydrologic information can be described in the context of the Refuge's designated Region of Hydrologic Influence (RHI), which is the relevant region for the collection of water quality and quantity information. In this case, HNWR's RHI is its intersecting 10-digit Hydrologic Unit Code (HUC-10) boundary (Figure 3). HUCs are used to 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 boundaries are a successively smaller classification system based on drainage, adapted from Seaber et al. (1987). The smaller HUC-12 boundaries are also evaluated herein, if they contained the primary Refuge source waters.



HUC	HUC Name	Area (acres)
07090001	Upper Rock River Watershed (HUC8)	1880454
0709000101	East Branch Rock River (HUC10)	128012
0709000102	West Branch Rock River (HUC10)	162386
070900010107	East Branch Rock River (HUC12)	25205
070900010203	Headwaters West Branch Rock River (HUC12)	28083
070900010206	W. Branch Rock River-Frontal Horicon Marsh (HUC12)	37883
070900010207	Horicon Marsh (HUC12)	30743
070900010204	Plum Creek (HUC12)	9682
070900010205	Mill Creek (HUC12)	13137

Figure 3 Hydrologic Unit Codes relevant to HNWR

Topography

High resolution bare-earth LiDAR data is currently available for HNWR's RHI, and the elevation and drainage maps reported in Figure 4 were created by the Upper Midwest Environmental Science Center (UMESC). Portions of the LiDAR digital elevation model displayed in the map reflect hydro-flattened data based on water elevations at the time of data collection, so not all topographical information is necessarily visible. General drainage patterns were derived from LiDAR information, though not at a fine enough scale to represent exceptionally accurate water flow conditions within the Marsh. Flowlines derived from coarser elevation data from the National Elevation Dataset (NED) are provided in the Water Resource Monitoring section and offer a better representation of the hydrology patterns through the Refuge.

Elevation around HNWR is generally even and low, ranging from 850 feet above mean sea level (MSL) in the Marsh area and some portions of the South Branch Rock River, to 1168 feet above MSL in areas directly east of HNWR's acquisition boundary. This ridge borders the Marsh, rising somewhat abruptly to approximately 250 feet above the lowlands and marking the western portion of the Niagara escarpment (USFWS 2007).

Topography west of the Marsh is more gradual and is marked with several potholes and shallow lakes. Other low areas within the RHI are found in the channels of tributaries to the Rock River. The geography of the rest of the Rock River Valley is mostly low and even, with some subtle hills sloping approximately 3 degrees and rising no more than 100 feet above the valley in the interior of the Basin (Schwarz, 1903). The landscape rises gradually to the east in Washington County, where glacial meltwater formed the Mid-Kettle Moraine, which is a network of rolling hills extending from Door County, southwest to Whitewater, WI.

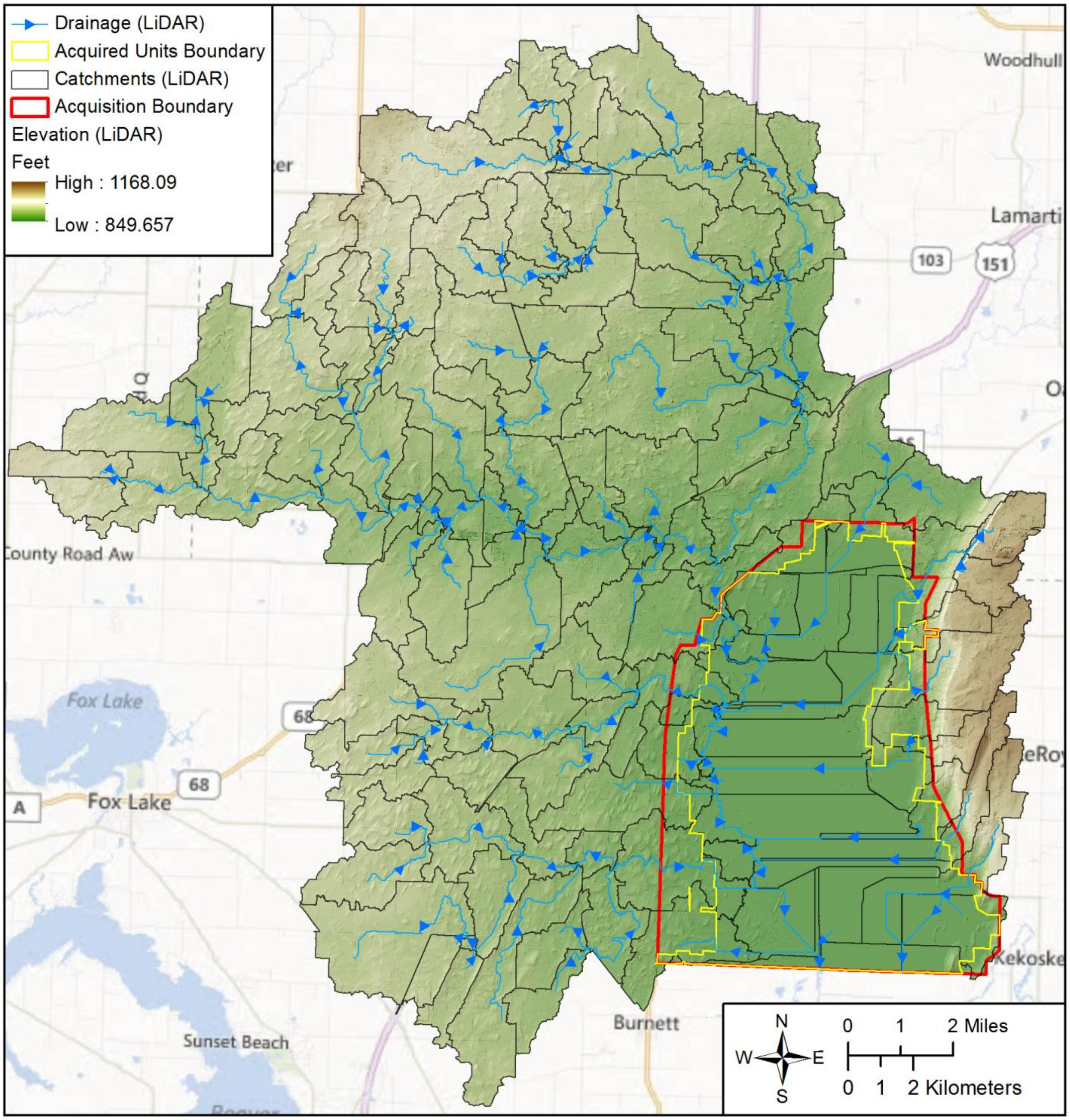


Figure 4 LiDAR data for HNWR's upstream RHI (created by UMESC)

Geology

Extensive information related to the Refuge's geologic history is provided in the CCP (USFWS 2007), which describes a landscape largely influenced by the Wisconsin Glacial Episode. This event occurred roughly 85,000 to 11,000 years ago and created moraines, one of which impounded glacial meltwater to create a lake where the Marsh is today. Water levels of this ancient lake continued to rise, but began dropping after the earthen dam was breached. This continued as the Rock River's channel evolved, but eventually it scoured down to a resistant Galena-Dolomite layer near Hustisford Rapids south of Horicon, which naturally impounded the waters of the Rock River once again. Fine sediments subsequently filled the Horicon Lake Basin and the landscape evolved into the marsh it is today.

Geologic features scattered in and around the Marsh are remnants from this glacial past. Other moraines, drumlin fields (areas of elongated hills or ridges of glacial drift or till), and glacial erratics (boulders with differing sizes or compositions of native rock because they were redeposited with glacial meltwater) are present across the landscape (USFWS 2007).

The Cambrian-Ordovician is the major aquifer system of HNWR and extends throughout the western ¾ of the boundary. This system consists of a sandstone/dolomite aquifer, as well as two sandstone aquifers divided by confining units. Unlike most other areas of the state, the east central portion Wisconsin's aquifer is characterized by calcium sodium sulfate chloride hydrochemical properties, possibly because of the migration of brines originating from Pleistocene-aged evaporate deposits in Lake Michigan (USGS 1992). Industrial withdrawals from this aquifer, primarily in Chicago, Illinois and Milwaukee, Wisconsin, have impacted groundwater quantity, effects from which have been felt at HNWR (USGS 1992).

The Maquoketa confining unit, consisting of Ordovician shale and dolomite, extends over Refuge lands and overlies the Cambrian-Ordovician system. Other underlying units that make up this system include, in descending order, the St. Lawrence-Franconia Unit, the Ironton-Galesville Aquifer, the Eau Claire Confining Unit, and the Mount Simon Aquifer. This lowermost aquifer is roughly 100 feet thick and lies approximately 600-1,025 feet below the surface near Horicon Marsh, while bedrock underlying the Marsh is primarily within depths of 5-50 feet of the land surface (WDNR 2011a).

The Silurian-Devonian aquifer system, which overlies the Maquoketa layer, is located just beyond the Refuge's boundary (Figure 5) (USGS 1992). This system is mostly comprised of highly fractured limestone and dolomite and has a lower conductivity than the Cambrian-Ordovician system (USGS 1992).

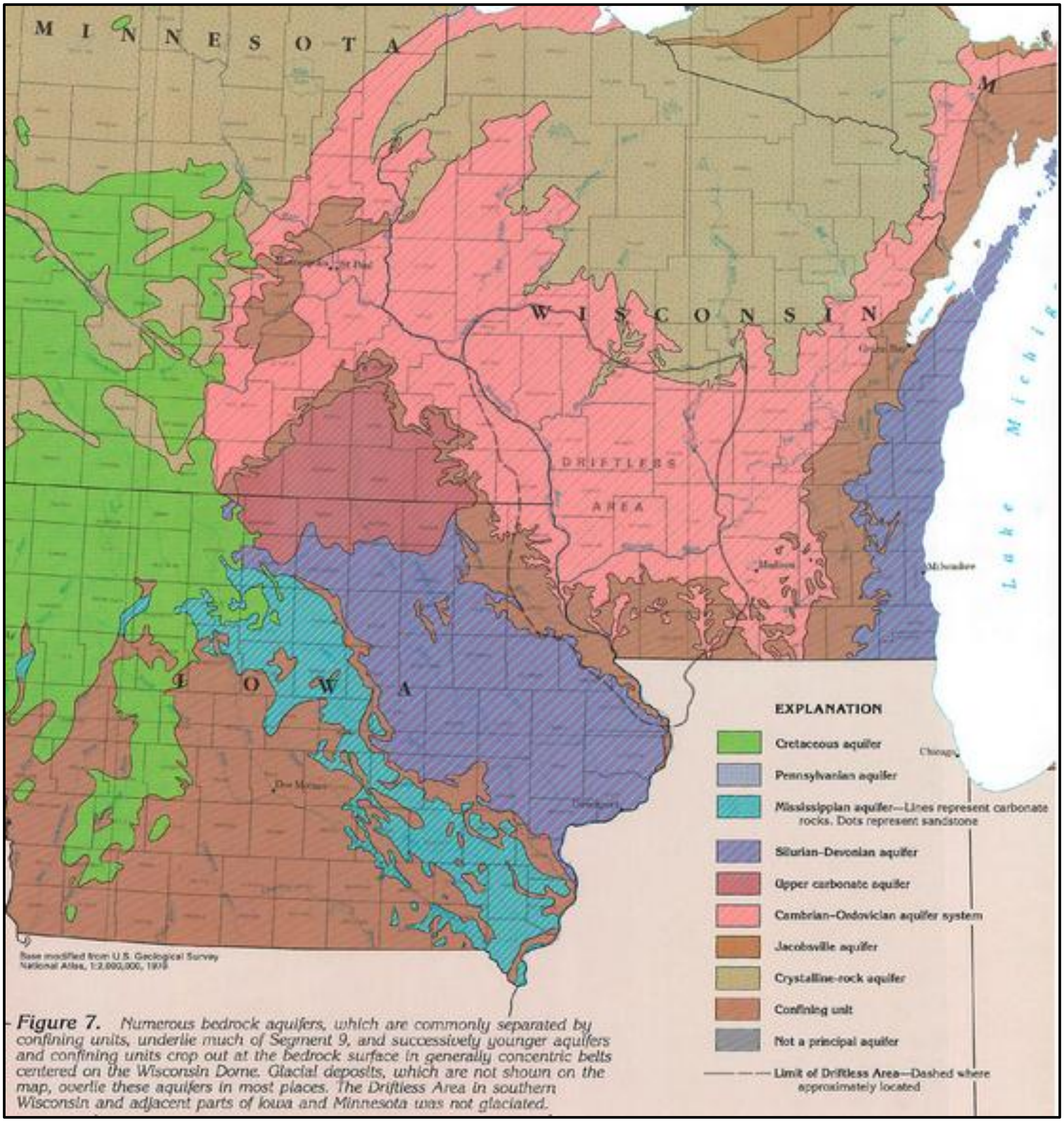


Figure 5 Major bedrock aquifers of the Midwest region (USGS 1992)

Soils

The NRCS provides detailed soils data, which is available at the county level through the Soil Survey Geography (SSURGO) Database (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). Official descriptions for soil types described below can be found through the NRCS site (https://soilseries.sc.egov.usda.gov/osdnamequery.asp)

HNWR has 42 soil series present, with various textures and slope conditions that make up approximately 83 soil type combinations (Figure 6).

The landscape of Horicon NWR is of glacial origins. The “Kettle Moraine” of the Wisconsin Glacial Episode runs down the east side of the state of Wisconsin and is responsible for shaping the drainage of the landscape and influencing soil development. The interior of the Refuge is a low depression, roughly 15,000 to 18,000 years old, a remnant from the last glacial action. This depression gave rise to poorly drained soils (Figure 7), primarily of Houghton series types (~56%). These series consists of very deep, very poorly drained soils formed in herbaceous organic materials more than 130 cm (51 inches) thick in depressions on lake plains, outwash plains, ground moraines, end moraines, and floodplains. Slopes generally range from 0 to less than 3 percent. The northern portion of this depression gave rise to Houghton mucky peat, which has a high organic matter content. The road bed running east and west may have had some influence on the soil development in this area, considering the abrupt boundary between this series and the Houghton muck, which makes up most of the Refuge area but is absent in this northern tip.

Surrounding the central depression of the Refuge are loamy soils such as the Pella and Palms series. Soils generally become coarser and more well-drained with distance up-gradient, and are primarily composed of glacial sediments in these areas. Native vegetation is primarily of Marsh grasses, sedges, reeds, buttonbrush, and cattails, with some water-tolerant trees near the margins of the bogs.

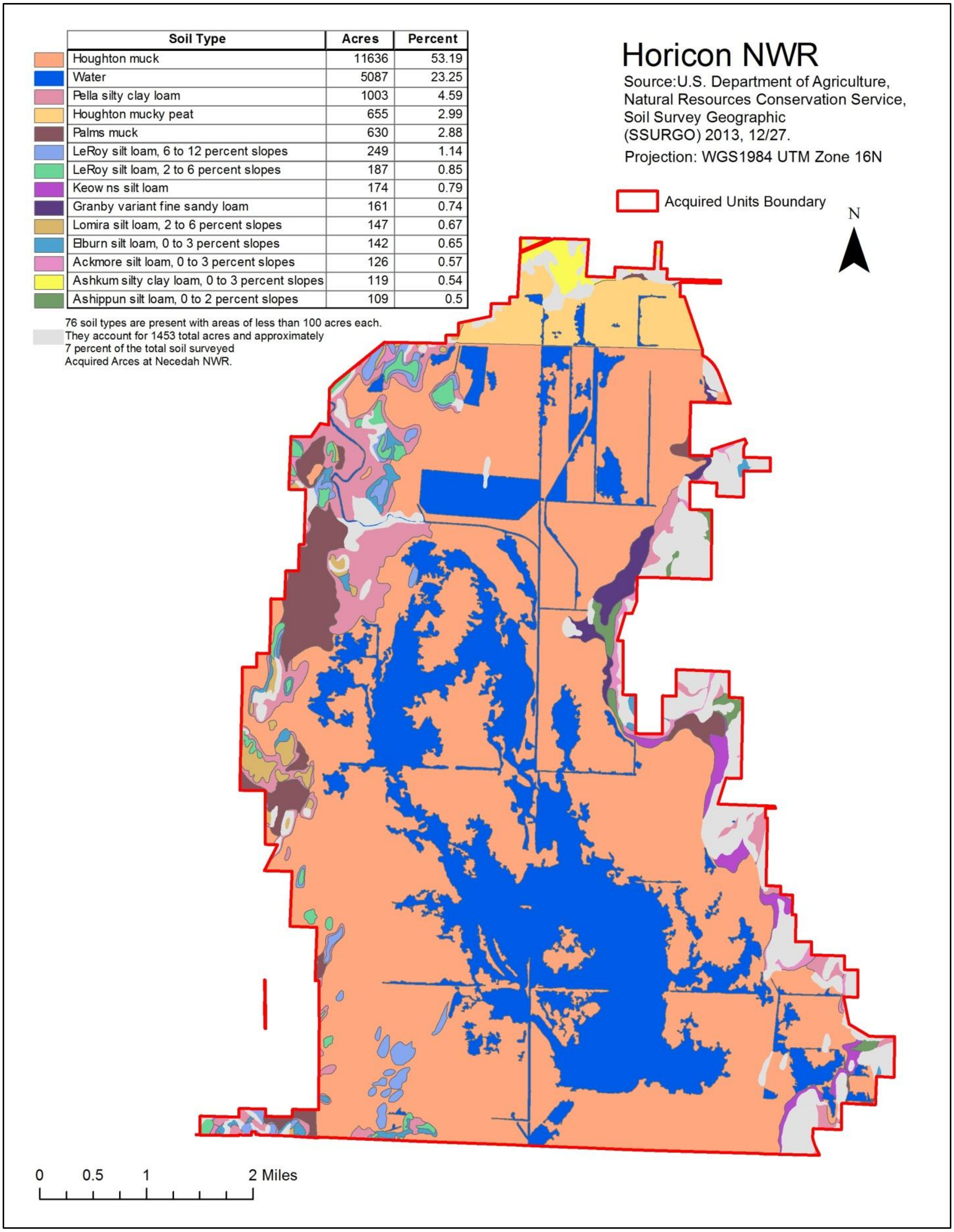


Figure 6 Soil types within HNWR's acquired units boundary (NRCS SSURGO database)

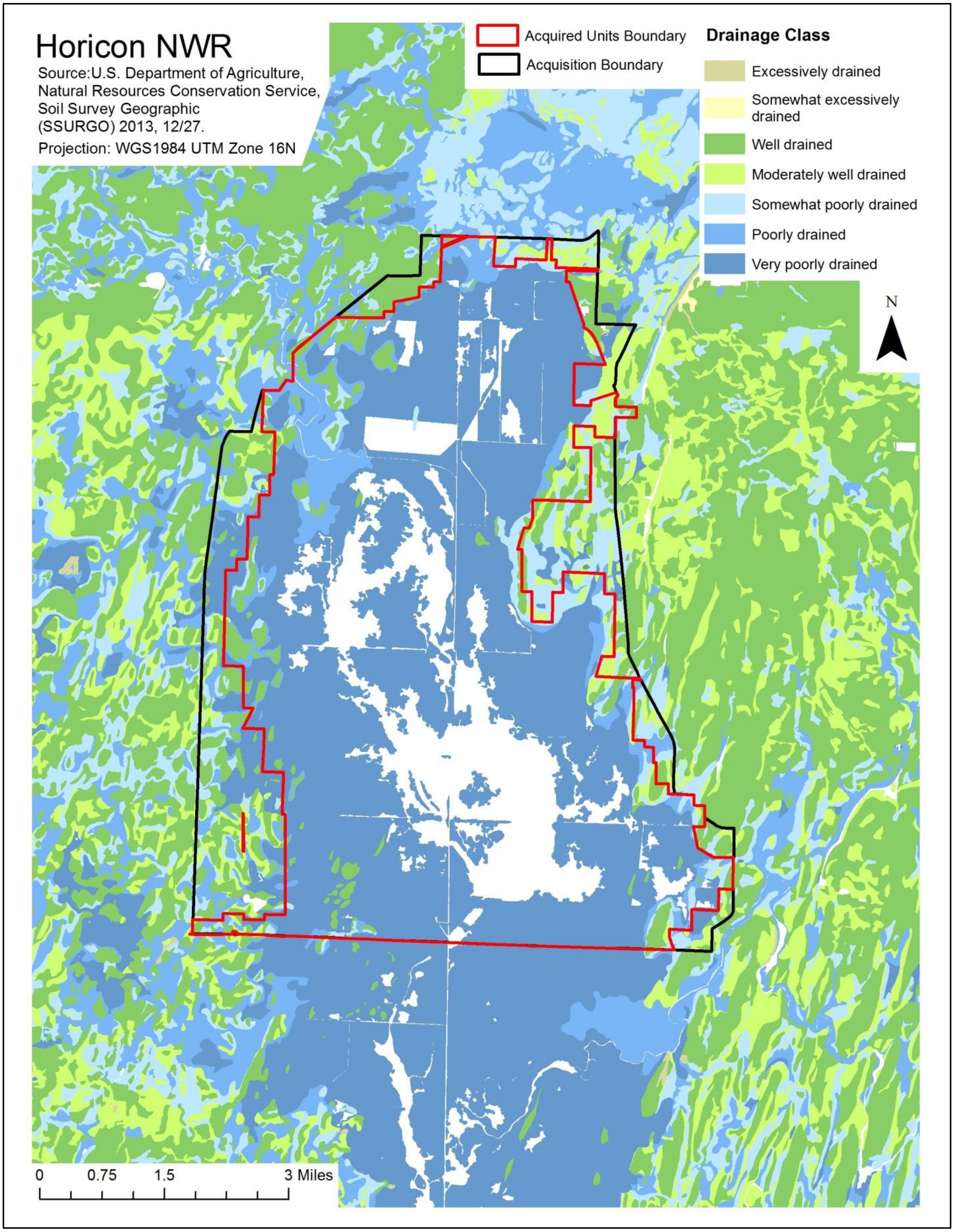


Figure 7 Soil drainage information relevant to HNWR (NRCS SSURGO Database)

Climate

Climate is defined within the WRIA as the typical precipitation and temperature conditions over years or decades. Climate trends and patterns will affect groundwater levels, river runoff, flooding regularity and flooding magnitude. The WRIA provides a broad overview and analysis of trends and patterns in precipitation and temperature for the region of the Refuge. This section describes HNWR's current climate, the HCDN Climate Network, PRISM interpolation of data relevant to HNWR, historic changes in climate, projected climatic changes, and hydrologic implications. There are also a number of models and studies that have evaluated current and anticipated trends in this part of the Midwest, which provide supplementary information and a more comprehensive analysis (e.g. Hayhoe et al. 2010, UCS 2009, WICCI 2011, Groisman et al. 2005, IPCC 2007, Kunkel et al. 2003, Lettenmaier et al. 2008).

Current Climatic Conditions

A general summary of HNWR's climate is provided in the CCP (USFWS 2007):

> *"…Horicon NWR's climate is typically continental, with cold winters and warm summers. The Refuge has an average annual temperature of 46 degrees Fahrenheit. July is the warmest month with an average temperature of 73 degrees Fahrenheit. The coldest month is January with an average temperature of 21 degrees Fahrenheit.*
>
> *Annual precipitation is about 28 inches, with approximately 20 inches of this occurring between April and September, and falling as rain. Snowfall averages 34 inches annually. Freezing usually begins around October 1 and lasts until May 12, making the length of the growing season an average of 142 days. Wind speeds average about 10.6 miles per hour throughout the year. March, April, and November have the highest wind speeds with an average of 12 miles per hour. Winds are normally from the south in the summer and the west in the winter (USFWS, 1995)."*

A regression equation based on precipitation and discharge data from 1971-2000 developed by the USGS estimated that roughly 60-69% of precipitation is lost to evapotranspiration in Fond du Lac and Dodge counties, and average evapotranspiration rates range between 51-60 cm/yr (Sanford and Selnick, 2012).

Average annual wind speeds at the Marsh, according to Wisconsin wind maps, were modeled to be 4.5-5 m/s at 30 meters above the surface, where hypothetical wind turbine hubs might exist. Areas immediately surrounding the Marsh show slightly higher wind speeds of 5-6m/s, and the southeastern portion of the state appears to have higher average annual wind speeds than other areas of Wisconsin (AWS Truepower, 2012). The recent construction of 86 wind turbines could have localized impacts beyond those directly felt by migratory birds and bats. For example, large wind farms can increase vertical mixing in the atmosphere, which often results in dryer, warmer surface air according to modelling by Baidya and Pacala (2004).

PRISM and USHCN Datasets

Weather information was obtained for HNWR (43°34'39.5"N 88°38'51.2"W) using the PRISM (Parameter-elevation Relationships on Independent Slopes Model) Data Explorer. *PRISM is an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, snowfall, degree days, and dew point (http://www.wcc.nrcs.usda.gov/climate/prism.html).* The PRISM interpolation method provides spatial climate information for the conterminous United States. This grid is created with temperature and precipitation datasets and accounts for potential variation with elevation. Other orographic, topographic, and atmospheric factors are also considered in this model. The PRISM information applicable to HNWR was used to compare data obtained from two stations from the U.S.

Historical Climatology Network ([USHCN]; Menne et al. 2012). The USHCN is a network of sites listed by the National Weather Service, which maintains standards in quality and continuity of data collection.

The closest USHCN stations are located at Fond du Lac, WI (NWS COOP ID: 472839), which is north of HNWR, and Watertown, WI (NWS COOP ID: 478919), south of the Refuge.

The average monthly temperatures at the PRISM site are very similar to those of the Fond du Lac and Watertown gages, though maximum and mean monthly temperatures at the Fond du Lac station are slightly lower than the PRISM parcel and Watertown sites in all months, particularly from January-March. For each station, temperatures peak in June-August, and are at their lowest in December-February, based on mean monthly temperatures (Figure 8). Average annual temperatures at these three sites range between 44.4-46.2 degrees F. While the average, minimum, and maximum temperatures for autumn are apparently consistent with trends since the 1950s (Figure 9), a decrease in maximum daily temperatures for autumn in this part of Wisconsin was identified by Kucharik et al. (2010).

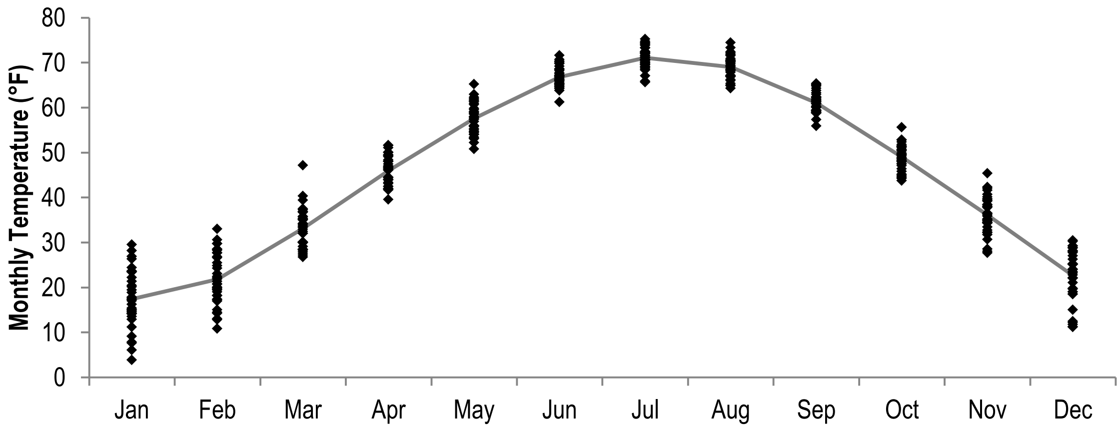


Figure 8 Monthly average mean temperatures (1975-2012) (http://prismmap.nacse.org/nn/index.phtml; x-coord: -88.647555 y-coord: 43.577653)

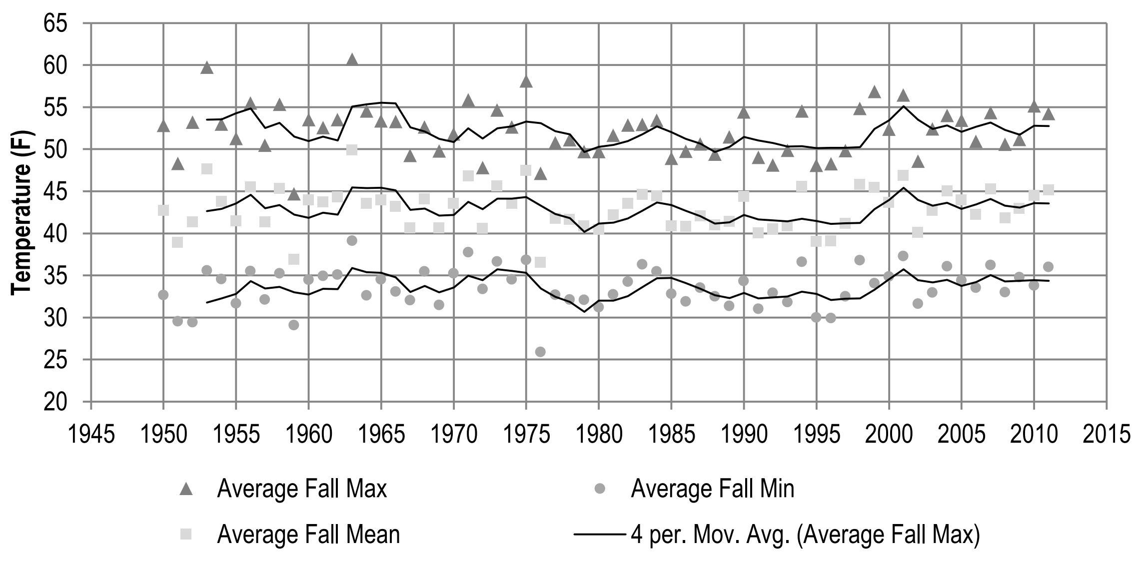


Figure 9 Oct-Nov temperature trends (1950-2011) (http://prismmap.nacse.org/nn/index.phtml; x-coord: -88.647555 y-coord: 43.577653)

Average monthly mean precipitation modeled at HNWR ranges from 1-4 inches, and the average monthly precipitation for the months of March-October is 3.29 inches according to the PRISM interpolation. The highest and lowest months for mean monthly rainfall at the PRISM parcel are consistent with patterns at the USHCN stations, with the peak occurring in June and July and the lowest average rainfall in December-February (Figure 10). Some extreme events have also occurred later in the summer and early fall, as indicated by the USHCDN records.

Other observations from the USHCN stations include a temporal increase in average annual precipitation since 1950, and this trend is statistically significant in the Watertown dataset. Because of the similar patterns between the interpolation of the PRISM parcel and USHCN information, this trend also likely applies to HNWR. Long-term records from the Fond du Lac and Watertown sites also show that 1955, 1958, 1962-1963, and 1976 were particularly dry years, based on average annual precipitation. Wetter than normal years in the area included 1960, 1965, 1978, 1985, 1990, 2004, 2006, 2008, and 2010.

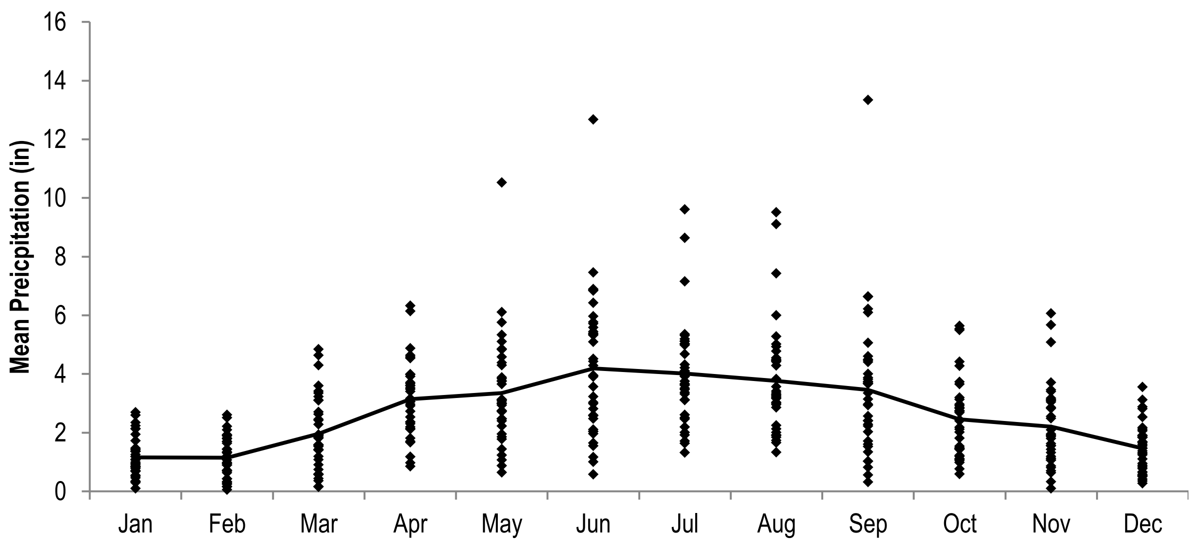


Figure 10 Mean monthly precipitation (1975-2012) (http://prismmap.nacse.org/nn/index.phtml; x-coord: -88.647555 y-coord: 43.577653)

Hydro-Climatic Data Network (HCDN)

In our assessment of the patterns in surface water quantity, we compared several of the sites qualitatively to a reference hydrograph obtained from the Hydro-Climatic Data Network (HCDN). 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). This network attempts to provide a look at hydrologic conditions without the confounding factors of direct water manipulation and land use changes. Peak discharge, average annual discharge, and annual monthly discharge trends were compared for this analysis.

The Rock River at Afton, WI (USGS 05430500) is one of two gages of the HCDN monitoring network within the Marsh's HUC8 (07090001) and provides the most relevant comparison of surface water trends, though it is located a significant distance away, southwest of the Refuge close to the Wisconsin border. While HCDN sites are intended to represent relatively undisturbed basins, discharge at this gage site is altered to some degree, since it receives managed flow from Horicon Marsh as well as Lake Sinnissippi. The magnitude of impact from these controls depend on the proportion of flow also received from unregulated waters. If flow in this portion of the Rock River receives an influential amount of water from Horicon Marsh, discharges at this gage would be controlled in part by management of Horicon Marsh's water resources. For example, Horicon Marsh was regulated as a deep water lake from 1846-1869 to power a sawmill, and downstream releases today are significantly different from amounts released during that time period. This particular alteration has no impact on the HCDN records, however, because monitoring at this gage began after the dam was removed and Horicon Marsh was reestablished.

Data from this gage demonstrates a statistically significant increase in average annual discharge over the period of record, and the increase is most apparent beginning in the early '70s (Figure 11). However, the increasing trend in discharge over recent years since the '70s is not statistically significant, which suggests the Rock River will likely level off at these higher flows rather than sustaining this increasing trend. The rise in water quantity at this gauge has been greatest in the months of May-July, based on monthly averages for the entire period of record. Average monthly discharges have increased to some degree in every month, however. Given that the magnitudes of annual peak flows have not increased significantly over time at this location, the increase in annual discharge in the Rock River may be attributed to wetter conditions overall rather than higher magnitude events.

Assuming this gage represents a relatively natural flow regime, this increase in average annual discharge may be attributed to changes in hydrology and climate in addition to any more-direct influences, such as flow regulation or land and water use changes. Thus, any identified trends noted in gages closer to the Refuge and farther upstream in this HUC could be caused by anthropogenic influences in combination with regional climate changes. Patterns at this gage support the finding that this part of Wisconsin is experiencing more rainfall than historic patterns, and the responsiveness of Rock River discharges to precipitation events suggests that HNWR waters are highly influenced by precipitation inputs, and do not demonstrate significant stability that may come with higher proportions of baseflow and groundwater inputs.

HNWR waters will need to be managed in such a way that adapts to these higher flows, especially during months when migratory shorebirds require drawn down mudflats, and in the summer when water volumes have increased most dramatically from historic levels based on data from the Afton, WI gage. With these higher flows have come higher rates of sediment, nutrient, and pollutant loading, which continue to threaten Refuge waters and wildlife. The Marsh bottom is likely to increase in elevation as a result of higher sediment loading associated with higher flows of the Rock River, especially in the management units in the northern section of the Marsh, and higher occurrence of backflows at the Main WCS may result from an increase in precipitation inputs to the watershed as a whole, and consequently greater impoundment influence of Lake Sinissippi and WDNR waters. Whether or not climate model predictions are accurate, simply the continuation of current conditions will encourage a yet flashier system because of this sediment infilling. HNWR will need to implement additional techniques to help buffer high magnitude storm events, which will possibly increase in frequency, while the basin's ability to absorb high fluxes diminishes with higher sedimentation rates.

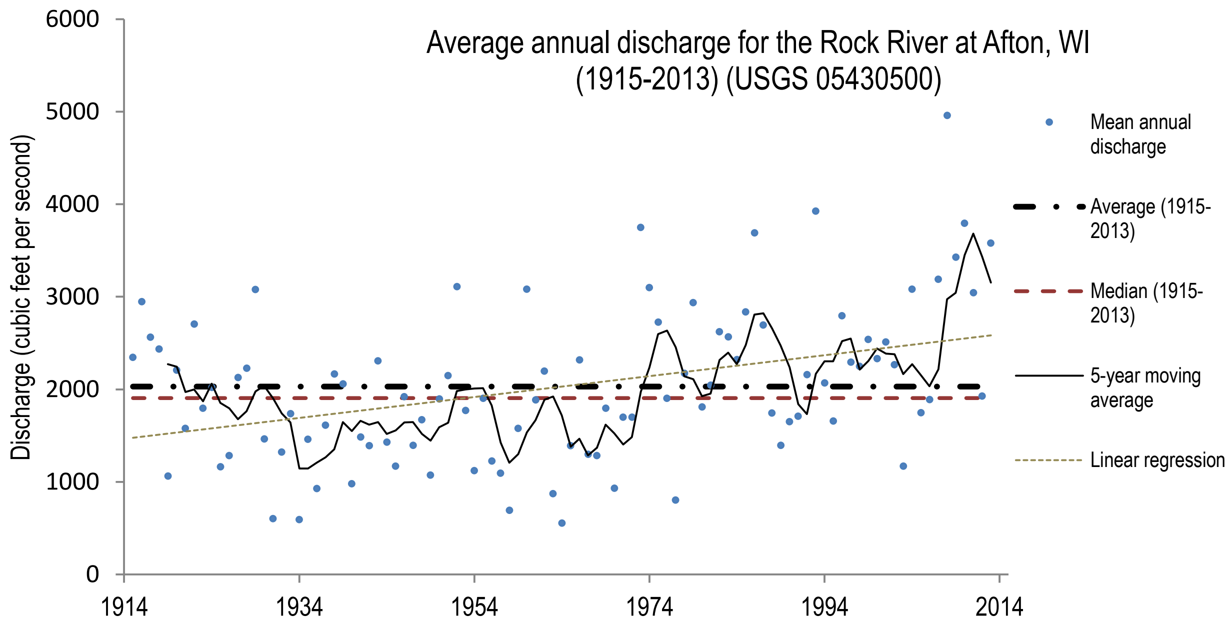


Figure 11 Average annual discharge for the Rock River at Afton, WI (1915-2013) (USGS 05430500); part of the HCDN

Historic Climate Changes in Wisconsin

Changes in climate across the state from 1950-2006 were reported by Kucharik et al. (2010). This portion of Wisconsin seems to have warmed, as indicated by higher daily maximum and average temperatures in winter and spring, and cold winter nights occurring less frequently. However, daily maximum and average temperatures have been cooler in summer and autumn seasons in Dodge and Fond du Lac counties, while daily minimum temperatures near HNWR have become warmer in all seasons. No trend is apparent on a seasonal scale for fall based on the PRISM interpolation information.

The average first date of the first fall freeze is approximately 4-6 days later near HNWR, and the last spring freeze occurs roughly 3-9 days earlier than it did in 1950. Since the area is experiencing a longer growing season, evapotranspiration rates from agricultural lands have likely increased and altered the basin’s water budget.

The majority of Wisconsin is wetter than it once was, as indicated by a 10% increase in annual precipitation from 1950-2006, most of which occurred in the fall. Fond du Lac and Dodge counties have increased in annual precipitation roughly by 50-100mm over the latter half of the 20th century (Kucharik et al., 2010). The frequency and magnitude of precipitation events have also been increasing since the 1950s.

Since temperatures have generally decreased in summer and fall while precipitation has increased, larger volumes of water are likely present on the surface or subsurface in summer and fall than there historically has been, when there was less rainfall and evapotranspiration rates may have been higher.

General trends in historic climate data can also be described using the Palmer Drought Severity Index (PDSI), which is calculated using precipitation and temperature data to evaluate severity and frequency of abnormally dry and wet periods (Palmer et al. 1965). Long-term PDSI data provided by the National Climatic Data Center seem to support the idea that conditions are wetter overall. According to the data, at least 12 severe to extreme droughts occurred between 1930 and 1977 (US NCDC, 2014). No extremely dry spells and few severe droughts have occurred since. In contrast, very moist spells were uncommon between 1930-1977, but have increased in frequency since, with several extreme events in 1986-1987 and 1993. Wet-dry cycles seem to have recently become more erratic but of lower magnitude and duration (Figure 12).

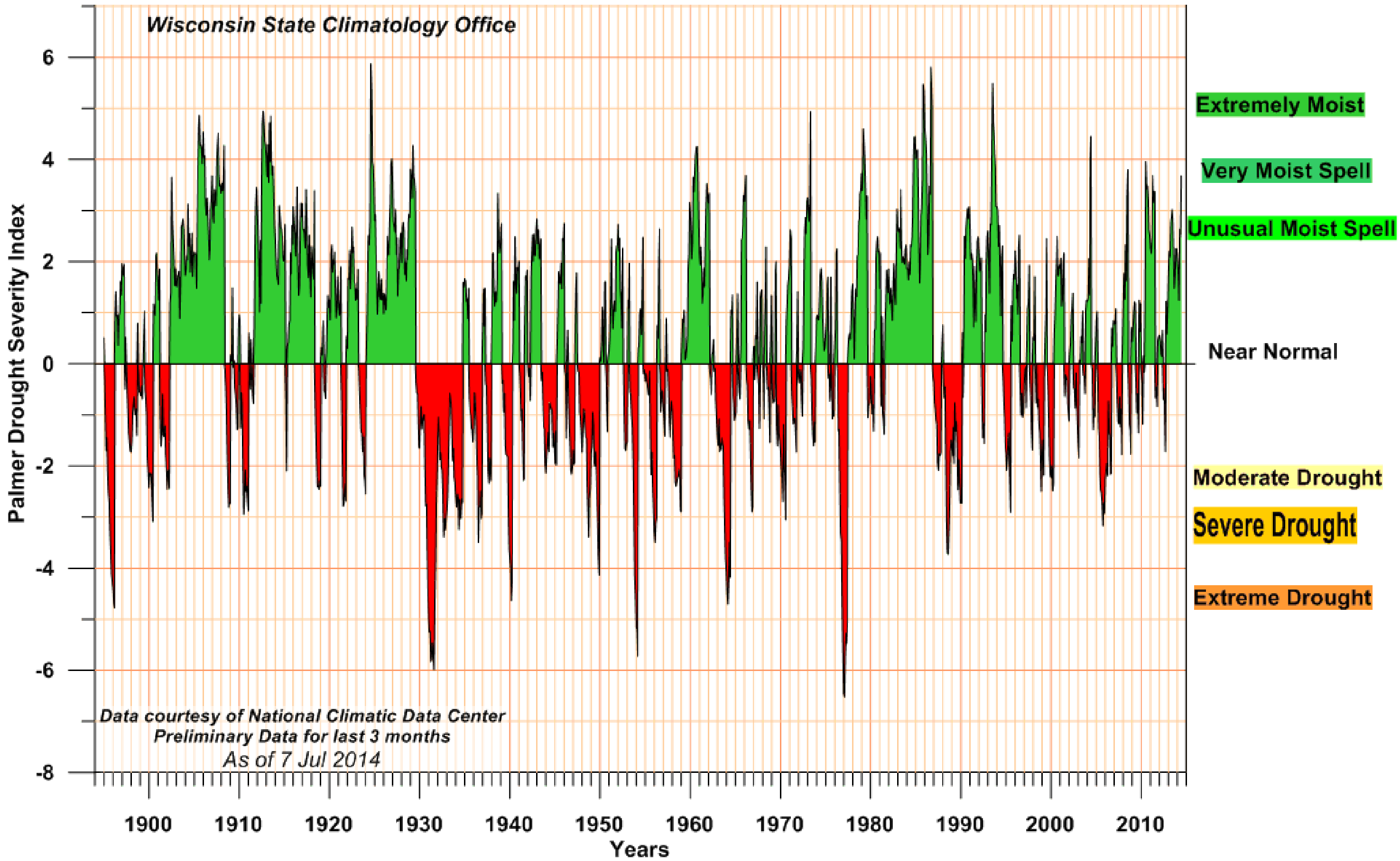


Figure 12 NCDC Palmer Drought Severity Index trends (1895-2014) for east central Wisconsin (Div 4706) (USNCDC 2014; http://www.aos.wisc.edu/~sco/clim-watch/graphics/pdsi-ts-06-l.gif)

Projected Changes in Climate

Climate models have many inherent limitations, mostly related to incomplete understandings of the various processes and feedbacks at play and the inability to predict future human inputs of greenhouse gases because of changes in technology, policy, and population.

According to predictions for Wisconsin, warming trends may continue. Significant warming of seasonal average temperatures is expected by 2055, and models predict the change will be the greatest during winter months (WICCI 2011). Dodge and Fond du Lac counties could experience an increase in average winter temperatures by 7.5-8 degrees Fahrenheit, an increase of 6 degrees Fahrenheit in autumn and spring, and 5 degrees Fahrenheit in summer. Particularly cold nights are projected to continue decreasing in frequency, while especially hot days will likely occur much more often. This prediction conflicts with the observed decrease in maximum summer and autumn temperatures reported by Kucharik et al. (2010) over the past several decades, and the lack of trend identified from the PRISM data.

Given the limitations associated with climate modelling, the most recent observed data [i.e., that which was reported by Kucharik et al. (2010) and observed in the PRISM dataset] offer the soundest evidence to base expectations for the immediate future, and provide the best guidelines for water management planning. Based on Kucharik et al.'s (2010) findings, maximum and mean daily temperatures of summer and fall could either continue to decline slightly, or maintain levels slightly lower than historic patterns. Similarly, daily maximum and average temperatures in winter and spring, as well as average minimum temperatures in all seasons, could either continue to increase or maintain elevated levels from past conditions.

While precipitation-related predictions are less certain than those for temperatures, various climate models agree that precipitation will increase across the entire state, especially in winter, and a higher proportion of future winter precipitation events will fall as rain (WICCI 2011). Fond du Lac and Dodge counties may experience an increase in winter precipitation by approximately 0.5 inches by 2055 compared to precipitation rates of 1980. In addition, Wisconsin is expected to experience more frequent high-magnitude precipitation events, as well as increased risk of drought across Wisconsin (WICCI 2011).

Though evapotranspiration rates could increase due to a longer growing season and increased soil exposure from recent land clearing in the watershed, runoff volumes will not necessarily decline or stabilize. Instead, water flow will likely become more difficult to manage, with drier periods between extreme storm events which could occur more often and transport more water and sediment. Though there have not recently been any "extreme" droughts based in the PSDI information (Figure 12 NCDC Palmer Drought Severity Index trends (1895-2014) for east central Wisconsin), the milder dry spells experienced by the Refuge have still been enough to adversely affect resources and activities. For example, the drought of 2005 lowered water levels enough to cancel the Refuge's youth duck hunt (USFWS, 2007).

Heavy rainfall over dry, drought-stricken soils during summer months, while more favorable than rainfall over already-waterlogged soils, does not necessarily eliminate runoff risks and often causes more erratic surface water flow. Soils can only absorb water at a specific rate, and when the precipitation rate exceeds that threshold, runoff occurs, causing a smaller fraction of water infiltrated into the subsurface than less-intense precipitation conditions may have allowed.

If the increasing trend in annual precipitation either persists or levels off in the immediate future, higher water inputs would not necessarily equate to additional water volumes or water depths within the Marsh Basin. Higher sediment loading rates could reduce the Marsh's water holding capacity, further elevating flood risks and creating a flashier system. The result could be a changed landscape, with displaced areas of seasonal or permanent flood waters, potentially extending outside HNWR's boundaries.

3. Water Resource Features

Water Management Units

HNWR has nearly 16,200 acres of managed wetlands in 19 different management pools (Table 5). Water level management of these units are carefully planned every year, and pool elevation proposals are included as part of the annual Marsh and water management plan. These impoundments are typically frozen December-April every year (USFWS 2007), but specific details about how each impoundment is managed can be found in the most recent Water Management Plan for Horicon NWR (USFWS 2015).

HNWR's main pool is significantly larger than the complexes to the north and east of it, spanning roughly 11,300 acres. According to the CCP, Main Pool's spillway elevation is 858 above MSL, with a drawdown elevation of 851 feet above MSL, however this information may be outdated. Bathymetry surveys should be conducted to measure HNWR's current management capacities and pool bottom elevations. Drawdowns occur every few years for the purpose of controlling cattail and encouraging hardstem bulrush growth; the most recent drawdown occurred in 2012 (USFWS 2014). Portions of the Pool have also had ditch plugs installed with the intent of reestablishing sheet flow and preventing ground and surface water flow from being transported down the ditches (USFWS 2007).

Smaller impoundments north of the Main Pool, such as Potato Lake, Leuhring Lake, Redhead Lake, and Teal Pool were developed in part to manage excessive erosion and sedimentation caused by poor agricultural practices upstream, particularly to the east of the Marsh (USFWS 1984). These pool levels are raised occasionally to buffer sediment inputs to the Main Pool. The CCP provides some details about the Refuge's past management practices of pools as well:

Mgmt. Unit	Acres
Main Pool	11313.29
Teal	971.25
Radke	748.69
Redhead	745.72
Luehring	482.4
Frankfurth	433.08
I-9	424.05
Potato	278.73
Stoney	223.41
I-3	123.09
I-8	106.45
I-2	83.27
I-5	81.52
I-4	67.83
I-10	50.67
Little Stoney	31.76
I-7	16.62
Luebke	14.03
Babbit	1.02

Table 5 HNWR's management units and acreage

"Annually, manage water impoundments as a complex of basins to provide wetland diversity and improve water quality for maximum benefits to migrating and breeding birds. Management will be within the capabilities of the wetland system as a whole and individual impoundments will be drawn down on a 3 to 10-year rotation. Water level manipulation allows managers to simulate different stages of the natural flood/drought cycle at the same time in different impoundments. This increases the diversity of habitat types and food resources in the wetland complex that are available to migrating and nesting birds. The emphasis is on semi-permanent wetlands, as these wetlands can be the most productive type. Management can increase this diversity by varying the water regime in each impoundment. The outcome will be interspersion of cover and openings which provide habitat."

One of HNWR's management objectives outlined in the CCP was, by 2015, to reestablish a more natural flow regime, mitigate sediment and contaminant issues, and reduce cattail growth by 20% from 2005. However, no data exists to measure the success of meeting these goals, and the Refuge is restricted by downstream dam management, which impedes their ability to reduce cattail and emulate a more natural hydrology. Currently, HNWR is coordinating with DNR on a conceptual planning model that will hopefully address these issues.

Additional water impoundment management recommendations were addressed in the CCP to maximize wetland diversity and water quality, particularly for migratory birds, while collaborating with WDNR and Lake Sinissippi water control activities. Water level management operations for the Marsh are constrained, however, because of downstream activities. The southern third of the Marsh, regulated by the WDNR, is limited because the dam managing Lake Sinissippi water levels is only about six inches lower than the WCS impounding waters of HMSWA. When water levels are high in Lake Sinissippi, the Rock River can be impounded many miles upstream, leaving WDNR with limited drawdown and cattail management abilities, which has left nearly the entire area south of the federally-regulated portion of the Marsh overrun with dense non-native cattail. Water levels downstream of Dike Road also cannot be raised higher than current maximum elevations because private lands would be flooded.

HNWR must account for these management constraints associated with the lower portion of the Marsh. Drawdowns from HNWR must be gradual and well-timed, unless properly coordinated, to avoid excessive discharges to WDNR's portion of the Marsh, which has already experienced excessive infilling and may have extensive areas of unconsolidated substrate that could easily be transported. At times, Refuge water resources have been directly affected by downstream management as well, with the State-regulated water levels rising higher than Refuge water elevations in Main Pool, causing backflow at the main WCS on Dike Road. This effect may occur more frequently in the future if average annual precipitation continues to increase, or if Lake Sinissippi management changes in response to sediment infilling problems by raising outlet elevations.

Water Control Structures

HNWR currently has 36 WCSs in place, including 31 stop log structures, 3 screw gates, 1 multifaceted structure with 2 stoplogs and 2electric slide gates, and 1 concrete spillway (Table 1, Figure 13 and Figure 14).

Id	Type	Impoundment	Status	Year
1	Stop log - Cement Full Round	I-2/I-3	In place	Unknown
2	Stop log - Cement Full Round	I-3/Stoney	In place	Unknown
3	Stop log -Single Concrete Half	I-4/I-3	In place	2006
4	Stop log - Full Round Riser	I-5/I-4	In place	Unknown
5	Stop log - Full Round Riser	Radke/Teal	In place	2014
6	Stop log - Half Round Riser	Radke/Redhead	In place	1999
7	Stop log - Cement Box	Radke/Redhead	In place	1999
8	Stop log - Half Round Riser	Babbitt/Teal	In place	1997
9	Stop log - Double Half Round Riser	Teal/Luehring	In place	Unknown
10	Stop log -Double Concrete Half	Redhead/MP	In place	2006
11	Stop log -Double Concrete Half	Teal/Main Pool	In place	2006
12	Screw gate - Pump Station - 3-way	Radke/Teal/Rdhd	In place	1999
13	Screw gate - Pump Station - 5-way	MP/T/Rdhd/L/P	In place	1975?
14	Stop log - Full Round Riser	Potato/MainPool	In place	Unknown
15	Stop log - Half Round Riser	Stoney/MainPool	In place	2010
16	Stop log - Half Round Riser	Redhead/Stoney	In place	2009
17	Stop log -Single Concrete Half	Luehring/MP	In place	2006
18	Screw gate - Pump Station - 2-way	Frnkfrth/MP	Inoperable pump	1993
19	Stop log - Full Round Riser	Frnkfrth/MP	In place	1993
20	Stop log - Full Round Riser	I-7/Main Pool	In place	Unknown
21	Stop log -Single Concrete Half	I-8/Main Pool	In place	2006
22	Stop log - Half Round Riser	I-8/I-9	In place	Unknown
23	Stop log -Single Concrete Half	I-9/Main Pool	In place	2006
24	Stop log - Full Round Riser	I-10/I-9	In place	Unknown
25	Stop log - Half Round Riser	Luebke/I-9	In place	2008
26	Stop log - Half Round Riser	Radke/Teal	In place	1999
27	Stop log - Half Round Concrete	salmnder/L Stny	In place	Unknown
28	Stop log - Full Round Mini	Lt Stny/Stoney	In place	2006
29	Stop log - Full Round Mini	I-5/Redhead	In place	2009
30	Stop log - Half Round Riser	14 Bay	In place	2009
31	Stop log - Half Round Riser	14 Bay	In place	2009
32	Stop log - Half Round Riser	14 Bay	In place	2009
33	Stop log - Half Round Riser	14 Bay W	In place	2009
34	Stop log - Half Round Riser	14 Bay E	In place	2009
35	2 Elec Slide Gates - 2 bays of stop logs	Main Dam	In place	2006
36	Spillway-Concrete 200 Ft	MP/DNR	In place	Unknown

Table 6 Water control structures found at HNWR

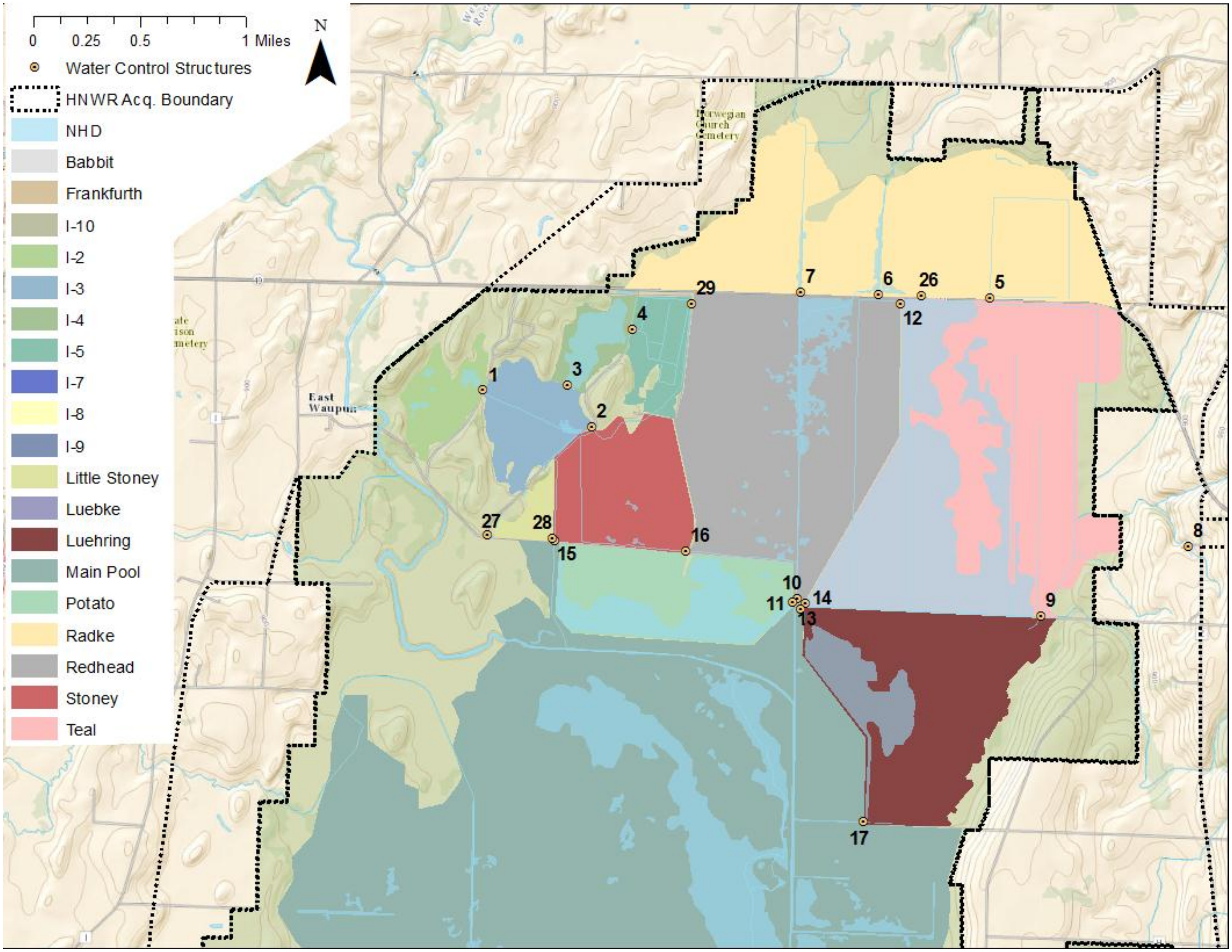


Figure 13 Water Control Structures found in the northern portion of HNWR

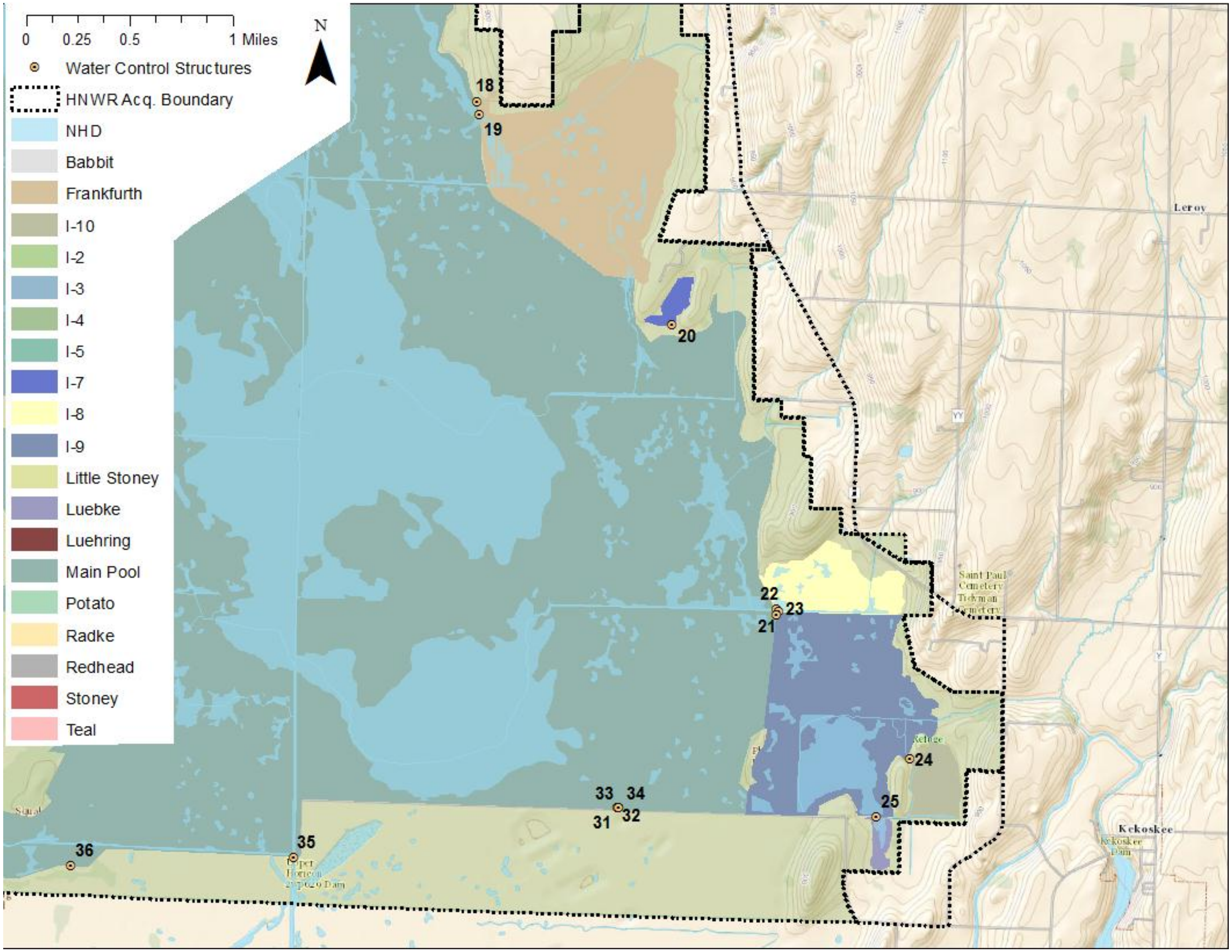


Figure 14 Water Control Structures found in the southern portion of HNWR

National Wetland 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.

The National Wetland Inventory classified roughly 71% of the Refuge's impounded acres as Freshwater Emergent Wetland. This category characterizes some portion of all of the management units, and makes up over 80% of the Frankfurth, I-10, I-3, I-8, Luehring, Potato, Radke, Redhead, Stoney, and Teal Units. Approximately 23% of the Refuge is categorized as "lake," with the greatest proportion in the I-5 Unit and the highest acreage in Main Pool. Freshwater Forested/Shrub wetland habitat also exists in several of the pools, particularly the I-7 impoundment. Less than 300 acres (2%) is classified by the NWI as "freshwater pond," which makes up a portion of all the units except for the Potato, Luebke, and I-5 impoundments. Some riverine habitat exists in Main Pool (170 acres, 1.6% of the Main Pool total acreage), and about 1% of the Refuge impounded acreage is classified as non-wetland. Most of the Marsh is considered a palustrine system with a dominance of emergent vegetation and floating vascular aquatic beds.

Additional tables and maps detailing NWI data, including the Cowardin classification (1979) codes of HNWR's wetland units, are found in Appendix A . Details associated with these codes can be found with the USFWS Wetland Code Interpreter (http://137.227.242.85/Data/interpreters/wetlands.aspx), and further explanation is provided in Appendix A

National Hydrography Dataset Flowlines (streams, creeks, and ditches)

The National Hydrography Dataset (NHD) is a vector geospatial dataset including information about the nation's lakes, ponds, rivers, streams, and other water features, part of the USGS's National Map. Within the acquired units boundary, the flowpaths identified by the NHD can be broken down based on type. The majority of the flowpaths were considered artificial paths or stream/river features. A map and table of relevant NHD information is provided in Appendix A , however a more accurate representation of Refuge flow is presented in Figure 17, with data derived from the National Elevation Dataset.

The NHD provides an approximate representation of general water flow 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. NHD data for HNWR appears to have several such inconsistencies, the most notable of which is the lack of a feature to represent flow through the 14-Bay stop log WCS, which receives a smaller fraction of flow than the Main WCS to the west.

4. Water Resource Monitoring

The WRIA identified historical and ongoing water resource related monitoring on or near the Refuge. Ground and surface water stations were considered relevant if located within the Refuge's HUC-10 and/or drainage areas adjacent to Refuge property. Relevant sites were evaluated for applicability based on location, period of record, extent of data, sampling parameters, trends, and date of monitoring. Water resource datasets collected on the Refuge 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. For example, the staff gages installed at multiple locations across the Refuge are a way to estimate water level and/or volume within the units and thus are considered to be a form of water quantity monitoring.

Water quality can include laboratory chemical analysis, deployed sensors or biotic sampling such as fish assemblages or invertebrate sampling. Biotic sampling is often used as an indicator of biological integrity, which is a measure of stream purpose attainment by state natural resources management organizations.

Potential water quality threats may be identified by comparing monitoring data with recommended standards. The EPA developed technical guidance manuals and nutrient criteria for various types of waters specific to different ecoregions. Those developed for rivers/streams and lakes/reservoirs for ecoregion VII are summarized below (USEPA 2000; Table 7 and Table 8). In addition, water quality standards and the associated measurement methodology can be found in Chapter 102 of the Wisconsin Administrative Code (http://docs.legis.wi.gov/code/admin_code/nr/100/102.pdf).

Total phosphorus (ug/L)	33
Total nitrogen (mg/L)	0.54
Chlorophyll a (µg/L) (Fluorometric method)	1.54
Chlorophyll a (µg/L) (Spectrophotometric method)	3.5
Turbidity (NTU)	1.7
Turbidity (FTU)	2.32

Table 7 EPA Recommended criteria for rivers and streams in ecoregion VII (level III) (EPA, 2000)

Total phosphorus (µg/L)	14.75
Total nitrogen (mg/L)	0.66 reported (0.57 calculated)
Chlorophyll a (µg/L) (Fluorometric method)	2.63
Secchi depth (meters)	3.33

Table 8 EPA Recommended criteria for lakes and reservoirs in ecoregion VII (level III) (EPA, 2000)

Several resources offer water quality and quantity datasets relevant to Refuge waters, and were utilized in compiling data for the WRIA. For example:

- 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.

- WDNR hosts the Surface Water Integrated Monitoring System (SWIMS), which provides water quality data for the state (http://dnr.wi.gov/topic/surfacewater/swims/). A functional water data map (http://dnrmaps.wi.gov/sl/?Viewer=SWDV) is also available and includes layers such as monitoring sites, satellite lake clarity monitoring data, dam and floodplain locations, impairments, and other water quality and water quantity information.

- Water quality and quantity data for active and inactive monitoring sites can also be accessed from the USGS National Water Information System (NWIS) database (http://www.waterqualitydata.us/).

- The Citizen-Based Water Monitoring Network was created as part of the Wisconsin Lakes Partnership, and a website is available for water quality reporting by volunteers of the Citizen Lake Monitoring Network. Data from these monitoring reports are easily available to the public (http://dnr.wi.gov/lakes/clmn/), and many of these datasets are included in SWIMS.

- Similarly, the Water Action Volunteers program provides additional data downloads of water quality information provided by volunteers throughout the state (http://watermonitoring.uwex.edu/wav/monitoring/database.html). The Upper Rock Drainage Basin (HUC 7090001) is included in this network.

- Data from several active water quality and quantity monitoring locations maintained by the USFWS is stored in the regional water monitoring WISKI database.

Water Monitoring Stations and Sampling Sites

The WRIA identified 10 monitoring sites considered applicable to the Refuge's water resources including 9 surface water monitoring sites and 1 groundwater monitoring station (see Appendix A Water Resource Information).

A list of 158 identified inactive sites that are relevant, but not necessarily directly applicable to the resources of concern, was also created and will be loaded into the ECOS WRIA application (https://ecos.fws.gov/wria).

Data from six (two active) USGS gages exist near the Refuge boundary and are relevant to HNWR's water resources. Four of these are north of the Marsh; three on the West Branch Rock River, and one (active) on the South Branch Rock River at Waupun. Another (active) is located on the Rock River at Horicon (Figure 15). The sixth station is located on the East Branch Rock River near Mayville and is less relevant to Refuge resources, but provides useful information for the Marsh as a whole. The discontinued USGS gage on the West branch of the Rock River near Waupun has been reestablished by the USFWS and currently collects continuous stage and water quality parameter data.

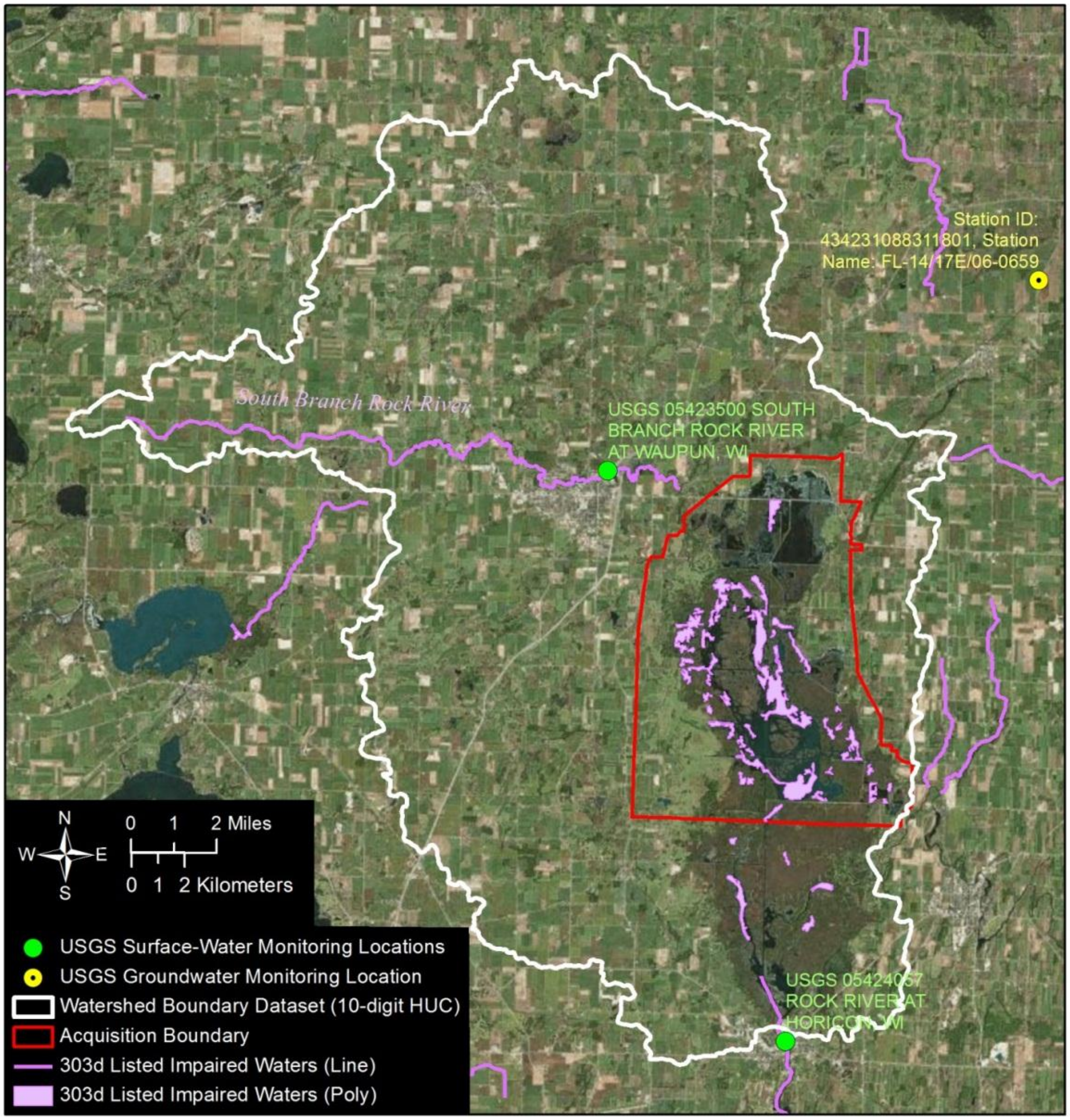


Figure 15 Locations of USGS surface and groundwater stations with extensive datasets

Included in the table of relevant monitoring sites are five sampling locations established by the USFWS, which are located within and near the Refuge boundary (Figure 16) and are part of a nutrient and sediment monitoring effort (2010-2011) (Gruetzman, 2011). Two sites are located on Refuge outlets (14-bay and Main WCS), one was established at Mill Creek, another at Plum Creek and one at the USFWS West Branch Rock River Hwy 49 gage site. Sub-watershed drainage areas and flowlines for these sampling locations have been delineated using National Elevation Dataset information (Figure 17).

Current USFWS led monitoring efforts are an extension of a larger assessment where the USFWS worked in conjunction with WIDNR and USGS to quantify Horicon Marsh’s water quality inflows and outflows. From 1997-2000 and 2009-2011 the USGS monitored water quantity and quality at three gages used in this sampling effort (USGS 05423510, USGS 05424000, USGS 05424057), while the USFWS sampled the two outlet sites for Refuge water located on the levee dividing the Marsh (14-Bay and Main WCS). Though the monitoring contract with the USGS ended in 2011 and the three gages were discontinued, the USFWS has since reactivated the gage representing the primary source of water supply for the Refuge portion of Horicon Marsh, USGS 05423510 (West Branch Rock River at State Hwy 49 near Waupun, WI). In 2012 streamflow and water quality data collection was re-initiated at this site and will continue to be used for Refuge water management and analysis purposes. In addition, water quality samples continue to be collected at the Main WCS, the 14-Bay WCS, Plum and Mill Creeks at the time of this report.

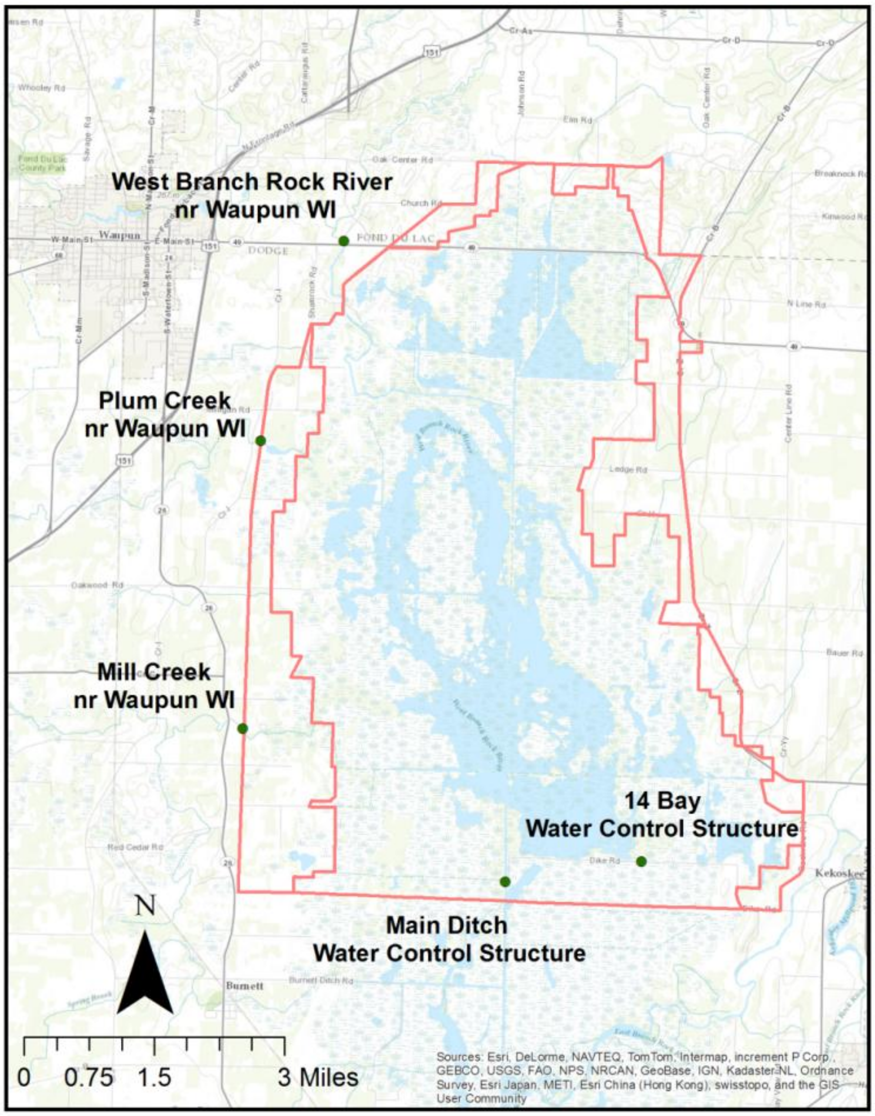


Figure 16 Current active USFWS sampling stations

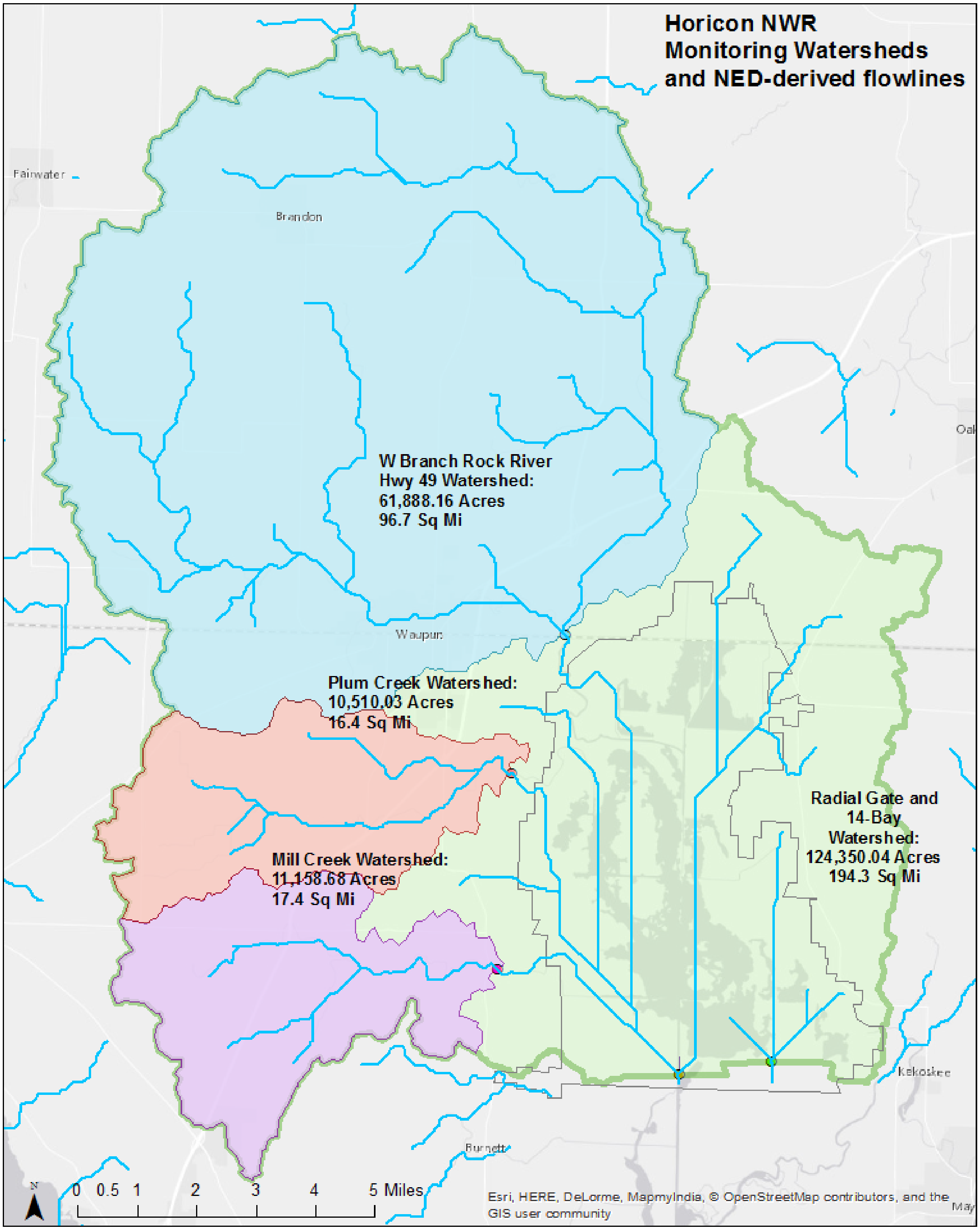


Figure 17 NED-derived drainage areas and flowlines of USFWS sampling locations.

The main findings from this monitoring confirmed that Refuge water resources receive substantial phosphorus loads from upstream drainages, as demonstrated by concentrations consistently higher than the criteria established in the TMDL report for the Rock River Basin (0.1 mg/L for non-wadeable streams, 0.075mg/L for wadeable streams). Impacts from high sediment loads on the Refuge, including sediment deposition in wetlands and cattail expansion, were also noted. More details and a summary of the monitoring statistics are available in the Water Quality Sampling Program Report (Gruetzman, 2011). Some of the findings from this report are included in the following sections.

In addition, water quality and quantity information may be found in the Flood Insurance Study for Fond du Lac County (pg. 45; http://dnrmaps.wisconsin.gov/dfsgenlib/fis/55039CV000A.pdf), which includes the West and South Branch Rock Rivers, and the Flood Insurance Study for Dodge County (pg 52; http://dnrmaps.wisconsin.gov/dfsgenlib/fis/55027CV000A.pdf), which contains information for reaches of the Rock River and Libby Creek.

West Branch Rock River

USGS 05423510 provides limited daily water quantity and quality data of the West Branch Rock River, the primary source of water for the Refuge. USGS data is available from 1997-2011, and the USFWS reinitiated monitoring at this location in 2012. This gage is located 860 feet above NAVD of 1988 and drains approximately 113 square miles, entering the Refuge several miles east of Waupun, WI. Much of this river was channelized in the past, but it has since returned to its migratory nature and courses through most of the Refuge as a meandering channel.

South Branch Rock River

Based on discharge statistics collected at USGS 05423500 on the South Branch Rock River, the monthly average flows usually peak in April while the lowest flows most often occur in September and December-January (Figure 18 and Figure 19). This monitoring gage represents approximately 64 square miles of the watershed above the Refuge and has a gage datum of 863.33 feet (NAVD 1988). Data is not continuous through the 1970s and ‘80s, but there is no apparent trend in peak annual streamflow for the years that have data (Figure 20). Discharge patterns may have changed since the 1950s and the gap in the record complicates detection of possible trends, but based on this information it appears that this portion of the watershed does not reflect the pronounced increase in annual mean streamflow seen at the Afton gage, much farther downstream.

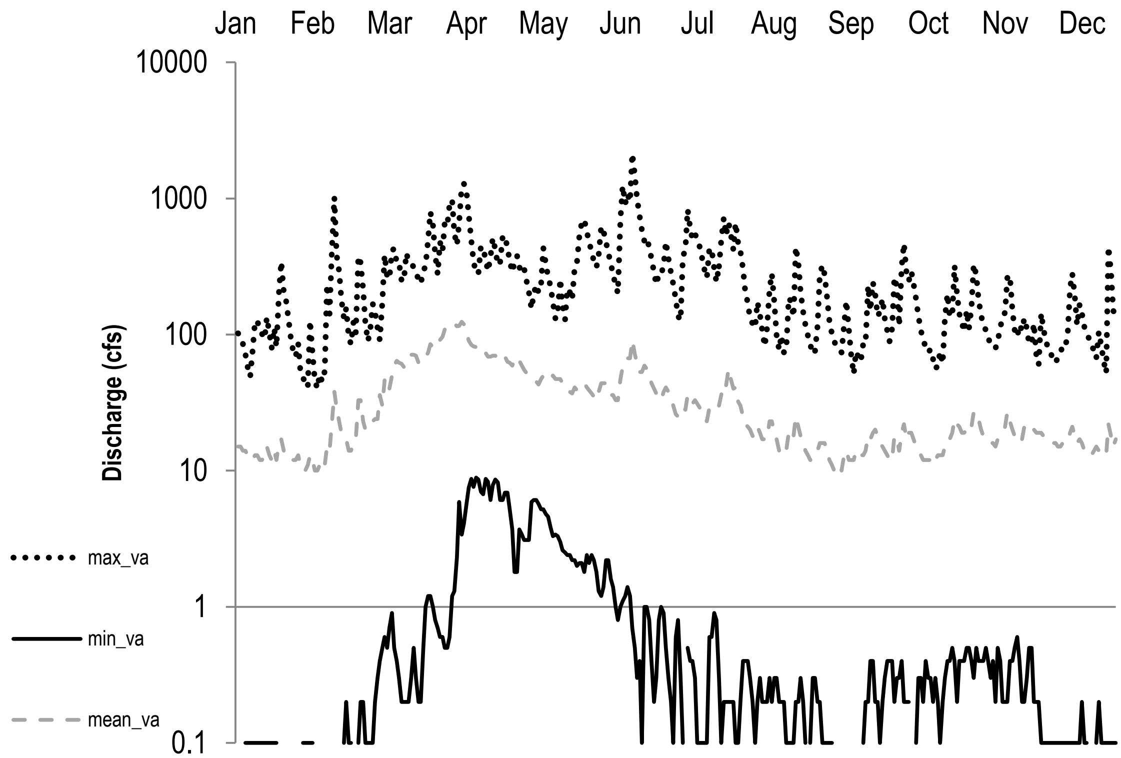


Figure 18 Graph of daily discharge stats from USGS site 05423500 (South Branch Rock River at Waupun, WI) 1949-2011

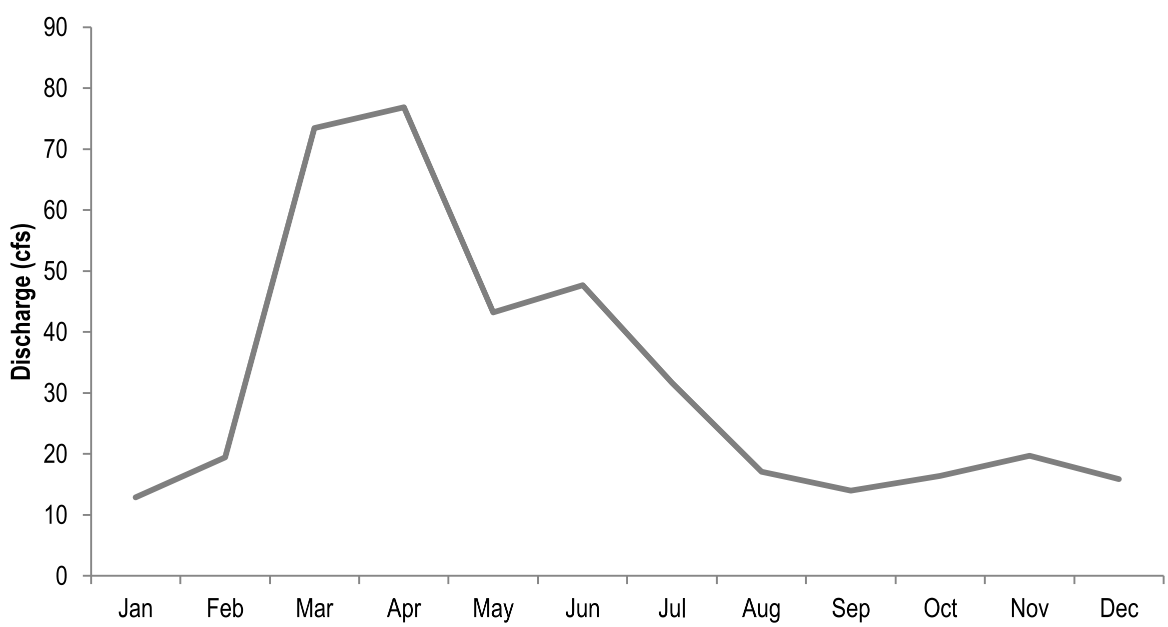


Figure 19 Monthly mean discharge at USGS 05423500 (South Branch Rock River at Waupun, WI) 1948-2011

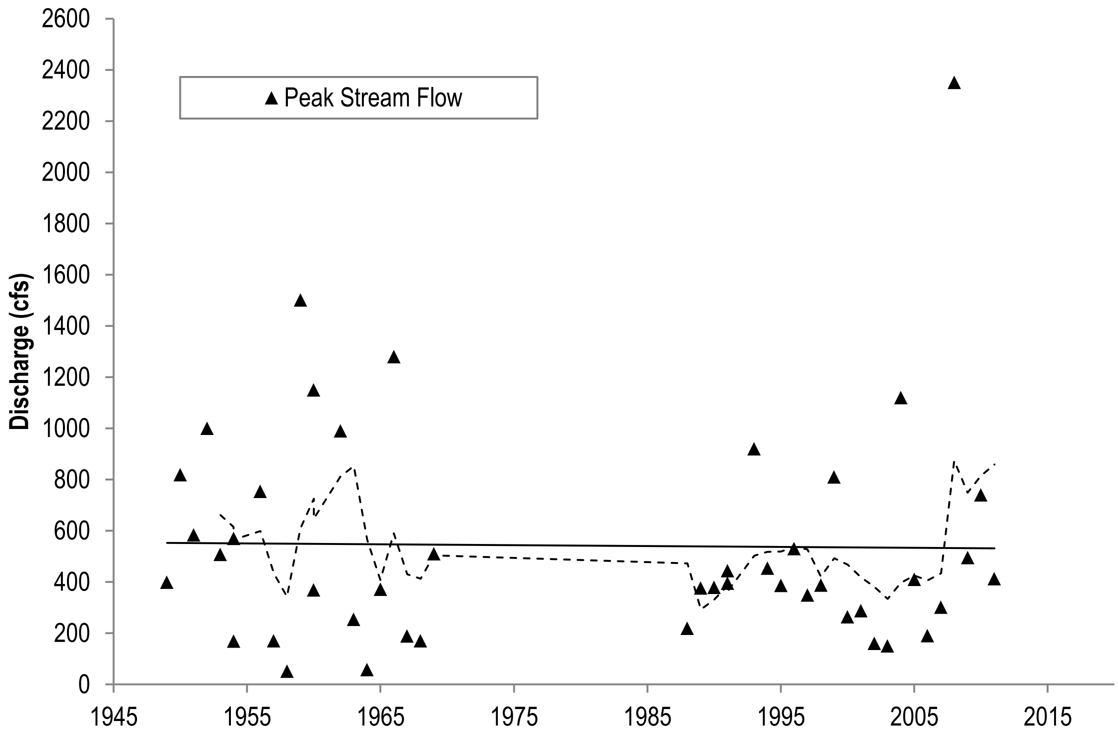


Figure 20 Annual peak streamflow data from 05423500 (South Branch Rock River at Waupun, WI) from 1949-2011

An Indicators of Hydrologic Alteration (IHA) analysis (Richter et al. 1996) was conducted on data from the USGS South Branch Rock River gage to evaluate differences in flow dynamics between the earlier (1949-1969) and later (1987-2014) records. The results show that high flow pulses are generally rising and falling at faster rates (ie, becoming more flashy) than they historically have been (see Appendix B). Though there is no clear difference in the annual maximum flows, the IHA revealed an increase in median 90-day minimum and maximum flows over the past 30 years, and there has been an increase in the median flows for all months except March. Annual flood frequency curves for the two records suggest that flows of all magnitudes are exceeded more often than historical records have shown (see). The IHA also reported a higher baseflow index in recent years. This metric describes the amount of groundwater input to a channel as a proportion to total runoff based on the amount of flow in the channel during low flow events. In summary, the South Branch Rock River is currently flashier and typically transmits a higher volume of water than it once had, though extreme flow events are comparable to early-record data.

Potential increases in high flow events and water volume can cause higher suspended sediment and nutrient loadings to Horicon Marsh, which may result in decreases in dissolved oxygen, more turbid waters, and reduced light attenuation. Such changes would disturb the natural ecology of the system by altering aquatic vegetation utilized by waterfowl and other aquatic life.

As the hydrology of the region changes and high flows potentially occur more frequently as a result of climate change, Refuge managers should adapt strategies to manage water accordingly, with consideration for reproduction and life history requirements of wildlife that HNWR was created to protect.

Rock River

The USGS 05424057 gage on the Rock River at Horicon has a drainage area of 456 square miles, including the entirety of Horicon Marsh, with a gage datum of 860 feet (NAVD 1988). This station characterizes Marsh water outflows and typically demonstrates highest maximum daily discharge in the month of June (Figure 21), though the average monthly discharge is highest in April and lowest in September and October (Figure 22). Simple linear regression and the 5-year moving average both exemplify an increase in annual peak streamflow values from 1998-2011 (Figure 23). The trend, however, is not statistically significant.

This gage was used in the USFWS water quality analysis for HNWR. It was found that the discharge at this site was not always greater than the combined discharge recorded at the inlet gages (USGS 05423510 and USGS 5424000). The Marsh is likely attenuating flood peaks by providing floodwater storage; a service that may benefit downstream lands but is likely to increase sedimentation and nutrient loading within the Marsh. Flood hydrograph analyses through the Marsh should be conducted to identify any discrepancies with precipitation and runoff patterns, and better-understand the Marsh's water budget (Gruetzman, 2011).

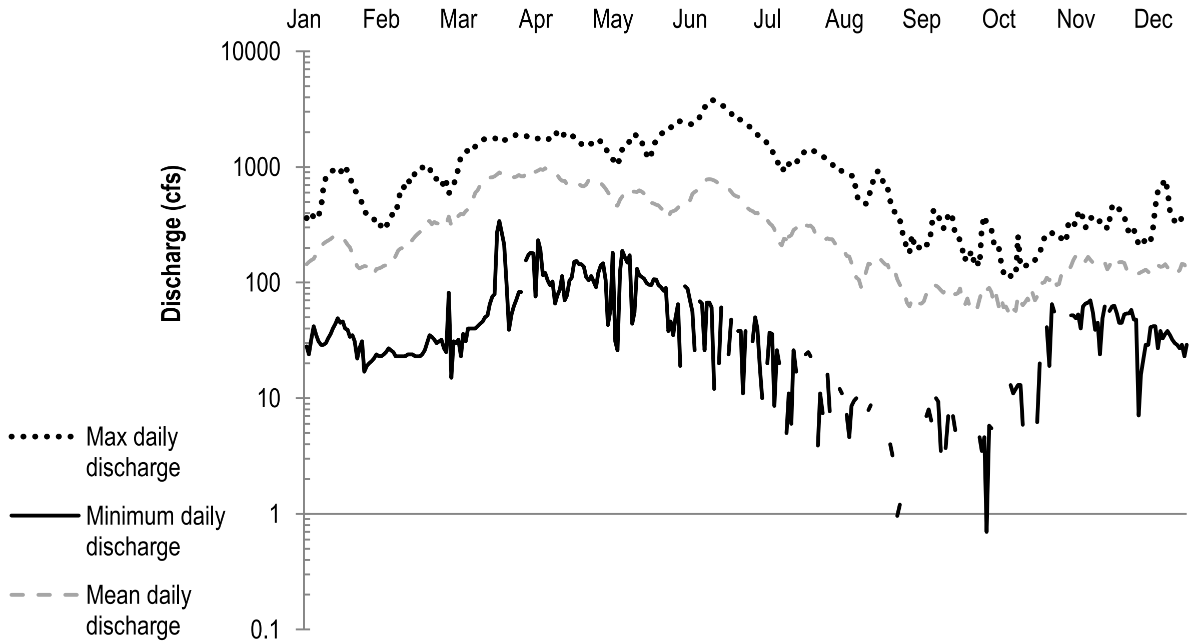


Figure 21 Daily discharge stats from USGS site 05424057 (Rock River at Horicon, WI) (1998-2011)

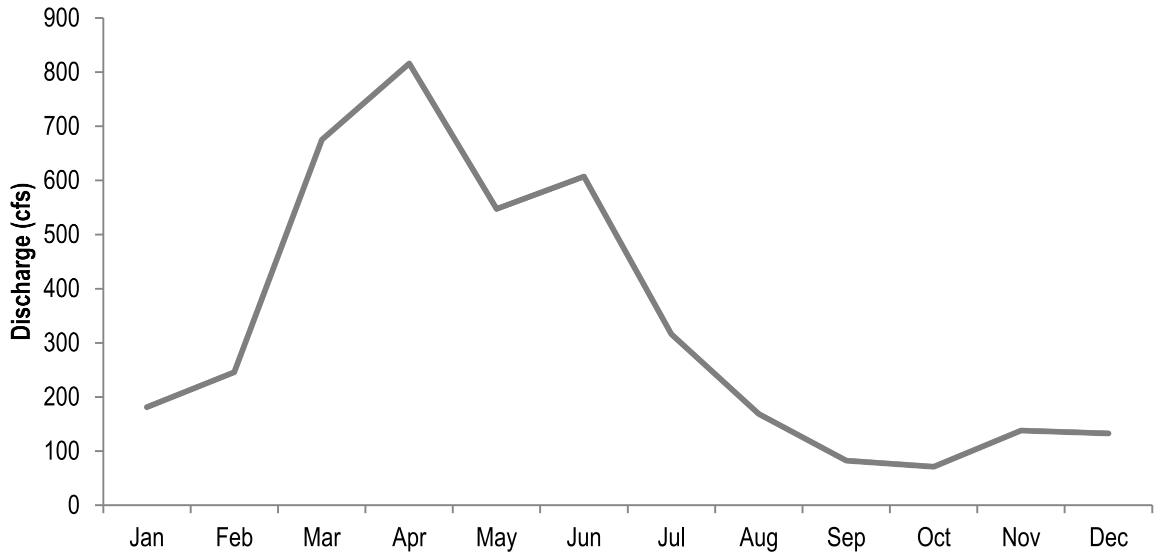


Figure 22 Monthly mean discharge at USGS 05424057 (Rock River at Horicon, WI) (1997-2011)

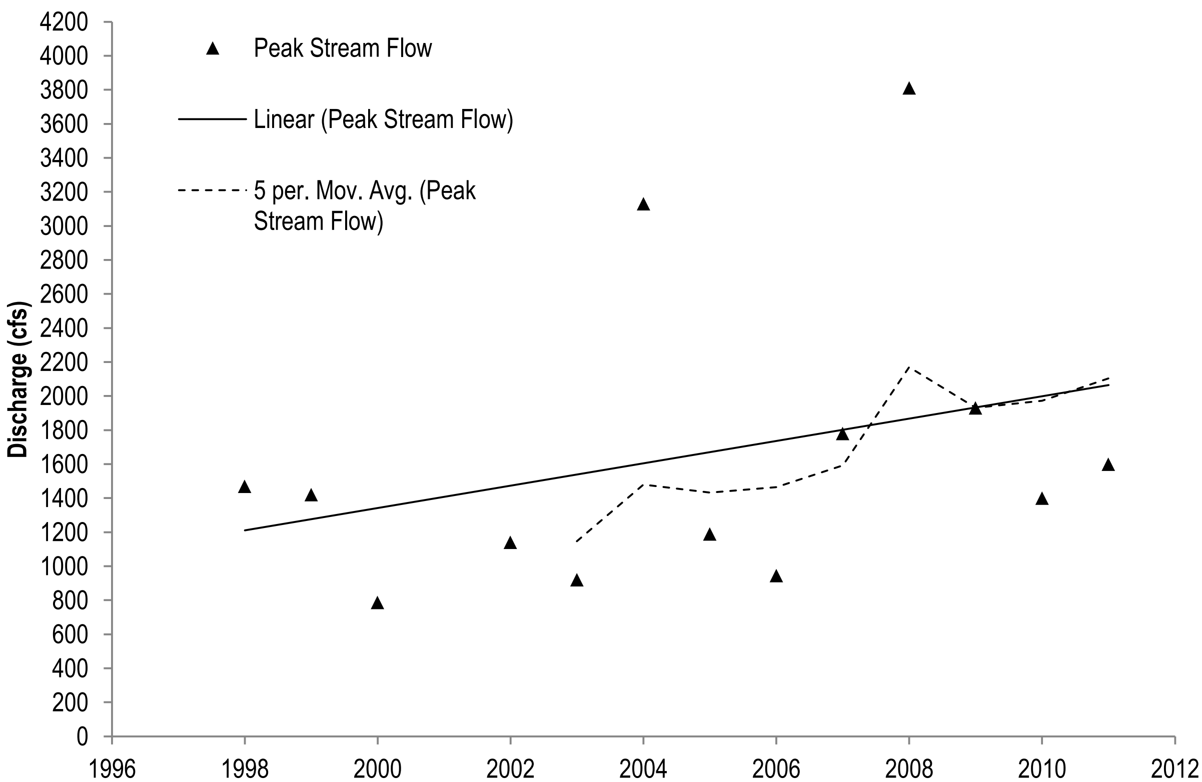


Figure 23 Peak streamflow data from USGS 05424057 (Rock River at Horicon, WI) 1998-2012

Groundwater elevation, flow, and quality

Groundwater and surface water relationships are an important component of water quantity and quality assessments. Groundwater infiltration rates of Horicon Marsh soils are approximately 3-6 inches per hour, and less than 3 inches per hour in the areas surrounding the Marsh, roughly estimated based on soil properties of the region (Juckem 2009). Subsurface flow evidently behaves similarly to surface water in this region, moving in the same general directions based on the Rock River Basin delineation.

According to generalized groundwater flow patterns, Refuge water resources are connected to groundwater in the city of Waupun. There appears to be a shallow groundwater divide southwest of the city, where some flow is discharged into Beaver Dam and Fox Lakes. However, nearly all the groundwater that may be subject to contamination from Waupun is directed toward Horicon Marsh. Anecdotal reports indicate that there may be springs or seeps within the Marsh. A review of aerial photos over multiple years show several consistent openings in the cattail mats that may indicate the location of springs. Further investigation is required to determine the role of groundwater on the Marsh’s water budget.

In addition, the Marsh and Refuge may be indirectly threatened by any groundwater contamination occurring near the city of Mayville, since groundwater in that area has been modeled to flow northwest toward HMSWA (Figure 24; Juckem 2009). However, the CAP states that groundwater threats associated with landfills south of this city are not immediate concerns for the Refuge, since water at these locations would need to travel long distances before discharging into Horicon Marsh (Warner et al. 2012).

Groundwater contamination susceptibility was also modeled by the WDNR based on generalized information about water movement, such as bedrock depth, bedrock type, soil characteristics, surficial deposits, and water table depths. Though the model does not factor in details about contaminant sources, areas around the Marsh were identified to have a relatively high susceptibility to groundwater contamination (Figure 25).

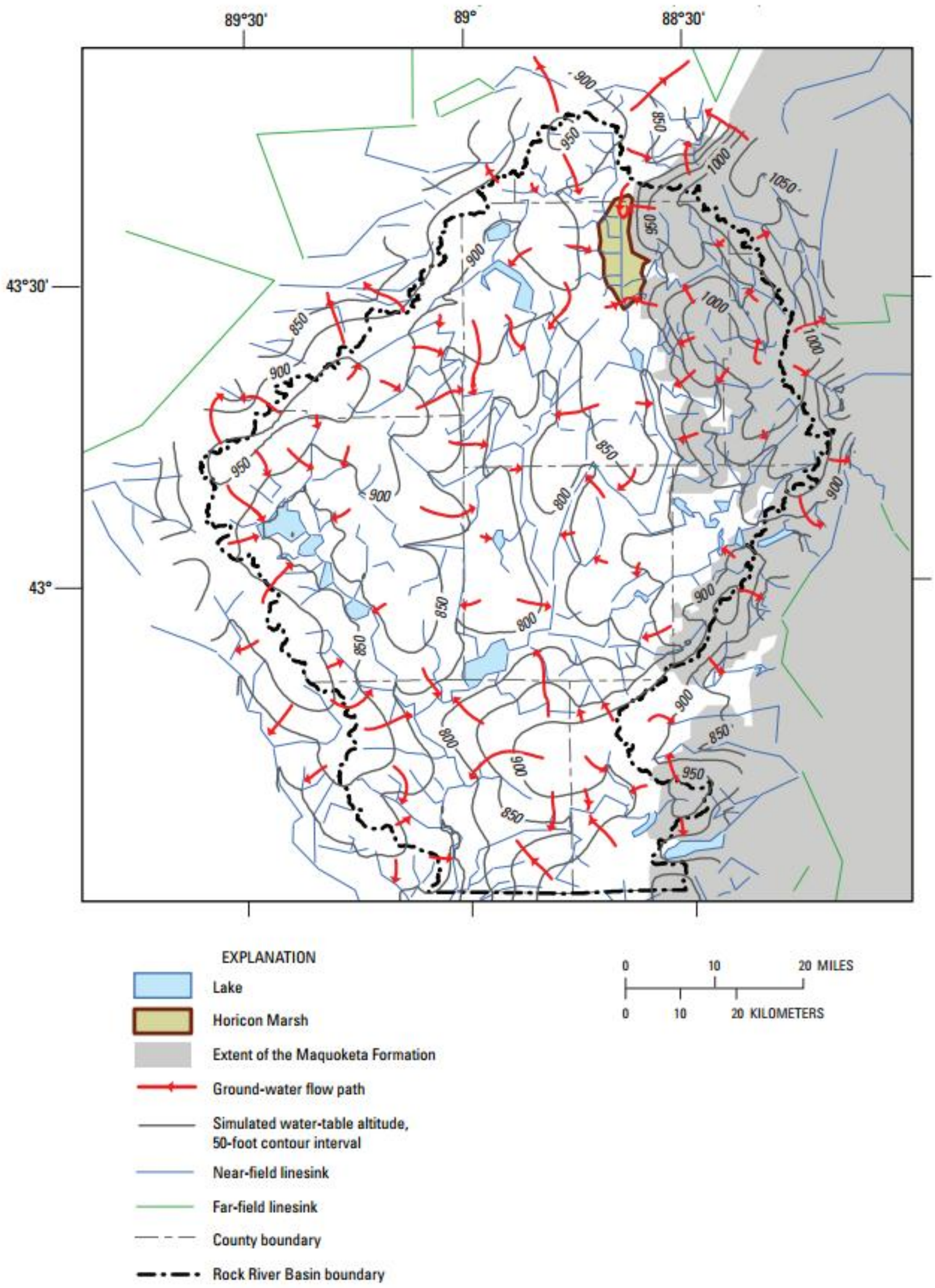


Figure 24 Groundwater flow and water table altitude for the Rock River Watershed modeled by the USGS (2009). The Marsh is highlighted in tan in the northern section of the Watershed.

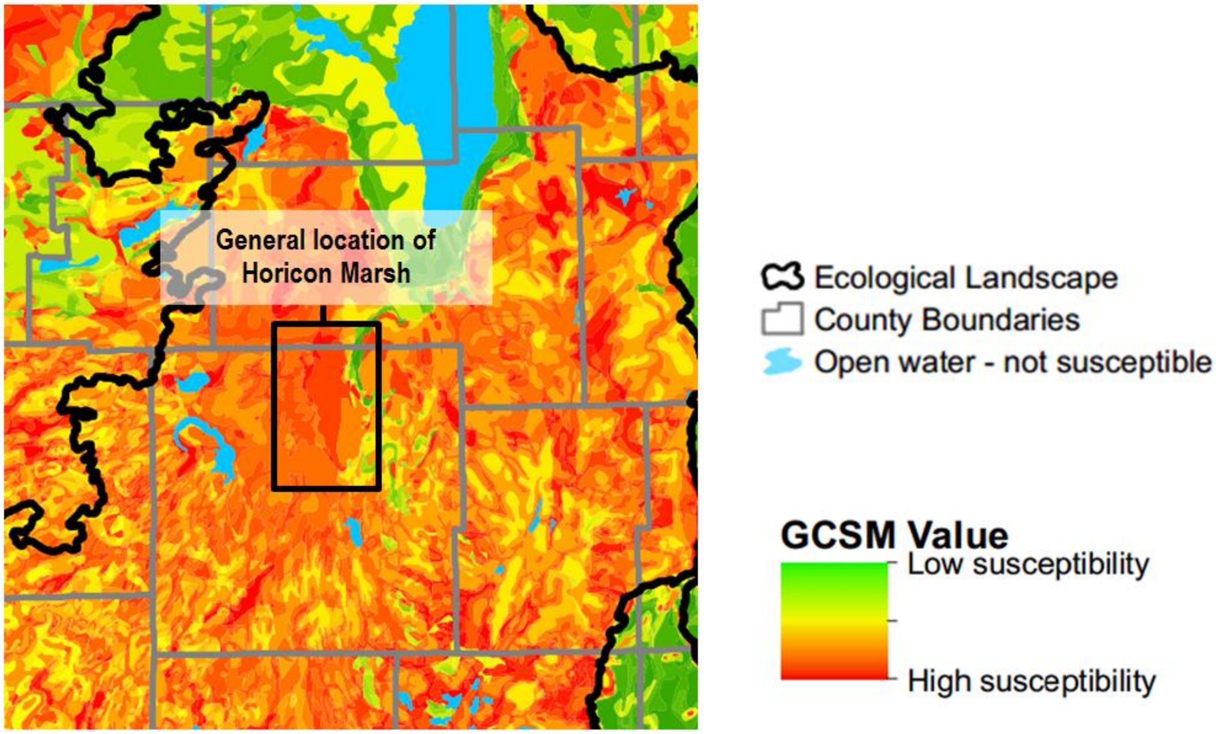


Figure 25 Groundwater Contamination Susceptibility Model (WDNR 2011b; http://dnr.wi.gov/topic/landscapes/documents/StateMaps/Map_S16_GCSM.pdf).

USGS 434231088311801, located northeast of the Refuge but outside of the relevant HUC-10, is the closest well with extensive groundwater data. This well is 506 feet deep and located 842.6 feet above NAVD 1988 in the Sandstone-Silurian Dolomite local aquifer system, which is highly fractured in this area, allowing rapid recharge rates as well as contamination risks (Bradbury and Batten, 2010). Though this aquifer only extends to the eastern border of the Refuge, the water table at this well still provides a valuable representation of regional groundwater behavior. Further, contamination threats associated with this bordering system are somewhat relevant to HNWR. A strong hydrologic connection between the upper-100feet of the Maquoketa layer and the overlying Silurian aquifer system was found to exist in southeastern Wisconsin, suggesting potential for contamination migration into the Maquoketa Unit (Eaton et al., 2000), which caps the Cambrian-Ordovician aquifer system underlying HNWR.

The data from the gage illustrates a general rise in water level from 1995-2011 (Figure 26), though the change is statistically insignificant. Its highest recorded water level was measured 61.85 feet below the surface on April 28, 2011, while the extreme low recording occurred on August 20, 1995 at 88.27 feet below the surface.

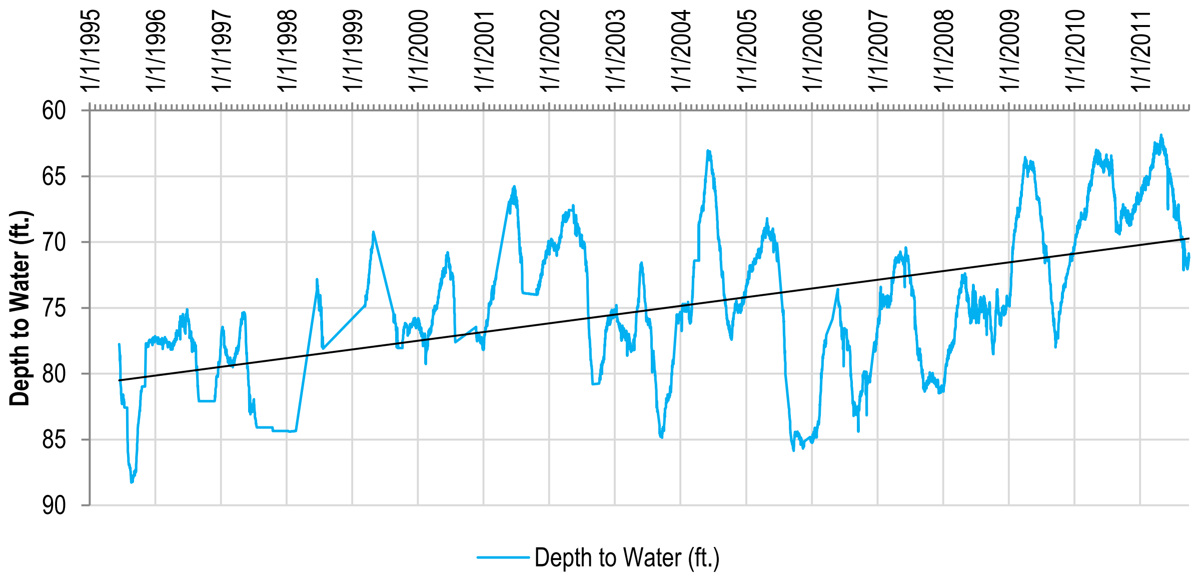


Figure 26 Depth to groundwater at West Branch Milwaukee River well near Bryon, WI - USGS 434231088311801, FL-14/17E/06-0659 (1995-2013)

Surface Water Quality

Many of the monitoring sites identified through the EPA STORET database house no data, house limited datasets, or are not in a location considered relevant by USFWS hydrologists. In addition to water chemistry data obtained from EPA and USGS databases, water quality information found in several reports and peer-reviewed journal articles were reviewed for applicability to Refuge water resource management. Summaries of individual water features are provided in the subsections below based on information identified in relevant monitoring datasets, literature, and 303(b)/303(d) reports/assessments. In addition, the findings from the CAP (Warner et al., 2012) are summarized, and the results of monitoring conducted by the USFWS and WIDNR are discussed and organized based on sampling location.

The USGS conducted a sediment and nutrient load estimation study for Horicon Marsh, with two study periods from 1997-2000 and 2010-2011. The West (http://waterdata.usgs.gov/nwis/uv?site_no=05423510) and East (http://waterdata.usgs.gov/nwis/nwisman/?site_no=05424000) Branches of the Rock River were monitored and loads were published in the Water Science Center Data Report, however a Scientific Investigations Report comparing the two monitoring periods has not yet been published. A detailed analysis of changes in loads between these periods would reveal the effectiveness of BMP implementation upstream of the Marsh.

303(b) reporting, 303(d) assessments and Category 4c

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.

Impairments currently exist for three water features within the Refuge RHI. These include the West Branch Rock River, South Branch Rock River, and Horicon Marsh. Rock River Basin TMDLs for phosphorus and sediment have been developed for over forty 303(d) listed waterbodies (http://dnr.wi.gov/topic/TMDLs/rockriver/), and were approved by the EPA on September 28, 2011. More details on the 2011 Rock River Watershed TMDLs and impaired waters can be accessed through the EPA Watershed Assessment site (http://www.epa.gov/waters/ir/index.html), or the WDNR's impaired water search tool (http://dnr.wi.gov/water/impairedSearch.aspx). Files associated with Wisconsin's most recent (2012) 303(d) assessment are also available on the WDNR website, and the draft review for the 2014 impaired waters assessment is currently underway and publicly available. A segment on Mill Creek is the only proposed listing update relevant to the Refuge. No impaired waters within HNWR or the RHI are proposed for delisting.

The major causes of impairment within the Upper Rock River Basin for which TMDLs have been developed include degraded habitat, low dissolved oxygen, sediment, and phosphorus. Impairments and assessment details for individual water features are included in the water quality summaries below. The lack of impairment listings for other water features relevant to the Refuge does not preclude issues of concern, however, because not all of these waterways have been assessed. Small creeks and wetlands do not have well-defined standards and are not typically assessed by state organizations. There are no fish consumption advisories within the Refuge units or RHI, and most of Wisconsin's mercury-related advisories are associated with water features in the northern portion of the state. The nearest water feature with fish consumption recommendations is Lake Winnebago, where fish have been found with higher concentrations of PCBs.

West Branch Rock River

As one of the main tributaries of Horicon Marsh, the West Branch Rock River is an important indicator of the Refuge's water quality. Its waters are likely adversely affected by nearby development, potentially indicated by the decreasing index of biological integrity (IBI) values found downstream of its confluence with the South Branch Rock River, which meanders through the city of Waupun. The West Branch Rock River was classified as "good" upstream of, and "fair" downstream of the confluence of these rivers, according to 2008 biosurveys.

Water quality monitoring conducted in 2013 shows that the West Branch Rock River suffers from high nutrient loading, with total phosphorus values consistent with those collected by USFWS in 2010-2011, as well as turbid waters well-above the threshold recommended by the EPA. In addition, total nitrogen concentrations in samples collected at several locations on the West Branch Rock River in 2000 exceeded recommended values and measured 0.69mg/L or higher.

Between 2010-2011, total phosphorus concentrations of the West Branch Rock River were measured to peak in winter and spring at the two water control sites downstream of the Marsh, though suspended sediment concentrations were lower compared with other times of the year. Generally, streamflow and nutrient loads are expected to decline in fall and winter, but this result could be due to phosphorus not being removed during the winter months, when biologic production is limited (Gruetzman, 2011).

Additional phosphorus sampling of the West and South Branch Rock Rivers, as well as their tributaries was conducted by Heim (2013). Results from the West Branch drainage revealed a lateral change in phosphorus concentrations, which increased with distance downstream. The highest concentration for this drainage was sampled near Highway TC. Ladoga Creek, which drains into the West Branch Rock River, was one of the healthiest sampling locations in the study, with cool water temperatures, low phosphorus concentrations (below the .075 mg/L threshold), and little siltation. Willow Creek was another low-P input, though siltation was an issue at this sampling location (Heim 2013).

The 2011 Rock River TMDL Report lists the West Branch Rock River (Mile 50-87.63, waters ID 11566) as impaired with degraded habitat due to total phosphorus, sediments, and total suspended solids, and not supporting its listed use for warm water sport fishery.

South Branch Rock River

The South Branch Rock River has suspended sediment, phosphorus, and dissolved oxygen problems, likely caused in part by upstream concentrated animal feeding operations (CAFOs), Hilltop Dairy and Double S Dairy. Several wastewater treatment discharge points that eventually drain into the River, including the Saputo Cheese Waupun Facility, Waupun Wastewater Treatment Facility, and National Rivet and Manufacturing Company, also likely degrade the water quality. Phosphorus threats associated with these point sources was addressed in 2002 after Wisconsin Administrative Code NR 216, the phosphorus rule, went into effect (Heim 2013). As a result of the rule's 1 mg/L criteria for discharge from wastewater treatment plants, the two biggest point source threats to the Marsh, Saputo Cheese and the City of Waupun, significantly reduced phosphorus loadings to the Upper Rock River Watershed.

Sampling by Heim (2013) on the River showed that of the five sampling locations associated with the South Branch Rock River, highest concentrations of total phosphorus were found in the tributaries entering the River near Highway MMM, which is downstream of a golf course and near Oak Grove Road. The South Branch drainage basin contributes overall higher levels of phosphorus than the West Branch drainage, so management and mitigation efforts focused in this basin may be more effective than in the West Branch Rock River.

The Rock River was identified by WDNR's non-point source ranking system as a stream highly-impacted with a high potential and capacity for improvement from BMP implementation. Specifically, proper fertilization rates, conservation tillage, and vegetative strips may be the most effective measures for sediment and total phosphorus reductions (Mbonimpa et al., 2012). Monoculture corn and urban landscapes are associated with excessive total suspended solids and total phosphorus in the Rock River Watershed, so increasing corn-soybean rotations and adopting Low Impact Development approaches may help with eutrophication issues in this area (Mbonimpa et al., 2014). Agricultural BMPs should be focused on fields that contribute the most phosphorus for practicality and effectiveness, since several studies have reported that less than 10% of the land is responsible for up to 90% of phosphorus loading (Kirsch et al., 2002).

Though several tributaries to Horicon Marsh have measured relatively high concentrations of nutrients and sediments, the West Branch Rock River and South Branch Rock River are the primary water features to target for restoration and mitigation activities. Though pollutant concentrations may be lower in these Rivers, their drainage areas are larger and flow volumes are higher, resulting in higher total loads delivered to the Marsh.

As the South Branch River flows through Waupun, it is also met by a lowhead dam, which creates a five-acre impoundment (WDNR 2010) near Harris Mill Park. The dam seems to be well-maintained and not at significant risk of failure, however the presence of such a structure still alters the physical and ecological state of downstream waters such as those feeding Horicon Marsh. For example, dams cause lateral channel changes as very fine sediments spill over the structure while larger particles are trapped, and the sediment-starved water often flows at higher velocities and erodes, incises, and scours downstream reaches to compensate for the absence of sediment (Poff et al., 1997).

According to the 2011 Rock River TMDL report, the South Branch Rock River (mile 0-3.58, waters ID 18232) was also found to be polluted with total suspended solids and total phosphorus, indicated by degraded habitat and low DO.

Plum Creek

This tributary to Horicon Marsh is roughly 14 miles in length, and several active SWIMS monitoring stations are located on this creek for fish, HBI, and habitat data. This stream is also monitored by the USFWS for sediment and phosphorus where it crosses Wild Goose Trail.

Water quality seems to improve slightly as this stream approaches the Marsh, as indicated by IBI values collected in 2004 (though this assumption is based on a small dataset from only three sampling locations). IBI values improved from “fair” to “good” longitudinally during this monitoring effort. Additional sampling at Plum Creek near Wild Goose Trail (10031044) in 2013 found total phosphorus and turbidity values exceeding criteria recommended by the EPA. Total phosphorus concentrations have been found to be highest at Plum Creek in May-October, and this stream exhibited the highest total phosphorus concentrations of the four sampling sites monitored by USFWS hydrologists in 2010, though it also had the lowest suspended solid concentrations (Gruetzman, 2011).

Mill Creek

Mill Creek is approximately 13 miles long, has seasonal low flows, and an intermittent nature. It is classified as a limited forage fish community (Heim, 2013), meaning its waters have a limited capacity to sustain fish and other aquatic life. Based on sampling from 2013, Mill Creek does not threaten water quality in the Refuge to the same degree as other inputs to the Marsh, such as Plum Creek. Dissolved oxygen, pH, and turbidity values were all within the ranges recommended by the EPA, and this is an insignificant source of total phosphorus loading compared to other sites. Total phosphorus concentrations did however exceed the EPA recommended values, and Mill creek (waters ID 11412) is a proposed 2014 impaired waters listing for total phosphorus, sediments, and degraded habitat. Like Plum Creek, suspended sediment at this stream typically peaked in June-October during FWS sampling efforts (Gruetzman, 2011).

While Mill and Plum Creeks drain primarily agricultural land, their slopes are relatively low compared to drainage inputs flowing into the Marsh from the east, which may relieve some of the issues and threats associated with sedimentation. For example, contamination from agricultural drainage may be less of a threat from these subwatersheds, since some contaminants bound to sediments are more likely to settle out before reaching the Marsh. If these deposition sinks remain unconsolidated, however, they still pose a risk of transport downstream with high flows. These legacy sediments may in that case become a bigger threat to Marsh resources if intense storms and extremely high flows occur more frequently as some climate change models predict. However, based on current data, adverse impacts from Plum and Mill Creeks are localized in the western portion of the Marsh, and pose as relatively low threats to the Marsh as a whole when compared with larger water inputs such as the West and South Branches of the Rock River.

This does not necessarily apply to phosphorus to the same degree, however. Total phosphorus for Mill and Plum Creeks showed a higher proportion of dissolved phosphorus compared with total phosphorus and dissolved phosphorus measured at the outlet WCS sites. This information could indicate that the phosphorus is more likely to be transported as dissolved phosphorus through these inlet streams, though this theory is based on a very limited dataset (Gruetzman, 2011). Therefore, any phosphorus that settles out with the sediments may help offset phosphorus loading to the Marsh, but is not likely the most significant transport mechanism associated with Mill and Plum Creeks.

Horicon Marsh

Horicon Marsh is roughly 14 miles long and three to five miles wide and is one of the largest freshwater wetlands in the country. It suffers from several water quality issues, of which sedimentation and deposition from upstream inputs, habitat degradation, and invasive species spread are likely the most problematic. Sedimentation is primarily caused by land use practices from upstream drainage basins, such as wetland drainage, fall plowing, farming adjacent to streams, agricultural practices over steep land, livestock grazing, and bank erosion (WDNR, 2010). The amount of annual sedimentation received by Horicon Marsh from these sources is determined, in part, by spring precipitation events. Based on average monthly sediment data from USGS 05423510 (1998-2011), the most sediment transported by the West Branch Rock River is delivered in the month of April with an average of nearly 21 tons/day. Sediment loads are also relatively high in the months of May-July. The lowest average monthly sediment transport rate at this gage was recorded in the month of December and was approximately 0.28 tons/day.

According to results of water quality sampling summarized by Gruetzman (2011), total phosphorus concentrations at the two outlet sites of the Marsh peak in November-March, and total phosphorus is typically higher at the 14-Bay WCS compared to the Main WCS west of it, as is suspended sediment compared to all of the other sampling locations. A higher proportion of total phosphorus has been measured as dissolved phosphorus from January-April 2010, suggesting that more of the phosphorus entering the Marsh during summer months is transported by suspended sediments (Gruetzman, 2011). Suspended sediments typically were at their lowest concentrations from December-March at these outlet sites.

Nutrient inputs from agricultural areas exacerbate cattail expansion (since cattails are especially effective at taking up phosphorus), algal growth, and dissolved oxygen problems. Pesticides and inorganic fertilizers also enter Horicon Marsh from surrounding agricultural inputs and are a potential threat to ecosystem functions.

Game fish such as pike, crappie, bluegill, and bass have all declined in population due to the Marsh's water quality and sedimentation problems. In addition to issues caused by surrounding land use, the Marsh has an overabundance of invasive carp. These fish intensify turbidity issues in the wetland and outcompete native species, and past attempts to control populations by drawdown and Rotenone use have been unsuccessful (WDNR, 2010). Other control measures by HNWR have included physical removal and stocking of predators such as northern pike (USFWS 2007). The Refuge is also cooperating with commercial fishermen to focus control areas where carp congregate in the winter. A tracking study may be implemented to identify wintering areas where future treatments may be targeted, similar to efforts at Malheur National Wildlife Refuge in Oregon.

The Marsh (Waters ID 11565) is listed as impaired with low dissolved oxygen and degraded habitat due to high total phosphorus, sediments, and total suspended solids, and is not supporting its designated use for fish and aquatic life (USEPA 2011). It was also identified by WDNR's non-point source ranking system as a waterbody highly-impacted with a high potential and capacity for improvement from BMP implementation.

Contaminants Assessment Process (CAP)

Sarah Warner (USFWS) completed the CAP in 2012 for HNWR. This included the identification of contaminant sources and pathways into HNWR, as well as recommendations for future water and sediment sampling sites. The major hydrologically relevant points within the CAP were (Warner, 2012):

- Agricultural nonpoint source pollution such as sedimentation, nutrient loading, pesticides, and runoff is the main cause of water quality degradation for Horicon Marsh. Siltation and sedimentation are especially concerning and are caused by wetland drainage, fall plowing, farming or grazing near stream banks, and farming on high gradients within the Basin. There are at least two CAFOs within the RHI, Hilltop Dairy and Double S Dairy, and several wastewater treatment discharge points upstream of the Refuge, including Brandon Wastewater Treatment Facility, Saputo Cheese Waupun Facility, Waupun Wastewater Treatment Facility, and National Rivet and Manufacturing Company. All of these points jeopardize water quality of the South Branch Rock River and receiving waters downstream, such as Horicon Marsh.

- Phosphorus and suspended sediments mainly enter the Marsh from the West Branch Rock River, but Plum Creek and Mill Creek also contribute significant amounts of phosphorous.

- Some point source pollution exists in developed areas and exacerbates nonpoint source issues. Specifically, pesticides and personal care products entering the Marsh from wastewater treatment facilities are not regulated by the EPA and could threaten Refuge water quality in the long term. The CAP identified 8 wastewater treatment plants/wastewater discharge points, half of which were upstream of the Marsh.

- Several spill-related contamination threats to Refuge water resources exist. Two Koch Petroleum pipelines located underground near the Marsh cause a risk of breaks or leakage of non-hazardous/volatile liquid products. Hazardous chemical spills, road salts, grain spills or other contaminants may enter the Refuge via Highway 49 runoff as well, which often has traffic carrying farm chemicals, livestock, and fuel. High levels of atrazine were detected in a study (WDNR 1995), and its potential use outside of Atrazine Prohibited Areas continues to threaten surface and groundwater resources.

- The Refuge's primary tributaries and discharge points should be monitored for water quality parameters and sediment contamination.

5. Water Law

In states that apply the riparian rights doctrine, landowners of property with naturally flowing surface water running through or adjacent to their property have rights to reasonable use of the surface water associated with the property itself. The "reasonable use" standard protects downstream users by ensuring that one landowner's use does not unreasonably impair the equal riparian rights of others along the same watercourse. Additionally, the law limits riparian rights to those rights "intimately associated" with the water; uses falling outside of this definition are usually considered unreasonable uses.[1]

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

Wisconsin follows a "regulated riparian" legal model which means the state relies on some common law principals and some legislatively designed programs, creating a hybridized water-law scheme. The state still uses a common law reasonable-use rule that matches the traditional rule across riparian states. When determining whether a riparian owner is using water in a reasonable manner, courts look at each issue on a case-by-case basis.[4] *However, the state courts have identified many factors to help guide the analysis. Specifically, the "subject matter of the use, the occasion and manner of its application, its object, extent and the necessity for it, to the previous usage, and to the nature and condition of the improvements upon the stream; and so also the size of the stream, the fall of water, its volume, velocity and prospective rise and fall, are important elements to be considered."*[5] *The state courts in State v. Michaels Pipeline Construction, Inc. changed the common law with regard to groundwater by bringing groundwater under the same reasonable-use analysis as surface water.*[6]

As in other riparian states, riparian landowners cannot infringe upon public rights on navigable waters.[7] *The public's water right includes the right to navigation, to fish, and, rather uniquely, to the enjoyment of natural scenic beauty.*[8]

The portion of the common law that Wisconsin replaced with statute relates to water withdrawals and diversions. The state courts have identified these statutes as having "the result of introducing an element of prior use into the Wisconsin water law," but they are to be strictly construed to the narrow purpose for which they were enacted.[9] *This means that in instances where the withdrawal and diversion statutes apply, a permit is analogous to ownership of a riparian right to use and vice versa—without a permit, a person does not have a riparian right to the use.*[10]

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1 John W. Johnson, United States Water Law: An Introduction 38 (CRC Press, 2009).
2 "Navigable," in this context, is a legal term of art that varies from state to state, separating public waters from those that are private. As a general notion, "navigable" means navigable in fact, which, historically, has been tested by whether or not a log or canoe could float on the water. *See, e.g.*, Paul G. Kent & Tamara A. Dudiak, *Wisconsin Water Law: A Guide to Water Rights and Regulations* 4 (University of Wisconsin-Extension, 2d ed., 2001).
3 The public trust doctrine, in most states, refers to the concept that state, as trustee to the public, preserves navigable waters "for public use in navigation, fishing and recreation." Black's Law Dictionary 1232 (6th ed. 1990). This prohibits the state from selling the beds to private parties.
4 *Sterlingworth Condo. Ass'n v. Dep't of Nat. Resources*, 205 Wis. 2d 710, 731 (Wis. Ct. App. 1996).
5 *Timm v. Bear*, 29 Wis. 254, 255 n.3 (Wis. 1871).
6 63 Wis. 2d 278 (Wis. 1974).
7 *State v. McFarren*, 62 Wis. 2d 492, 499 (Wis. 1974).
8 *Muench v. Public Service Comm'n*, 261 Wis. 492 (Wis. 1952).
9 *Omernick v. Dep't of Nat. Res.*, 71 Wis. 2d 370, 373 (Wis. 1976); *State* ex rel. *Chain O' Lakes Protective Ass'n v. Moses*, 53 Wis. 2d 579, 583 (Wis. 1972).
10 *Id.*

The permit program applies to withdrawals from streams for agriculture, irrigation, and maintaining lake water levels,[11] and it applies to both streams and lakes for large-scale diversions, meaning diversions of two million gallons-per-day during a 30-day average and 100,000 gallons-per-day if diverting water from a Great Lakes basin to a location outside.[12] As a result of old statutes from the Nineteenth Century, cranberry bogs are specifically exempt from these regulations.[13] Applications for a permit must contain very detailed information about the project itself and data about the withdrawal.[14] Additionally for large-scale diversions, applicants must determine an alternative water source, anticipate effects on the Great Lakes basin or Mississippi River basin, and describe the conservation measures the applicant will implement.[15] If the withdrawal is from a stream for agriculture or other type of irrigation, the application must include "written statements of consent to the withdrawal from all riparian owners who are making beneficial use of the water proposed to be withdrawn."[16]

DNR will only approve a permit for a large-scale diversion after notice to the public and a hearing if (1) the diversions do not injure public rights, and (2) either the water diverted is "surplus water," or if not, the other riparian landowners consent to the diversion.[17] "Surplus water" means any "water of a stream that is not being beneficially used[;]" this determination is made by DNR.[18] Once issued, DNR will review the permit no less than once every five years, and permittees must annually report its volume and rate of withdrawal and water loss.[19] DNR can revoke the permit if the water level drops below the surplus level, or if the agency finds that the diversion is "detrimental to the stream."[20] If the stream is given "trout designation" (discussed below) by DNR, then the agency may revoke for conservation purposes.[21] For groundwater, DNR requires a person to obtain a permit before drilling a well with the ability to withdraw 100,000 gallons-per-day.[22] Groundwater permits must not adversely impact or reduce the supply of public utilities.[23]

The state also implemented numerous permit programs regarding structures in the water.[24] Dam permits require compliance with many more provisions, including a requirement that at least 25% of the stream's natural flow passes through the dam at all times.[25] All permit programs look to one standard, however: whether the structure will impact the public rights discussed above.[26]

DNR has the responsibility of classifying lakes and streams as part of its fishery resource management duties. First, DNR determines which streams are fish Refuges for the purpose of securing "the perpetuation of any species of fish and the maintenance of an adequate supply thereof."[27] This duty requires DNR to regulate private and commercial fisheries, manage state fish Refuges, and propagate fish resources through state hatcheries.[28] Within the fish Refuges, it is illegal to "take, disturb, catch,

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[11] Under its delegated authority, DNR may also raise streams and lakes for conservation purposes through diversions or other means. Wis. Stat. Ann. § 30.18(8).
[12] Wis. Stat. Ann. § 30.18. The provision relating to diversions outside of Great Lakes basins results from the Great Lakes Basin Compact, which was discussed in more depth in the "Michigan" section.
[13] Wis. Stat. Ann. § 94.26.
[14] Wis. Stat. Ann. § 30.18(3)(a)
[15] Wis. Stat. Ann. § 281.35(5)(a).
[16] *Id.*
[17] Wis. Stat. Ann. § 30.18(5).
[18] Wis. Stat. Ann. § 30.01(6d).
[19] Wis. Stat. Ann. § 30.18(6).
[20] Wis. Stat. Ann. § 30.18(5).
[21] *Id.*
[22] Wis. Stat. Ann. 281.17.
[23] *Id.*
[24] Wis. Stat. Ann. §§ 30.12–30.16, 30.19–30.20
[25] Wis. Stat. Ann. § 31.34.
[26] *See, e.g.*, Wis. Stat. Ann. § 13.12.
[27] Wis. Stat. Ann § 23.09(2)(c).
[28] Paul G. Kent & Tamara A. Dudiak, *Wisconsin Water Law: A Guide to Water Rights and Regulations* 71 (University of Wisconsin-Extension, 2d ed., 2001).

capture, kill or fish for fish" in any manner or any time.[29] The state has designated numerous areas throughout the state as Refuges which can be found in the state Administrative Code.[30] Second, the DNR can give certain streams "trout designation" and then classify those streams within a range from Class I to III, with Class I streams containing a self-sustaining trout population, among other characteristics. Such designation has the effect of adding an extra layer of DNR approval before withdrawal or diversion permits, discussed above, are issued.[31]

At a regional level, as a state between many important interstate an intercontinental water bodies, Wisconsin participates in the Great Lakes Basin Compact, the Council of Great Lakes Governors, and interstate agreements that protect the Boundary Waters and the Mississippi River.[32] While instream flows do not have a strong presence in Wisconsin water law, many of the measures the state has taken to protect its fishery resources work in tandem with the goals of FWS.

Groundwater Law

Additional details about Wisconsin's groundwater law can be found on the WDNR's website (http://dnr.wi.gov/topic/groundwater/documents/GCC/Report/WIgroundwaterLaw.pdf) and are summarized below.

Wisconsin's Comprehensive Groundwater Protection Act (WCGPA) outlines a regulatory structure on the basis that all groundwater aquifers in the state should be protected equally. This differs from the USEPA's proposed nationwide aquifer classification approach, which prioritizes aquifers entitled to protection based on potential use and vulnerability. As part of WCGPA, the DNR must continually determine groundwater quality standards for prioritized contaminants with consideration for recommendations by the Department of Health Services and input from other agencies. This list of standards is included in chapter NR140, Wisconsin Administrative Code (http://docs.legis.wisconsin.gov/code/admin_code/nr/100/140.pdf).

WCGPA also requires that regulatory programs are implemented by all state agencies to assure compliance, and a statewide monitoring program has been executed as part of groundwater legislation to collect and manage aquifer data. Likewise, the University of Wisconsin System and several state agencies have cooperated since 1992 in groundwater research and monitoring activities to improve understanding of basic geology, soils, and groundwater hydrology of the state (http://dnr.wi.gov/topic/Groundwater/GCC/research.html). These regulatory, research, and management activities by various agencies are all organized by the Groundwater Coordinating Council.

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[29] *Id.*
[30] Wis. Admin. Code § 26.01 *et seq.*
[31] *Omernick v. Dep't of Nat. Res.*, 71 Wis. 2d 370, 373 (Wis. 1976).
[32] Kent & Dudiak, *supra* n.235 at 27–28.

The WCGPA is additionally responsible for:

- ❖ Expanding zoning authority to protect groundwater resources
- ❖ Allowing counties, cities, or towns to implement ordinances controlling waste disposal and the land-application of manure
- ❖ Clarifying county's authority to regulate well construction and pump installation for private wells
- ❖ Requiring consideration for water supply contamination when assessing property values
- ❖ Recognizing a surface/groundwater link and the impacts of wells on groundwater quantity and quality
- ❖ Defining Groundwater Management Areas to coordinate management in southeastern Wisconsin and in the Lower Fox River Valley
- ❖ Creating guidelines for the evaluation, monitoring, and construction of proposed high-capacity wells to assess potential environmental impacts, particularly for wells:
    - within a Groundwater Protection Area (within 1,200 feet of an outstanding or exceptional resource water or trout stream)
    - that may have a significant impact on a spring with discharge of at least 1 cfs 80% of the time or more
    - wells where over 95% of withdrawls will be lost from the basin
- ❖ The creation of the Groundwater Advisory Committee
- ❖ Requiring the annual reporting of any withdrawals statewide over 100,000 gpd averaged over 30 days, as part of the Great Lakes Compact and 2007 Wisconsin Act 227. General permits are issued for such withdrawals, individual permits are required for withdrawals over 1 million gpd for 30 days, and water use permits (general and individual) establish the authorized amount and requirements for reporting
- ❖ WDNR's requirements to implement a water conservation and efficiency program, develop a statewide water resources inventory, and publish a water use report every five years

Geospatial Data Sources

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

2. High resolution LiDAR data (1 m cell size) is currently available from The Upper Midwest Environmental Sciences Center (UMESC). Notably, this most recent elevation data is available in the North American Vertical Datum (NAVD 1988), which will demonstrate a slight difference from the datums (1912 and NAD 1929) used to calculate the elevations for the river gages, levee heights and Corp management of the river.

3. The National Wetland Inventory- USFWS. 1985-1986. National Wetlands Inventory website. U.S. Department of the Interior, USFWS, Washington, D.C. http://www.fws.gov/wetlands/

4. Background aerials are from the U.S. Department of Agriculture National Agriculture Imagery Program.

5. The National Hydrologic Dataset (NHD) is produced as a cooperative effort by the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), and other federal and state agencies.

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Appendix A Water Resource Information

National Wetland Inventory

The NWI was completed using color Infrared images from the 1990s for Wisconsin. More recent aerial infrared images have been created for the purpose of habitat monitoring, and are available for the years 1996, 1999, 2000, 2001, and for every year since 2003 (USFWS 2007).

The NWI includes the hierarchical Cowardin wetland classification information, the highest level which is Systems, with five divisions: marine, estuarine, riverine, lacustrine, and palustrine. The second level is Subsystems, which characterize structure and inundation regime. The third level is Classes, which characterize substrate material and vegetation type. Classes are further divided into finer categories of Substrate or Vegetation type in the fourth level. A habitat may also be categorized by any of 47 modifiers, including various water regimes, water chemistry parameters, soil parameters, and human modifications. Details associated with these codes can be found with the USFWS “Wetland Code Interpreter” (http://137.227.242.85/Data/interpreters/wetlands.aspx).

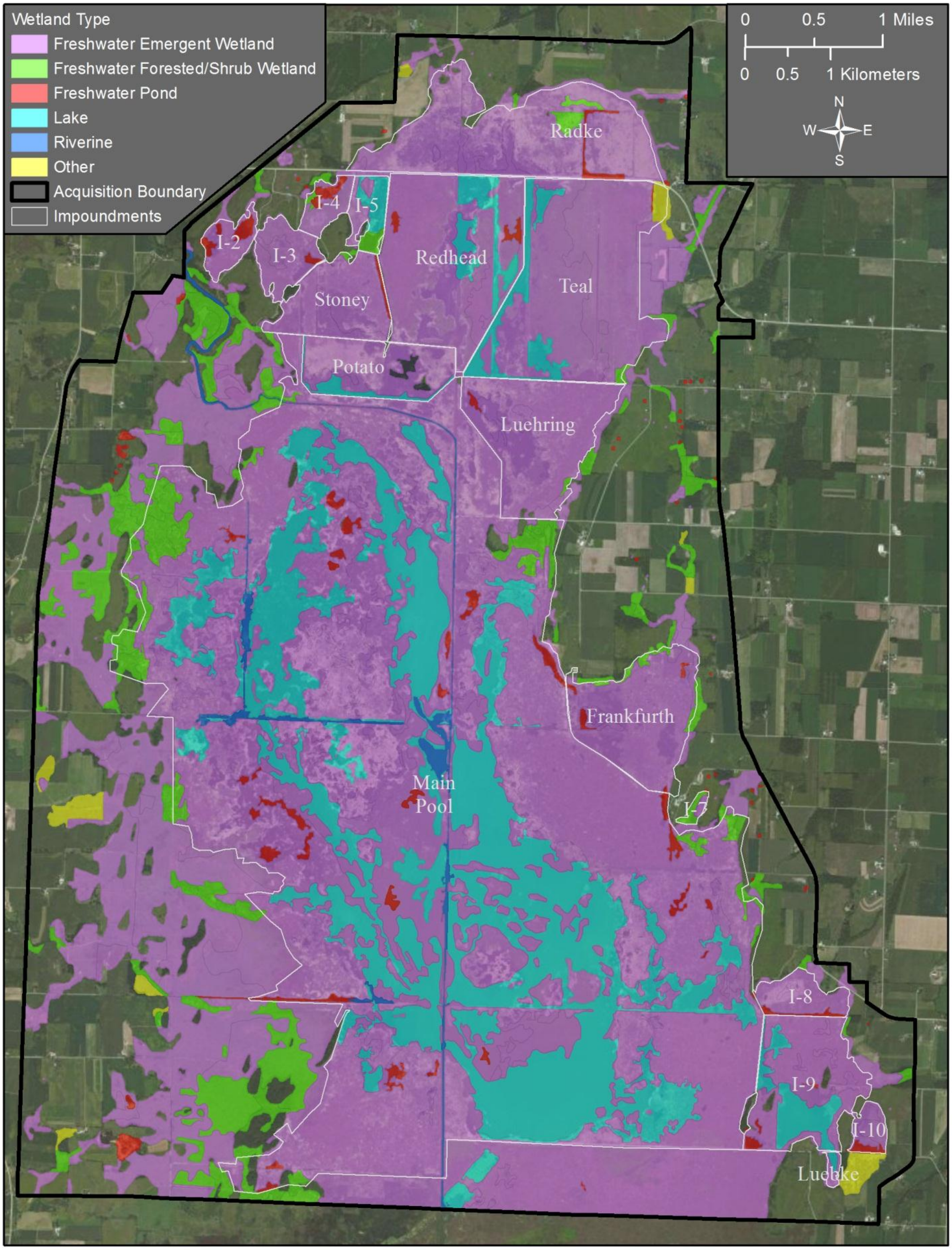

Figure 27 National Wetland Inventory information for HNWR's acquisition boundary and management impoundments

Wetland Type	Freshwater Emergent Wetland	Freshwater Forested/Shrub Wetland	Freshwater Pond	Lake	Other Wetland (Palustrine Farming)	Riverine	Non-wetland
Frankfurth	91.40%	4.00%	2.50%	0.00%	0.00%	0.00%	2.10%
I-10	80.50%	0.00%	17.20%	0.00%	0.00%	0.00%	2.30%
I-2	73.30%	0.00%	24.90%	0.00%	0.00%	0.00%	1.80%
I-3	95.30%	0.00%	3.40%	0.00%	0.00%	0.00%	1.30%
I-4	71.10%	5.50%	22.00%	0.00%	0.00%	0.00%	1.40%
I-5	35.90%	16.30%	0.00%	46.80%	0.00%	0.00%	1.10%
I-7	31.90%	57.30%	0.20%	0.00%	0.00%	0.00%	10.50%
I-8	88.10%	0.50%	9.10%	0.00%	0.00%	0.00%	2.30%
I-9	66.60%	0.00%	2.30%	27.20%	0.00%	0.00%	3.90%
Luebke	63.50%	0.00%	0.00%	33.80%	0.00%	0.00%	2.60%
Luehring	97.40%	0.60%	0.90%	0.40%	0.00%	0.00%	0.80%
Main Pool	64.30%	2.70%	1.50%	29.00%	0.00%	1.60%	0.90%
Potato	82.30%	0.00%	0.00%	11.50%	0.00%	0.00%	6.10%
Radke	91.50%	3.20%	2.60%	0.00%	0.10%	0.00%	2.60%
Redhead	83.80%	0.00%	2.00%	13.50%	0.00%	0.00%	0.70%
Stoney	95.80%	0.90%	1.90%	0.00%	0.00%	0.00%	1.40%
Teal	85.50%	0.60%	0.20%	11.80%	1.70%	0.00%	0.20%
TOTAL	70.80%	2.40%	1.90%	22.70%	0.10%	1.10%	1.10%

Table 9 Wetland types found within HNWR acquisition boundary and management units

Wetland Code	Wetland Type	Sum (acres)	Percent
L1UBG	Lake	3,484.01	17.00%
L1UBH	Lake	81.11	0.40%
L2EMF	Lake	11.83	0.06%
L2UBGx	Lake	40.54	0.20%
PEM/UBG	Freshwater Emergent Wetland	90.46	0.44%
PEMA	Freshwater Emergent Wetland	205.59	1.00%
PEMC	Freshwater Emergent Wetland	11,415.89	55.71%
PEMF	Freshwater Emergent Wetland	3,257.19	15.89%
Pf	Other	139.32	0.68%
PFO1/EMBg	Freshwater Forested/Shrub Wetland	215.65	1.05%
PFO1/SS1Bg	Freshwater Forested/Shrub Wetland	177.59	0.87%
PFO1Bg	Freshwater Forested/Shrub Wetland	279.27	1.36%
PFO1C	Freshwater Forested/Shrub Wetland	2.41	0.01%
PFO2Bg	Freshwater Forested/Shrub Wetland	9.24	0.05%
PFO4/EMBg	Freshwater Forested/Shrub Wetland	18.89	0.09%
PFO4Bg	Freshwater Forested/Shrub Wetland	40.69	0.20%
PFO5/UBG	Freshwater Forested/Shrub Wetland	14.09	0.07%
PSS1/EMBg	Freshwater Forested/Shrub Wetland	394.88	1.93%
PSS1Bg	Freshwater Forested/Shrub Wetland	84.7	0.41%
PUBGh	Freshwater Pond	3	0.01%
PUBGx	Freshwater Pond	6.92	0.03%
PUBH	Freshwater Pond	277.26	1.35%
PUBHx	Freshwater Pond	45.66	0.22%
R2UBH	Riverine	197.14	0.96%
Total	---	20,493.33	100.00%

Table 10 Wetland codes for wetland types found within HNWR acquisition boundary

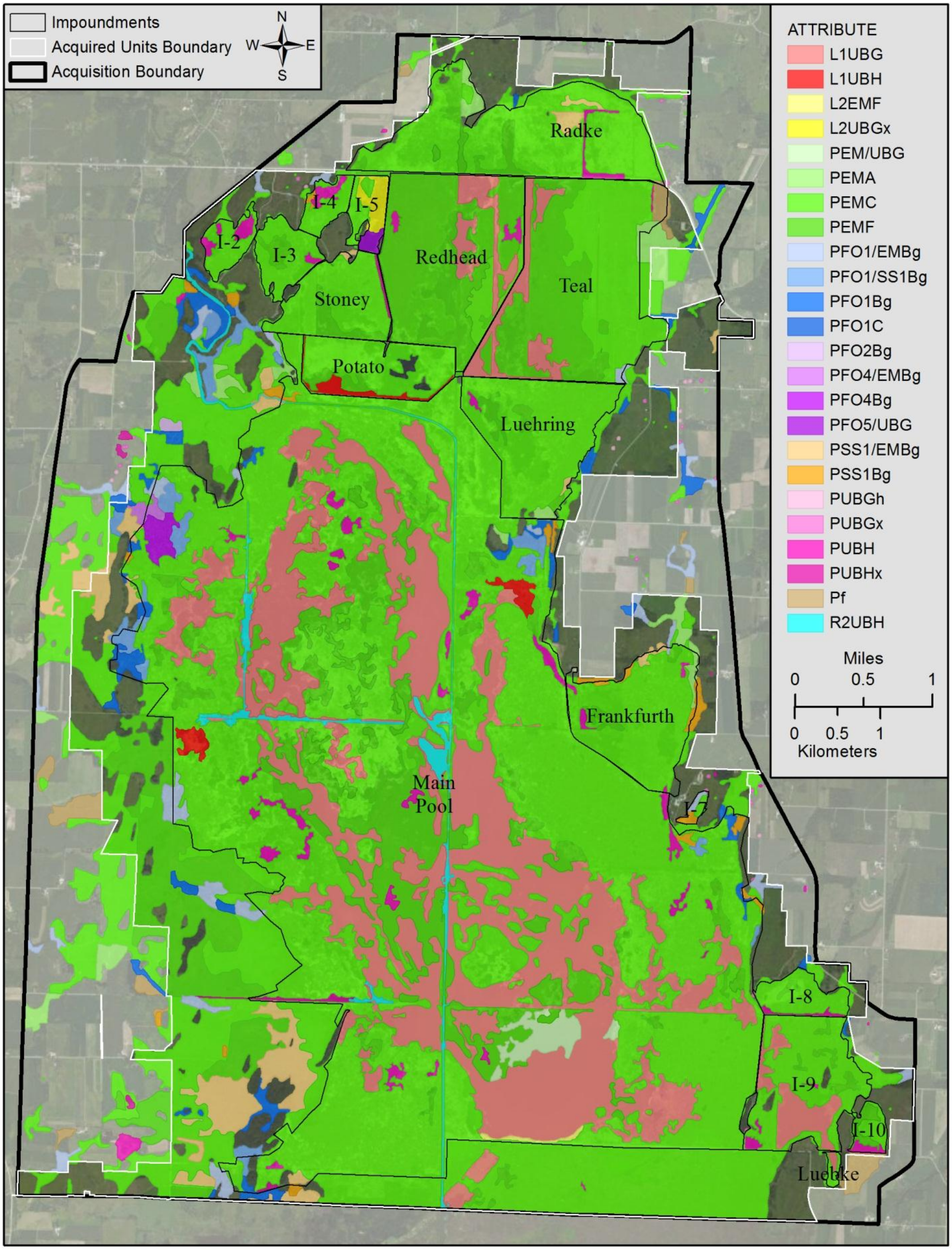

Figure 28 National Wetland Inventory wetland codes for HNWR's acquisition boudnary and management impoundments

National Hydrography Dataset

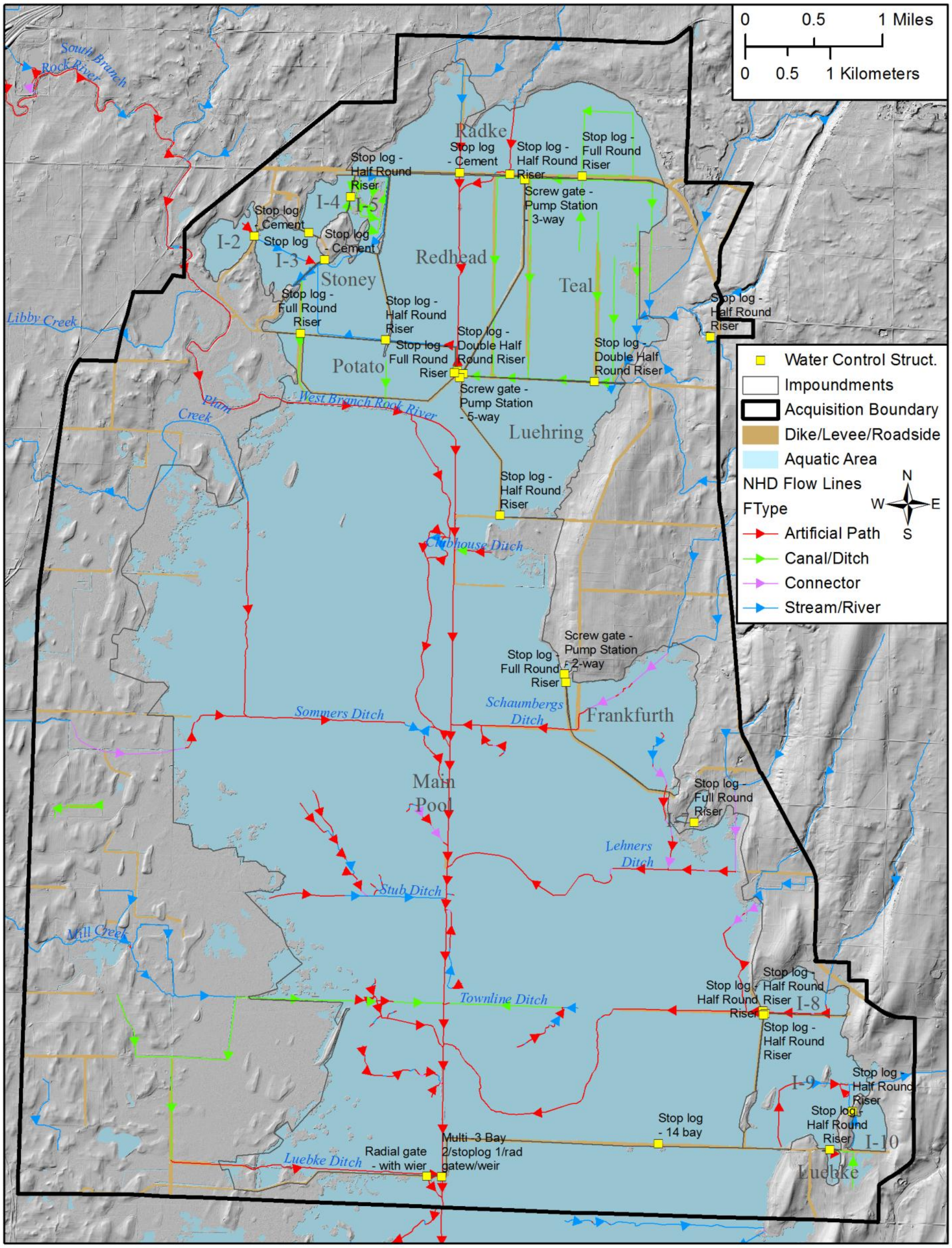

Figure 29 NHD information within HNWR's acquisition boundary

Description	Total miles
Connector	3.27
Canal/Ditch	19.43
Stream/River	26.73
Artificial Path	36.46

Table 11 NHD flowpath types within HNWR acquired boundary

Water Feature	Total miles of stream upstream of the Refuge
South Branch Rock River	20
West Branch Rock River	38
Libby Creek	1.8
Plum Creek	14
Clubhouse Ditch	0.26
Sommers Ditch	1.3
Schaumbergs Ditch	1.1
Stub Ditch	0.52
Lehners Ditch	0.57
Mill Creek	10
Townline Ditch	1.1
Luebke Ditch	2.7

Table 12 NHD named water features within HNWR acquisition boundary

Water Monitoring Information

#	Site Name	ID with Link (if available)	Alternate ID (Link)	Responsible Organization(s)	Data Available	Comments	Active ?
1	West Branch Rock River nr Waupun WI **	USFWS 433802088410401	USGS 05423510 WIDNR_WQX-203131	USFWS, Wisconsin Department of Natural Resources, USGS Wisconsin Water Science Center	Daily discharge, suspended solids, P, inverts (2010-present); Some WQ and invert data from WIDNR (1998-2013)	Represents major source of water supply for Refuge. Part of FWS sediment/nutrient sampling effort. USGS data (USGS ID listed below) available 1997-2011. USFWS reinitiated continuous stage and water quality monitoring at this location in 2012. Minimal WQ and invert data from WIDNR near this location. Additional invert sampling available downstream (WIDNR_WQX-143263)	Y
	West Branch Rock River at State HWY 49 near Waupun, WI *	USGS 05423510	USFWS 433802088410401 WIDNR_WQX-203131	USFWS, Wisconsin Department of Natural Resources, USGS Wisconsin Water Science Center	Daily discharge, suspended solids, phosphorus data (1997-2011)	Retired USGS gage reestablished as part of FWS sediment/nutrient sampling effort (USFWS ID listed above). USGS data (2010-2011) used as part of USFWS water quality analysis for the Refuge.	N
2	Main Ditch WCS **	USFWS 433138088384001	USGS 05423615	USFWS	P/susp. solid samples (2010-present) Streamflow estimated (2010-2011)	Within Refuge. Data collected and funded by USFWS. Monitoring data also housed in NWIS (USGS 05423615, listed below).	Y
	West Branch Rock River at Main WCS near Kekoskee, WI *	USGS 05423615	USFWS 433138088384001	USFWS	P/susp. solid samples (2009-present)	USGS ID assigned to monitoring data collected by USFWS. (Same as USFWS# 433138088384001, listed above)	N
3	14 Bay WCS **	USFWS 433152088364701	USGS 05423616 WIDNR_WQX-10022928	USFWS	P/susp. solid samples (2010-present) Streamflow estimated (2010-2011); minimal WQ/ambient condition samples from WIDNR (04/2008-05/2008)	Within Refuge. Data collected and funded by USFWS. Monitoring data also housed in NWIS (USGS 05423616, listed below).	Y
	West Branch Rock River at 14 Bay WCS near Kekoskee, WI **	USGS 05423616	USFWS 433152088364701 WIDNR_WQX-10022928	USFWS	P/susp.solid samples (2009-present)	USGS ID assigned to monitoring data collected by USFWS. (Same as USFWS# 433152088364701, listed above)	N
4	Plum Creek nr Waupun WI **	USFWS 433601088421001	N/A	USFWS	Suspended sediments, phosphorus (2010-present)	Just outside of Refuge boundary	Y

5	Mill Creek nr Waupun WI **	USFWS 433307088422001	N/A	USFWS	Suspended sediments, phosphorus (2010-present)	Just outside of Refuge boundary	Y
6	Rock River at Horicon, WI *	USGS 05424057	WIDNR_WQX-143036 WIDNR_WQX-143308 WIDNR_WQX-143342	USGS Wisconsin Water Science Center, Wisconsin Department of Natural Resources	Daily discharge, extensive nutrient, sediment, DO, and other data (1978-present)	Downstream of Refuge boundary and just outside of HUC10, but on the Rock River; part of FWS sediment/nutrient sampling effort (2010-2011)	Y
7	East Branch Rock River Near Mayville, WI *	USGS_05424000	N/A	USGS Wisconsin Water Science Center	Daily discharge, suspended solids, P, peak streamflow, nutrients/water chem data (1949-2011)	Downstream of Refuge boundary and just outside of HUC10, but on the Rock River; part of FWS sediment/nutrient sampling effort (2010-2011)	N
8	South Branch Rock River at Waupun, WI	USGS 05423500	N/A	USGS Wisconsin Water Science Center	Daily discharge, WQ, water chem (1948-present)	Continuous discharge data, but minimal, outdated WQ information (1987-1994); Upstream of Refuge boundary, USGS-05423510, and WIDNR_WQX-203128	Y
9	West Branch Rock River near Waupun, WI	USGS 05423000	WIDNR_WQX-203105	USGS Wisconsin Water Science Center, Wisconsin Department of Natural Resources	Daily discharge, WQ, water chem, P, N, total fixed solids, BOD (1948-2000)	Discharge and WQ data outdated (1948-1981); WIDNR water chem data (1997-2000)	N
10	FL-14/17E/06-0659	USGS 434231088311801	N/A	USGS Wisconsin Water Science Center	Hourly groundwater depth (1985-present)	Highest recorded water level 61.85 ft below surface on April 28, 2011. Lowest: 88.27 ft below surface on Aug 20 1995.	Y

* Data used as part of FWS sediment/nutrient monitoring (2010-2011)
**Active USFWS water quality monitoring site

Table 13 Water quality and quantity monitoring information relevant to HNWR

Appendix B Indicators of Hydrologic Alteration Analysis for the South Branch Rock River

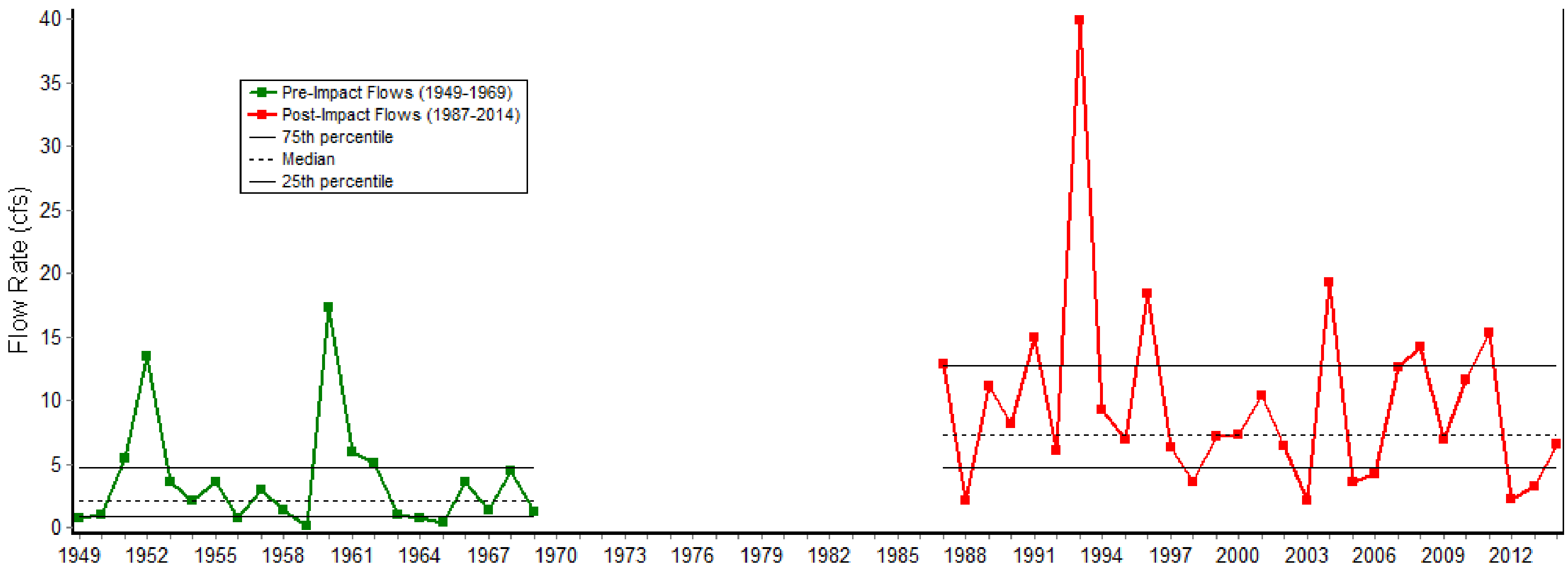

Figure 30 South Branch Rock River (USGS05423500) 90-day minimum flow rates (1949-1969, 1967-2014)

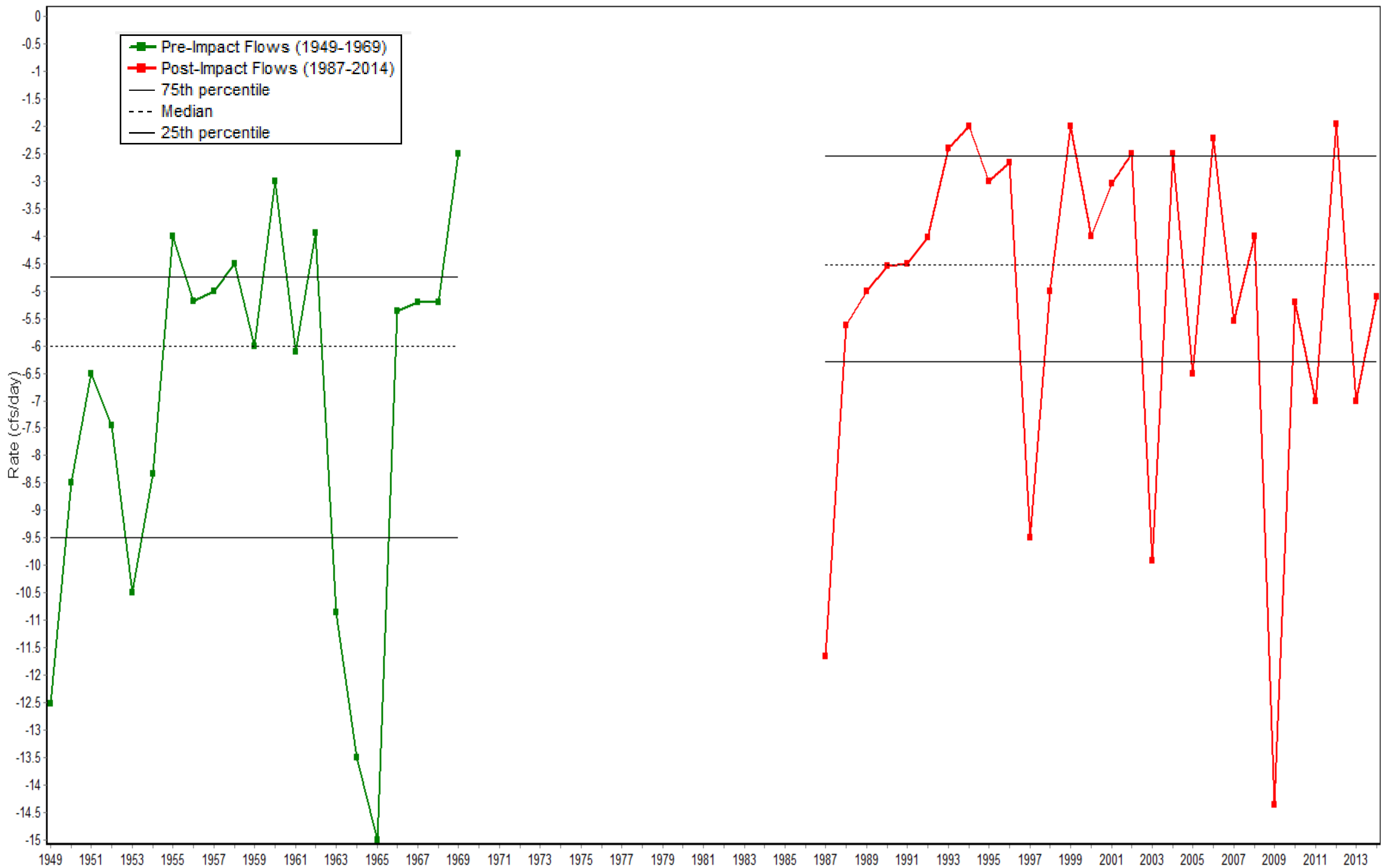

Figure 31 South Branch Rock River (USGS05423500) high flow pulses fall rates (1949-1969, 1967-2014)

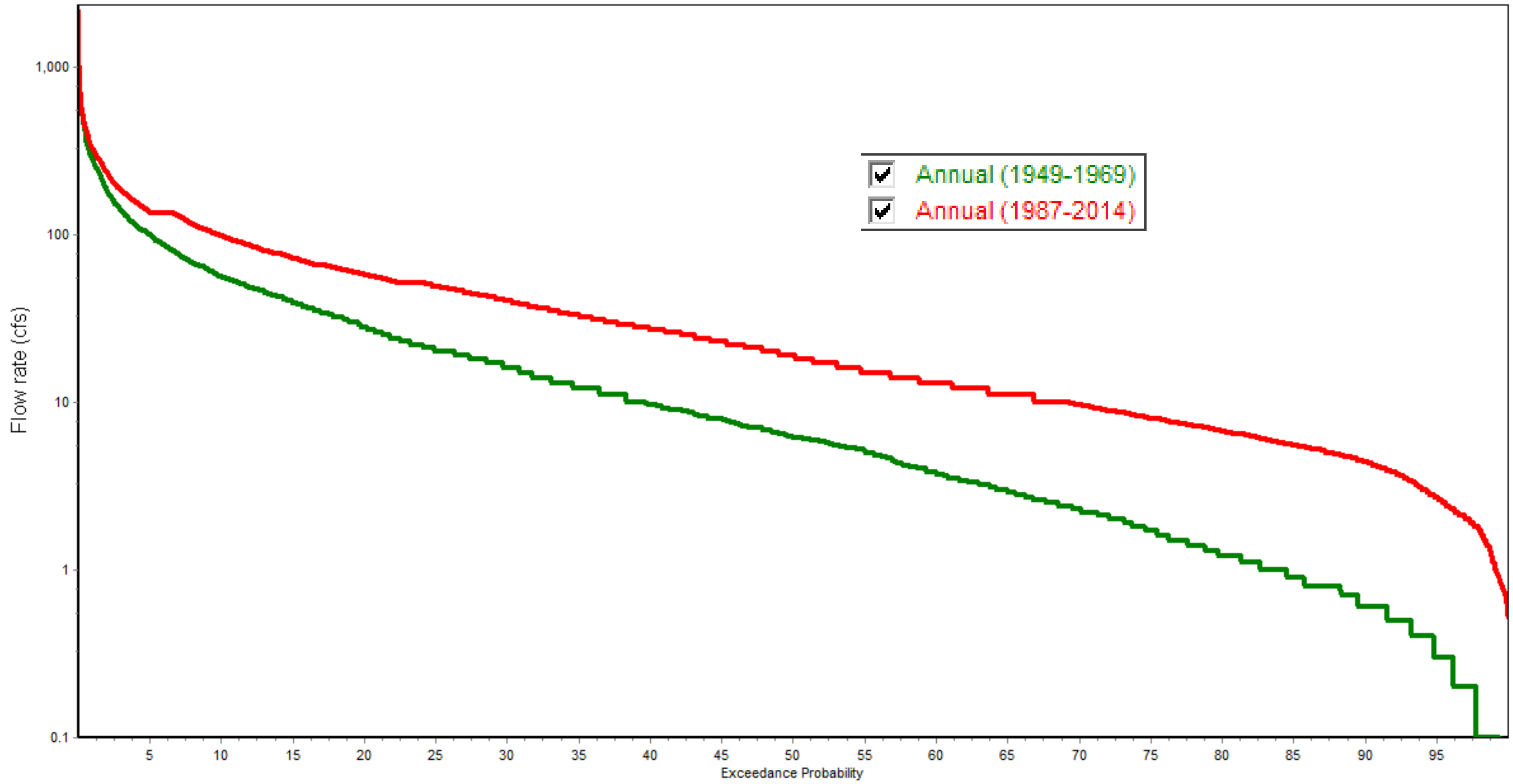

Figure 32 South Branch Rock River (USGS05423500) flow duration curves (1949-1969, 1967-2014)

Division of Biological Resources, Region 3
5600 American Blvd. West, Suite 990
Bloomington, MN 55437-1458

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

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