Regional Water Study

Wabash Headwaters Region

Jacobs Engineering Group Inc.

Report to Indiana Finance Authority

January 2025

Acknowledgments

We gratefully acknowledge those who contributed to this report with their time, their data, and their insights.

Water Study Advisory Committee

- Indiana Department of Environmental Management
- Indiana Department of Natural Resources
- Indiana Farm Bureau
- Indiana Finance Authority
- Indiana University
- Purdue University
- U.S. Geological Survey
- White River Alliance

Local Stakeholders

- Berne Water Department
- Blackford County
- Blackford County Economic Development Corporation
- Bluffton Utilities Water Department
- Camden Water Utility
- Carroll County Economic Development Corporation
- Cass County Economic Development Corporation
- Duke Energy
- Flora Water Works
- Fort Wayne City Utilities
- Grant County Economic Growth Council
- Hartford
- Huntington County United Economic Development Corporation
- Indiana American Water
- Jay County Development Corporation
- Miami County Economic Development Authority
- Montpelier
- Peru Utilities
- Silver Lake Water Works
- Town of Andrews
- Upper Wabash River Basin Commission

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Citation

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Abstract

This *Wabash Headwaters Region Regional Water Study* (study) presents estimates of historical water use throughout the Wabash Headwaters Region and projects estimates of water demand through 2070 for water using sectors, including public water supply, industry, energy, irrigation, rural livestock production, and self-supplied households. Demand projections were calculated using a regression-based approach to correlate economic, population, and climate factors that influence water use for individual users and within sub-watersheds within the Wabash Headwaters Region study area (study area).

Additionally, a water balance approach was used to calculation potential water historical water availability for the period 2007-2022 considering baseflows (flows from groundwater that flow upward to streams and rivers), reservoir storage and releases, return flows (water returning to the streams and rivers through direct discharges or infiltration), water use and minimal instream flow requirements within the planning region. By considering the return flows in the analysis, the water balance approach accounts for the consumptive use rather than the water demand only. The historical components included in the historical water balance were then adjusted to reflect a reasonable climate scenario and projected demands through 2070.

The results of the historical and future water balance analysis are presented spatially for each of the 10 sub-basins within the planning area as well as for the region. Results are also presented on an annual and seasonal basis to provide information on potential water supply constraints in the future.

Approximately 70% of the groundwater use with the study area is supplied by groundwater sources. The largest users historically have been public water systems (utilities) and industries. This is not expected to materially change in the future. Overall water demand is expected to grow by 9% or million gallons per day (MGD) by 2070. While there is some seasonality in demand patterns, it is not as pronounced as in other regions due to the relatively small irrigation usage as compared with industrial and public water supply uses.

By the Numbers

- The largest historical demands in the Upper Wabash Region are industrial and public water supply (39% and 37%, respectively).
- Approximately 70% of the water supply is obtained from groundwater sources, with the remainder withdrawn from surface water sources.
- The maximum consumptive use observed historically was approximately 26% of groundwater and surface water withdrawals.
- Water demand is expected to increase approximately 9% from 81.8 MGD in 2022 to approximately 89.8 MGD in 2070.
- While groundwater will likely remain the primary water source for the region, a modest shift (5%) from groundwater to surface water use is anticipated.
- Cumulative excess water availability is projected to remain relatively stable, though seasonal variations are anticipated to shift due to climate and hydrological changes.
    - Summer: Decreases expected across most sub-basins (-3% to -20%), except Sub-basins 4 and 9 (increases of 8% and 9%, respectively).
    - Fall changes range from -11% to -32%
    - Winter: Increases expected across most sub-basins (3% to 21%), except Sub-basin 9 (decrease of -6%).
    - Spring increases range from 14% to 39%.

The cumulative excess water availability the study area is expected remain similar to historical conditions with some changes in seasonality due to changes in climate and hydrology. The summer and fall months are projected to exhibit less natural baseflow conditions throughout the study area. Decreases in summer and fall natural baseflow, during already low flow periods, presents the largest potential challenge in balancing water demands when water demands can make up a large percentage of streamflow during these periods. However, with the increase in winter and spring natural baseflow, there may be opportunities to better utilize reservoirs in the study area to help offset reductions in natural baseflow during the summer and fall months.

Executive Summary

The Indiana Finance Authority (IFA) is conducting a series of regional water supply studies to assess 50-year water demand and supply availability throughout the state of Indiana. This report presents an assessment of historical and future water demands and availability within the Wabash Headwaters Region through the year 2070.

The Wabash Headwaters region is in the northern third of Indiana. Because the Wabash Headwaters Region study area (study area) is defined by surface water watershed hydrologic boundaries rather than administrative jurisdictions, the region includes all or most of Blackford, Carrol, Cass, Grant, Huntington, Jay, Miami, Wabash, Wells, and Whitley counties and portions of Adams, Allen, Auglaize (Ohio), Darke (Ohio), Delaware, Fulton, Howard, Kosciusko, Madison, Mercer (Ohio), Noble, Randolph, Tippecanoe, and White counties. Data from upstream portions of the watershed within the state of Ohio were considered in the study.

To facilitate a comprehensive analysis of regional water demand and supply dynamics, the study area was delineated into 10 sub-basins, corresponding to smaller hydrologic areas (Figure ES-1). The Wabash River, which flows southwest into the downstream North Central Region, underscores the importance of inter-regional coordination and data sharing.

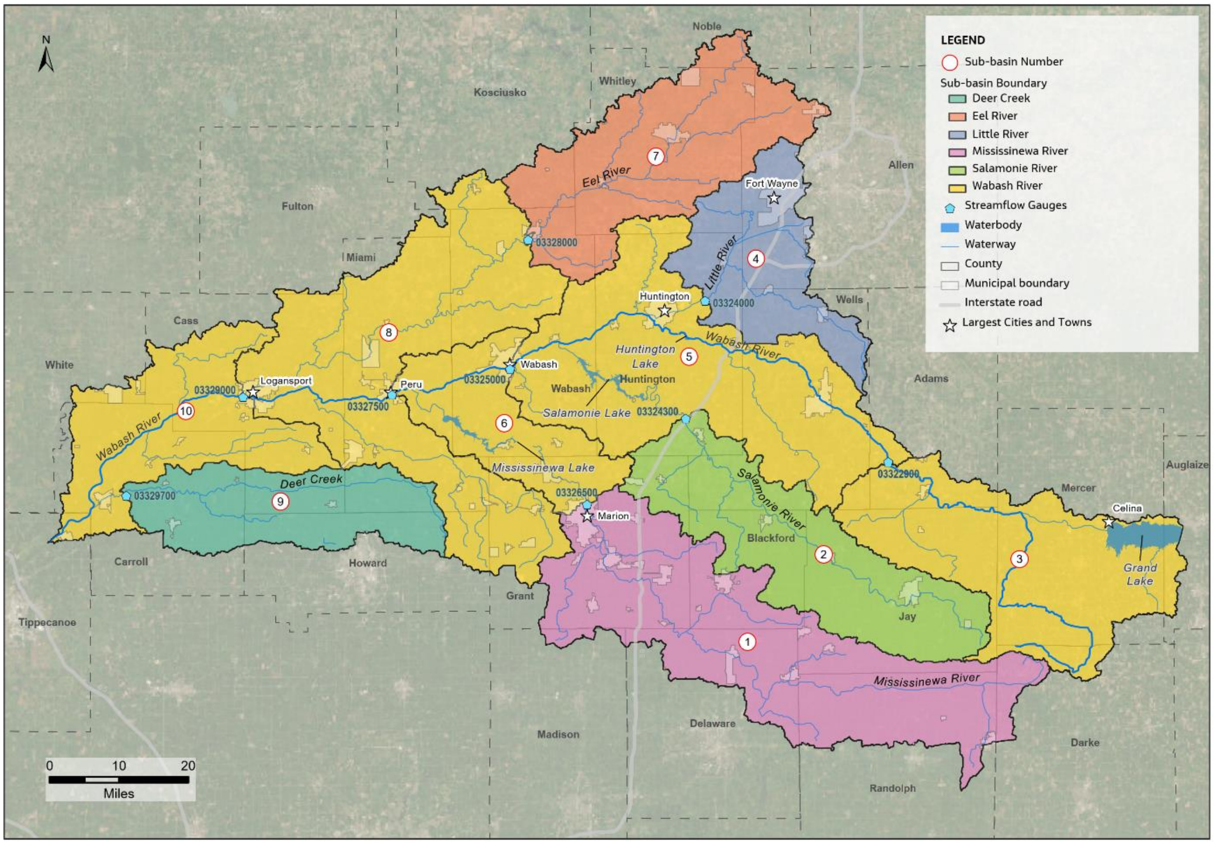


Figure ES-1. Wabash Headwaters Region Study Area and Sub-basins

Study Purpose and Objectives

IFA is undertaking regional water planning studies in 10 hydrologic regions across the state of Indiana to gather and analyze data regarding current and future water demand and supplies pursuant to Senate Enrolled Act 416. This study will analyze historical and projected water demand and supply data through 2070, identify associated risks, and recommend future water planning strategies at regional, sub-basin, county, and statewide levels.

The primary objective of this study is to develop a comprehensive, 50-year water demand and supply forecast extending to 2070. This forecast will serve as a critical tool to support informed planning and decision-making for the region. Objectives include the following:

- Analyze historical and future water demands for the Wabash Headwaters watershed using diverse data sources and stakeholder insights.
- Develop a 50-year water demand forecast considering factors like population, economy, climate, and sector-specific needs (for example, public supply, agriculture, industry, energy, rural, and minimum instream flow requirements to meet ecosystem and habitat needs).
- Assess historical and projected future water supply availability within sub-basins and the entire study area for their capacity to meet demands and instream flows through 2070.
- Analyze and present sub-basin-specific information within the study area.
- Characterize future risks (for example, water supply deficits, water quality concerns) and recommend strategies to address data gaps and mitigate risks.
- Summarize study results in a user-friendly format for water users, planners, and decision makers.

Regional Overview

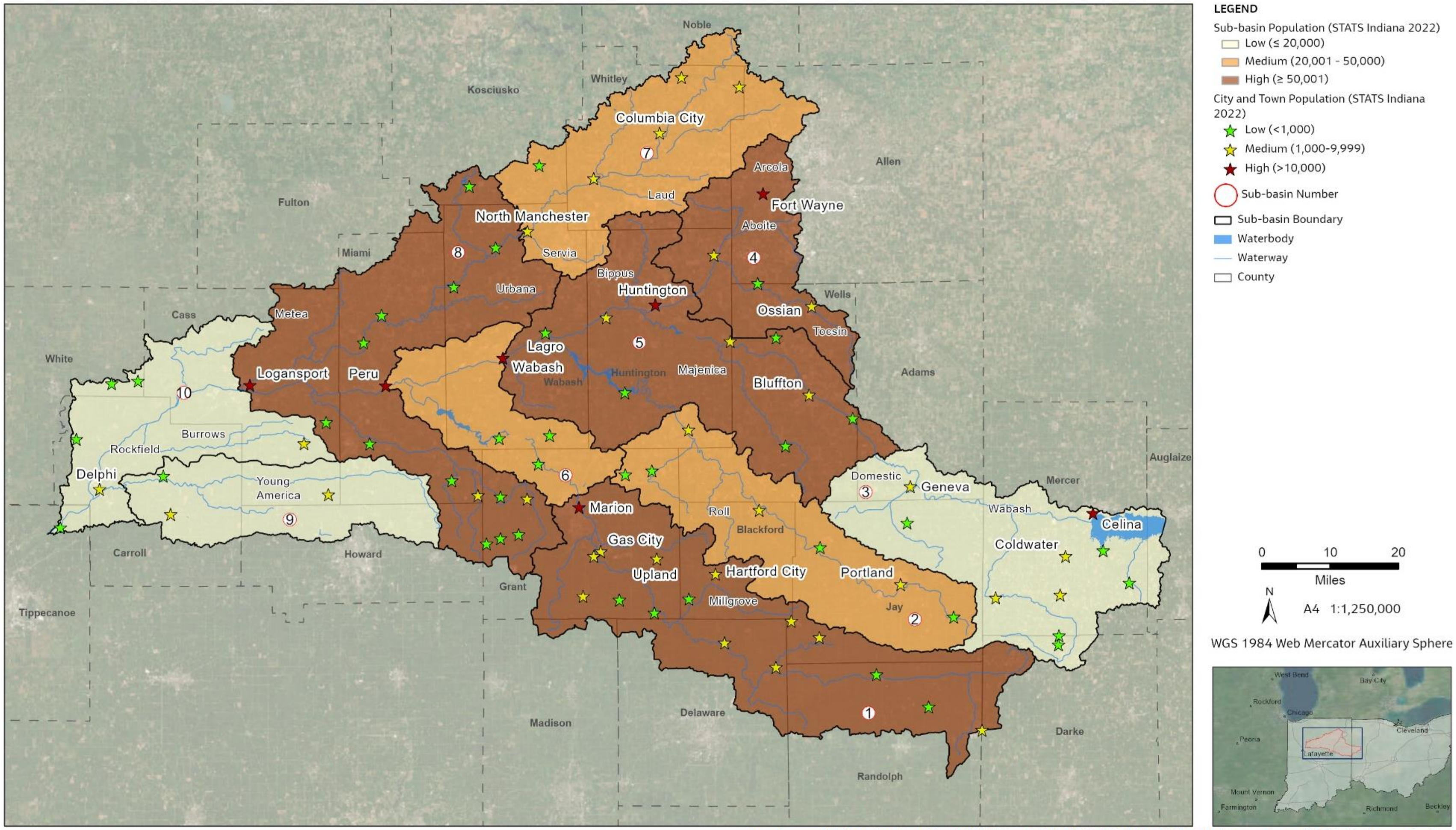
The Wabash Headwaters Region is defined by hydrological boundaries which form drainage basins that contribute flow to surface water (streams, rivers, and reservoirs) and groundwater (aquifers that are sediment or rock formations that lay below the ground surface) within the study area. This approach recognizes how water moves across county and state jurisdictional boundaries and is essential for accurately assessing surface water and groundwater availability to meet human and environmental needs.

The Wabash Headwaters Region Study Area (study area) is composed of five primary hydrological units, identified numerically by the U.S. Geological Survey. This includes the Upper Wabash (05120101), Salamonie (05120102), Mississinewa (05120103), Eel (05120104), and the Middle Wabash-Deer (05120105). While the majority of the Wabash Headwaters Study Area is within the state of Indiana, portions of the Mississinewa and Upper Wabash hydrological units extend into Western Ohio. While this study focuses on the region within the state of Indiana, information about water demand and flows within the state of Ohio that affect water supply within the study area were gathered and analyzed in this study.

Population

In 2022, the Wabash Headwaters Region was home to approximately 323,000 people based on the Census American Community Survey (U.S. Census Bureau, 2022a). The regional distribution of this population is shown on Figure ES-2. Reflective of the rural characteristics of the region, the average population density for the entire study area is approximately 90 people per square mile.

The largest urban center in the study area is the city of Marion, located in Grant County, which accounts for 9.1 percent (%) of the region’s total population. The next largest urban centers are Logansport and Huntington in Cass and Huntington Counties, respectively. The rural and agricultural communities outside the urban centers collectively constitute approximately 56% of the study area’s population



Data Sources: CEC North American Atlas (2024),IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure ES-2. Wabash Headwaters Region: City, Town, and Sub-basin Populations

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Economy

The Wabash Headwaters Region supports a diverse economy, encompassing manufacturing; limestone, clay, sand, and gravel quarrying; biofuel production; agriculture; and livestock operations. The economy within the study area is supported primarily by agriculture and manufacturing, with most employment engaged in agricultural operations (U.S. Census Bureau, 2022). Outside of agriculture, the Wabash Headwaters Region economic drivers also include quarries, manufacturing facilities, retail businesses, and biorefineries.

Climate

The Wabash Headwaters Region has a humid continental climate characterized by long, warm, wet summers and freezing, snowy, windy winters. With an average annual max temperature of 94.5 degrees Fahrenheit (°F) and an average annual minimal temperature of 10.2°F, the Wabash Headwaters Region experiences a significant temperature fluctuation throughout the year. Based on data from 1985 to 2022, July is the warmest month with average daily highs of 84.0°F and average daily lows of 62.8°F, and January is the coldest with average daily highs of 32.7°F and average daily lows of 17.1°F.

Located in a wet region of the United States, the Wabash Headwaters Region received an average of approximately 42 inches of annual precipitation between 1985 and 2020 (NOAA, 2024). Historical data show gradual increases in average temperatures and increasing precipitation for the entire basin (Widhalm et al., 2018). These trends are expected to increase the area of the floodplains around the Wabash River and its major tributaries.

Water Resources Overview

Groundwater resources are a major source of drinking water in the Wabash Headwaters study area and are used to support energy production and irrigation as well as industrial, commercial, and agricultural operations. Groundwater is obtained from underground aquifer systems, which are formations that contain permeable geologic materials that are saturated with potable water. The productivity of an aquifer depends on the interconnected porosity, the volume of connected voids within the formation, the hydraulic conductivity, the ease by which fluid passes through the formation, and the recharge rate (Fenelon et al., 1994).

Various sand and gravel aquifers are available within unconsolidated deposits, some of which can yield as much as 2,000 gallons per minute (Fenelon et al., 1994). In addition to groundwater, some water users in the study area obtain water through surface intakes from streams and rivers. Figure ES-3 shows the major rivers and reservoirs in the study area.

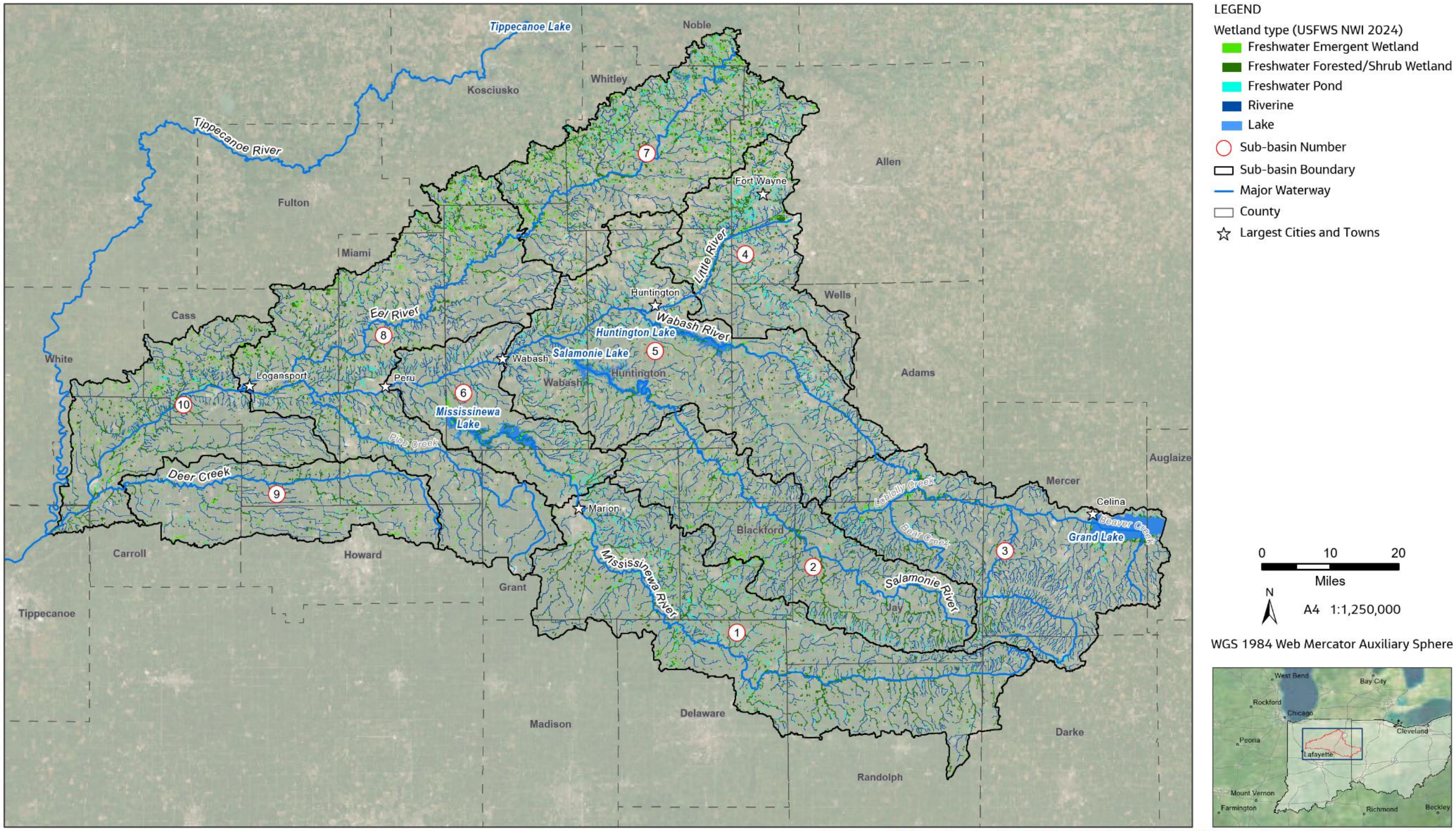

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Figure ES-3. Rivers and Reservoirs in the Wabash Headwaters Region

Historical and Future Water Demands

In 2022, there were 235 unique Significant Water Withdrawal Facilities (SWWFs) operating 467 groundwater wells and 79 surface water intakes within the Wabash Headwaters Region. Significant water withdrawal facility (SWWF) is a water pumping installation or other equipment that can withdraw more than 100,000 gallons of water from the ground, surface, or both in one day. SWWF owners must register with the Indiana Department of Natural Resources (IDNR) and report their annual water use within three months of the end of the year (IDNR, 2024). Figure ES-4 shows the general locations of groundwater wells and surface water intakes throughout the study area. The majority of the SWWFs provide water for public water supply (utilities), agricultural irrigation, manufacturing activities, or mineral withdrawals. In 2022, the highest water demand from SWWFs were public water suppliers and industrial operations. The study area is also home to multiple agricultural operations, several biofuel refineries, and a steel producer.

Historical Water Demand

Reported water use was collected from 1985-2022 for various sectors, including public supply, industrial, agricultural, and other uses. The public supply and industrial sectors represent the largest water demand since 1985, despite a slight decrease in recent years. Between these two sectors, the majority of water use is non-consumptive use, meaning that it is returned to the system. Figure ES-5 presents historical water use in the study area. The Wabash Headwaters Region used approximately 29.8 billion gallons of water in 2022 for an average daily use of 81.8 MGD. The largest water demand was in the industrial uses sector, with an average demand of 32.3 MGD, followed by the public water utilities with an average demand of 30.2 MGD in 2022. Figures ES-6 and ES-7 summarize water demand by sector within each sub-basin in 2022.

Future Water Demand

A multiple regression-based approach was used to identify population, climatic, and economic variables that influence water use, and to assess the relative influence of these factors on demand. This approach produced region-wide, sub-basin, and county-forecasts of demand for each sector through 2070. The water demand for the Wabash Headwaters region in the year 2070 is estimated to be 9% greater than the withdrawal observed in 2022. Figure ES-8 shows the most recent (2022) historical water demand by sector and the future (2070) water demand forecast. Energy production and miscellaneous registered facilities are not shown in the pie charts because they represent less than 1% of the total water demands in the region and their demand is not expected to surpass the 1% threshold. In 2070, energy production is expected to use 0.08 MGD and miscellaneous uses are expected to use 0.04 MGD. Industrial demand is expected to have the largest increase in water demand. The self-supplied sector represents residential users with their own well.

Growth in anticipated water demand is driven by explanatory variables like temperature, precipitation, population, inflation adjusted consumer price index, and median household income and increases in future demands for the concentrated animal feeding operation/confined feeding operation, industrial users, and public water utilities. Future climate conditions used for forecasting were adapted from two previous studies (Byun and Hamlet, 2018; Hamlet et al., 2019) that evaluated projected changes in climate and streamflow over the Midwest and Great Lakes Region and the state of Indiana, respectively. Future climate and streamflow datasets were available covering Indiana for a suite of Coupled Model Intercomparison Project Phase 5 Global Circulation Models.

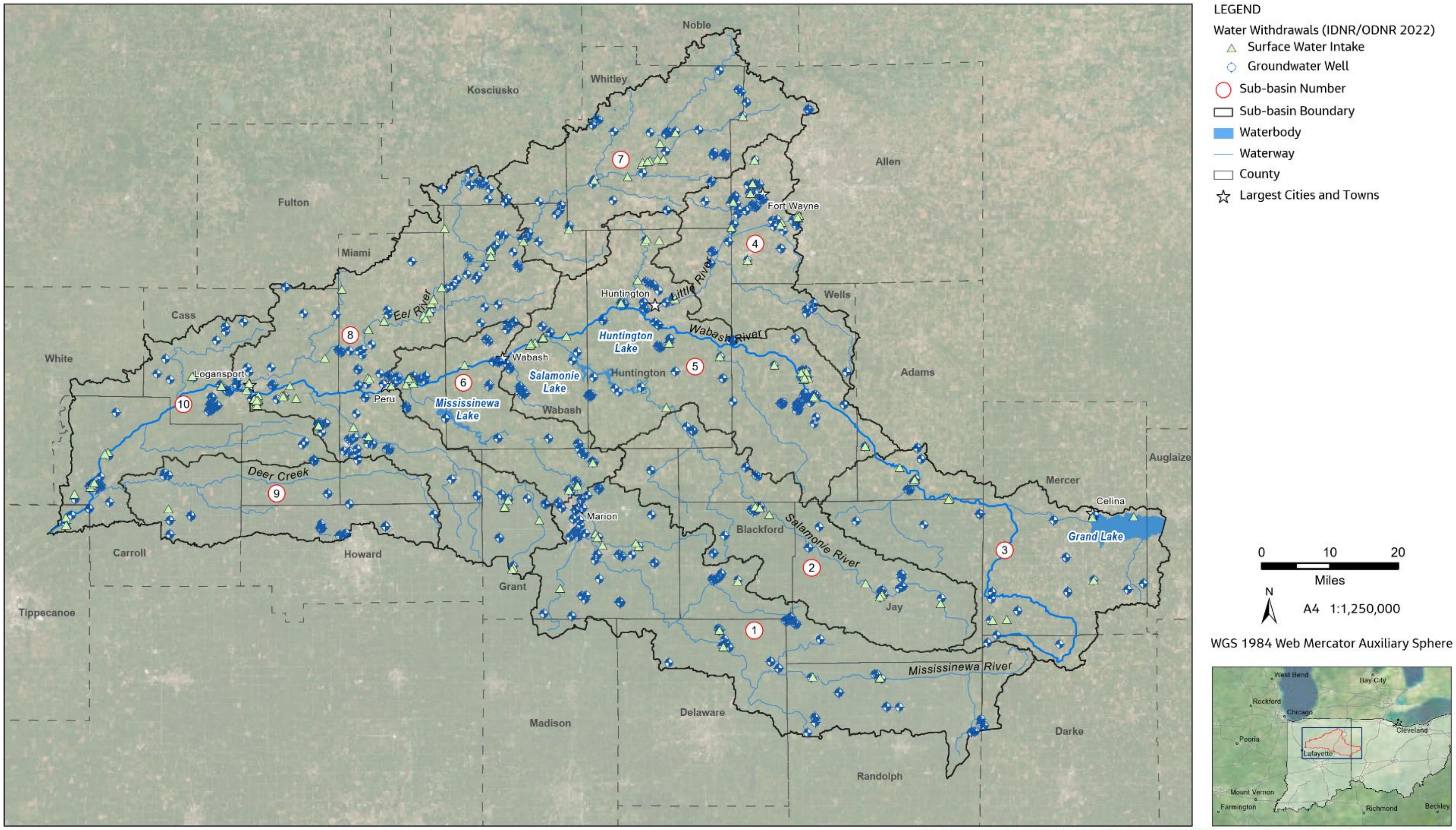

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Figure ES-4. Water Withdrawal General Locations by Source in the Wabash Headwaters Regions

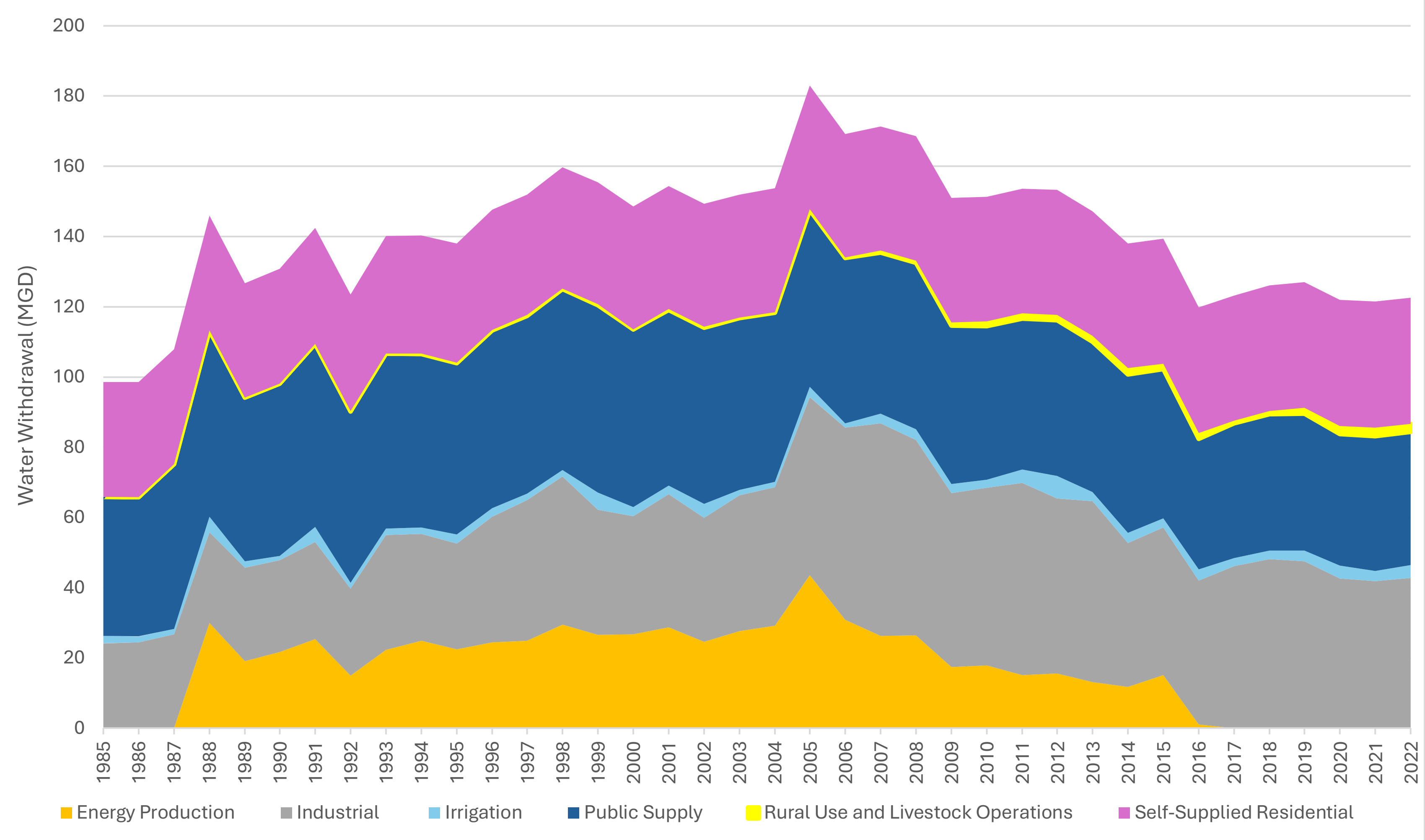

Figure ES-5. Historical Annual Average Daily Withdrawals by Sector, 1985-2022

Note: Miscellaneous registered facilities are not shown because their demand has not exceeded 1% of the total water demands in the region.

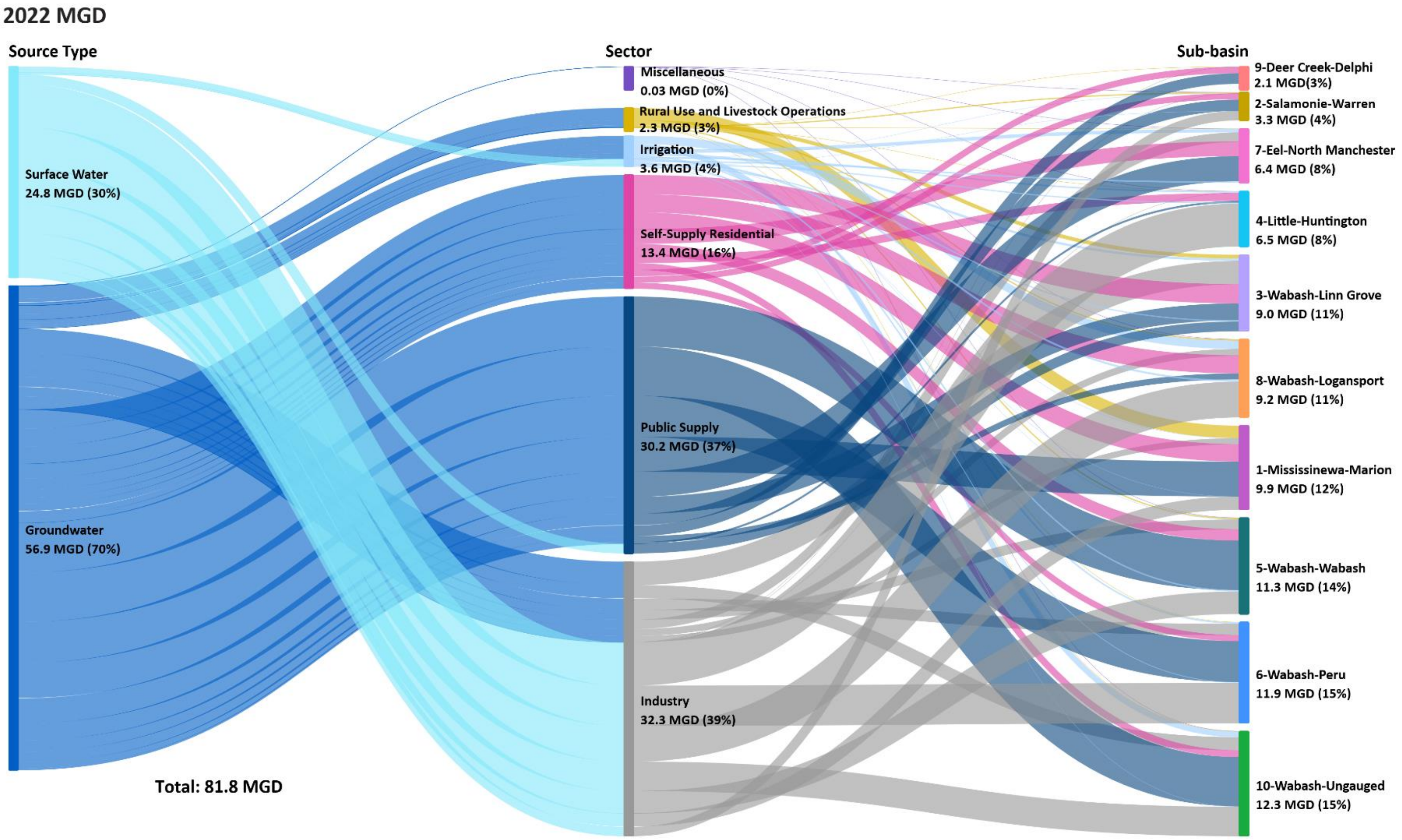

Figure ES-6. Annual Water Use by Sector in Each Sub-basin by Water Source in the Wabash Headwaters Region (2022)

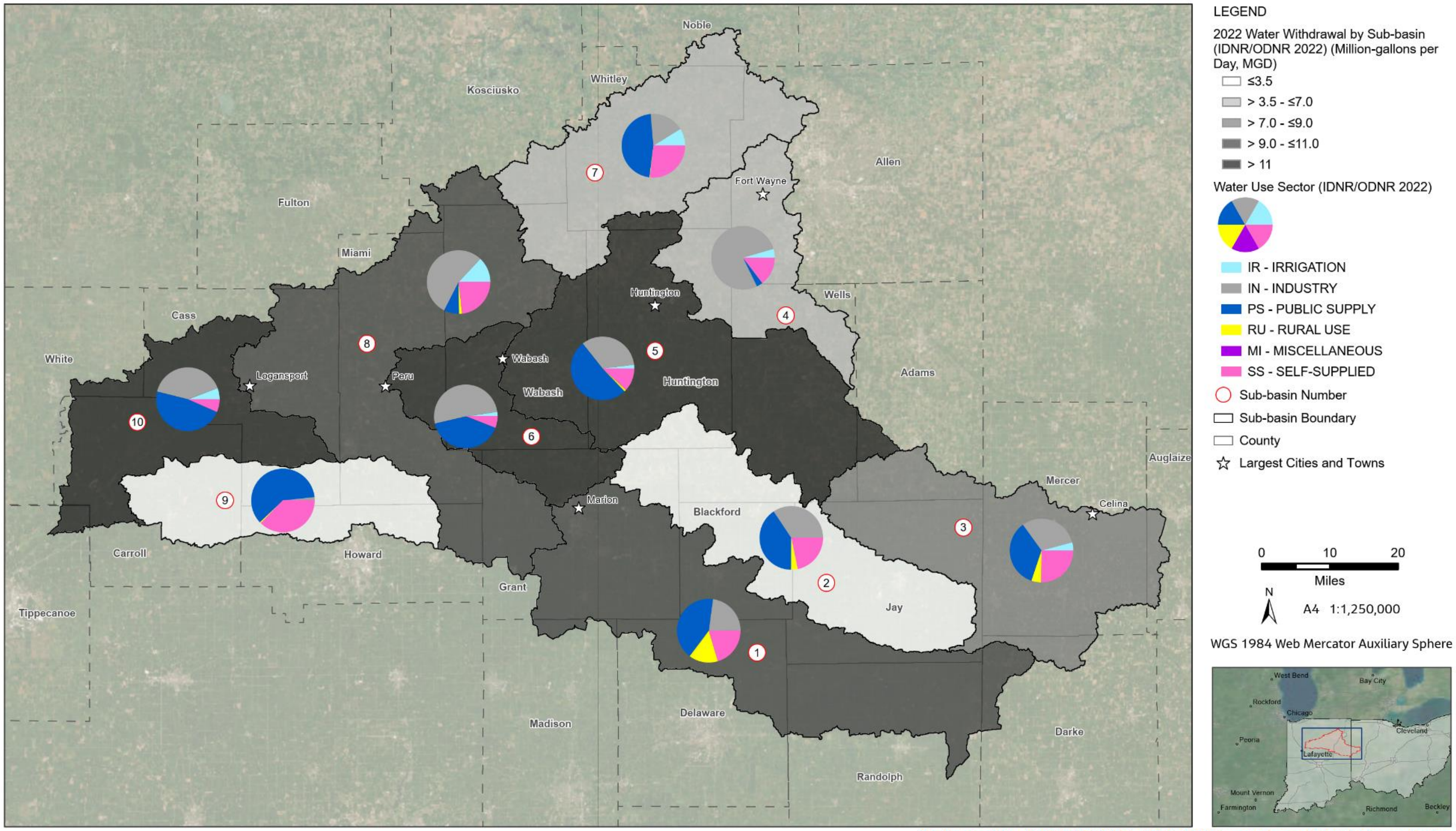

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Figure ES-7. Water Use by Sub-basin and Water Use Category in the Wabash Headwaters Region (2022)

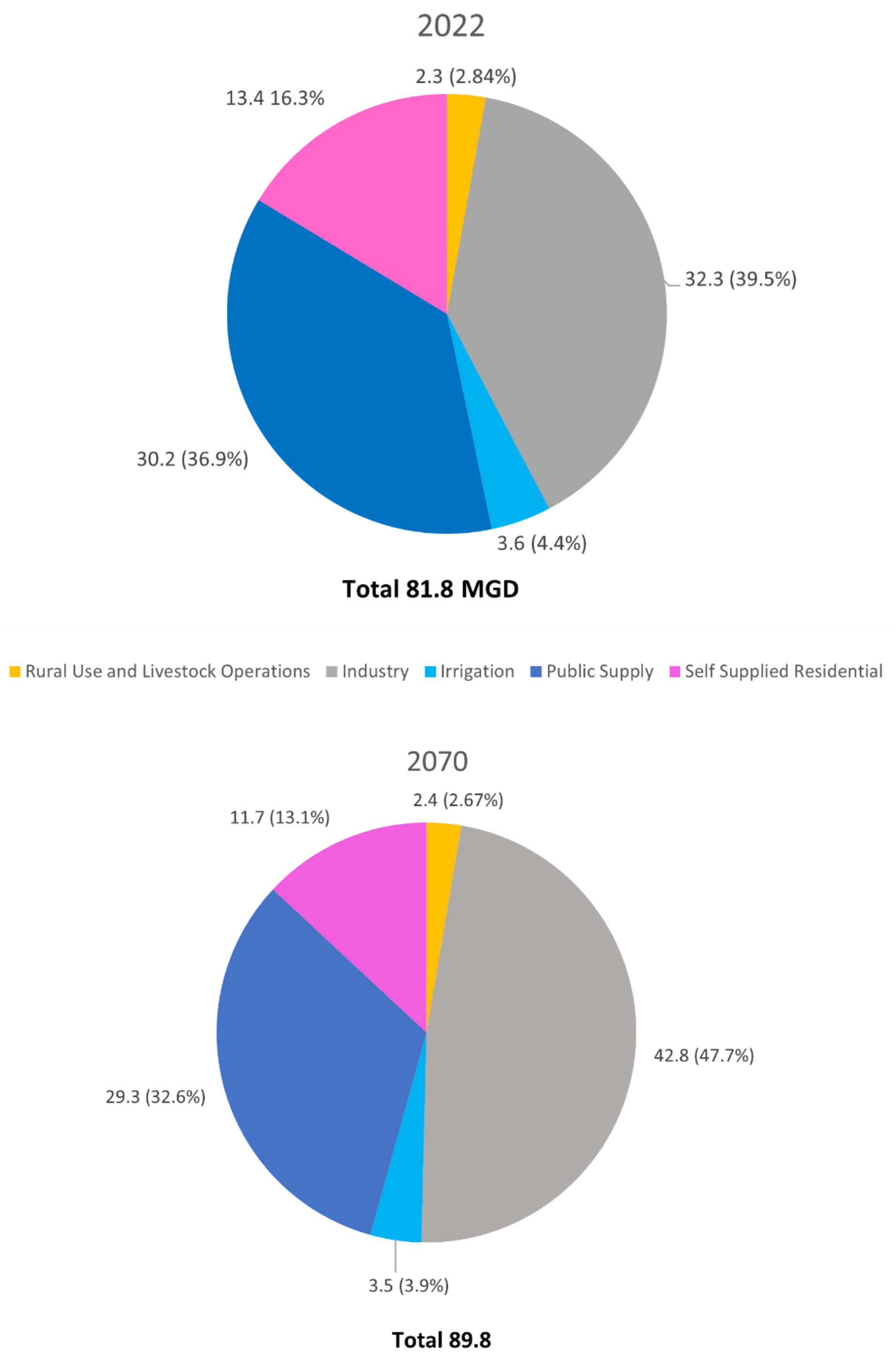


Figure ES-8. Historical (2022, top) and Future (2070, bottom) Water Demands per Sector for the Wabash Headwaters Region

Historical and Future Water Supply Availability

Historical and future water availability in the region was assessed and quantified, building on methodologies developed from previous regional water studies in Indiana (Letsinger and Gustin, 2023; IFA, 2021). The water availability analysis aims to characterize monthly water availability based on local hydrology, stream hydraulics, instream flow requirements, return flows, flood control reservoir operations, and anthropogenic uses of water as defined by the water demand analysis. The water availability analysis is a watershed-based inventory of current (2007 through 2022) and future (2023 through 2070) water availability to support ongoing water resources planning and management efforts in the region. The watersheds used in the analysis correspond to the sub-basins presented on Figure ES-1 and described in Appendix A.

Historical measured data and analytical techniques were used to characterize, quantify, and evaluate components of water availability for each sub-basin in the Wabash Headwaters Region. Three metrics are used for this analysis: water availability, excess water availability, and cumulative excess water availability. The first two metrics are estimated at the sub-basin level and the last term at the sub-basin level but accounting for the effect of upstream sub-basins. The following briefly describes the terminology:

- **Water availability** is characterized as the net baseflow remaining in the stream after net instream flow requirements are met and sub-basin's reservoir operations are accounted for. Water availability accounts for reliable supplies that are available while ensuring that instream flow requirements and flood control factors are prioritized.
- **Excess water availability** is quantified to evaluate the water supply remaining after consumptive use. The consumptive use is considered to acknowledge there is a portion of the surface water and groundwater withdrawals that is returned to the system. The excess water availability provides an evaluation of whether supplies are sufficient to meet water use demands within a sub-basin.
- **Cumulative excess water availability** is quantified to account for regional water availability within the study area and at each sub-basin considering upstream contributions. This metric is especially important for the water supply assessment of the downstream study area, the North Central Indiana region.

Historical Water Supply Availability

Monthly water availability, excess water availability, and cumulative excess water availability were evaluated from January 2007 through December 2022. Table ES-1 presents annual average water availability, excess water availability, and cumulative excess water availability across all sub-basins in the study area. Major influences on water availability include water released from the 3 flood-control reservoirs located within the study area, allocation for minimum instream flow requirements, return flows (non-consumptive water discharged into creeks and rivers), groundwater and surface water withdrawals, and climate factors such as rainfall and temperature.

In general, historical water availability and excess water availability are relatively similar because overall water withdrawals and consumptive use (also known as net return flows) are low compared with study area baseflow conditions and instream flow requirements (Table ES-1). Ultimately, annual historical cumulative excess water availability is positive across all sub-basins. While the Wabash Headwaters Region has opportunities for water use expansion, further evaluation should be considered to characterize “negative water availability” (herein referred to as potential shortages) at the individual sub-basin and seasonal levels. In addition, further analysis on the downstream effect on potential water use expansion to the North Central region needs to be considered.

Table ES-1. Historical Annual Average Water Availability by Sub-basin (1985-2022)

Sub-basin Number and Name	Historical Annual Average		
	Water Availability (MGD)	Excess Water Availability (MGD)	Cumulative Excess Water Availability (MGD)
1 Mississinewa-Marion	151	149	149
2 Salamonie-Warren	72	72	72
3 Wabash-Linn Grove	134	137	137
4 Little-Huntington	53	53	53
5 Wabash-Wabash	116	112	374
6 Wabash-Peru	88	88	610
7 Eel-North Manchester	117	116	116
8 Wabash-Logansport	81	79	805
9 Deer Creek-Delphi	80	79	79
10 Wabash-Ungauged	131	136	1,010

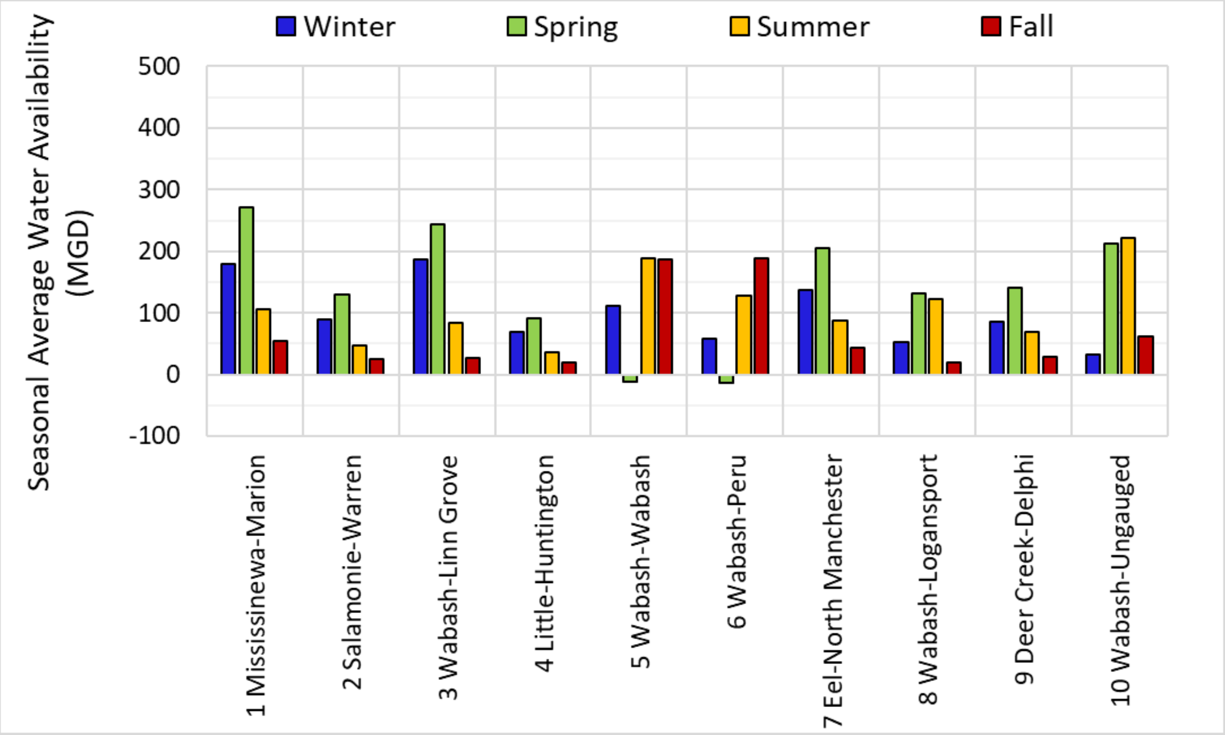


Figure ES-9. Historical Seasonal Average Water Availability by Sub-basin

In addition to annual evaluation of water availability, a seasonal approach to summarizing monthly water availability was employed to characterize seasonal variability in supplies and demands that can have an impact on water availability: winter (December through February), Spring (March through May), Summer (June through August) and Fall (September through November).

Figure ES-9 compares seasonal average water availability for all sub-basins in the study area. All Sub-basins except 5 Wabash – Wabash and 6 Wabash - Peru, have positive seasonal average water availability throughout all four seasons, with more water availability during the winter and spring months and less during summer and fall months.

The following key findings summarize the most relevant insights and observations from the historical availability assessment:

- **The upstream conditions as well as the specific characteristics of the sub-basin influence the water availability results.** In this region, there are two distinct groups:
  - Sub-basins crossed by tributaries to the Wabash River (Sub-basins 1, 2, 4, 7, and 9) and the headwaters of Wabash River (Sub-basin 3). In these sub-basins, cumulative excess water availability is lower as there are no other upstream sub-basins that contribute with additional flow to them and streamflows are smaller.
  - Sub-basins crossed by the Wabash River and with flood control reservoirs influence (Sub-basins 5, 6, 8 and 10). In these sub-basins, cumulative excess water availability is higher and excess water availability seasonal pattern is modified by the reservoirs operations.
- **Water availability, excess water availability, and cumulative excess water availability are all positive on an annual basis.** Positive water availability and excess water availability during the historical period suggests that water demands are generally smaller than the available water supply in all sub-basins throughout the Study Area on an annual basis. Sub-basins' water availability and excess water availability are relatively similar because overall water withdrawals and consumptive use are low compared to groundwater contributions to streamflow (natural baseflow) and minimum instream flow requirements throughout the study area. Cumulative excess water availability is also positive throughout the Study Area (see Sub-basin 10 values), highlighting the interconnection of sub-basins and the availability of water supply as a region.
- **While there may be opportunities for expansion of water use in the Wabash Headwaters Region, further evaluation should be considered to characterize "negative water availability" at the individual sub-basin level, at a seasonal level and downstream effect to North Central Region.** Both positive and negative excess water availability can occur on a seasonal basis within a given year depending on climate and hydrology. Thus, the evaluation of excess water availability is transient and whether water shortage or excess water occurs will depend on seasonal and annual conditions. Also, further analysis on the downstream effect on potential water use expansion to the North Central region needs to be considered.
- **Variability in water availability and excess water availability are generally driven by variability in natural baseflow conditions.** Natural baseflow conditions vary both seasonally and from year to year causing similar variability in water availability and excess water availability. During summer and fall months, and in drier years, when natural baseflow conditions are lower, the balance between supply and demand within the Study Area exhibits a much narrower margin creating negative water availability or water shortages in some sub-basins during some months. This variability is especially relevant in sub-basin crossed by tributary rivers (sub-basins 1,2, 4, 7 and 9) and at the headwaters of Wabash River (sub-basin 3).

- **During summer when river flows are low and water demand is high, the net return flows can represent a significant source of additional instream flows.** For example, in Sub-basin 4 Little-Huntington, the smallest sub-basin in the region, and in Sub-basin 3 Wabash-Linn Grove, the estimated net return flows represent in some months more than 40% of the observed streamflow. A case study for the Wabash River, indicated that during months of reduced flows, the upstream volumetric flow of treated wastewater discharge is approximately equivalent to or greater than the entire volumetric flow of the Wabash River (Wiener et al., 2015).
- **Reservoir operations have a significant influence on seasonal water availability within the sub-basins that contain these reservoirs.** Flood-control reservoirs operated in Sub-basins 5 and 6 have a significant influence on seasonal water availability in these sub-basins due to the storage and release of water to meet reservoir operational criteria. Winter and Spring water availability tend to be lower in Sub-basin 5 and 6, as compared to other sub-basins, due to the reservoirs primarily storing water which negatively influences the water availability balance. Conversely, water stored during the Winter and Spring is generally released during the Summer and Fall months causing the water availability in sub-basins 5 and 6 to be relatively larger than other sub-basins.
- **Reservoir operations increase cumulative excess water availability in Summer and Fall seasons in downstream sub-basins.** Flood-control reservoirs in Sub-basins 5 and 6 sustain summer and fall season flows in downstream sub-basins increasing the cumulative excess water availability in these sub-basins.

Future Water Supply Availability

Forecasts for monthly water availability, excess water availability, and cumulative excess water availability were evaluated from January 2023 through December 2070. Each water availability term was projected into this time frame to account for future changes in demand, changes to inter-annual timing and magnitude of streamflow, and continued operation of the three flood-control reservoirs present in the study area. Assumptions associated with the development of future water availability terms can be found in Appendix A.

The future period developed for water availability assessment contains a prescribed frequency of wet, normal, and dry years. Evaluation of projected water availability, in comparison to historical conditions, was conducted by selecting a 16-year series of future years centered around 2065 that correspond with historical years for the basis of comparison. Figure ES-10 shows the cumulative excess water availability for each sub-basin during the different seasons for Historical and future periods (second column). Also, forecasted changes as a percentage are shown to evaluate the influence of changes in climate, hydrology, and demand on water availability throughout the study area centered on the 2060s period.

In general, winter cumulative excess water availability is projected to increase across all sub-basins, except for Sub-basin 9 Deer Creek-Delphi which exhibits a small decrease in winter cumulative excess water availability. The future water availability variation among seasons is expected to be greater in the future compared to historical conditions, given the projected trend where winter and spring months become wetter and summer and fall become drier. Winter increases in cumulative excess availability range from 3 to 21%. Similarly, spring cumulative excess water availability is projected to increase across all sub-basins ranging from an increase of 14 to 39%. On the other hand, summer decreases in cumulative excess water availability range from -3 to -20%. Fall cumulative excess water availability is projected to decrease across all sub-basins ranging from -11 to -32%.

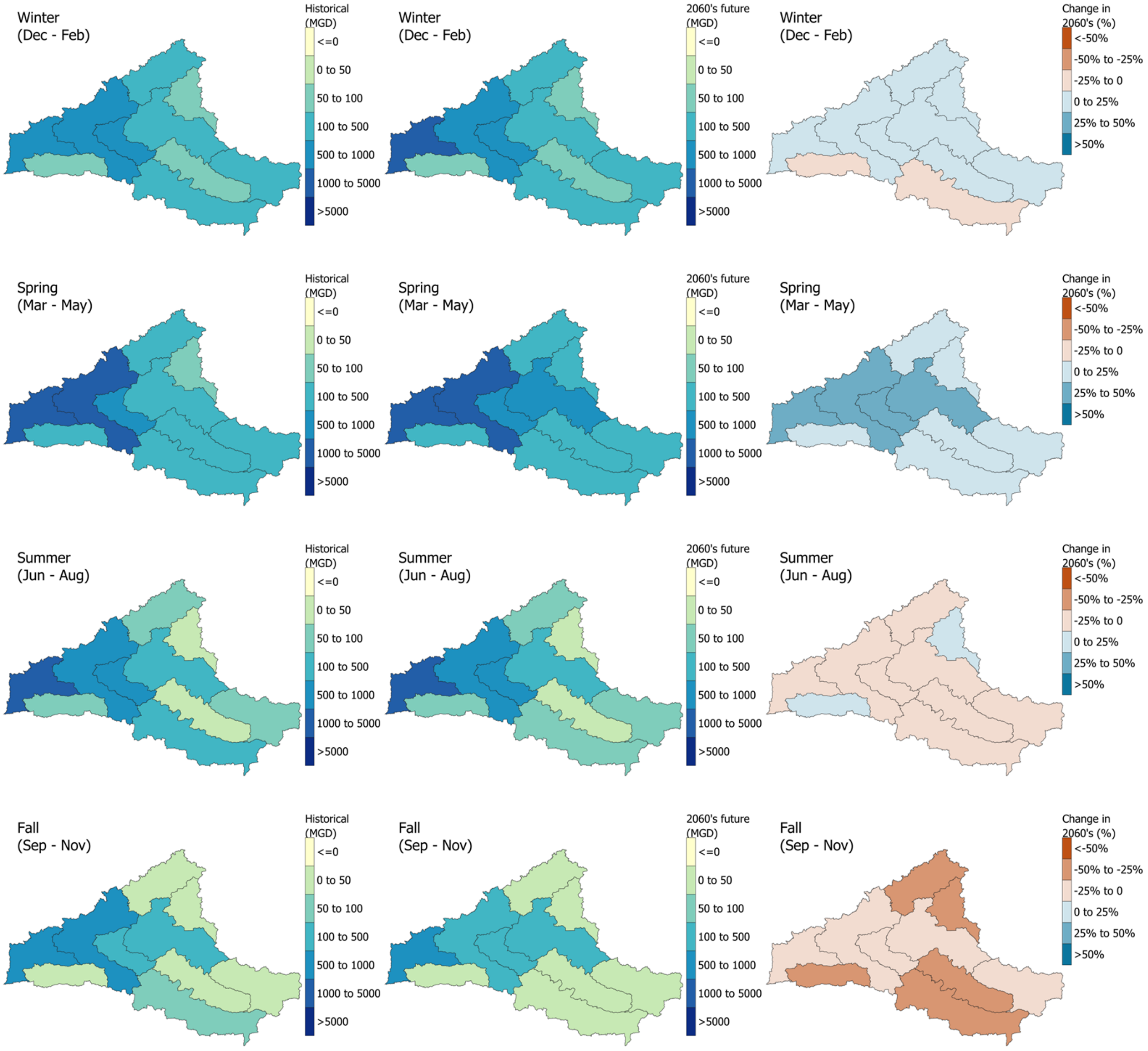
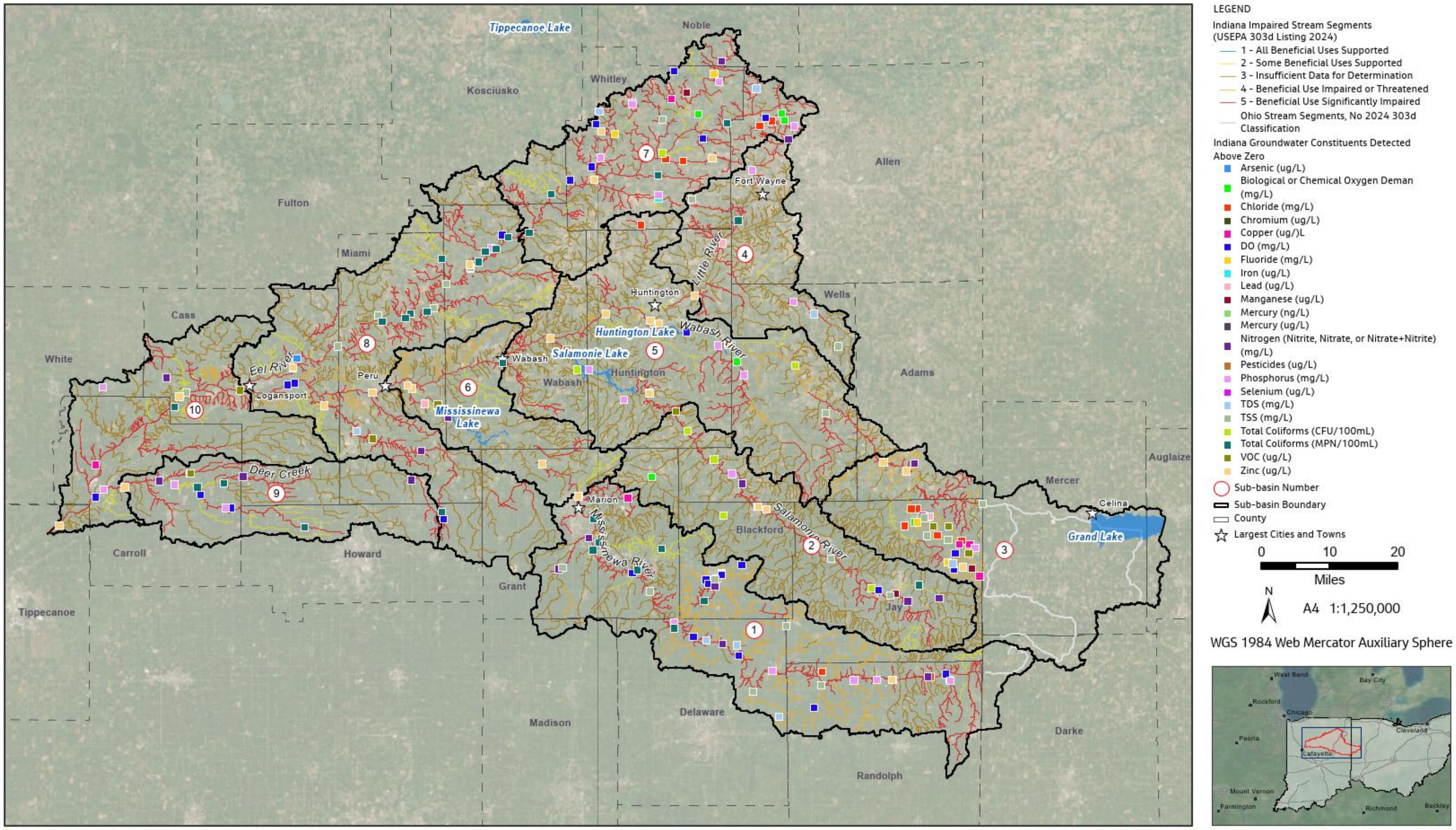


Figure ES-10. Historical and Future Cumulative Excess Water Availability and Future Changes in the Wabash Headwaters Region

Water Quality

According to the 2024 Indiana Integrated Water Monitoring and Assessment Report (IDEM, 2024a), human-generated wastes, such as septic systems and landfills, cause spikes in nitrate levels, and manmade activities and substances, such as underground injection wells, industrial activities, confined feeding operations, oil spills, road salts, and fertilizers, are the main sources of groundwater contamination (IDEM, 2024a). Historically, the Wabash Headwaters Region has experienced some water quality concerns considering the regional economic makeup has a heavy emphasis on the industrial and agricultural sectors. For example, the Upper Mississinewa River previously exceeded the calculated maximum amount of a pollutant that a body of water can receive while still meeting water quality standards (Total Maximum Daily Load (TMDL)) in 2017 addressing *E. coli* and impaired biotic communities (IDEM, 2022). Further the Wabash River in 2006 for *E. coli*, nutrients, impaired biotic communities, DO, and pH. In 2006, the U.S. Environmental Protection Agency-approved TMDL for the Wabash River, which established nitrate + nitrite and phosphorus targets for Indiana and Ohio, though segments of the river still appear on the 303(d) impaired waterbodies list for Indiana (IDEM, 2022). Figure ES-11 shows the assessed surface waterbodies and the respective 303(d) listing categories identified in the 2024 water quality assessment.

Water contamination often starts on land or in surface water bodies and travels through permeable surfaces to reach groundwater sources, making surface water and alluvial aquifers more susceptible to contamination than deeper aquifers. The study area has significant rivers, such as the Wabash and Eel Rivers, that are surrounded by freshwater emergent and forested wetlands (USFWS, 2024), specifically on northern and southern regional borders, increasing contamination impact potential and intensity.



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
\\ausyd0vs01\GISProj\US_Wabash\Apps\Wabash_Mapping_v3.aprx/EEXM100_Wabash_F021_WQImpairedWaterbodiesAndContamLocs_v05 | Date: 19/12/2024

Figure ES-11. Impaired Surface Waterbodies and Detected Groundwater Constituents in the Wabash Headwaters Region

Susceptibility to groundwater contamination is based on the layer thickness and material. Silts, sands, sandy clay, and sand and gravel materials can be vulnerable depending on the overlying materials. Where thick clay deposits or thick till is overlying the aquifer, the permeability is generally lower from the barrier. Hydrogeologic settings with a shallow water table and highly permeable materials generally correspond to higher aquifer recharge and vulnerability to contamination. Hydrogeologic settings such as surficial outwash, surficial alluvium, and natural lakes have a higher susceptibility to contamination because they tend to follow exposed surface water sources, such as the Wabash River, and have little to no surface barrier. Vulnerability may be correlated to aquifer recharge (inches per year), or the total volume of water per unit area infiltrating the aquifer from the land surface, and this was used to characterize the study area for aquifer sensitivity.

Public water utilities have vocalized water quality concerns other than PFAS, such as biological oxygen demand (BOD) loading, as well as elevated iron and manganese concentrations in the surface waterbodies. Generally, these water quality concerns are removed during the drinking water treatment process; however, utilities in Grant County, such as the Town of Converse and Peru Utilities, have noted challenges in treating for elevated levels of iron and manganese in the source water (Preliminary Engineering Reports; Commonwealth, 2023; Wessler, 2019). Other utilities in counties, such as Huntington, Howard, Jay, Wabash, and Wells, have noted higher BOD loading corresponding to groundwater contamination. Huntington and Howard counties have many industrial dischargers where industrial wastewater effluent may have higher BOD loading. Utilities in Wabash and Wells counties have noted that combined sewer overflows and failing septic system impact groundwater contamination and BOD loading. City of Portland in Jay County noted National Pollutant Discharge Elimination System permit violations of BOD loading were responsible for killing fish in the Salamonie River. Therefore, various sources of groundwater contamination could be responsible for water quality concerns across the study area.

Risks, Uncertainties, Opportunities, and Recommendations

Conducing historical analysis and forecasting water demand and supply availability over a 50-year period has inherent risks and uncertainties. In addition, data gaps for which assumptions were made incorporated some degree of uncertainty. While reviewing available data water availability results, opportunities and recommendations were identified to improve the water supply analysis and water supply forecasts aiming to mitigate risks and reduce uncertainties. These identified risks opportunities and recommendations are summarized in this section and discussed in more detail in Section 6. The risks and uncertainties, as well as opportunities and recommendations, are presented in the following categories:

- Overall Risks and Uncertainties
- Water management and planning
- Data and technical considerations

Risks and Uncertainties

Risk and uncertainties identified during the study include the following:

- **Water demand increases resulting from future economic and population changes increasing water demand:** This study used rigorous methods to estimate future demand through 2070; however, various factors could influence actual water use in the future such as significant changes to economic influences that could result in increased water demand in the agricultural and industrial sectors or increases in population that could result in increased demand for public water supply and self-supplied residential users. While not analyzed in this study, increased water use could have implications for additional (or expanded) infrastructure.

- **Seasonal source water supply availability:** While the results of the study analyses indicate no significant negative water supply availability generally throughout the region in annual basis, there is the potential for limitations on surface or ground water availability on a seasonal basis, especially during dry years and sub-basins without upstream sub-basins that contribute with additional flow to them and with smaller streamflow. Also, in smaller sub-basin net return flows during summer when river flows are low and water demand is high, the net return flows can represent a significant source of additional instream flows. Appendix D presents seasonal water availability results by sub-basin. The season water supply availability could represent a regional risk if future demand increase beyond what is forecast in this study, supplies are reduced based changing hydrology or if reservoir operations with the study area change to manage potentially different flooding conditions in the future.
- **Climate change**: Observed temperature and precipitation trends are different over the last few decades as compared with longer-term historical trends. This study used results of a climate change scenario for the State of Indiana (Cherkauer et al., 2021) to forecast potential changes in water demand and supply availability. As presented in Appendix B, other climate futures are possible which could change both future water demands and supply availability.
- **Water quality:** The Wabash Headwaters Region includes many impaired surface water resources (those with water quality below minimum standards). If the water quality trends continue, costs of water treatment could increase and requirements for effluent discharge quality standards could become more stringent. Additionally, there are localized public water systems within the study area that are currently unable to meet drinking water quality standards with their existing treatment plants.

Opportunities and Recommendations

Following are some opportunities and recommendations identified as a result of this study:

- Water demand and water use efficiency:
  - Expand funding and technical assistance for water loss prevention programs to include main replacement, advanced metering, and similar investments, especially for small utilities.
  - Consider local policies and programs to reduce outdoor water use, including lawn watering sprinkler ordinances or incentives for installation of low water using landscapes and irrigation systems.
- Seasonal water availability and storage
  - Consider measures to reduce seasonal consumptive use for outdoor watering within public supply systems and for large irrigation users as an initial first step to reduce seasonal use.
  - Evaluate the potential for aquifer storage and recovery near water demand centers in the event that additional storage is needed in the future.
  - Refinement of net return flows to gain additional insight for potential mitigation measures in small sub-basins for seasonal and drought potential negative excess water availability.

- Existing reservoir operations:
    - Develop a reservoir operations model to perform a comprehensive reservoir water balance to incorporate evaporation, precipitation in the reservoir, and other losses to improve accuracy as well to facilitate analysis impact of climate change and optimization scenarios that affect flooding and the volume, rate, and timing of downstream releases.
    - Assess the condition and design of the existing dams to determine the potential of storing additional water during some seasons or conditions. If the dams can accommodate a potential change of operations, study the potential reallocation of the stored water to meet future downstream demand and instream flow needs.
    - Evaluate variations of operating rules and forecast-informed reservoir operation regimes to determine the potential for meeting the authorized purposes of the reservoirs and downstream needs throughout the Wabash River basin.
- Water quality:
    - Continue water quality monitoring and assessments.
    - Conduct pilot tests of various best management practices that reduce need for application of pesticides and fertilizers and reduce run-off throughout the Wabash River Basin.
    - Consider incentives to encourage landowners to increase their voluntary participation in watershed management and protection plans and programs.
- Climate change and variability:
    - Develop and incorporate high-resolution climate models into future water planning studies with more complete analysis of multiple climate scenarios.
    - Consider adaptation strategies to prepare for potential futures and extreme weather events that could increase demands or affect water supply availability.
    - Conduct detailed studies on potential changes in floodings and potential effects on reservoir operations that could impact water supply availability throughout the Wabash River basin.

Additional technical recommendations regarding data and supply estimation and validation are included in Section 6.

Contents

Appendices

A	Data Methodology
B	Integration Future Climate Demand Supply Projections
C	Water Demand Results
D	Water Supply Results

Tables

Figures

Acronyms and Abbreviations

ACRONYM	TERM
7Q10	lowest average stream flow for 7 consecutive days with recurrence interval of 10 years
µg/L	microgram(s) per liter
ATTAINS	Assessment, Total Maximum Daily Load Tracking and Implementation System
BOD	biological oxygen demand
CAFO	concentrated animal feeding operation
CFO	confined feeding operation
CPI	Consumer Price Index
EPA	United States Environmental Protection Agency
ESA	ethanesulfonic acid
GPCD	gallon(s) per capita per day
GPD	gallon(s) per day
GWMN	groundwater monitoring network
IAC	Indiana Administrative Code
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IFA	Indiana Finance Authority
MCL	maximum contaminant level
MG/L	milligram(s) per liter
MGD	million gallon(s) per day
MHI	median household income
MSL	mean sea level
MW	megawatt(s)
NAD	National Address Database
N/A	not applicable
n.d.	not dated
NPDES	National Pollutant Discharge Elimination System
OA	oxanilic acid
PER	preliminary engineering report
PFAS	per- and polyfluoroalkyl substances

ACRONYM	TERM
PPB	part(s) per billion
Q90	value at which stream flow has been greater than that value.90% of the time
SWWF	significant water withdrawal facility
TAF	thousand acre-feet
TMDL	total maximum daily load
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VOC	volatile organic compound
WMP	watershed management plan
°F	degree(s) Fahrenheit

Glossary

Term	Meaning
Alluvial (aquifer)	Unconsolidated geologic sediment of any grain size deposited by a river, stream, or creek.
Anthropogenic	Man-made or influenced by man. Anthropogenic refers to interventions by humans, such as water withdrawals from aquifers and streams, reservoirs to impound and manage stream flows, wastewater returns, land use, land-cover modifications, and sources of contamination.
Aquifer	Subterranean voids, generally as bedrock fractures or interstitial voids in sand and gravel alluvium, that facilitate the flow of groundwater.
Baseflow	The part of a flowing water body that represents the stream-adjacent groundwater surface and is not associated with runoff.
Baseline scenario	The foundational reference that outlines a likely situation and outcome to occur that can be used as a reference for water supply planning.
Basin (watershed)	The contributing land area that drains water, such as rainfall or snowmelt, to a basin outlet. Also called a drainage basin or catchment. In this report, it represents the combined sub-basins and covers the study area known as Wabash Headwaters.
Bedrock	Any lithified geologic material that remains intact and in place where it was deposited.
Cambrian Period	A geological period that began 538.8 million years ago and ended 485.4 million years ago.
Capture	Pumping an extraction well “captures” water in a zone around the well. Extraction wells can be used to remove contaminated groundwater for treatment and further disposal
Change factor	A number reflecting the future proportional change in monthly stream flow simulated by a hydrologic model that incorporates future temperature, precipitation, and/or other meteorological input data. The change factor is applied to historical streamflow conditions to reflect potential future changes in streamflow.
Confluence	The convergence of two rivers.
Conjunctive use	Coordinated management use of surface water and groundwater supplies aiming to maximize of the overall water resources.
Consumer Price Index	A measure of the average change over time in the prices paid by consumers for a basket of goods and services. It is calculated by the Bureau of Labor Statistics and includes various categories such as food, housing, transportation, and medical care. The index is usually used to gauge inflation and cost of living.
Consumptive water use	The percent of water withdrawals that are not returned to waterways. For example, irrigation water is estimated to have an 80 percent consumptive use

Term	Meaning
	rate meaning the plant transpires 80 percent of the applied irrigation water and 20 percent of the irrigation water is either runoff or percolates into the groundwater. Water extracted from an available water source that does not return to the system because it is evaporated, or transpired (that is, by irrigated crops or landscapes),.or was consumed by humans or livestock.
Devonian Period	A geological period that began 419.2 million years ago and ended 358.9 million years ago.
Dewatering	The removal of surface water or groundwater by pumping to facilitate excavations for construction or mining.
Discharge	Streamflow volume rate, usually measured in cubic feet per second (cfs).
Drift	The general term for sediment deposited by glaciers.
Erosion	The process where natural forces like wind or water gradually wear away and transport soil, rock, or other earthen materials from one location to another, essentially changing the shape of the land over time.
Evapotranspiration	The removal of water from the earth's surface and vegetation through the processes of evaporation and transpiration. Evaporation is water lost to the atmosphere during application of water to the ground surface. Transpiration is the release of water through the leaves of a plant and varies depending on temperature, relative humidity, wind, soil type, soil moisture, sunlight intensity, and type of crop.
Excess water availability	Water supply remaining after consumptive water uses are considered. In this study, the parameter is used to evaluate of whether sub-basin supplies are sufficient to meet its water demands. The portion of water availability in a stream (at the subbasin outlet) that could be used to support additional surface water or groundwater withdrawals without impacting instream flows or existing surface water and net groundwater withdrawals.
Geology	The study of the earth, its structure and composition, and the types of processes acting on it.
Glacial lobe	A curved projection of glacial ice.
Glacial till (till)	An often thick, poorly sorted, clay-rich, unconsolidated geologic deposit that is created by the movement of a glacier.
Groundwater	Water that occurs beneath the land surface and fills the pore spaces of the alluvium, soil, or rock formation in which it is situated. It excludes soil moisture, which refers to water held by capillary action in the upper unsaturated zones of soil or rock.
Groundwater recharge rate	The amount of water per time that is added to a groundwater aquifer through the process of infiltration. Recharge can occur vertically or horizontally.
Headwaters	The most up-gradient, or first-order, tributary watersheds contributing water and sediment downstream to the stream network.
Hummock	A rounded mount of earth, knolls, ridges, or piles of ice.

Term	Meaning
Hydraulic Conductivity	A measure of how easily water can move through a material, defined as the volume of water that moves through a unit area of a porous material.
Hydrograph	A graph that shows a discharge overtime at a specific location and point in time. A streamflow (tributary or main steam river) hydrograph, showing shows measured streamflow (y-axis) over time (x-axis), reflecting streamflow from the area upstream of the measurement point.
HYSEP	A software tool for separating and analyzing streamflow hydrographs into baseflow and precipitation components.
Ice Thrusting	The movement of rock fragments by ice and the resulting deformation and shearing of bedrock and glacial sediments.
Kame	An irregularly shaped hill or mound of sand, gravel, and till deposited by a melting glacier.
Kettle	A depression left behind after partially buried ice blocks melt.
Lacustrine	Relating to or associated with lakes.
Local Relief	The difference in height between the highest and lowest points in an area.
Loess Deposits	Layers of fine, wind-blown silt and dust that are rich in minerals and are usually buff or yellowish brown in color.
Maximum Daily Demand Factor	The ratio of the maximum daily water use to the average daily water use.
Median Household Income	A measure of the income level earned by a given household where half of the households earn more, and half earn less. It provides
Minimum Instream flow Requirement	Instream flows are minimum stream flows required to support the ecological health of the stream, recreational use, and water quality. In this study, the minimum stream flows requirement was computed based on historical measured data at each sub-basin for the period of 1990 through 2020. This term is also referred as Cumulative minimum instream flow requirement as it is computed based on measured streamflow which represents flows accumulated from upstream flows. The 7Q10, defined as the lowest 7-day average flow in a stream that occurs once every 10 years and the Q90, defined as the minimum flow that is present 90% of the time in a stream, are used to determine the minimum requirements.
Mississippian Period	A geological period that began 358.9 million years ago and ended 323.2 million years ago.
Monthly Reports of Operation	Detailed documents that summarize the amount of water withdrawn by a facility over the course of a month. These reports are essential for monitoring and managing water resources, ensuring compliance with regulatory requirements, and promoting sustainable water use (EPA, n.d.). Key components of these reports typically include: • Daily Withdrawal Volumes: The amount of water withdrawn each day from various sources such as surface water, groundwater, or both.

Term	Meaning
	• Source Information: Details about the sources of water, including location and type (e.g., river, well). • Usage Data: Information on how the withdrawn water is used, such as for industrial processes, irrigation, or public water supply. • Compliance Metrics: Data to ensure that the facility is adhering to regulatory limits and guidelines. • Environmental Impact: Information on any measures taken to mitigate the environmental impact of water withdrawals. These reports help regulatory agencies and stakeholders track water usage patterns, identify trends, and make informed decisions about water resource management.
Moraines	Ridges or mounds that consist of intermixed clay, silt, sand, gravel, cobbles, and boulders.
Natural Baseflow	The groundwater contribution of streamflow which is discharged from aquifers to streams. Streams can have gaining (groundwater contribution to the stream) or losing (water loss from the stream bed to recharge groundwater) reaches. Natural baseflow is an estimate of the groundwater discharge contribution to a stream reach without considering anthropogenic (man-made) interventions such as water withdrawals or wastewater-return flows. In this study, this term is also referred as Cumulative natural baseflow
Natural streamflow	The streamflow that would be measured if anthropogenic (man-made) effects of surface-water and groundwater withdrawals and wastewater return flows were removed.
Net baseflow	Total groundwater contributions to streamflow within the sub-basin estimated based on cumulative baseflow as it is computed based Natural streamflow which represents natural flows accumulated from upstream flows.
Net minimum instream flow requirement	Portion of the cumulative minimum instream flow requirement that represents the minimum instream flow that needs to be provided by the sub-basin. Estimated as the difference of the sub-basin cumulative requirement minus the Net requirement of the upstream sub-basins.
Net reservoir releases	Difference between reservoir outflows and reservoir inflows to characterize whether the reservoir located at the sub-basin is storing or releasing water downstream. In this study, there are only three reservoirs that were considered in the water availability, two in sub-basin 5 and one in sub-basin 6.
Observation well	A subsurface borehole (groundwater well) that, instead of pumping, is used to observe and monitor the water table elevation.
Ordovician Period	A geological period that began 485.4 million years ago and ended 443.8 million years ago.
Outstanding Resource Waters	A component of the federal Clean Water act that allows states to identify pristine waterways that constitute an outstanding state resource due to their exceptional water quality, statewide ecological importance, and/or unique recreational value.

Term	Meaning
Outwash	The geologic alluvium deposited by meltwater from a receding glacier.
Paleozoic Era	A geological era that began 538.8 million years ago and ended 251.9 million years ago.
Public Supply	Water that is withdrawn by public and private water suppliers and then delivered to various users. These users can include domestic households, commercial establishments, industrial facilities, and public services such as parks, firefighting, and municipal buildings. A PS can be a community system that serves a large population, or a system such as a school that has their own water well(s).
Physiography	The study of the physical features of the Earth's surface.
Pleistocene Epoch	The geological epoch known as the Ice Age, that lasted from about 2.58 million to 11,700 years ago, and was characterized by repeated glacial cycles.
Reservoir reallocation	The process of changing how water is stored and released in a reservoir.
Reservoir	A large natural or artificial lake used as a source of water supply.
Return flow	Withdrawals or extracted water returned to system after use and treatment. In this study, for the main water users, return flows represent the discharge to surface waters from facilities permitted by the NPDES program, such as wastewater treatment plants. For the irrigation users, CFO/CAFOs, and self-supplied residential, a fix monthly fraction is assumed.
Runoff	Precipitation that is unable to infiltrate into a groundwater aquifer surficial soils and instead flows along the earth's surface towards nearby streams, creeks, or other depressions.
Significant Water Withdrawal Facility	Any water withdrawal installation or equipment that has the capability of withdrawing more than 100,000 gallons of water per day from ground water, surface water or a combination of both. These facilities must be registered and report their water usage annually toe sure proper management and conservation of water resources. The owner of a SWWF must also report annual water use within three (3) months after the end of each calendar year. (IDNR, 2024)
Slump	A block of soil or rock that moves down a curved slop, breaking as it rotates and leaving steps along the slope.
Strata	Horizontal layers of sedimentary rock or soil that are separated by visible surfaces called bedding planes.
Streamflow	Streamflow discharge, usually measured in cubic feet per second (cfs).
Stream gauge	Equipment to measure streamflow at a given location where a flowing body of water is confined to a known geometry to facilitate the measurement of flow volume and other flow statistics.
Subbasin	A portion of a watershed defined by a drainage region between a downstream USGS gage station and one or more upstream USGS gage stations.

Term	Meaning
Subcrop	A buried rock formation.
Surface water	Water supply obtained from streams, lakes, and reservoirs.
Terminus	The end of a glacier.
Till	Sediment deposited by a glacier composed of clay, sand, gravel, and boulders of various size and shape.
Tributary	A river or stream flowing into a larger river or lake.
Unconfined aquifers	An aquifer that does not flow beneath an impermeable geologic layer and is free to flow in accordance with gravity. Sometimes called "water table aquifer" in shallow wells.
Unconsolidated	Geologic material (such as sediment, alluvium, soil, and till) that has not gone through the process of lithification.
Water availability	In this study, water supply availability is characterized as the net natural baseflow remaining in the stream after net instream flow requirements are met, and sub-basin reservoir operations are accounted for. The sub-basin's water availability is an estimate of reliable supplies that are available while ensuring that net minimum instream flow requirements and flood control factors are prioritized.
Water demand	The amount of water required for different purposes and in different water use sectors, such as for public supply, industrial, irrigation, and self-supplied residential. In this study, the terms 'water withdrawal', 'water use', and 'water demand' are used interchangeably. Historical water demand is quantified by water withdrawal volumes for the water users registered in the Significant Water Withdrawal Facility database from the Indiana Department of Natural Resources. For the non-registered livestock operations and self-supplied residential users historical water demand is estimated.

1 Introduction

The Indiana Finance Authority (IFA) is conducting a series of regional water supply studies to assess 50-year water demand and supply availability throughout the state of Indiana. The Wabash Headwaters region is 1 of 10 planning regions in the state (Figure 1-1). The Wabash Headwaters Region includes the uppermost segment of the mainstem of the Wabash River and the tributary watersheds contributing water and sediment to downstream reaches of the river. This region comprises the northern third of Indiana. Because the study area is defined by watershed hydrologic boundaries rather than administrative jurisdictions, it covers a number of counties. The region includes all or most of Blackford, Carrol, Cass, Grant, Huntington, Jay, Miami, Wabash, Wells, and Whitley counties and portions of Adams, Allen, Auglaize (Ohio), Darke (Ohio), Delaware, Fulton, Howard, Kosciusko, Madison, Mercer (Ohio), Noble, Randolph, Tippecanoe, and White counties. Data from upstream portions of the watershed within the state of Ohio were considered in the study. The study area was divided into sub-basins to understand water use and supply availability within smaller areas. Last, the mainstem of the Wabash River flows to the southwest into the downstream North Central Region, which requires coordination and data sharing between the study teams. This report provides information on historical water demands and water availability and forecasts within the study area through the year 2070.

1.1 Purpose and Authority

IFA is undertaking regional water planning studies in 10 hydrologic regions across the state of Indiana to gather and analyze data regarding current and future water demand and supplies pursuant to Senate Enrolled Act 416. This study involves collecting and analyzing historical water demand and water supply availability data, as well as forecasting demands and supply availability for a 50-year period through 2070. The study also includes identifying potential risks associated with water supply availability and recommendations for future water planning within the study area - regionally and within individual sub-basins – in addition to recommendations that may apply to the entire state.

1.2 Study Objectives

The overall goal of this study is to provide a 50-year (through 2070) water demand and supply forecast that provides a foundation for future planning and decision-making within the Upper Wabash River watershed. Specific objectives include:

- **Data Analysis:** Utilize publicly available data and insights from stakeholders to analyze historical and future water demands.
- **Demand Forecasting:** Develop a 50-year water demand forecast, considering factors such as population growth, economic activity, climate change, and water needs for various sectors (public supply, agriculture, industry, energy, rural, and instream flows).
- **Supply Assessment:** Estimate historical and projected water supply availability within hydrological sub-basins to meet future demands and instream flow requirements.
- **Sub-basin Analysis:** Analyze and present water demand and supply information for specific sub-basins within the study area.
- **Risk Assessment:** Identify potential future risks, including water supply deficits, water quality issues, and other challenges, and provide recommendations to address data gaps and mitigate risks.

- **Results Dissemination:** Summarize study findings in a clear and actionable format to support water users, planners, and decision-makers.

This study serves as a foundational analysis, providing data and insights to support the development of future water plans. While it offers recommendations for future water planning, it does not constitute a specific, actionable water plan.

1.3 Report Organization

This report is organized to present regional context and study findings at various levels of detail, ranging from an executive summary to detailed appendices documenting data, methodologies, and results. Following this introductory chapter, the report includes sections described as follows:

- **Section 2 Study Area Overview**: This section presents a characterization of the study area to provide context for the water demand and water supply availability analyses, results, and conclusions. Characteristics, including socioeconomic conditions, land use, climate, physiography, and geology, and an overview of the study area are presented.
- **Section 3 Water Demand:** Information regarding methodologies, models, and data sets used for analysis, historical water use, and future water demand is presented in this section.
- **Section 4 Water Availability**: Similar to Section 3, the methodologies, assumptions and data sets, historical water supply availability, and future water supply availability are presented in this section.
- **Section 5 Water Quality**: This section describes current water quality conditions, including impaired surface water bodies and groundwater contamination sources that limit availability for drinking water and other uses.
- **Section 6 Opportunities, Risks and Recommendations**: Risks such as data gaps, potential seasonal water supply availability, water quality concerns, and other conditions are presented in this section. Opportunities for water management, including water use efficiency (water conservation), storage, and reuse are also presented. The section concludes with recommendations for future studies and initiatives.
- **Section 7 References:** The references provide citations for the data sources used for the study.
- **Appendices**: The appendices provide additional information regarding data sources, methodologies, and assumptions used in the study, as well as detailed results and findings regarding demand and water supply availability. Last, the appendices provide brief summaries of demand forecasts for the counties that are fully encompassed by the study area.

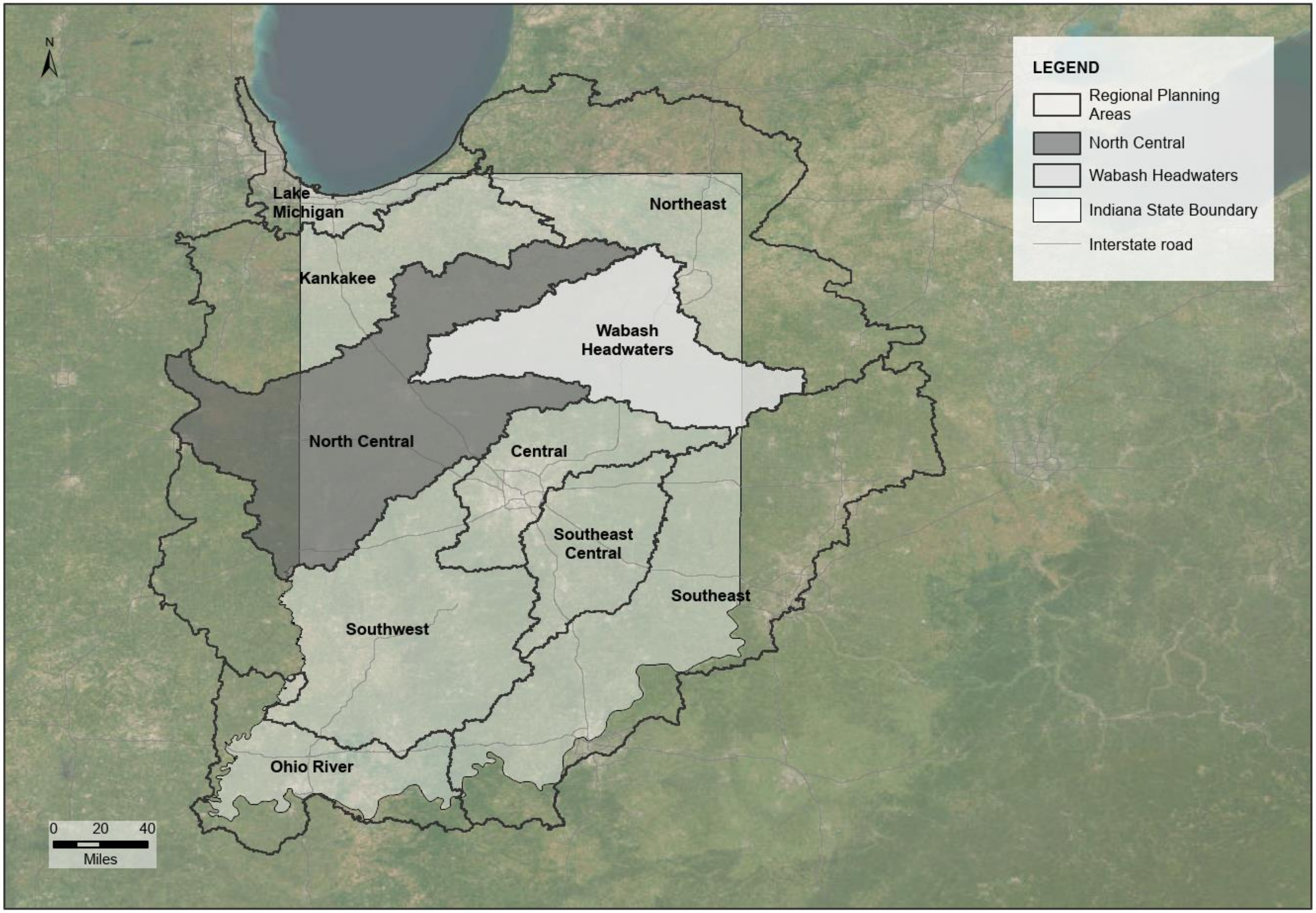


Figure 1-1. Regional Water Planning Study Boundaries

2 Study Area Overview

The Wabash Headwaters Region is defined by hydrological boundaries that form drainage basins that contribute flow to surface water (streams, rivers, and reservoirs) and groundwater (aquifers that are within rock formations and sediment deposits below the ground surface) within the study area. This approach recognizes how water moves across county and state jurisdictional boundaries and is essential for accurately assessing surface water and groundwater availability to meet human and environmental needs.

The Wabash Headwaters Study Area comprises five primary hydrological units identified numerically by the United States (U.S.) Geological Survey (USGS, n.d.). This includes the Upper Wabash (05120101), Salamonie (05120102), Mississinewa (05120103), Eel (05120104), and the Middle Wabash-Deer (05120105). While the majority of the Wabash Headwaters Study Area is within the state of Indiana, portions of the Mississinewa and Upper Wabash hydrological units extend into western Ohio. While this planning study is focused on the region within the state of Indiana, information about water demand and flows within the state of Ohio that affect water supply within the study area were also gathered and analyzed.

Watersheds are composed of smaller areas, or sub-basins, that contribute flows from creeks and river tributaries with the larger watershed. For this study, sub-basins within the study area correspond to portions of the identified hydrological units which are delineated by the drainage areas between a downstream USGS stream gauging station and one or more upstream USGS stations as shown on Figure 2-1. This sub-basin definition facilitates the effective assessment of water supply availability for the study given the analysis approach. The sub-basin delineation process is described in Appendix B, and sub-basin names used in the report are provided in Table 2-1. Throughout the report, the sub-basins may be referred to in the text and figures by either their number or their name.

This section summarizes the region’s socioeconomic characteristics, land use, climate, geology and physiography, water demand sectors, and water users and sources.

2.1 Socioeconomic Characteristics

The Wabash Headwaters Region supports a diverse economy, encompassing manufacturing, quarrying, biofuel production, agriculture, and livestock operations. The following section will delve into the economic characteristics of the study area, highlighting critical industries with historically significant water demands. The economy within the study area is supported primarily by agriculture and manufacturing, with the majority of employment engaged in agricultural operations (U.S. Census Bureau, 2022). Outside of agriculture, the Wabash Headwaters Region economic drivers also include quarries, manufacturing, retail businesses, and biorefineries.

In 2022, Indiana’s labor force consisted of more than 3,300,000 persons with a labor participation rate of 63% (U.S. Department of Labor, 2022). Within the study area, more than 150,000 people were employed, representing an average employment rate of 58%. The reported average median household income in 2022 was $60,023, which was 15% below Indiana’s overall median household income of $69,477 (U.S. Census Bureau, 2022). The poverty rate in the study area varied from county to county, but averaged approximately 13%, which is slightly above the state average of 12.3% (U.S. Census Bureau, 2022). In the United States, the poverty rate is defined as the percentage of a population within or below a certain household income related to the number of people in the household. The poverty threshold is adjusted annually for inflation.

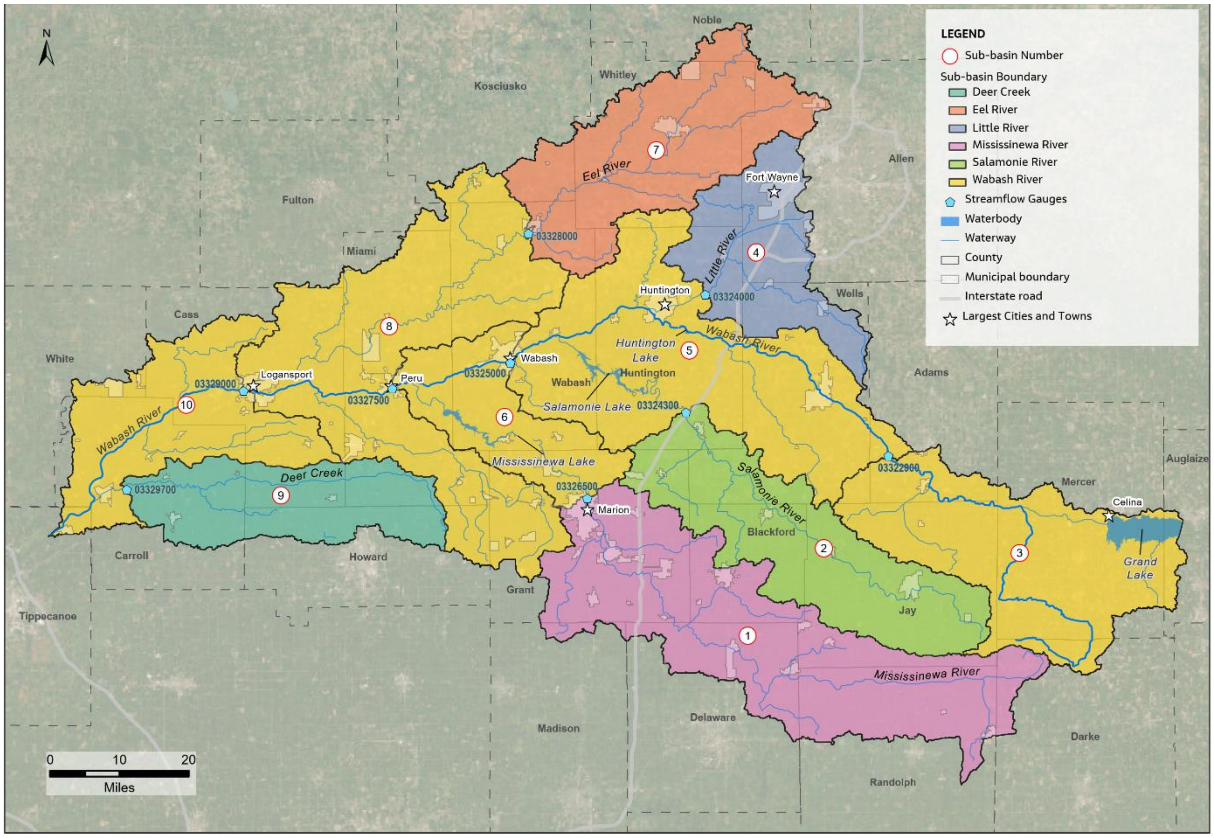


Figure 2-1. Wabash Headwaters Region Study Area and Sub-basins

Table 2-1. Sub-basins in the Wabash Headwaters Region

Sub-basin Number	Sub -basin Name: River-Nearby Town	USGS Station Number	Crossing River	Nearby Town at Outlet
1	Mississinewa-Marion	03326500	Mississinewa	Marion
2	Salamonie-Warren	03324300	Salamonie	Warren
3	Wabash-Linn Grove	03322900	Wabash	Linn Grove
4	Little-Huntington	03324000	Little	Huntington
5	Wabash-Wabash	03325000	Wabash	Wabash
6	Wabash-Peru	03327500	Wabash	Peru
7	Eel-North Manchester	03328000	Eel	North Manchester
8	Wabash-Logansport	03329000	Wabash River	Logansport
9	Deer Creek-Delphi	03329700	Deer Creek	Delphi
10	Wabash-Ungauged	Ungauged	Wabash River	Ungauged

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2.1.1 Population

The Wabash Headwaters Region, home to roughly 323,000 residents in 2022 according to the U.S. Census Bureau, exhibits a predominantly rural character (U.S. Census Bureau, 2022a). The regional distribution of this population is shown on Figure 2-2, which identifies each city, town, and sub-basin. Table 2-2 reports more precise population numbers and population densities for each sub-basin. Reflective of the rural characteristics of the region, the average population density for the entire study area is approximately 90 people per square mile, as seen in Table 2-2.

The largest urban center in the study area is the City of Marion, located in Grant County, which accounts for 9.1 percent (%) of the region's total population. The next largest urban centers are Logansport and Huntington in Cass and Huntington Counties, respectively. The rural and agricultural communities outside the urban centers collectively constitute approximately 56% of the study area's population.

The following sections highlight three major industries in the study area: Cultivated Crop and Animal Agriculture, Power Generation, and Quarries. These industries historically have used significant amounts of water and play a critical role in the local economy.

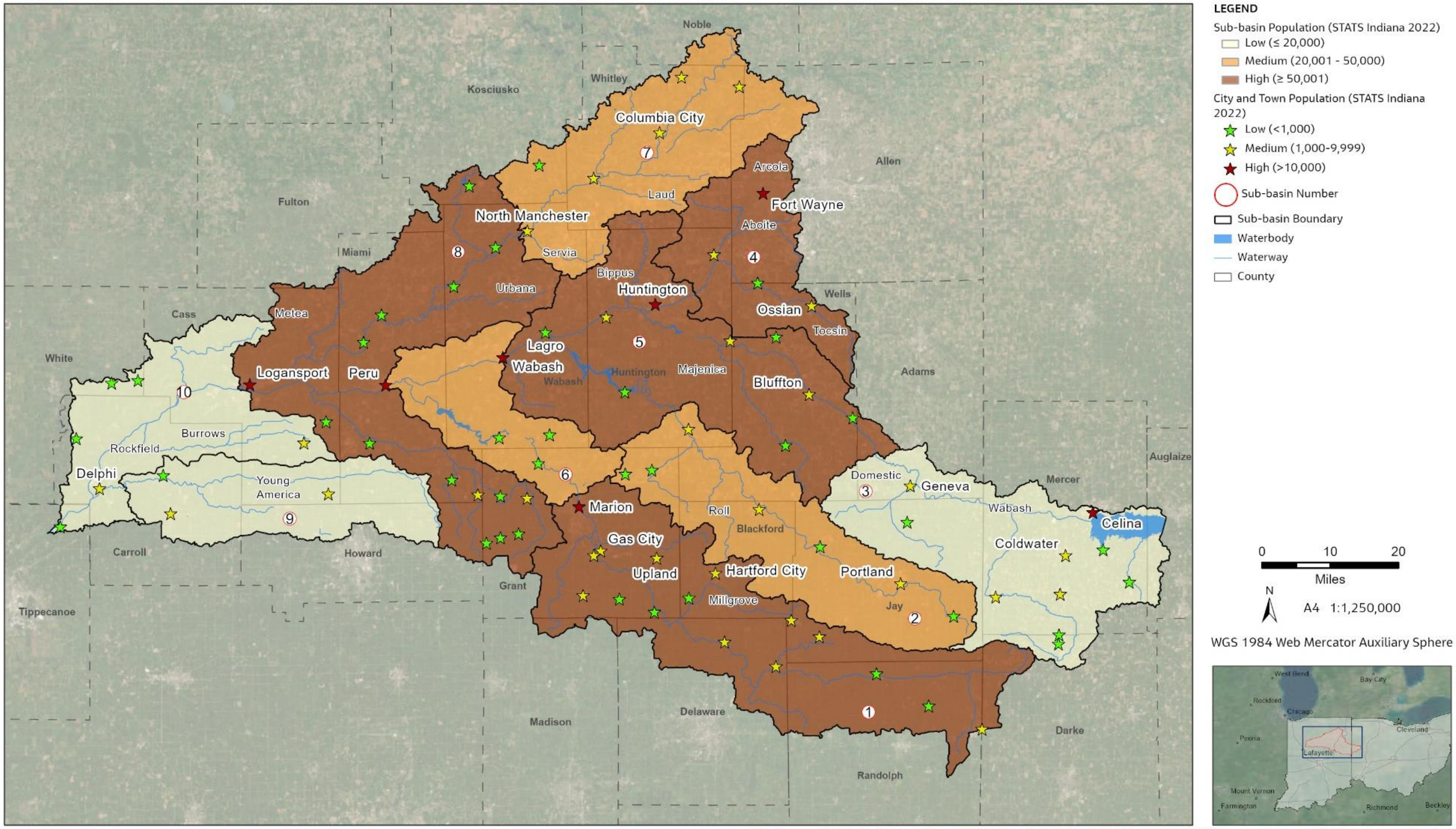
2.1.2 Agricultural Irrigation and Livestock Operations

Agricultural production, including farming and livestock operations, plays a significant role in the study area economy, and provides employment for approximately 12,000 people (STATS Indiana, 2023). According to U.S. Department of Agriculture (USDA) Census of Agriculture, in 2022, there were more than 5,700 farms within the headwaters sub-basin region with approximately 4,800 being used for crop production. The agricultural census defines a farm as any land that has produced or sold a minimum of $1,000 in agricultural products. (USDA, 2024).

Key cultivated crops within the study area consist of corn, soybeans, and small grains. Farm cropland covers approximately 1,681,287 acres of land with 92% of this land used for harvested crops (USDA, 2024). Swine are the most common animal raised by livestock operations in the study area with more than one million hogs and pigs residing on at least 350 farms. There are also more than 1,000 farms that collectively house approximately 80,000 cattle.

Livestock operations in the study area consist of small and large facilities. While both contribute to the local economy, larger operations, such as confined feeding operations (CFOs) and Concentrated animal feeding operations (CAFOs), tend to have a greater impact on the regional economy. A CFO is defined in Indiana as any animal feeding operation engaged in the confined feeding of at least 300 cattle, 600 swine or sheep, or 30,000 fowl (such as chickens, turkeys, or other poultry). A CAFO is a large CFO with at least 700 dairy cows, 2,500 adult swine, or 82,000 laying hens. CAFOs that discharge pollution to waters of the United States are required to have a National Pollutant Discharge Elimination System permit (NPDES) (Ebner, 2021).

In Indiana, all farms CAFO-sized or smaller and meet the state's definition of a CFO are regulated under specific state laws (IC 13-18-10 and 327 IAC 19). Administrative Code 327 15 provides facilities the option of affirming that they are not discharging pollution into waters of the state through accounting for the distribution and responsible application of generated manure products (IAC 327 15). Indiana regulations mandate that waste management systems be designed to prevent surface water discharge. To date, no CFO in Indiana has obtained an NPDES permit for this purpose (IDEM, 2024). In 2022, approximately 472 regulated livestock operations were in the study area, 20% of which are in Sub-basin 8 Wabash-Logansport, a watershed which encompasses portions of the Eel and Wabash Rivers upstream of Logansport (IDNR, 2022). Refer to Section 3, Section 3.1.5 for additional CAFO and CFO information.



Data Sources: CEC North American Atlas (2024),IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure 2-2. Wabash Headwaters Region: City, Town, and Sub-basin Populations

Table 2-2. Wabash Headwaters Region 2022 Population by Sub-basin

Sub-basin Name	Sub-basin Number	2022 Population	Area Square Miles	People per Square Mile (Density)
Mississinewa-Marion	1	83,203	682	122
Salamonie-Warren	2	22,478	425	53
Wabash-Linn Grove	3	5,337	494	11
Little-Huntington	4	66,922	263	254
Wabash-Wabash	5	54,339	630	86
Wabash-Peru	6	30,133	228	132
Eel-North Manchester	7	46,515	419	111
Wabash-Logansport	8	61,253	681	90
Deer Creek-Delphi	9	14,112	275	51
Wabash-Ungauged (east of Lafayette, IN)	10	17,667	343	51
	Total	**401,958**	**4,445**	**90.4 (average)**

2.1.3 Energy Production

In 2022, there were 16 power-generating facilities in the Wabash Headwaters Region. These facilities generate energy from various sources, including biomass, natural gas, petroleum, solar, and wind; they collectively produce more than 540 megawatts (MW) of power annually, as shown in Table 2-3 (U.S. Energy Information Administration, 2024). The largest power generator is Montpelier Electric Generation, which produced approximately 233.1 MW in 2021. This plant is also the only significant water withdrawal power-generating facility in the study area.

According to the U.S. Department of Energy, in 2022, the electric power generation sector employed 17,949 people in the state of Indiana. Within the Wabash Headwaters study area, the energy production sector employed an estimated 1,500 residents. Of those employed by the energy production and power generation sectors, more than 84% worked in clean energy facilities, such as Biofuels and Renewable Generation (Keyser et al., 2022; U.S. Energy Information Administration, 2024).

Between 1988 and 2021, there were three power generation facilities within the study area with reported water withdrawals and registered as SWWs in 2012, the Peru power plant was decommissioned and later demolished in 2017 (Gerber, 2016). The Logansport Generating Plant was decommissioned in 2016 and razed in 2022 (Paul, 2022). Both coal-fired power plants had been in service for more than 100 years. The natural gas power plant, Montpelier Electric Generating Station, has not reported significant water withdrawals since 2021.

Table 2-3. Power Generation Facilities in the Wabash Headwaters Region

Facility Name	Utility Name	Primary Source	Total MW
Montpelier Electric Generating Station	Kimura Power LLC	Natural gas	233.1[a]
Bitter Ridge Wind Farm, LLC	Bitter Ridge Wind Farm, LLC	Wind	130
Bluff Point Wind Facility	Bluff Point Wind, LLC	Wind	119.7
Logansport Solar	Cardinal Renewables	Solar	16
Peru 2	Indiana Municipal Power Agency	Solar	9.5
Columbia City Solar Park	Indiana Municipal Power Agency	Solar	4.3
Celina Solar Project 1, LLC	Celina Solar Project #1, LLC	Solar	4
Oak Ridge LFGTE	Wabash Valley Power Assn, Inc	Biomass	3.2
Jay County LFGTE	Wabash Valley Power Assn, Inc	Biomass	3.2
IMPA Peru Solar Park	Indiana Municipal Power Agency	Solar	3
Peru 3	Indiana Municipal Power Agency	Solar	2.9
Deer Creek PV	Indiana Michigan Power Co	Solar	2.5
Gas City Solar Park	Indiana Municipal Power Agency	Solar	2.5
Peru (IN)	City of Peru - (IN)	Petroleum	1.8
Gas City 2	Indiana Municipal Power Agency	Solar	1.8

Source: U.S. Energy Information Administration, 2024

[a] Montpelier Electric Generating Station has not reported any water withdrawals since 2021.

2.1.4 Quarries

Quarries produce geologic materials, such as limestone, clay, sand, and gravel, that are used throughout and beyond the study area. These quarries play a role in the economy by providing employment opportunities and essential materials that support local communities. According to the U.S. Bureau of Labor Statistics in 2023, the quarry industry employed approximately 160 people throughout the state of Indiana, which is less than 1% of the labor force. The number of quarries registered in the SWWF database fluctuated slightly between 1985 and 2022, as shown on Figure 2-3. The number of active quarry facilities with reported significant water withdrawals peaked between 2000 and 2003 at 25. In 2022, 21 quarry facilities reported significant water withdrawals (Figure 2-3).

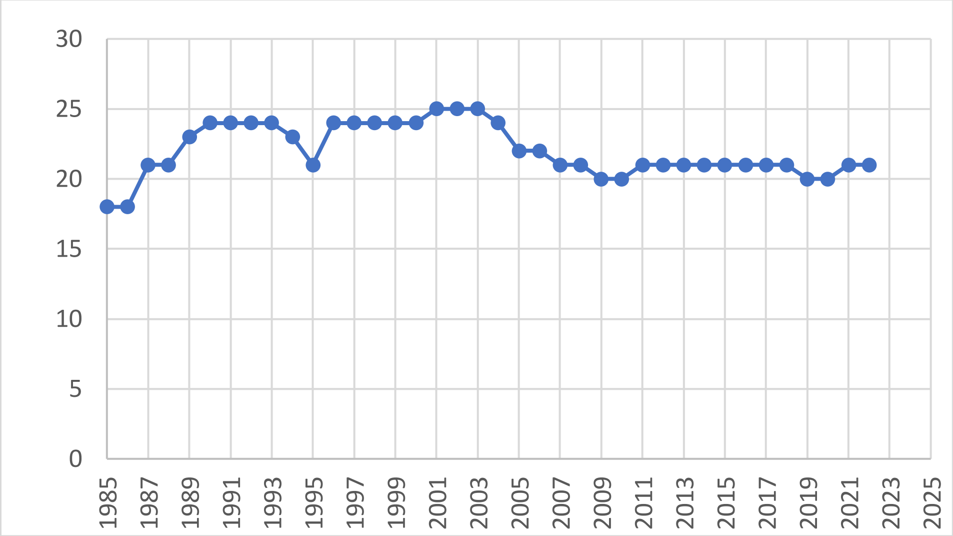

Figure 2-3. Annual Quarry Facilities Reporting Significant Water Withdrawals in the Study Area between 1985 and 2022

2.2 Land Use

The Wabash Headwaters Region consists of approximately 7,680 square miles and fully encompasses 10 counties and portions of 13 others, most of which lie within the state of Indiana. The study area is dominated by agricultural land use, with more than 78% of the area dedicated to agricultural production (Dewitz, 2021). Of this land, cultivated crops constituted more than 75% of the land cover with hay pastures accounting for 2.8%. Much of the agricultural land is not irrigated. Developed land, such as residential, commercial, and industrial uses, account for approximately 8% of the land cover in the study area. The largest developed area is the city of Marion, which is approximately 40 square miles. Forests and wetlands account for 12.5% of the land cover in the study area (Dewitz, 2021). Figure 2-4 maps the various land uses, showing that the vast majority of this land is used for cultivated crops.

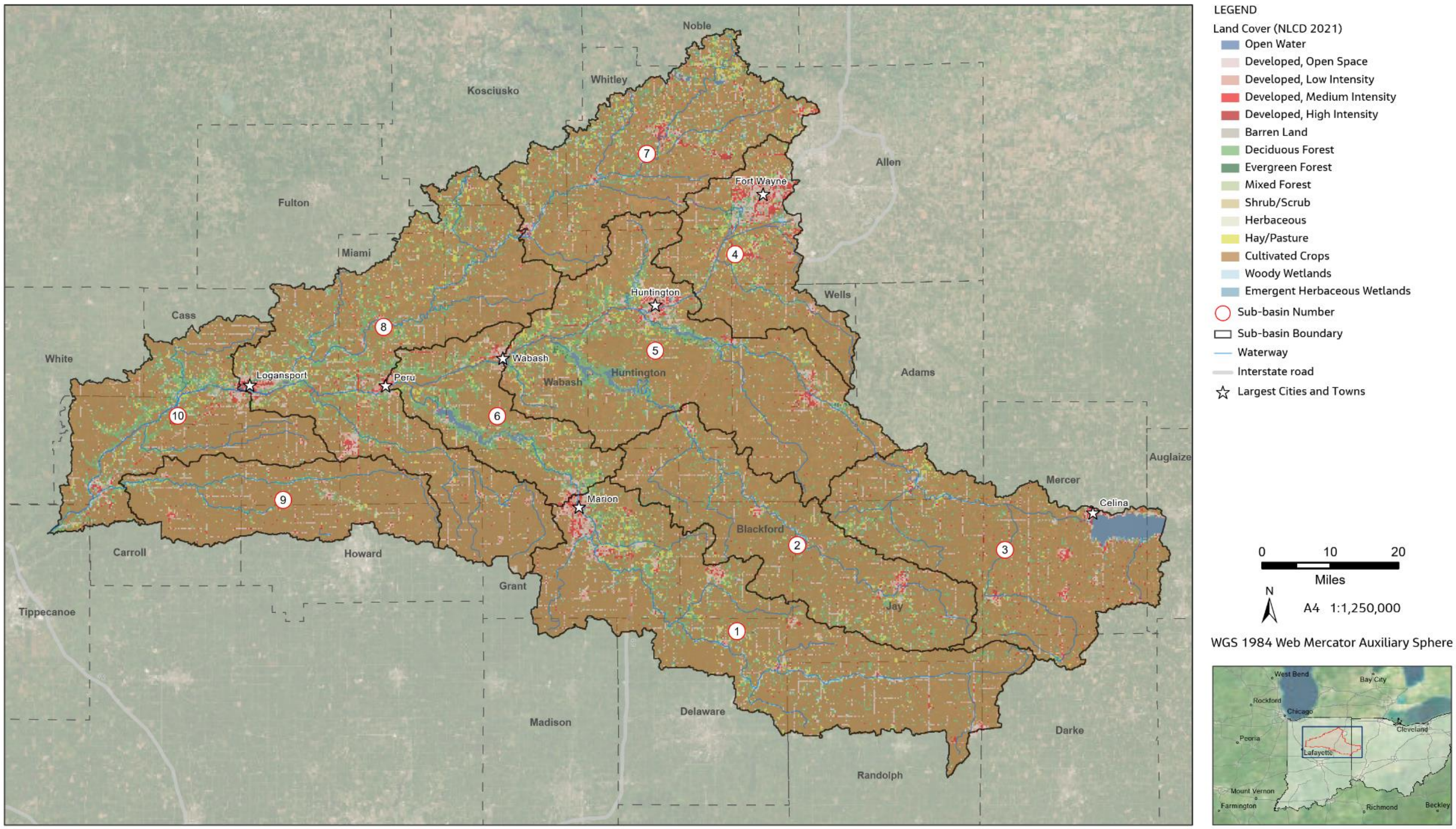

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Figure 2-4. Land Use in the Wabash Headwaters Region

2.3 Climate

The Wabash Headwaters Region has a humid continental climate characterized by long, warm, wet summers and freezing, snowy, windy winters. The seasonality of climate and land use causes a corresponding variation in groundwater levels, which generally rise during the first half of the year when recharge is the largest and discharge (spring flow, upward seepage into surface water bodies, and well pumping) is decreasing, and decline in the second half of the year when recharge is the lowest and discharge is increasing. Generally, average temperature and precipitation values are relatively consistent across the study area. Historical data since 1985 show gradual increases in average temperatures and increasing precipitation for the entire basin (Widhalm et al., 2018). These trends are expected to increase the area of the floodplains around the Wabash River and its major tributaries.

2.3.1 Temperature

With an average annual high temperature of 85.2 degrees Fahrenheit (°F) and an average annual low temperature of 15.1°F, the Wabash Headwaters Region experiences a significant temperature fluctuation throughout the year. The highest recorded temperature since 1985 was 91.5°F in Carroll County (July 2012), and the lowest was 5.8°F in Whitley County (February 2015). Based on data from 1985 to 2022, July is the warmest month with average temperatures of 73.5°F, and January is the coldest with average temperatures of 26.2°F. Figure 2-5 shows the average maximum monthly temperature recorded in each sub-basin for the period 2010-2020, which ranges from 60.55°F to 61.54°F. Historical data from 1985 to 2022 show average temperatures have increased at an average rate of approximately 0.028°F per year. The RCP8.5 climate scenario projects maximum monthly temperatures between 2060 and 2070 to be, on average, 7.6°F higher than average temperatures between 2010 and 2020.

2.3.2 Precipitation

Located in a wet region of the United States, the Wabash Headwaters Region received an average of approximately 40.2 inches of annual precipitation between 1985 and 2022. This rainfall is distributed evenly throughout the area, with average annual precipitation for individual counties usually between 39 and 41 inches. However, precipitation varies seasonally and annually. Although well distributed throughout the year, precipitation is generally the highest (more than 4 inches per month in May, June, and July. Conversely, there is generally a slight reduction in precipitation during the winter months, with the months of January and February receiving, on average, the least amount (less than 2.5 inches per month). This winter precipitation keeps the soil moist into the spring and summer months, helping to minimize drought conditions (USDA, 1982-1992). The highest reported monthly precipitation for a county since 1985 was approximately 14.5 inches in Cass County in July of 2003, and the lowest was approximately 0.1 inches in both Whitley and Wabash Counties in February of 1987.

From an annual perspective, precipitation varies from year to year. Annual rainfall for the study area has ranged from 32 inches to 51 inches between 1985 and 2022. A slight increase in annual precipitation has been observed since 1985. Annual precipitation for the years 1985 through 1994 averaged 39.1 inches, versus an average annual precipitation of 41.3 inches for the years 2013 through 2022. Figure 2-5 presents historical average monthly precipitation between 2010 and 2020 for each sub-basin. All sub-basins averaged between 3.43 and 3.62 inches of monthly precipitation over this decade.

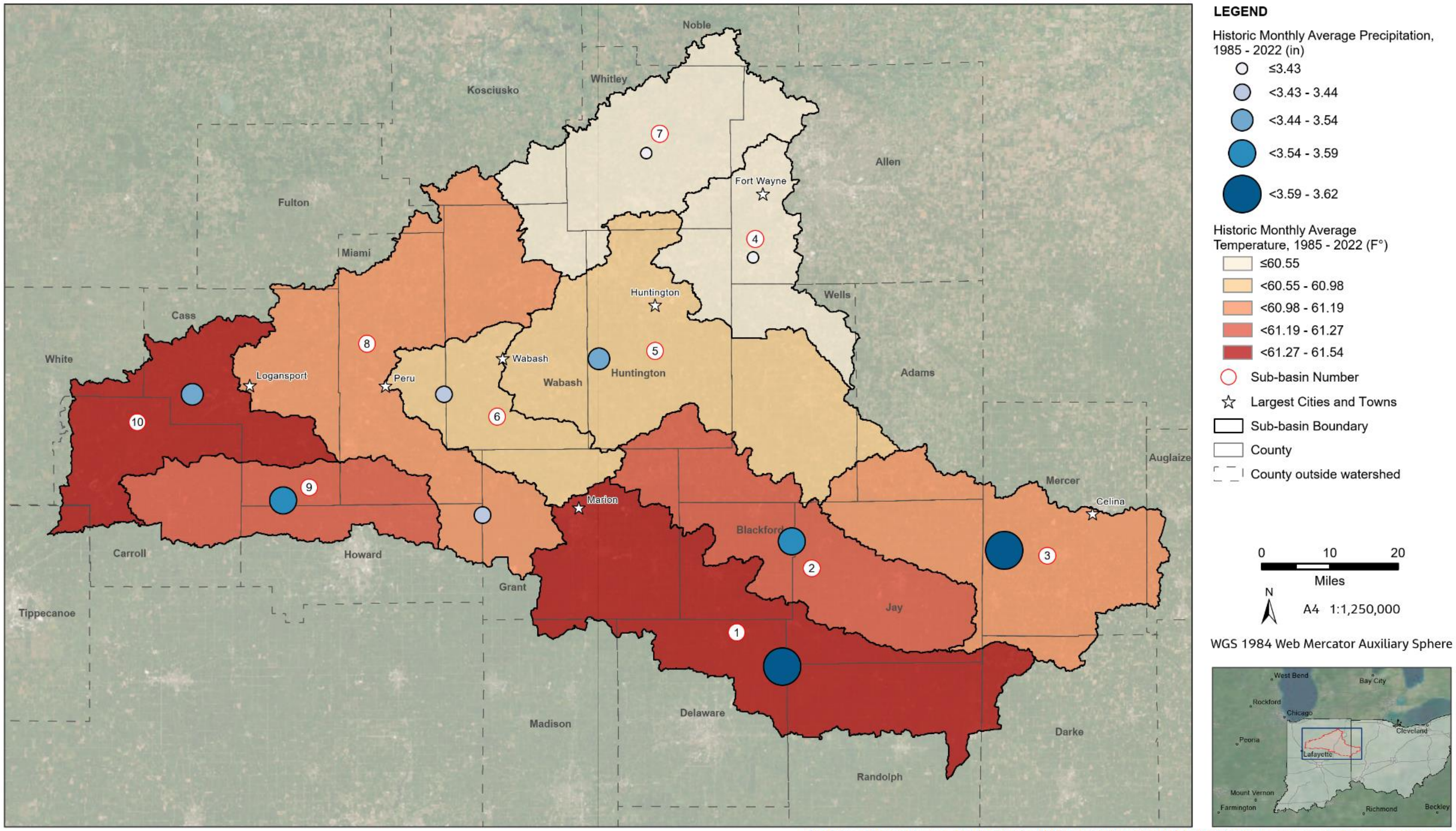

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Figure 2-5. Historical Temperature and Precipitation in the Wabash Headwaters Region

2.3.3 Flood Protection

The Wabash Headwaters Region is a relatively flat landscape, typified by an undulating plain comprised of glacial till (Dolan and Parker, 2005). The elevation within the region ranges from 650 ft above mean sea level (msl) to approximately 1,100’ msl. The flat, flood-prone areas bordering the Wabash River are limited by the surrounding topography. This topography is the result of a complex interplay of geological processes, including tectonic shifts, glacial activity, and the river's historical path. The most extensive floodplains are found along the main channel of the Wabash, particularly in its lower reaches (Armitage et al., 2009).

In the Wabash Headwaters Region, four reservoirs have been constructed to alleviate downstream flooding and provide recreational opportunities (USACE, 2011). Flood relief projects within the study area include the construction of a levee to protect the city of Delphi and the construction of the Huntington, Salamonie, and Mississinewa reservoirs owned and operated by the U.S. Army Corps of Engineers (USACE). The primary purpose of these reservoirs is to prevent detrimental flooding downstream (USACE, 2011).

These reservoirs have prevented millions of dollars of flood damage within and downstream of the study area (USACE, 2011). The portion of the study area that benefits the most from the three-reservoir system (from a flood management perspective) includes the cities of Wabash, Peru, and Logansport, as well as approximately 60,000 acres of surrounding agricultural land and related developments (USACE, 2011). Water storage and release from the reservoirs based on operational rules during different seasons impacts water available within this region as well as regions receiving flows from the mainstem of the Wabash River.

2.4 Geology and Physiography

Understanding the physiography and geology of the study area is vital to understand water availability and retention within its landscapes and aquifers. The following sections will describe key components and differences of the physiographic areas within the Wabash Headwaters Region. In addition, the geology of the area will be explored by examining the historical processes that lead to the existing bedrock formations and unconsolidated deposits that underlie the study area.

2.4.1 Physiography

Physiography is the study of the physical features of the Earth’s surface. The physiography of a region is determined by the complex history of bedrock and unconsolidated sediment deposition. The distribution of various bedrock formations and the subsequent erosion of these bedrock layers results in topographical characteristics that influence the deposition and formation of future unconsolidated deposits (Hill, 2016). The geological history of a region determines its eventual physiographic features. It is helpful to understand the physiographic features of the study area and how they were formed because they are responsible for the drainage and flow of surface water throughout the basin.

Apart from occasional bedrock exposures near major rivers and tributaries, the Wabash Headwaters region’s physiography was formed by glacial activity during the Pleistocene Epoch. Regions are divided into physiographic units based on topographical and geological similarities. The Pleistocene glacial events resulted in three major physiographic areas in Indiana: the Northern Moraine and Lake Region, the Central Till Plain Region, and a southern zone dominated by bedrock landforms. These regions may be further divided into smaller physiographic units based on more distinguishing physical characteristics. Most of the Wabash study areas lies within the Central Till Plain Region, which includes the Tipton Till

Plain and the Bluffton Till Plain as shown on Figure 2-6; however, northern portions of Sub-basins 7, 8, and 10 are within the Northern Moraine and Lake Region's Warsaw Moraines and Drainageways and Auburn Morainal Complex (Figure 2-7; EPA, 2024).

The Northern Moraine and Lake Region is characterized by moraines, till plains, outwash plains, and kettle lakes (Hill, 2016). Within the basin, this physiographic region occupies the land north of the Eel River. A western physiographic unit, called the Warsaw Moraines and Drainageways, is characterized by a row of outwash fans that span the land to the northwest of the Packerton Moraine, which marks the southeast boundary (Gray, 2000). This unit occupies portions of Sub-basins 7, 8 and 10, and many loose sediments from this land are deposited into the study region by the Tippecanoe River (Fenelon et al., 1994).

In contrast to the Warsaw Moraines and Drainageways, the Auburn Morainal Complex to the east covers portions of Sub-basins 4 and 7. This unit was formed by interlobate moraines, created when two or more glaciers meet and experience ice thrusting and slumping, which results in the occurrence of protrusions, surface depressions, and local relief of up to 150 feet. Some of these depressions did not have sufficient means of surface drainage and have formed kettle lakes. Many of the major moraines formed by the Erie Lobe terminate in this region and have formed till ridges with moderate relief (Gray, 2000).

The Central Till Plain Region occupies the flat, central region of Indiana and a vast majority of the land within the boundaries of the study area - all land south of the Eel River. Underlain by ground moraines and thick glacial till, this area can generally be characterized by flat to gently undulating land surfaces and poor drainage. Surface relief is generally less than 10 feet per 1,000 feet. The regression of the most recent glaciation created a succession of large end moraines ranging from 1 to 6 miles wide in the northeastern area called the Bluffton Till Plain (Fenelon et al., 1994). This physiographic unit covers a majority of the study area and is defined by the extent of four concentric Erie Lobe end moraines, including the Union City Moraine, which marks the southwest boundary of the Bluffton Till Plain (Gray, 2000).

To the southwest of the Bluffton Till Plain is a second physiographic unit within the Central Till Plain Region called the Tipton Till Plain. In this region, ice froze overtop a flat bedrock surface and melted in place, resulting in relatively uniform deposition of unconsolidated deposits and even flatter landscapes than the Bluffton Till Plain (Gray, 2000). Loamy glacial till and scattered loess deposits have produced fertile soil that drains more easily than the Bluffton Till Plain to the east and has been mostly deforested for the purpose of agriculture (Woods et al., 1998).

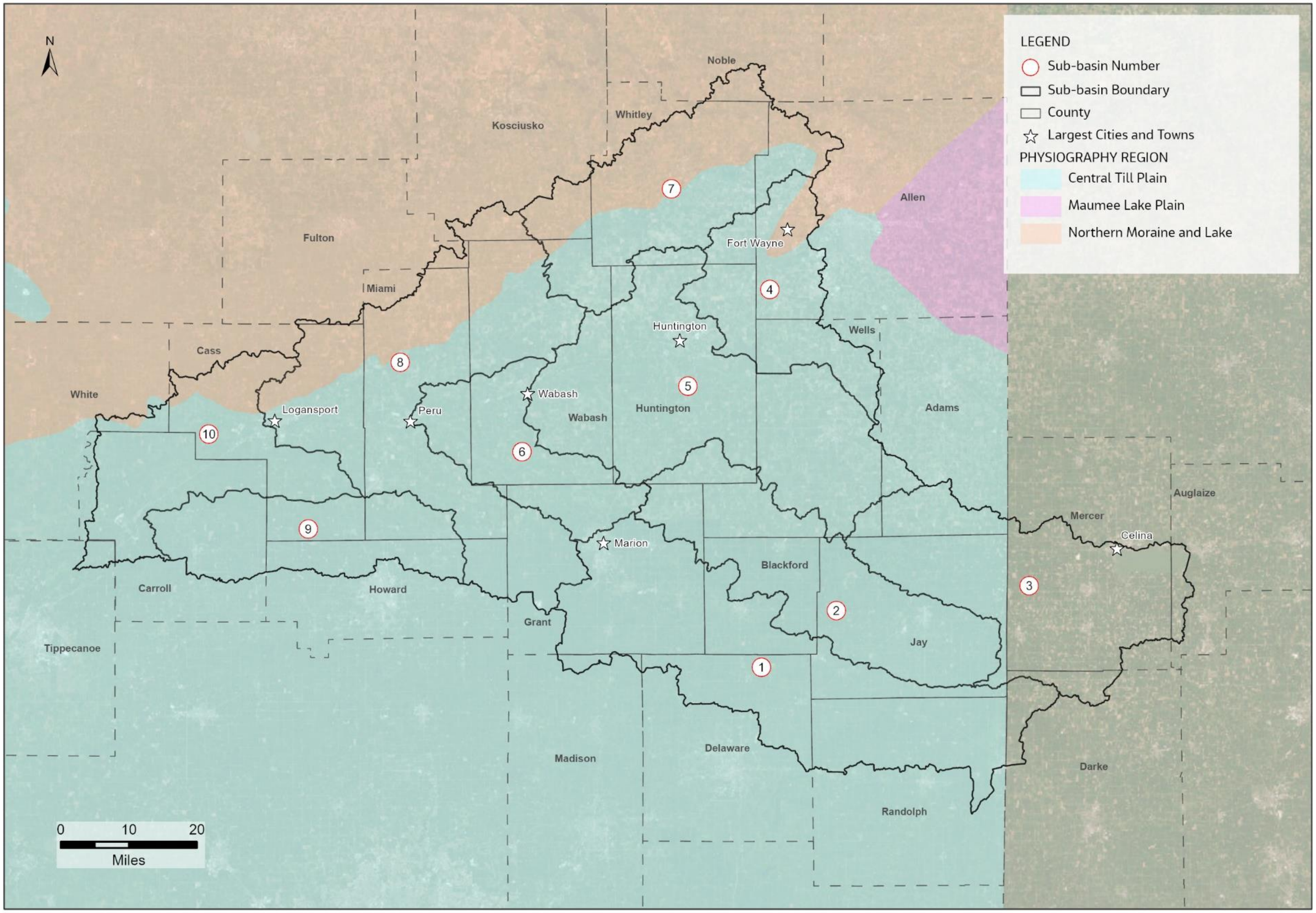


Figure 2-6. Physiographic Divisions in the Wabash Headwaters Region

2.4.2 Geology

The geology of the study area includes both bedrock and unconsolidated deposits. The bedrock encompasses the hard sedimentary rock units that mostly subcrop (lie below) unconsolidated deposits. Conversely, unconsolidated deposits are the looser materials overlying the bedrock that have not yet gone through the process of lithification. The geology of the study area is important because the thickness, hydraulic conductivity, and erosional characteristics of each stratum affects the distribution and flow of groundwater and the formation of physiographic features. Figure 2-7 provides a broad overview of the various geological materials exposed at the surface (Gray, 1989) throughout the Wabash Headwaters Region.

2.4.2.1 Bedrock

Indiana overlies three regional bedrock structures; the Cincinnati Arch plunges northwest across the state with flanks on either side of the arch that slope down to the Michigan Basin to the northeast and the Illinois Basin to the southwest. Generally, bedrock strata are thinner near the crest and grow in thickness as they move down the flanks toward the basins. The dip of the geologic units towards the basins and subsequent erosion of the tilted surface results in older rocks being nearest to the surface along the crest of the arch, compared to thicker layers of younger rock in the basins. The Wabash Headwaters Region is positioned almost entirely on the crest and the northeastern flank of the Cincinnati Arch. The study area also lies above the Buried Lafayette Bedrock Valley, a network of ancient bedrock trenches, formed by erosion from glacial meltwater, that converge near the City of Lafayette.

Bedrock consists primarily of limestones, dolomites, sandstones, and shales that were deposited throughout the Paleozoic Era. Basal pre-Paleozoic Era igneous and metamorphic rocks deposited during the Precambrian underlie the oldest and deepest sedimentary bedrock layers (Thompson et al., 2015). These Precambrian hard rocks range from 2,000 to 3,500 feet in thickness and are not exposed in Indiana, being completely covered by younger sedimentary bedrock (Fenelon et al., 1994; Thompson et al., 2015).

After a sequence of sandstones were deposited during the Cambrian Period, a series of Ordovician sandstones, shales, and carbonate rocks ranging from 1,000 to 1,400 feet in thickness were deposited (Fenelon et al., 1994). This Ordovician bedrock subcrops the drift along three segments of the Lafayette Bedrock Valley. Following the Ordovician units are an often-undifferentiated group of Silurian and Devonian carbonates consisting mainly of dolomites with interbedded limestones and shales (and traces of anhydrite and gypsum in the Ohio headwaters area). This layer consists of the Pleasant Mills Formation, Louisville Limestone, and the Wabash Formation, among others (Thompson et al., 2015).

From the remainder of the Devonian Period to the Early Mississippian Period, a major drop in sea level exposed the Cincinnati Arch and deposited New Albany Shale into the two basins (Fenelon et al., 1994; Thompson et al., 2015). This layer of shale subcrops the drift in small portions of Tippecanoe, Carroll, Whitley, and Noble Counties. The remainder of the Mississippian Period saw the deposition of mostly limestone and sandstone, including the Rockford Limestone, Saint Genevieve Limestone, the Cypress Formation, and the Tobinsport Formation, among others (Thompson et al., 2015). This was followed by a period of extreme erosion that stripped most of the Late Devonian, Mississippian, and younger deposits from the carbonate bedrock surface. This period of erosion capped off the pre-Quaternary formation of bedrock sediments, which laid the foundation on which glacial lobes would later deposit massive amounts of drift.

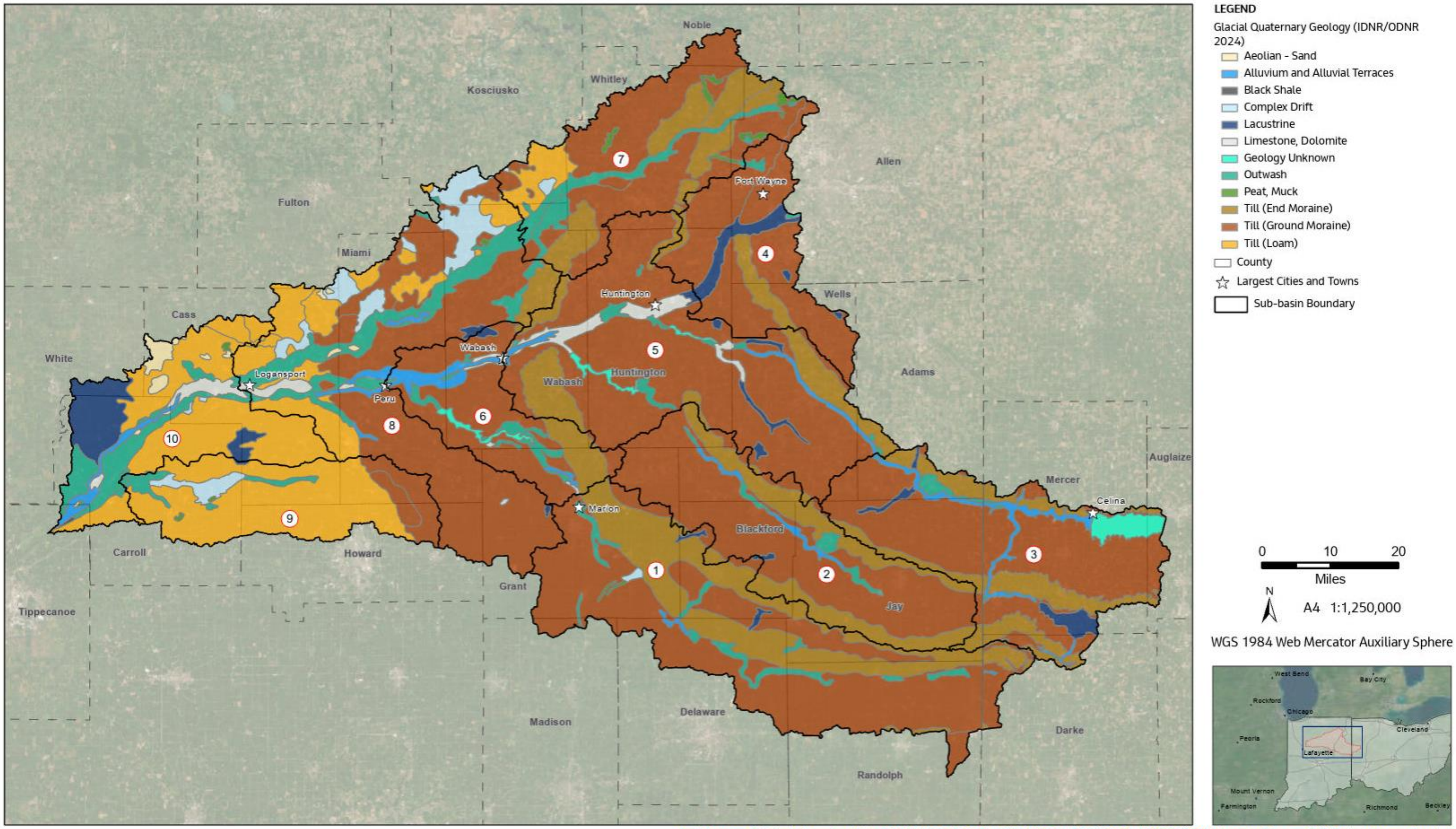
2.4.2.2 Unconsolidated Deposits

During the Pleistocene Epoch of the Cenozoic Era, Indiana experienced the movement of several thick glacial bodies into and out of its region. The most recent of these glaciation events is known as the Wisconsin glaciation, during which the Lake Michigan, Saginaw, and Huron-Erie Lobes all advanced southward from modern-day Canada and converged in northern Indiana. Before this, the movement of pre-Wisconsin glaciers eroded the existing landscape and ultimately filled the entire Lafayette Bedrock Valley with sediment in the form of ground moraines, end moraines, loam till, and outwash (Fenelon et al., 1994). This glaciated surface was subsequently covered with additional unconsolidated deposits by the advance of the Wisconsin glacial lobes. Because the composition of unconsolidated deposits is typically consistent within a physiographic region, the formation of these unconsolidated units will be discussed based on physiographic location.

In the Northern Indiana Lake Country region, the convergence of the Huron-Erie Lobe and the Saginaw Lobe demolished any existing glacial moraine depositional structures from pre-Wisconsin advances and deposited large amounts of unsorted clay, silt, sand, and gravel along the convergence boundary of these two lobes, forming the Packerton Moraine and leaving thick deposits of loam, ground moraines, and complex drift (Fenelon et al., 1994). The unconsolidated units in this area are typically more than 300 feet thick and reach up to 550 feet of thickness along the Packerton Moraine on the southeast boundary of the Warsaw Moraines and Drainageways region (Naylor et al., 2016).

The northeastern area of the Tipton Till Plain, bounded by the Eel River to the north and the Mississinewa River to the west, was covered with a clay-loam till in the form of ground moraines during the Wisconsin glaciation (Fenelon et al., 1994). Then, the Mississinewa, Salamonie, and Wabash end moraines formed sequentially and concentrically as the terminus of the Huron-Erie Lobe regressed in a northeast direction. These formations strongly influence the flow paths of the Mississinewa, Salamonie, and Wabash Rivers from the Ohio headwater region and through the Wabash Headwaters region. Land between the Eel River and the Little/Wabash River channel still contains between 100 and 300 feet of Wisconsin drift, whereas south of the Little River, drift is commonly less than 100 feet thick (Naylor et al., 2016). Furthermore, substantial portions of Wells County, Grant County, and the floodplain along the east-to-west segment of the Wabash River contain between 0 and 50 feet of unconsolidated deposits (Naylor et al., 2016). The branches of the Buried Lafayette Bedrock Valley coincide with some of the thickest drift layers in the study area , where bedrock trenches have been filled with more than 500 feet of unconsolidated deposits (Naylor et al., 2016). The northwest area of the Tipton Till Plain is bounded by the Wabash River to the north and the Mississinewa River to the east) contains ground moraines covered by glacial outwash and till, resulting in a loamy till surface with intermittent patches of complex drift and ground moraine till becoming exposed as you move closer to the Mississinewa River (Fenelon et al., 1994). Drift layers range from 0 to 250 feet in thickness, increasing south of the Wabash River, where the Tipton and Iroquois Complexes are located in Carroll and Howard Counties (Naylor et al., 2016).

Since the retreat of the Wisconsin glacier, unconsolidated sediment deposition has been minimal, consisting only of loess deposits, alluvial deposits, and the accumulation of organic plant remains. Loess deposits consist predominantly of silt and fine sands that are redistributed throughout the region via wind. Alluvial deposits consist of reworked sand and gravel that have accumulated along the major drainages. Last, muck, peat, and marl form in swampy areas from the accumulation of plant remains. Alluvial deposits as well as peat and muck formations can be seen scattered over more vast drift layers (Fenelon et al., 1994).



Data Sources: CEC North American Atlas (2024),IN Gov (2024), TIGER (2024), USGS (2021), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure 2-7. Geology in the Wabash Headwaters Region

2.5 Water Demand Sectors

In the Wabash Headwaters Region, both groundwater and surface water sources have historically been used. Groundwater is the primary source in the area representing approximately 70% of total water use in 2022, especially for residential, rural, and irrigation uses. Groundwater resources include both unconsolidated and bedrock aquifers. Most wells in the area are finished in unconsolidated aquifers due to their proximity to the surface and ease of access. In some places where the bedrock surface is relatively shallow, unconsolidated deposits are sometimes bypassed in favor of deeper, more locally productive bedrock aquifers (Fenelon et al., 1994). The highest concentration of wells can be found near cities and along major rivers. Cities with the largest number of wells in the study basin include Fort Wayne, Bluffton, Marion, Peru, and Logansport.

Surface water resources in the Wabash Headwaters study area include the Eel, Little, Mississinewa, Salamonie, and Wabash Rivers and their tributaries. Most registered intakes are in or near cities along these major rivers and are implemented by industrial users and a few public utilities. The sources and uses of water are described more fully in Section 3.

2.6 Water Users and Sources

In 2022, there were 235 unique SWWFs operating 467 groundwater wells and 79 surface water intakes within the Wabash Headwaters Region. Figure 2-8 shows the general locations of groundwater wells and surface water intakes throughout the study area. Reported withdrawals support variety of different activities and industries in the study area. The majority of the SWWF are reported withdrawals for public water supply (utilities), agricultural irrigation, manufacturing activities, or mineral extraction. In 2022, the highest water demand from SWWFs were public water suppliers and quarry operations. The study area is also home to multiple agricultural operations and biofuel refineries, as well as a steel producer. Figure 2-9 shows all water users by sector and their locations within the Wabash Headwaters study area.

2.6.1 Groundwater Sources

Groundwater is a major source of drinking water in the Wabash Headwaters study area and is used to support energy production, irrigation, industrial, commercial, and agricultural operations. Groundwater is obtained from underground aquifer systems, which are formations that contain permeable geological materials that are saturated with potable water. The productivity of an aquifer depends on the interconnected porosity, the volume of connected voids within the formation, hydraulic conductivity (the ease by which fluid passes through the formation), and the recharge rate (Fenelon et al., 1994).

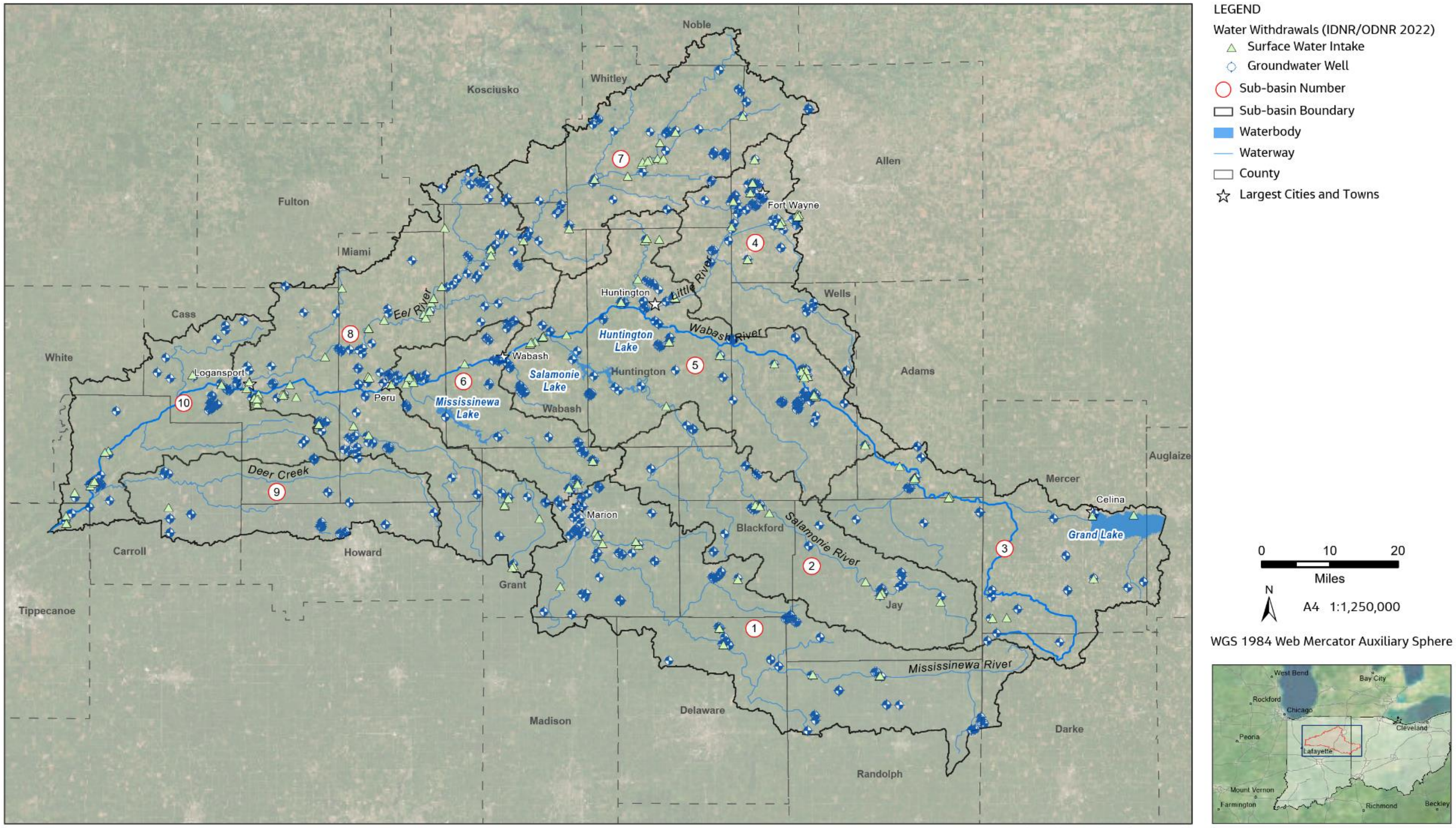

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Figure 2-8. General Locations of Significant Water Withdrawal Locations by Source in the Wabash Headwaters Region

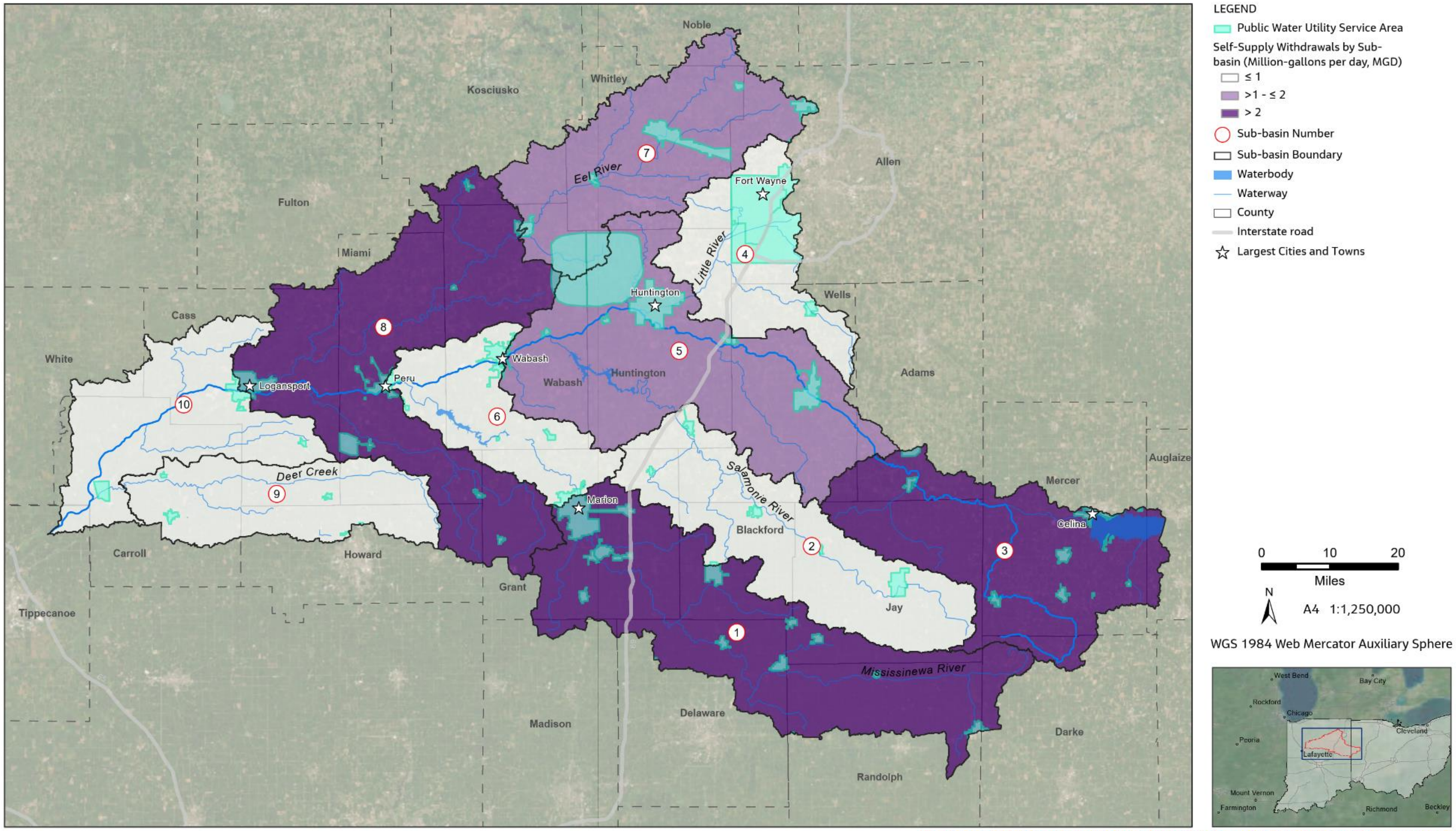

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Figure 2-9. Self-Supplied Water Users in the Wabash Headwaters Region

Various sand and gravel aquifers are available within unconsolidated deposits, some of which can yield as much as 2,000 gallons per minute (Fenelon et al., 1994). In addition, the underlying bedrock layer of Silurian and Devonian carbonates is capable of yielding several hundred gallons per minute in some locations (IDNR 2009). Aquifer classifications and their corresponding locations and yields throughout the study area are discussed in the following sections.

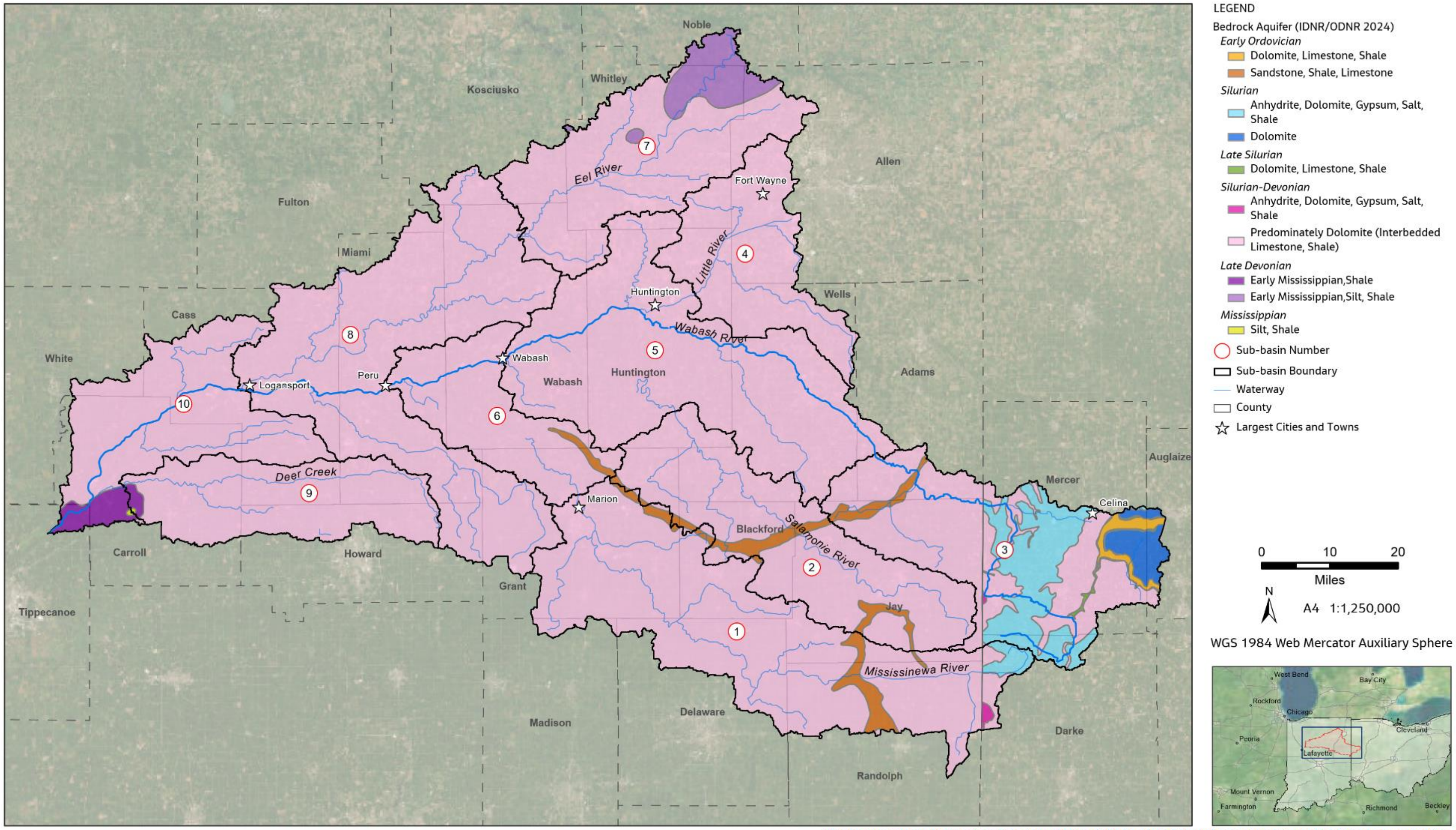
2.6.1.1 Bedrock Aquifers

The bedrock aquifers present in the Wabash Headwaters study area generally have lower yields than their overlying unconsolidated aquifers. However, bedrock aquifers are widespread and continuous; therefore, their groundwater resources can be a reliable water source for domestic uses when necessary.

The principal bedrock aquifer system in the Wabash Headwaters study area is the Silurian and Devonian carbonate aquifer system, which is present in every sub-basin (IDNR, 2009)~~.~~ Karstification, defined as the dissolution of carbonate rock by acidic water, has formed many secondary openings near the bedrock surface along preexisting fractures, joints, and bedding planes. Consequently, carbonate bedrock aquifers tend to have the largest yields close to their upper surface where enlarged solution openings are present, and generally become less productive with depth (Fenelon et al., 1994). The thickness of these aquifers can range from less than 100 feet to more than 850 feet, and well depths are typically between 100 and 200 feet (IDNR, 2009). Significant Water Withdrawal Facilities using bedrock aquifers in the area generally report yields between 100 and 600 gallons per minute, but some wells can have yields approaching 2000 gallons per minute (Fenelon et al., 1994; IDNR, 2024). Figure 2-10 shows the uppermost bedrock units present throughout the study area, differentiated by their age and mineral composition.

2.6.1.2 Unconsolidated Aquifers

Unconsolidated glacial deposits in the Wabash Headwaters study area contain an abundance of aquifers within their sand and gravel facies. These formations can be grouped into three broad categories: surficial sand and gravel aquifers, discontinuous sand and gravel aquifers, and buried sand and gravel aquifers (Fenelon et al., 1994). Figure 2-11 shows the locations of the various surficial, discontinuous, and buried unconsolidated aquifers throughout the study area, serving as a visual reference as they are described in the following sections.



Data Sources: CEC North American Atlas (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure 2-10. Bedrock Aquifers in the Wabash Headwaters Region

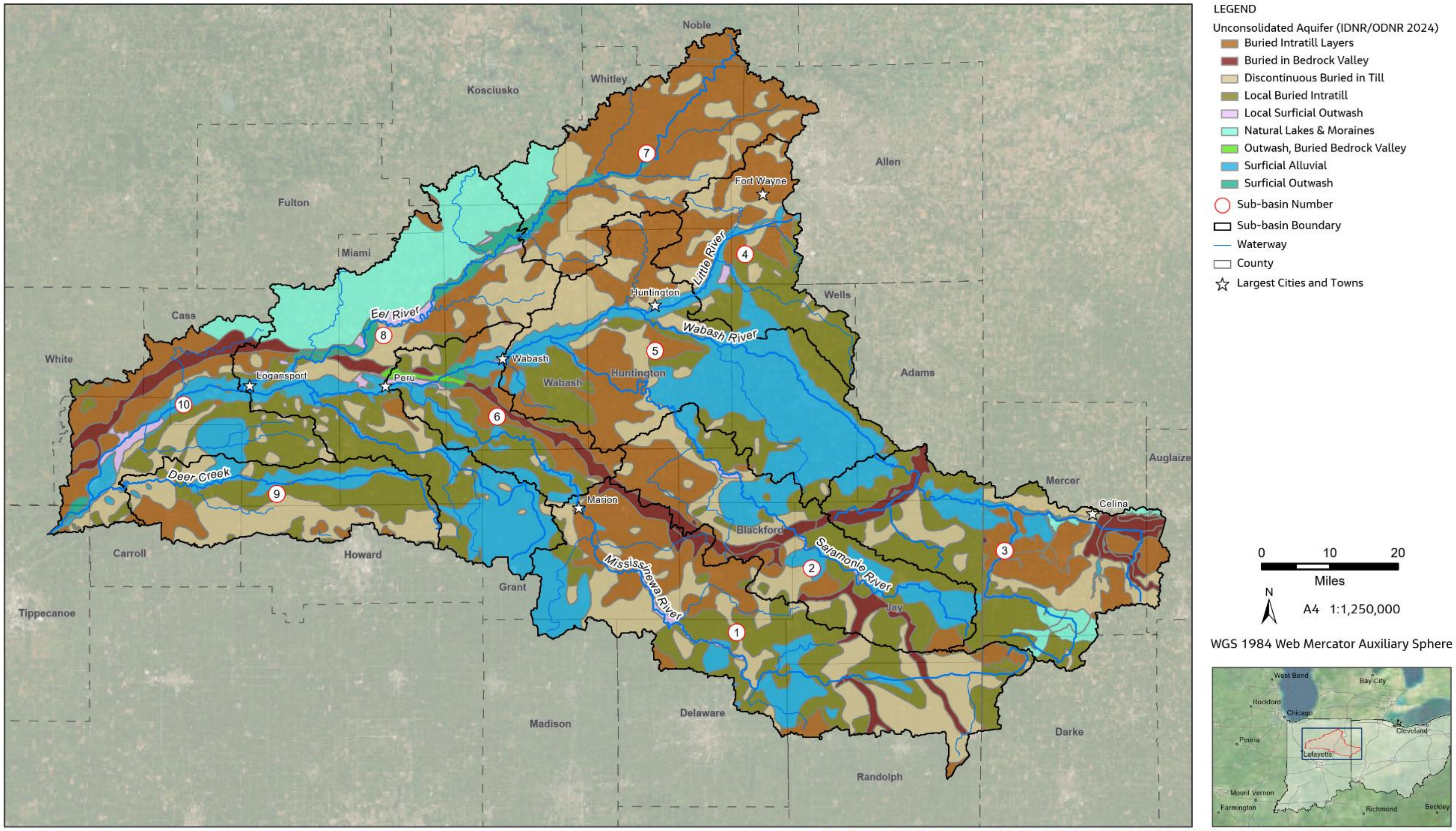

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Figure 2-11. Unconsolidated Aquifers in the Wabash Headwaters Region

Surficial Sand and Gravel Aquifers

Much of the study area downstream from Logansport is covered with surficial sand and gravel that has been deposited at or near the land surface by wind, alluviation, and glacial meltwater outwash. Most of these deposits are along major drainage valleys that once served as glacial meltwater channels. The largest of these surficial aquifers encompass the Wabash River downstream from Logansport, and additional aquifers are present in drainages south of the Wabash River, especially in Grant and Wells Counties (Figure 2-11). However, because of their proximity to the land surface and lack of confining layer, these aquifers can be easily contaminated, and as a result many of them are not viable options for groundwater withdrawals (IDNR, 2009).

Discontinuous Sand and Gravel Aquifers

Discontinuous sand and gravel aquifers refer to small, scattered lenses of sand and gravel found within thicker layers of clay-rich till. These aquifers are primarily located north of Eel River but have also been found in various locations throughout the study area (Figure 2-11).

Most wells that draw from these discontinuous aquifers penetrate multiple small aquifer lenses and are typically deeper than those that penetrate buried sand and gravel aquifers (Fenelon et al., 1994). This is so they draw from multiple aquifer sources and can accommodate drawdown (the reduction of the water level within an aquifer due to the low permeability of the surrounding material and over pumping). Individual lenses are commonly less than 5 feet thick, but discontinuous aquifer systems collectively can exceed 200 feet in thickness. Typical yields are between 100 and 300 gallons per minute, making these aquifers viable options for domestic needs and some industrial and commercial purposes (IDNR, 2009).

Buried Sand and Gravel Aquifers

The most hydrologically productive sand and gravel units present in the Wabash Headwaters study area consist of alluvial, outwash-plain, and valley-train deposits that have since been overlain by additional layers of finer-grained deposits (Nelson, 2022). These formations are generally extensive and continuous, and are referred to collectively as buried sand and gravel aquifers. However, because of uneven depositional surfaces, erosion, and glacial scour, the depth and thickness of these sand and gravel units are nonuniform and their interconnectedness is unpredictable (Fenelon et al., 1994).

In most places, sand and gravel aquifers are a basal layer between the underlying bedrock and the overlying glacial till. These buried intratill layer aquifers are most common north of the Wabash River where the largest yields have been reported. Yields in Whitley County can exceed 2,000 gallons per minute (IDNR, 2009). Sand and gravel aquifers are also numerous and extensive in the Tipton Till Plain area south of the Wabash River (Figure 2-11). These aquifers typically produce less than 1,000 gallons per minute but are suitable for domestic users and some high-capacity users (IDNR, 2009).

The Lafayette Bedrock Valley contains a buried bedrock valley aquifer system with high yields observed along Loblolly Creek in Jay and Adams Counties, and near the city of Richvalley in Wabash County where the aquifer crosses the Wabash River (Fenelon et al., 1994). Many cities, including Geneva, Marion, La Fontaine, and Peru derive part of their municipal water supply from these bedrock valley aquifers. Wells penetrating this aquifer system have reported the highest yields in the study area with up to 2,600 gallons per minute where hundreds of feet of deposits exist within the bedrock valley. Wells are typically between 100 and 300 feet deep (IDNR, 2009).

2.6.2 Surface Water Sources

In addition to groundwater, some water users in the study area obtain water through surface intakes identified on Figure 2-8. Figure 2-12 shows the major rivers and reservoirs in the study area, which will be discussed in the following sections.

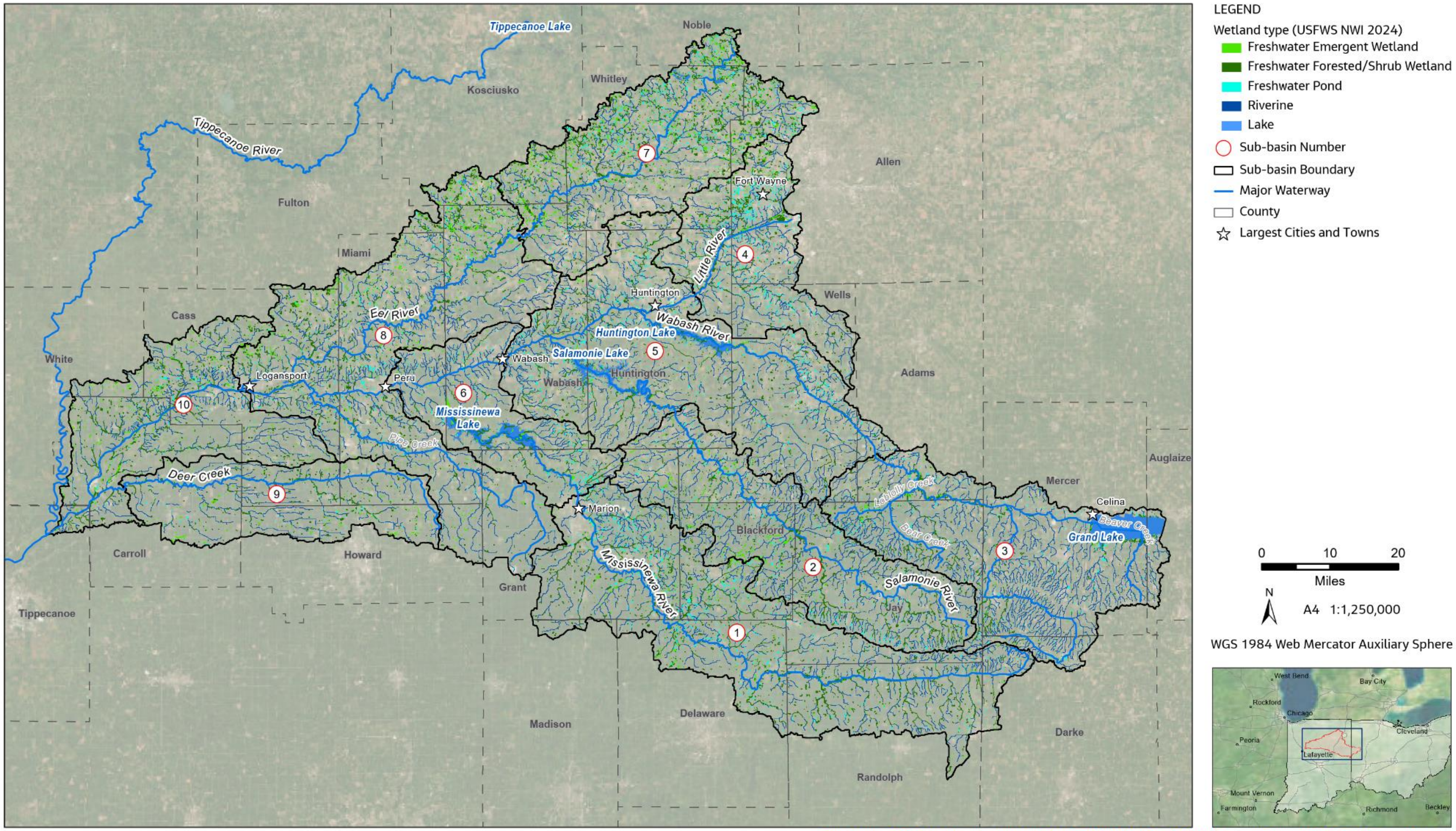
2.6.2.1 Rivers

The Wabash River is more than 450 miles long from its source in Darke County, Ohio to the confluence with the Ohio River (IDNR, 2009) and drains 32,910 square miles within Ohio, Indiana, and Illinois, with 23,921 square miles of this area located in Indiana. The Wabash headwaters lies in the Ohio portion of the study area, where it combines with Beaver Creek, which drains Grand Lake in Mercer County. The Wabash River initially flows northwest through Sub-basins 3 and 5. Just downstream of the confluence between the Wabash River and the Little River in Huntington County, the Wabash changes orientation, flowing southwest through Sub-basins 5, 6, 8, and 10, after which it flows more southward on the west side of Indiana through the middle and lower Wabash River management basins. USGS has numerous monitoring locations throughout the drainage basin where flow and gauge height data are collected.

As a result of the glacial movements that affected the geology and physiography of the region, the eastern portion of the Wabash Headwaters Region is shaped like a bowl, resulting in a general northward downslope of land. The Wabash, Salamonie, and Mississinewa Moraines lie in a concentric pattern on the slope of this bowl and stretch northwest across the study area (Figure 2-13). These moraines serve as drainage collection barriers, preventing drainage flow between the moraines from reaching the center of the bowl and, instead, redirecting this flow northwest along the southwest edges of these moraines, forming the Wabash, Salamonie, and Mississinewa Rivers, respectively (Fenelon et al., 1994).

At the Indiana-Ohio state line, the Wabash River channel sits at an elevation of approximately 835 feet above sea level. From the state line to Bluffton City, the river follows the edge of the Wabash Moraine and drains Sub-basin 3 Wabash-Linn Grove and portions of Sub-basin 5 Wabash-Wabash. Downstream from Bluffton, the river breaks off from the edge of the Wabash Moraine and begins flowing more in the west direction over bedrock and toward the Little River. The Little River is 20.2 miles long and was formed as the primary outflow channel from Lake Maumee, an ancestor of Lake Erie, and now drains Sub-basin 4 Little-Huntington (INRC, 2024). The Wabash River converges with the Little River just downstream of Huntington City in Sub-basin 5 Wabash-Wabash. Just upstream of this confluence is the Huntington Reservoir, a flood control reservoir connected to the Wabash River that regulates its flow. Elevation of the Wabash River channel just downstream of this reservoir is approximately 700 feet above sea level (Fenelon et al., 1994).

After merging with the Little River, the Wabash River changes direction and flows over the bedrock layer southwest into Wabash County. The Salamonie River discharges into the Wabash River near the town of Lagro in Sub-basin 5 Wabash-Wabash. The Salamonie River is 84.4 miles long and drains Sub-basin 2 and part of Sub-basin 5 Wabash-Wabash (INRC, 2024). A flood control reservoir on the Salamonie River just upstream of its mouth regulates flow from the Salamonie to the Wabash River. Downstream of this confluence, the Wabash River narrows as it cuts through an opening in the Mississinewa Moraine. The river continues to flow over bedrock to Rich Valley in Sub-basin 6 Wabash-Peru, at which point it widens as it crosses over the Lafayette Bedrock Valley, where bedrock is buried and the Wabash flows over a thick layer of unconsolidated deposits. The channel elevation at this location is approximately 635 feet above sea level (Fenelon et al., 1994).



Data Sources: CEC North American Atlas (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure 2-12. Rivers and Reservoirs in the Wabash Headwaters Region

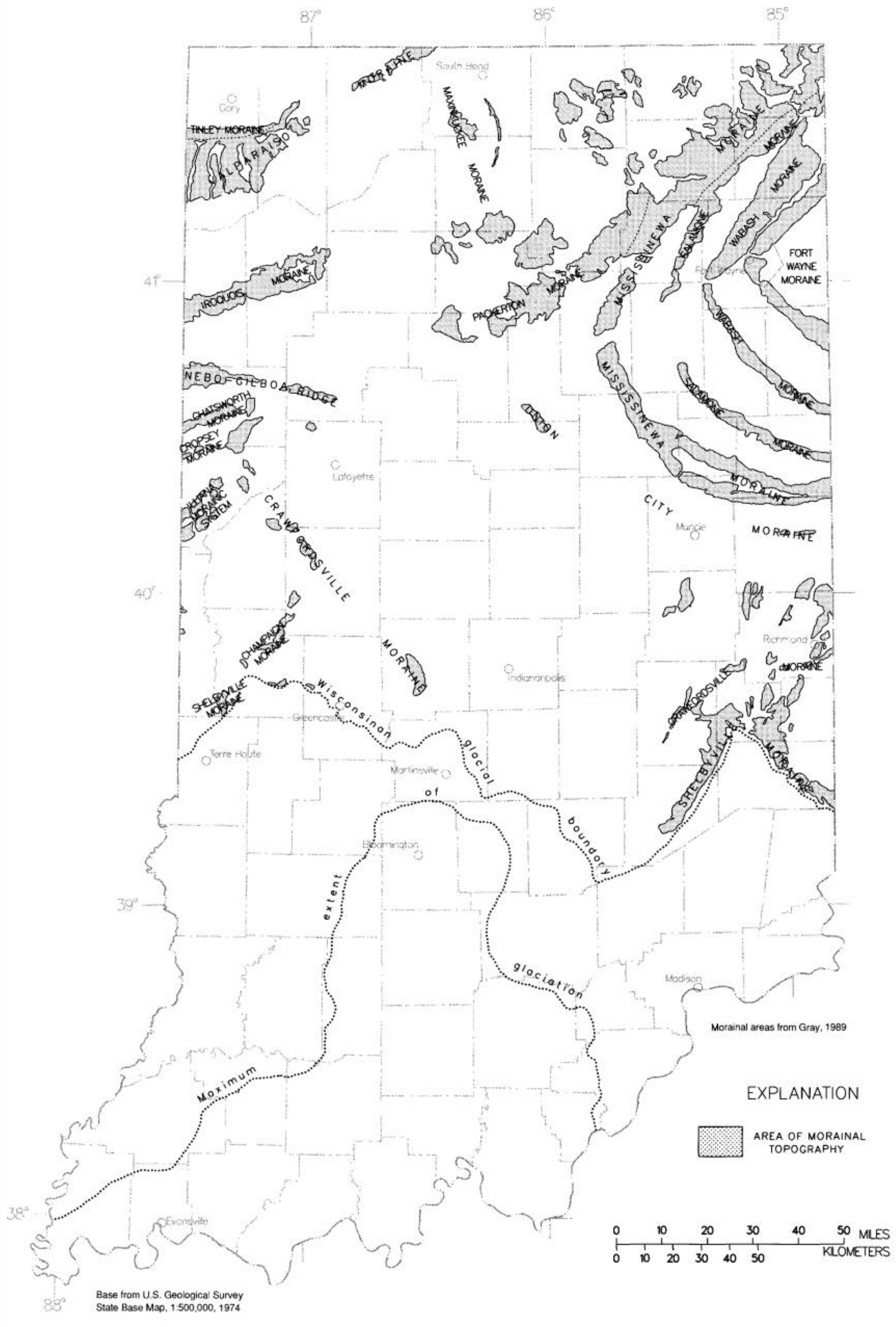


Figure 2-13. Morainal Topography of Indiana (Gray, 1989)

Note: The Mississinewa, Salamonie, and Wabash Moraines (upper right corner) lie in a concentric pattern and form the drainage barriers for the Mississinewa, Salamonie, and Wabash Rivers, respectively.

The Mississinewa River is the next major tributary to the Wabash River. This river collects drainage flow from a small portion of Ohio and most of Sub-basins 1 and 6, carrying it 109.75 miles through sub-basins 1 and 6 before discharging to the Wabash River just upstream from the City of Peru in Sub-basin 6 Wabash-Peru. From Peru to the city of Georgetown in Sub-basin 10 Wabash-Ungauged, the Wabash River flows almost directly west, again flowing over the bedrock layer. After collecting drainage flow from the southern half of Sub-basin 8 Wabash-Logansport, Pipe Creek discharges into the Wabash River. Then, just downstream in Logansport, the Eel River discharges into the Wabash River on its north bank. Like the Little River, the Eel River also used to function as an outflow/overflow channel for glacial Lake Maumee. This river currently drains Sub-basin 7 Eel -North Manchester and the northern part of Sub-basin 8 Wabash-Logansport while traversing 51.2 miles of land (Fenelon et al., 1994; INRC, 2024).

Seventeen SWWF intake locations currently withdraw from the Mississinewa River and its tributaries, and these intakes are concentrated around the cities of Marion and Gas City. In addition, 38 SWWF intake locations currently withdraw from the Wabash River between Richvalley and Logansport, most of which are near the cities of Peru and Logansport.

At Georgetown, the Wabash River changes orientation and begins to flow southwest. In Sub-basin 10 Wabash-Ungauged, just downstream from the city of Delphi, Deer Creek (a 5.9-mile-long stream that collects drainage flow from Sub-basin 9 Deer Creek-Delphi) discharges into the Wabash River (Indiana Natural Resources Commission, 2024). Then, just upstream of Lafayette, the Wabash River merges with the 86.47-mile-long Tippecanoe River, the largest tributary to the Wabash River (INRC, 2024). Although this confluence is just outside of the study area, sediment loadings from the Tippecanoe River are so substantial that they can be found more than 15 miles upstream of the mouth of the Tippecanoe River. As a result of this sediment loading and local stratigraphy, the Wabash River flows over sand, gravel, and other unconsolidated, non-aquifer materials downstream from the city of Delphi. (Fenelon et al., 1994). Between the cities of Logansport and Lafayette, 11 SWWF intake locations exist, concentrated around the city of Delphi. Sub-basin 9 Deer Creek-Delphi only has one SWWF intake location (in the city of Flora).

2.6.2.2 Reservoirs

In this study area, three reservoirs have been constructed for the purposes of flood management and recreation. These reservoirs are the J. Edward Roush Lake or Huntington Lake, Salamonie Lake, and Mississinewa Lake. Final construction of the lakes was completed in 1968. The system helps to prevent flooding in the Wabash Headwaters region and downstream watersheds. The locations of these reservoirs are shown on Figure 2-12.

Between the reservoirs, there is a total of 785,100 acre-feet of storage spanning a total area of 6,775 acres (USACE, 2021). The three lakes can discharge a total of 301,400 cubic feet per second (USACE, 2021). Each reservoir has three pools to help with flood protection: the winter pool, summer pool, and flood pool; the spillways are operated to maintain the desired pool level. Although precipitation values are slightly lower in the winter, the frozen terrain prevents soil infiltration, resulting in the highest seasonal runoff. Therefore, the winter pool generally has the lowest water level to accommodate this larger water collection. The summer pool is kept at a higher water level to maintain water levels for recreational activities during the dry season, and the flood pool is the average level the water elevation gets to during a flood.

Mississinewa Lake is the westernmost reservoir of the three. The outflow continues 5.3 miles north to Peru where it enters the Wabash River. The lake has an area of 3,210 acres. The Mississinewa dam has a maximum height of 140 feet and a length of 8,000 feet (USACE, 2024b). This lake has a storage of 368,400 acre-feet and a maximum discharge of 122,400 cubic feet per second, with 809 square miles of drainage land upstream from the dam that contribute flow to the lake. The winter pool is 712 feet above sea level, the summer is 737 feet, and the flood is 779 feet (USACE, 2024b).

Edward Roush Lake is the easternmost reservoir of the three; it is on Wabash River, with the longitudinal ends of the lake serving as both an intake to and discharge from the Wabash. The dam is on the west side of the lake where it discharges to the Wabash. The lake has an area of 900 acres, and it provides water to roughly 60,000 acres of agricultural land (IDNR, 2021a). The lake has a storage of 153,100 acre-feet, and a maximum discharge of 121,800 cubic feet per second. The maximum height of the dam is 91 feet, and it has a length of 6,500 feet. The water drainage area above the dam is roughly 707 square miles. The winter pool is 737 feet above sea level, the summer is 749 feet, and the flood is 798 feet (USACE, 2024a).

Salamonie Lake is between the other two reservoirs. The lake lies along the Salamonie River. The dam is on the west side of the lake, where it discharges to the river. The Salamonie River flows from the dam for 2.7 miles before entering the Wabash River. The lake has a storage of 263,600 acre-feet and a maximum discharge of 57,200 cubic feet per second. The area of the lake is 2,665 acres with t a maximum dam height of 133 feet, and a length of 6,100 feet. The drainage area above the dam is 553 square miles. During the winter months, the winter pool is kept relatively low to allow for extra surface runoff during heavy precipitation or snowmelt. The winter pool is 730 feet above sea level, summer pool is 755 feet, and flood pool is 793 feet (USACE, 2024c).

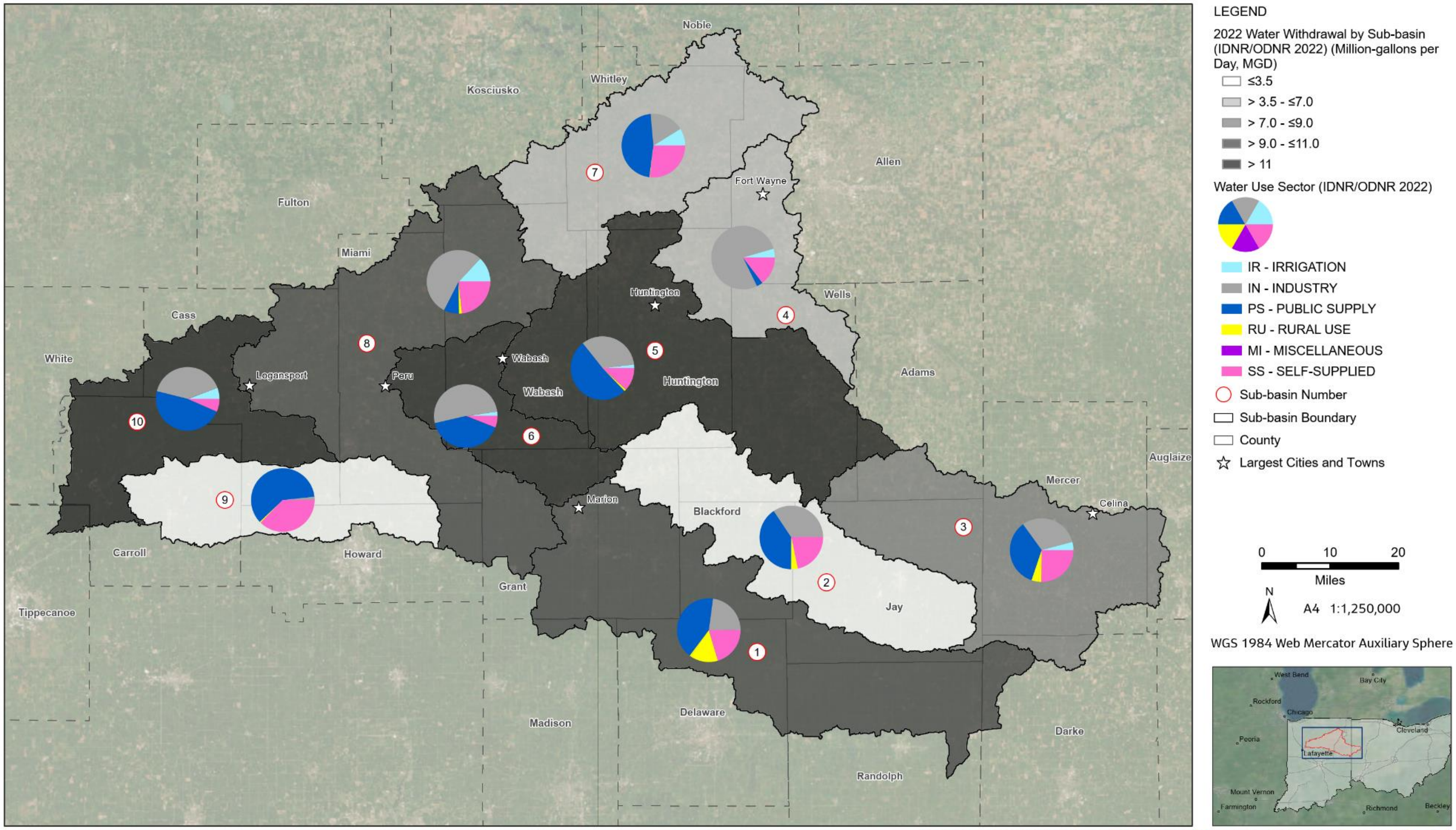
3 Water Demand

Water demand analysis and forecasting provide important information for water resource planning. This section documents the historical water demand analysis for the study area and the approach to forecast future water demand using population, climate, and economic variables. This analysis was conducted at a watershed level to support the water availability analysis described in Section 4. The watersheds used in the analysis correspond to the sub-basins presented on Figure 2-1 and described in Appendix A. Throughout this report, the terms 'water withdrawal,' 'water use,' and 'water demand' are used interchangeably.

Figure 3-1 shows water demand by sub-basin and water use sector in the region, presented in millions of gallons per day (MGD). The Wabash Headwaters Region used approximately 29.8 billion gallons of water in 2022, averaging 81.8 MGD. Industrial users are the largest water demand sector with an average use of 32.3 MGD, followed by public water utilities with an average use of 30.2 MGD. Since 1985, these two sectors have dominated water demand, despite a slight decrease in recent years. A significant amount of water was used for energy production between 1987 and 2016 (Figure 3-2), but that sector is negligible at present due to the decommissioning of several coal-fired power plants. For the industrial and public supply sectors, most water use is non-consumptive use, meaning that it is ultimately returned to the system as discharge.

Future water demand in the region was calculated using reported or estimated historical monthly water use for the most significant water use sectors. Additional demand estimates were estimated for self-supplied users and livestock operations (CAFOs) because they do not have historical records but constitute an important part of the water demand profile for the region. The water demand analysis is an account of current (2007 through 2022) and projected future (2023 through 2070) water demands intended to guide ongoing and future water resources planning and management efforts in the region. The content of this section includes the description of the water demand sectors, forecasting methodology, and a discussion of historical and future water demand results. Figure 3-3 shows the most recent (2022) historical water demand by sector and the future (2070) water demand forecast modeled as part of this study.

Energy production and miscellaneous registered facilities are not shown in the pie charts because they represent less than 1% of the total water demands in the region and their demand is not expected to surpass the 1% threshold. In 2070, energy production is expected to use 0.08 MGD and miscellaneous uses are expected to use 0.04 MGD. Industrial demand is expected to have the largest increase in water demand.



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure 3-1. Water Use by Sub-basin and Water Use Category in the Wabash Headwaters Region, 2022

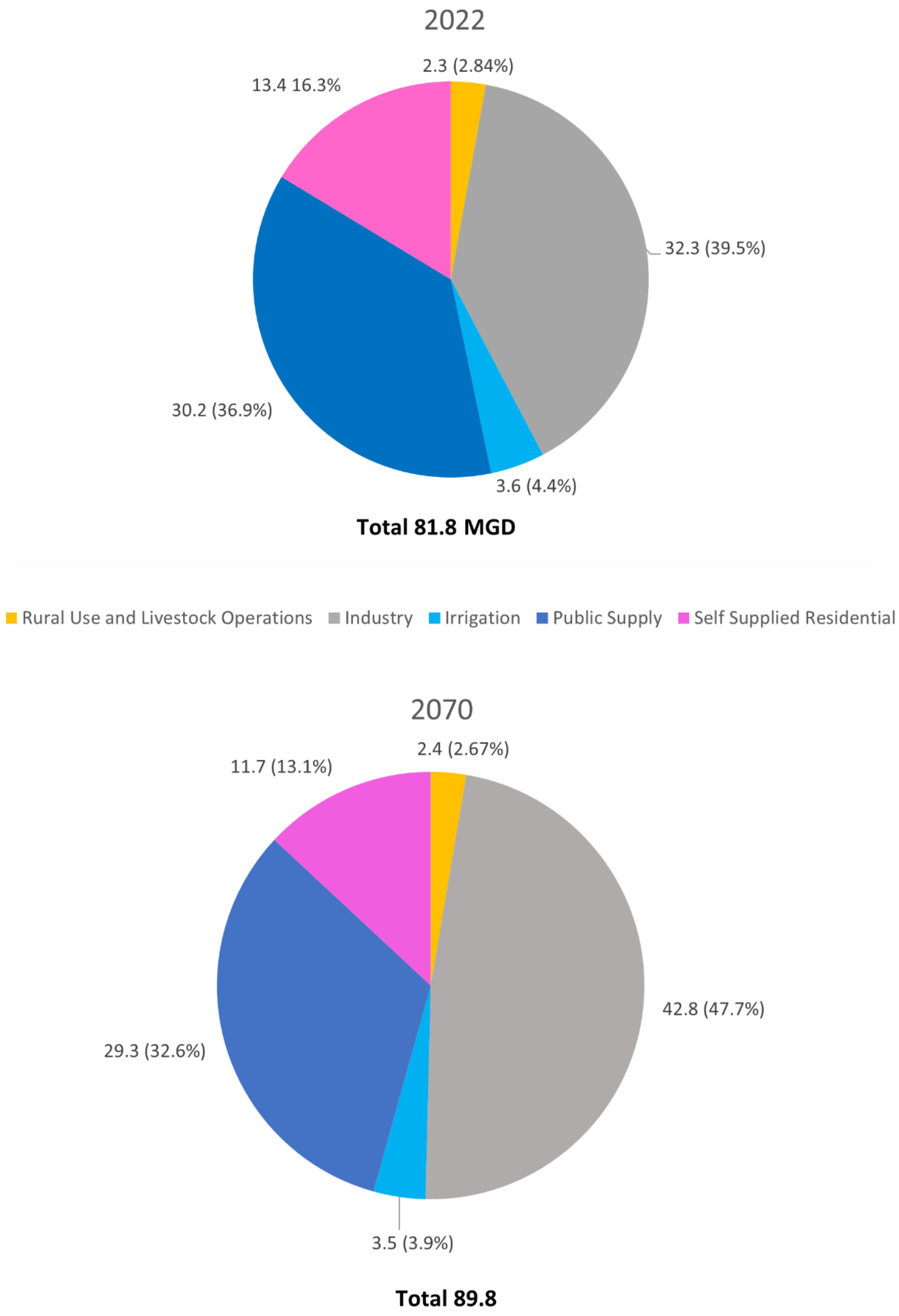


Figure 3-2. Historical (2022, top) and Future (2070, bottom) Water Demands per Sector for the Wabash Headwaters Region

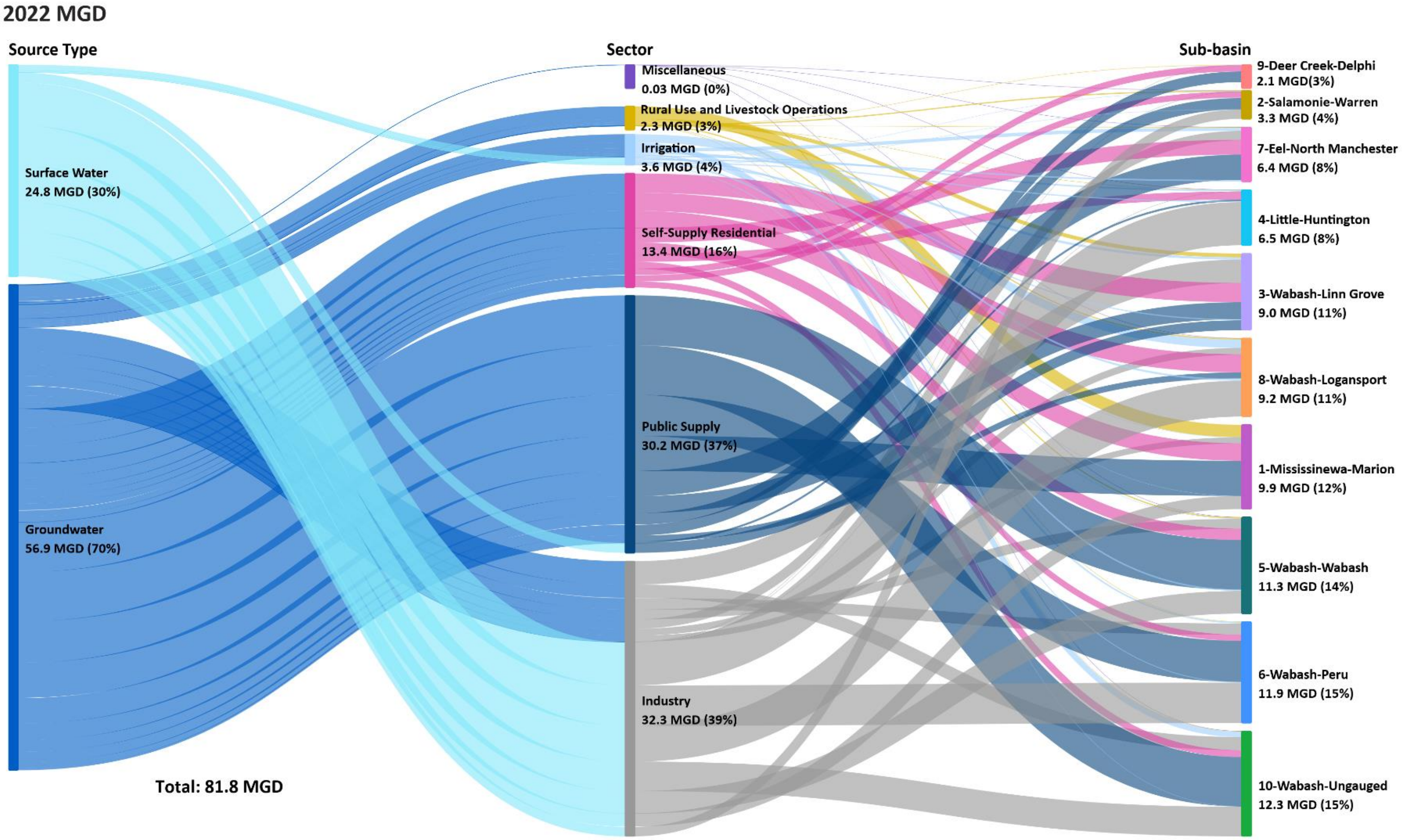


Figure 3-3. Annual Water Use by Sector in Each Sub-basin by Water Source (Surface Water or Groundwater) in the Wabash Headwaters Region (2022)

3.1 Historical Water Demand (1985 through 2022)

Most of the historical water demand data were gathered from the Indiana Department of Natural Resources (IDNR) Significant Water Withdrawal Facility (SWWF) database and supplemented using the Monthly Reports of Operation (MRO) for public supply utilities for more detailed withdrawal data. While the SWWF database summarized monthly withdrawals per user from 1985 to 2022, the MRO are documents that report daily withdrawal data for municipal water utilities. The major use sectors listed in the SWWF database are public supply, industrial, irrigation, rural use (including large livestock operations), and miscellaneous uses (mainly fire departments). In addition to these recorded demands, water demand for self-supplied users such as rural residences and smaller livestock facilities were estimated for the region. Figure 3-3 shows the main water use sectors in the region and the breakdown of their water withdrawals per sub-basin during 2022. The water demands and sub-basins in the Sankey diagram are arranged by quantity of water withdrawn in 2022 from smallest to largest. Larger amounts of groundwater are used in the mainstem of the Wabash River corridor, primarily by public water utilities. The smaller communities in the upper part of the basin use a larger proportion of self-supplied residential water than those downstream. Most of the industrial water demand relies on surface water. Figure 3-4 shows the historical average daily withdrawals for each water use sector in each sub-basin.

Each water-use sector -is discussed in detail in the following sections. The SWWF database indicates the water source (that is, groundwater well or surface-water intake) for each facility, and it is assumed that livestock operations and self-supplied residential users utilize groundwater sources. Figure 3-5 shows the average daily water withdrawals in 2022 from groundwater and surface water sources for this region by sub-basin. Approximately 70% of the water is pumped from groundwater sources, while the remaining 30% is obtained from surface water sources. In 2022, the industrial sector obtained most of their water from surface water sources, while public water utilities withdrew the majority of their water from groundwater sources. Figures 3-6 and 3-7 show the distribution of surface water intakes and groundwater wells for both public supply and the collective sum of industrial, energy production, and miscellaneous withdrawals.

3.1.1 Industry

Industrial facilities accounted for the highest water withdrawals in the Wabash Headwaters Region. Industrial users with their own water source include mining operations (quarries, aggregate, sand, and gravel), manufacturing, biorefineries, transportation, food production, and warehouses. Figure 3-8 shows the locations of these industrial users by category, and Figure 3-9 shows the average annual withdrawals for industrial users by category. Indiana is a leading manufacturing state in the Midwest and has the highest percentage of industrial water use in the nation (Dieter et al., 2018). Manufacturing, which is one of the most water-intensive industries, plays a major role. Indiana’s industrial sector uses water for processing, cooling, steam generation, and cleaning (Indiana American Water, n.d.). Between 1985 and 2022, the average water withdrawal for industrial water users was approximately 30.5 MGD (Figure 3-9). Withdrawals from industries in the state of Ohio accounted for 7% or 2.32 MGD of daily withdrawals in 2022. Note that industries receiving water from utilities are not included in this analysis; rather, their demand is included in the totals for public water suppliers. Figure 3-10 shows the average withdrawals for each industrial sector for the region by sub-basin. The average consumptive use for the industrial sector ranges between 6-23% depending on the industrial process (Shaffer, 2009). For this study, the return flows for industry were estimated based on the NDPES monitoring data as reported by each registered facility.

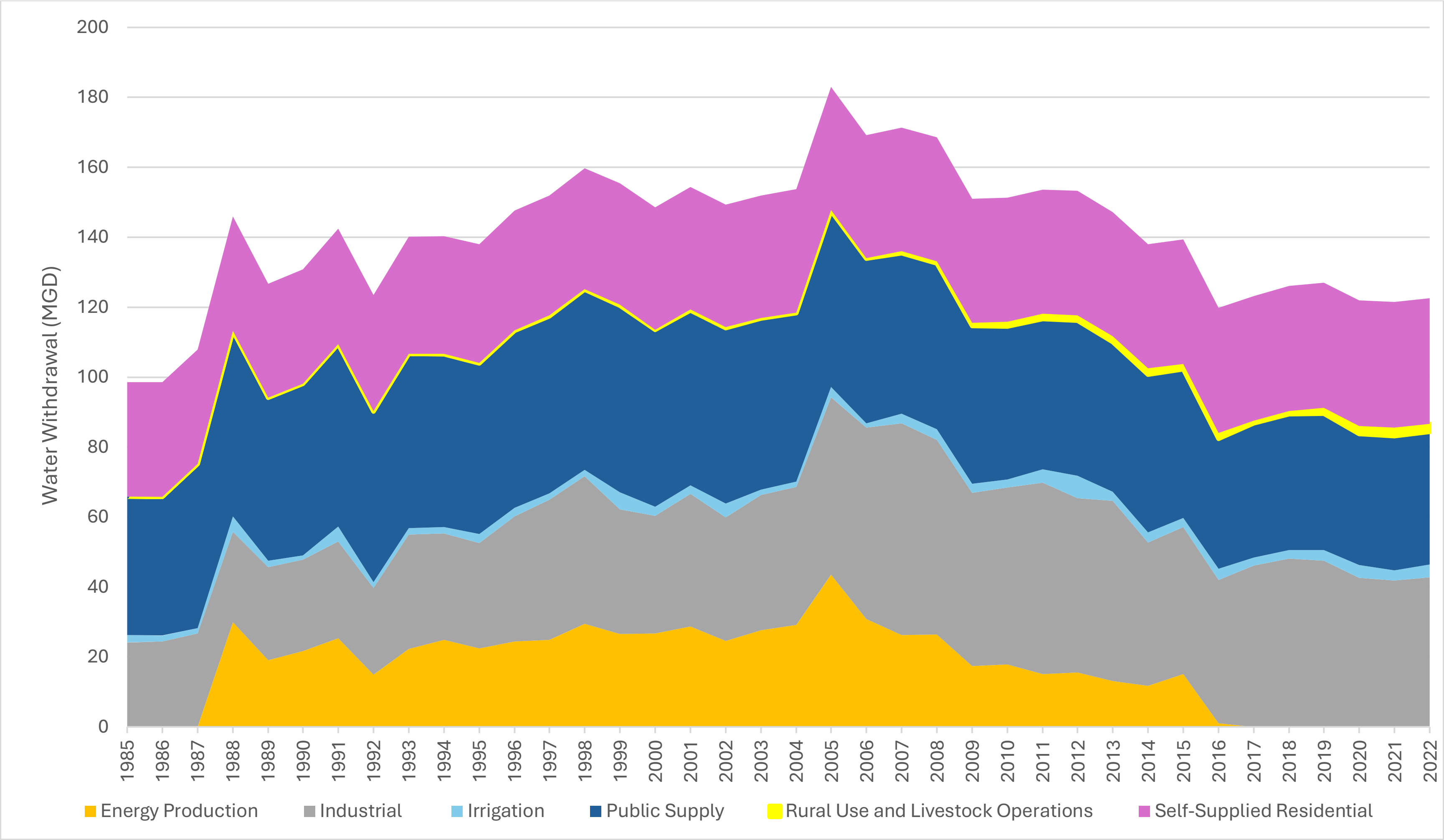


Figure 3-4. Historical Annual Average Daily Withdrawals by Sector, 1985-2022.

Note: Miscellaneous registered facilities are not shown in the figure because their demand has not exceeded 1% of the total water demands in the region.

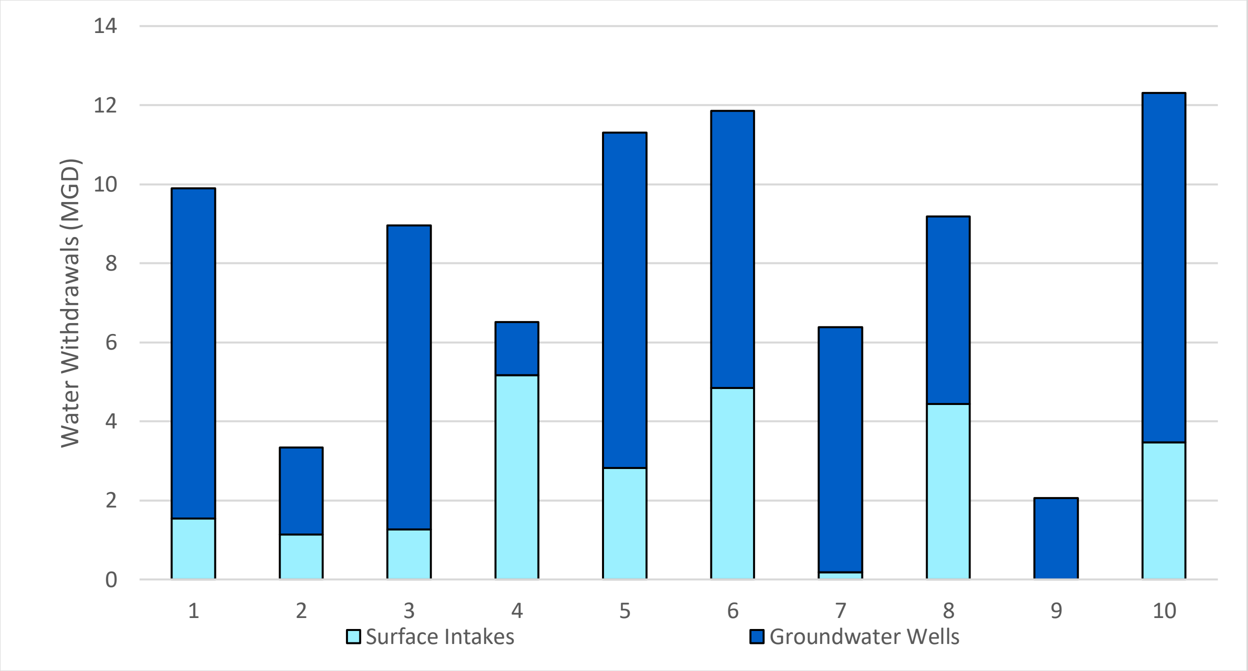
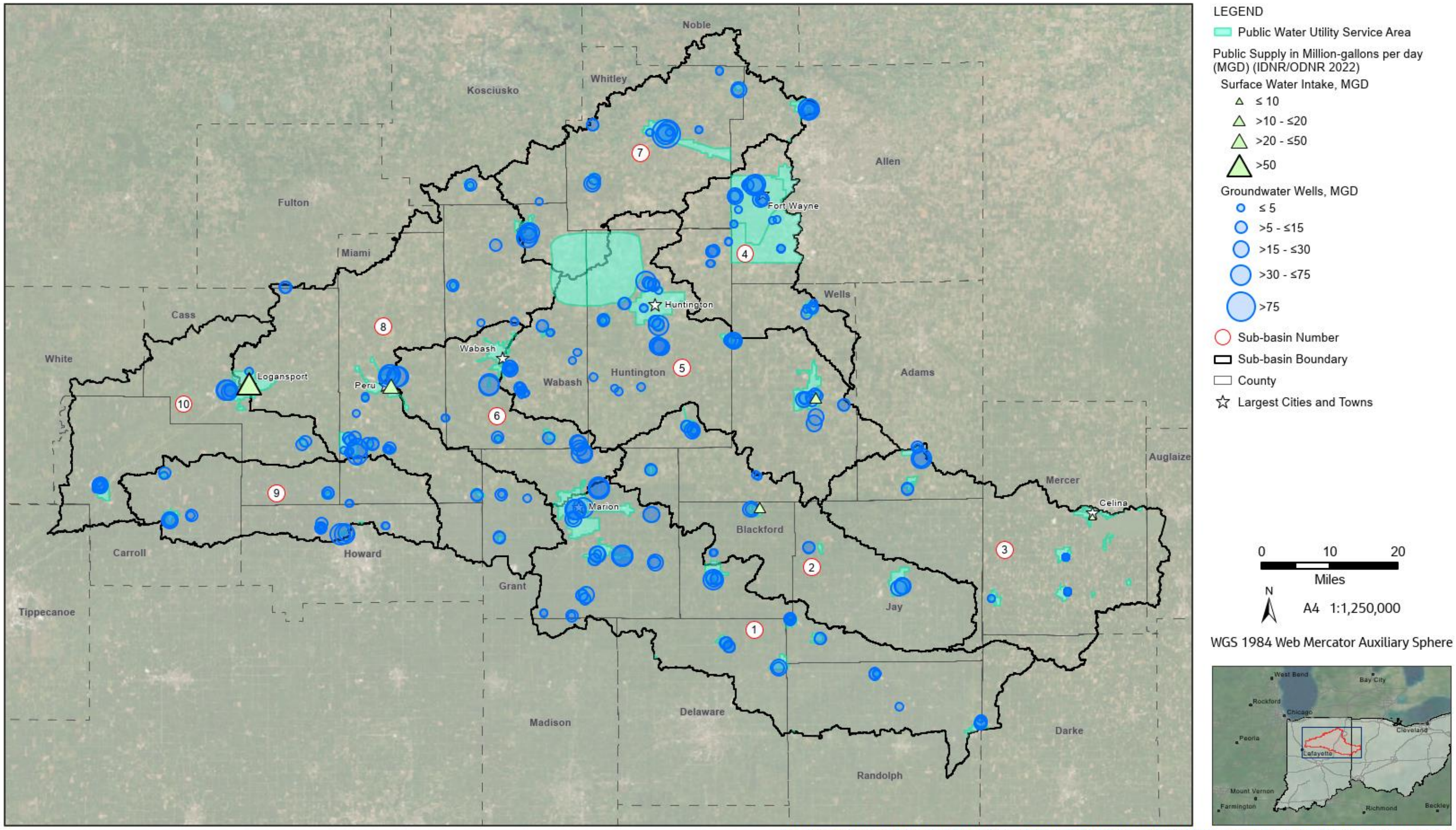


Figure 3-5. Annual Average Withdrawals by Source per Sub-basin (2022)



Data Sources: National Atlas of US (2014),IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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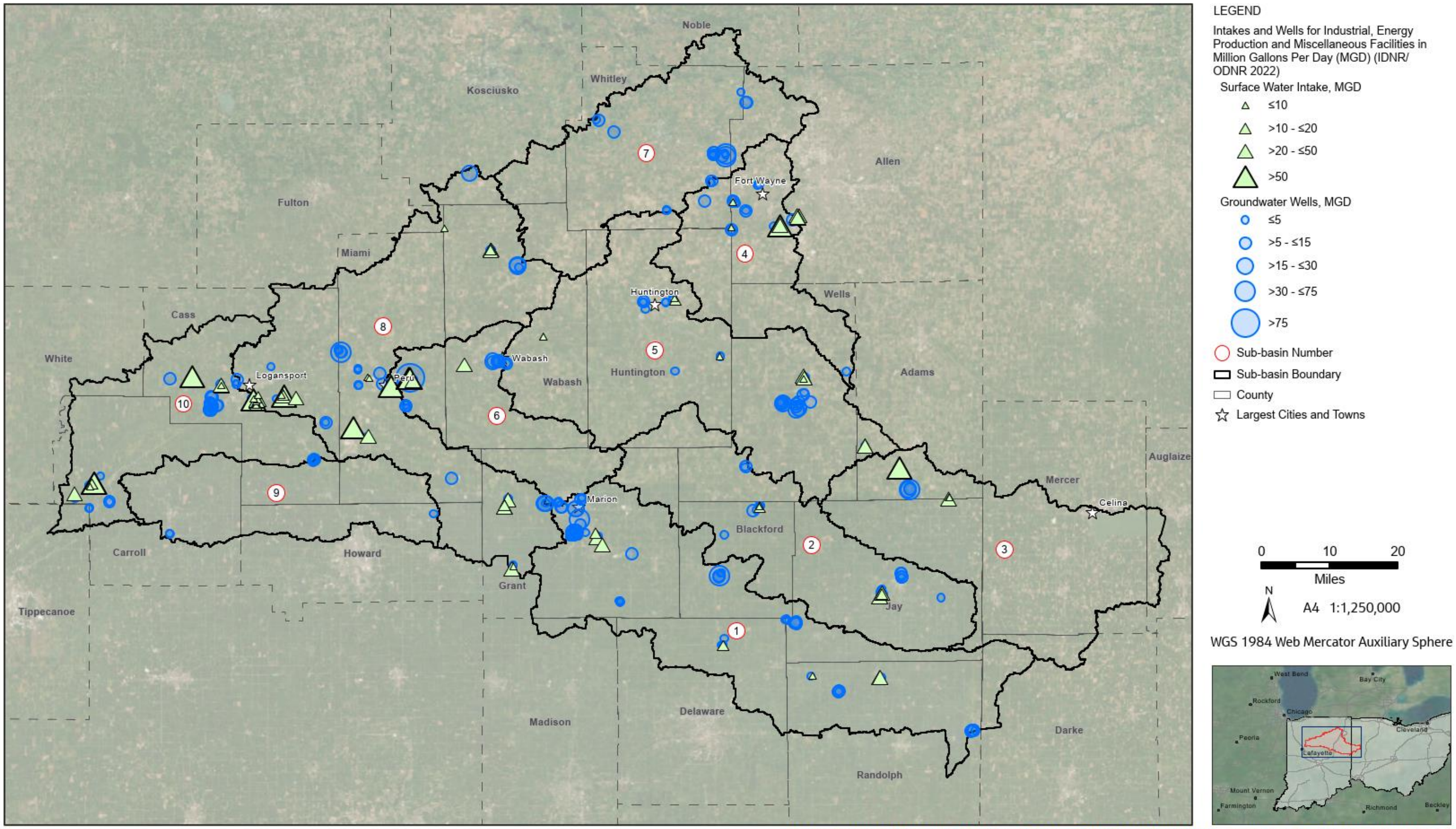
Figure 3-6. General Locations and Daily Public Supply Withdrawals by Source per Water Utility (2022)



Data Sources: National Atlas of US (2014),IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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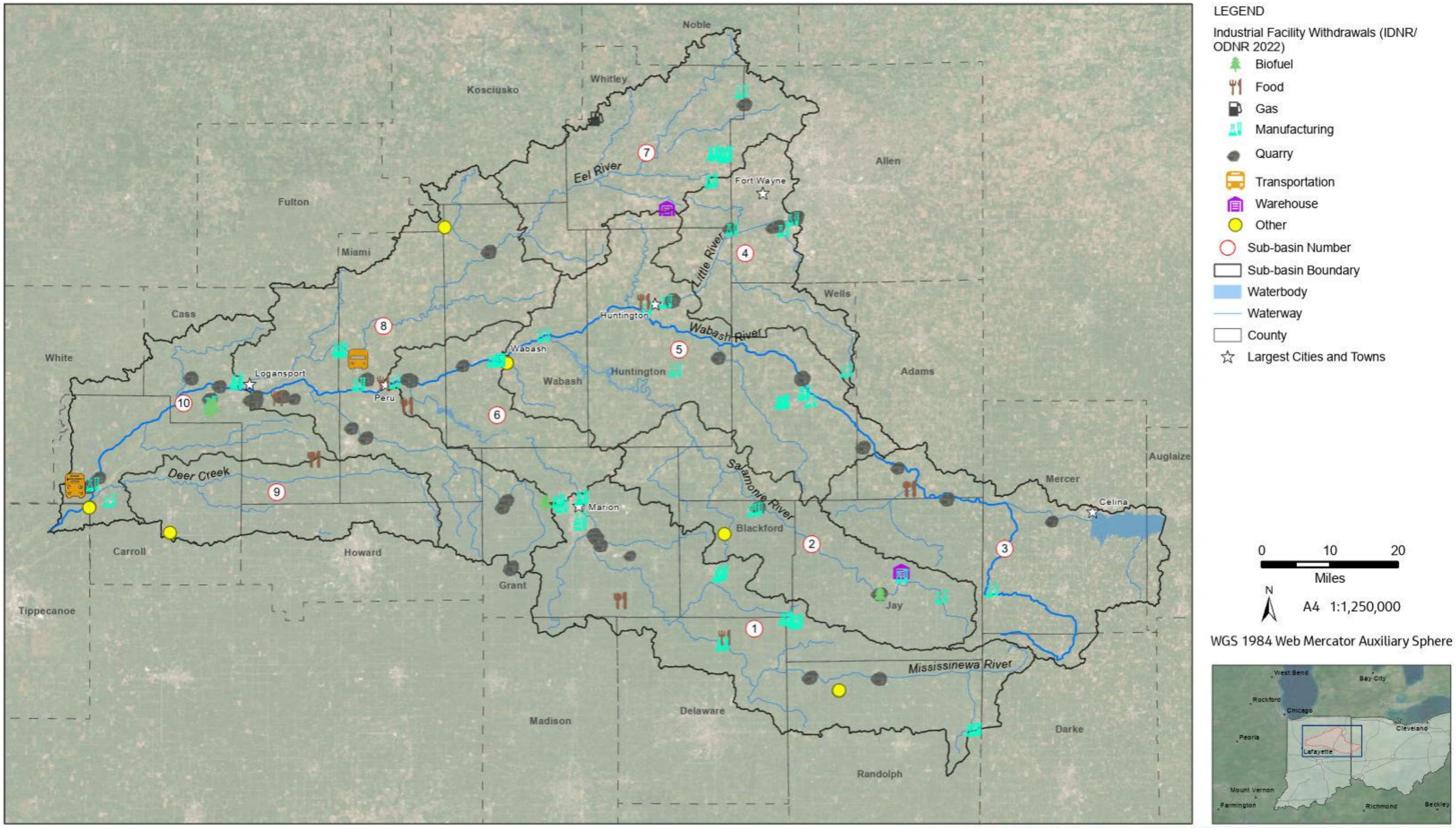
Figure 3-7. General Locations and Annual Withdrawal Rates for Industrial, Energy Production, and Miscellaneous Withdrawals by Source per Registered Facility (2022)



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure 3-8. Industrial Users in the Wabash Headwaters Region

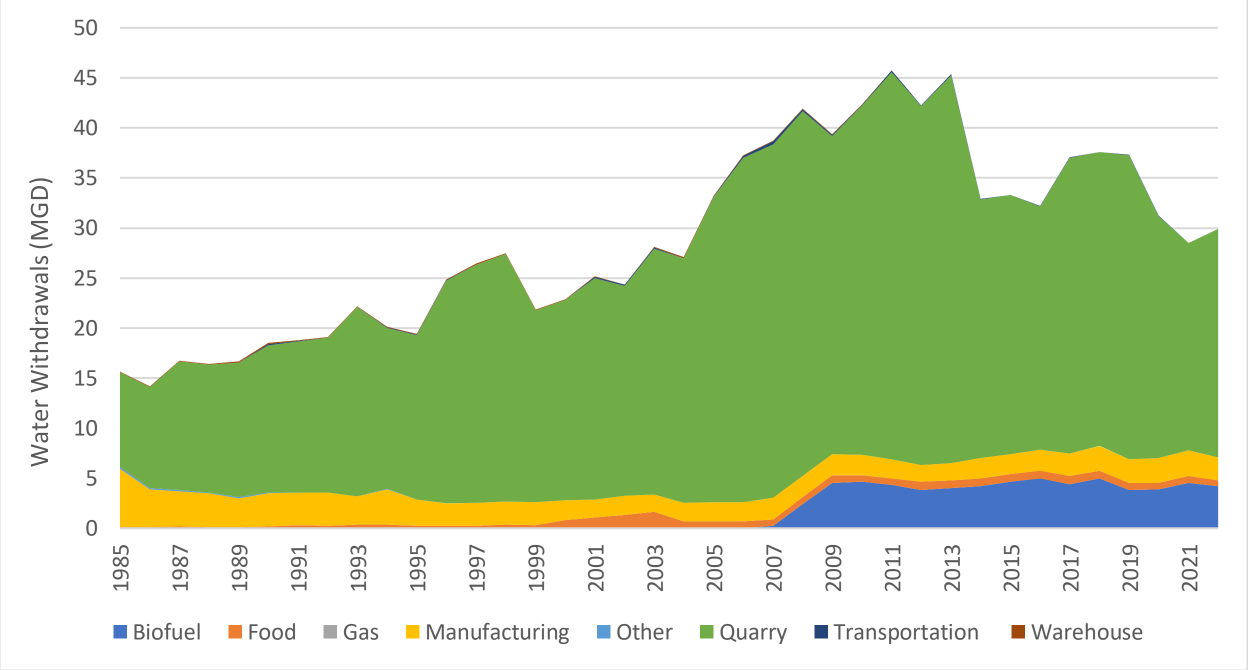


Figure 3-9. Annual Average Withdrawals per Industrial Facility Type (MGD) (1985 through 2022)

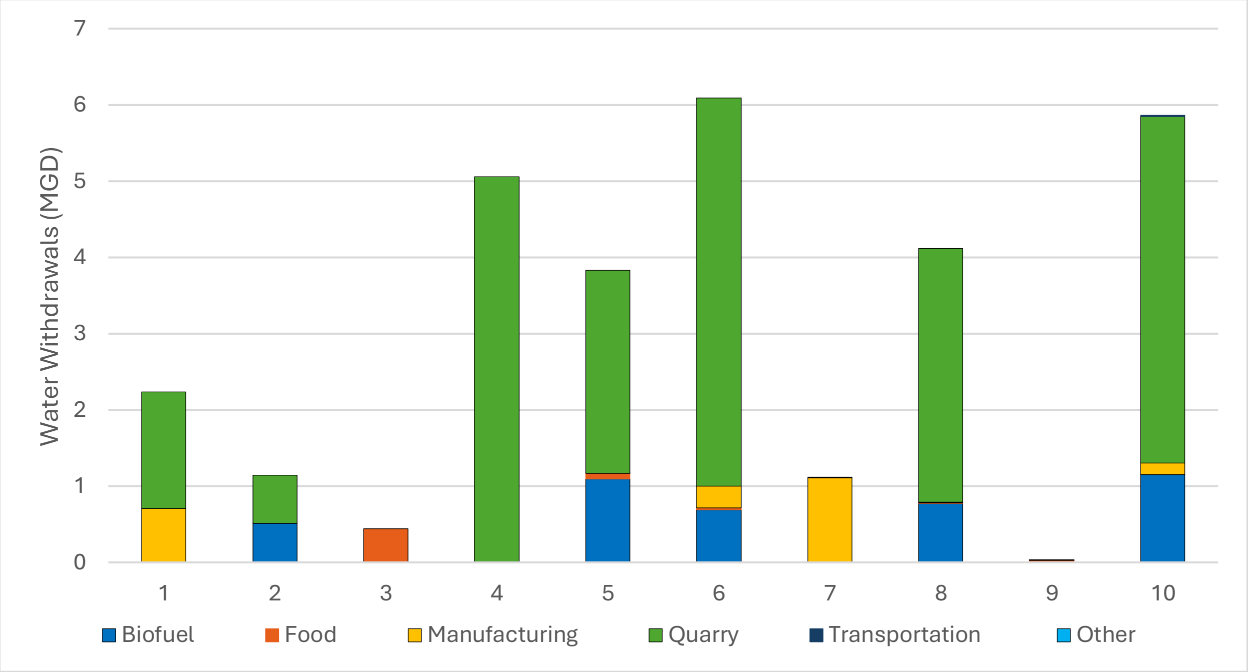


Figure 3-10. Annual Average Withdrawals (MGD) by Industrial Facility Type per Sub-basin (2022)

In 2022, industrial sector withdrawals in Indiana averaged 30 MGD with quarry facilities constituting 70% of total industrial water withdrawals. Quarries withdrawals are used for dewatering extraction sites, with approximately 10% for consumptive use (Shaffer and Runkle, 2007). Between 1985 and 2022, quarry facility withdrawals averaged 23.8 MGD and peaked in 2013 at 38.7 MGD. Since then, withdrawals have declined slightly, totaling 22.8 MGD in 2022. Quarry facilities are found throughout the study area (except for Sub-basin 3 Wabash-Linn Grove and Sub-basin 9 Deer Creek-Delphi) and predominantly rely on surface water sources, which accounted for 97% of quarry withdrawals in 2022 (Figure 3-11).

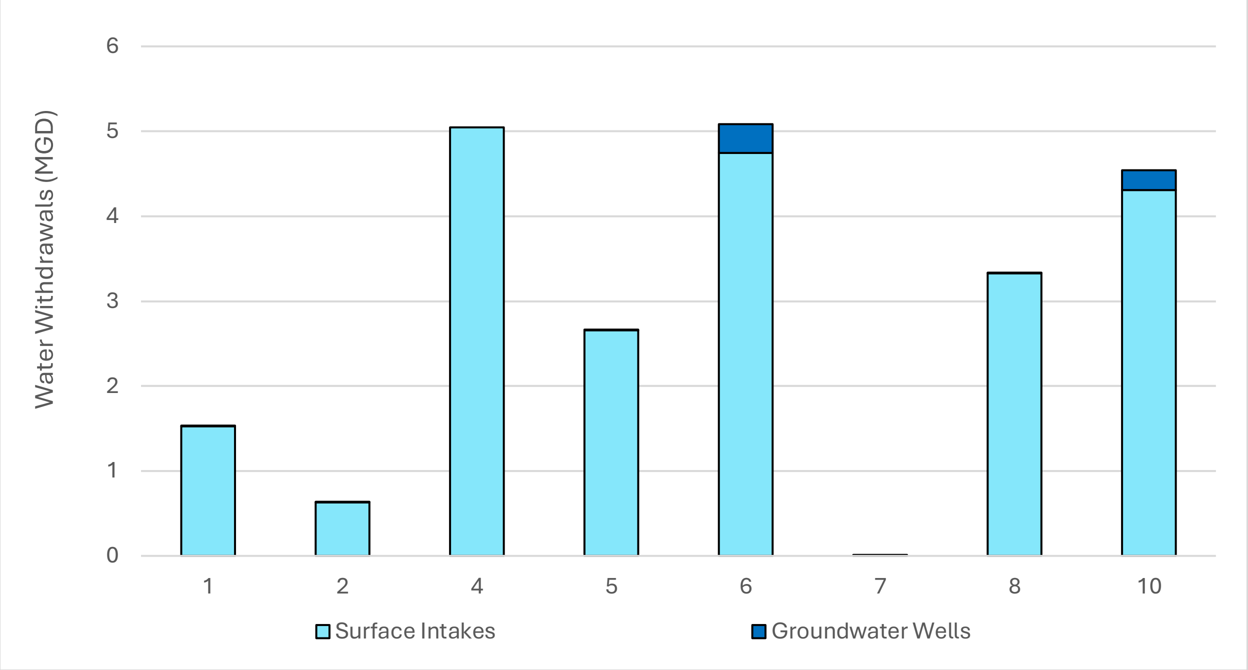


Figure 3-11. Annual Average Daily Withdrawals for Quarries by Source per Sub-basin (2022)

After quarries, manufacturing facilities had the next largest water withdrawal in the industrial sector in the study area, averaging 2.5 MGD between 1985 and 2022. Since 2002, the manufacturing water withdrawals have shown no upward or downward trend, averaging 2.1 MGD. A single manufacturing facility in Ohio within Sub-basin 3 Wabash-Linn Grove accounted for 15% of Ohio's industrial water usage inside the study area. Many of the industrial facilities in Indiana are often supported by public supply water utilities (Letsinger and Gustin, 2024.

In 2007, biorefineries began operating in the study area, starting with Central Indiana Ethanol in Grant County within Sub-basin 6 Wabash-Peru. By 2022, four additional biofuel refineries with significant water withdrawal permits where operating in Cass, Jay, Wabash and Wells counties. During the study period, water withdrawals for biofuel production averaged approximately 3.9 MGD, being sourced primarily from aquifers using groundwater wells.

3.1.2 Public Supply

The public supply sector has the second largest reported water withdrawals in the Wabash Headwaters study region. The public supply sector includes public utilities that provide water for commercial, industrial, and domestic users, as well as withdrawals for schools and parks for drinking water and sanitary needs. Figure 3-12 shows the public supply registered facilities, their service areas, and their current generalized water source locations. Between 1985 and 2022, water withdrawals in the public supply sector averaged 35.1 MGD, peaking in 1999 with an average daily demand of 39.7 MGD. Over the past decade, demand in the public supply sector has been steady, with demand averaging 30.2 MGD in 2022 (Figure 3-13). Public supply consumptive use is based on water that is used by diverse customer types such as residential, commercial, and industrial. For this reason, it will have seasonal variations where consumptive use is highest in the summer (median 22% for 1999-2004) and lower in the spring (median 3% for 1999-2004). The higher consumptive use (Shaffer, 2009) was observed during the months of low rainfall and high temperature. For this study, the return flows for industry were estimated based on the NDPES monitoring data as reported by each registered facility.

Public utilities in the study area predominantly rely on groundwater wells as their primary source water type. In 2022, 94.8% of all withdrawals (28.6 MGD) were pumped from underlying aquifers. Within study area, there no active surface water intakes for public utilities in the Indiana portion. The only active surface water intake withdrew 1.1 MGD in 2022 and is located in the eastern portion of the Sub-basin 3 Wabash-Linn Grove in Ohio.

More than 50 public water utilities are active in the Wabash Headwaters study area, (refer to Table 3-1). These water systems vary widely in the number of customers they serve, and some of the service areas for these utilities overlap. The two largest public water utilities in the study area, Fort Wayne - City Utilities (Three Rivers Filtration Plant) and Indiana American Water Kokomo, both draw from surface water sources; however, the intakes are outside this study area. In these cases, only the volume of water extracted from within the watershed was considered and aggregated into the sub-basin total. To calculate return flows as part of the water availability analysis (Section 4), the portion of the service areas within the study region were used to allocate water use within utility service areas that straddle the watershed boundary.

A few utilities sell water to other utilities and must be evaluated to determine if the import or export of water among public water utilities affects the water balance within the region. For example, Fort Wayne City Utilities serves the largest population in the region, but most of its service area and water withdrawal intakes are outside the Wabash Headwaters study area. They also export more water than any other utility with a reported 379 MG per year to New Haven Water Department (IFA, 2022) outside the study area.

During interviews conducted for this water study, representatives from economic development organizations and water utilities in the study area provided information regarding continuing challenges surrounding water availability and quality. As a result of these difficulties, some utilities rely upon purchased water from neighboring communities, and are exploring alternative and/or additional water sources.

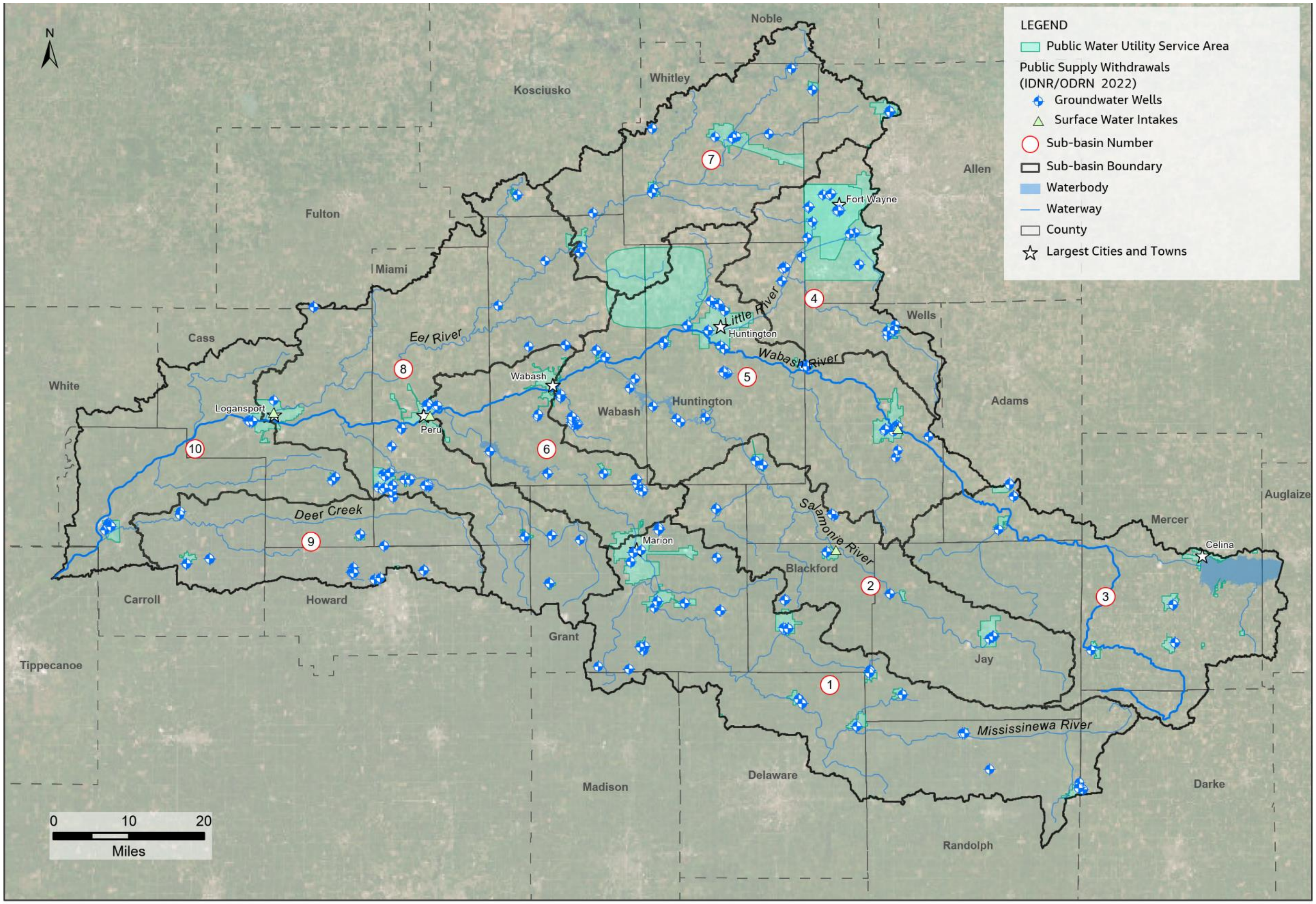


Figure 3-12. General locations for Public Water Supply (Utilities) Withdrawals in the Wabash Headwaters Region

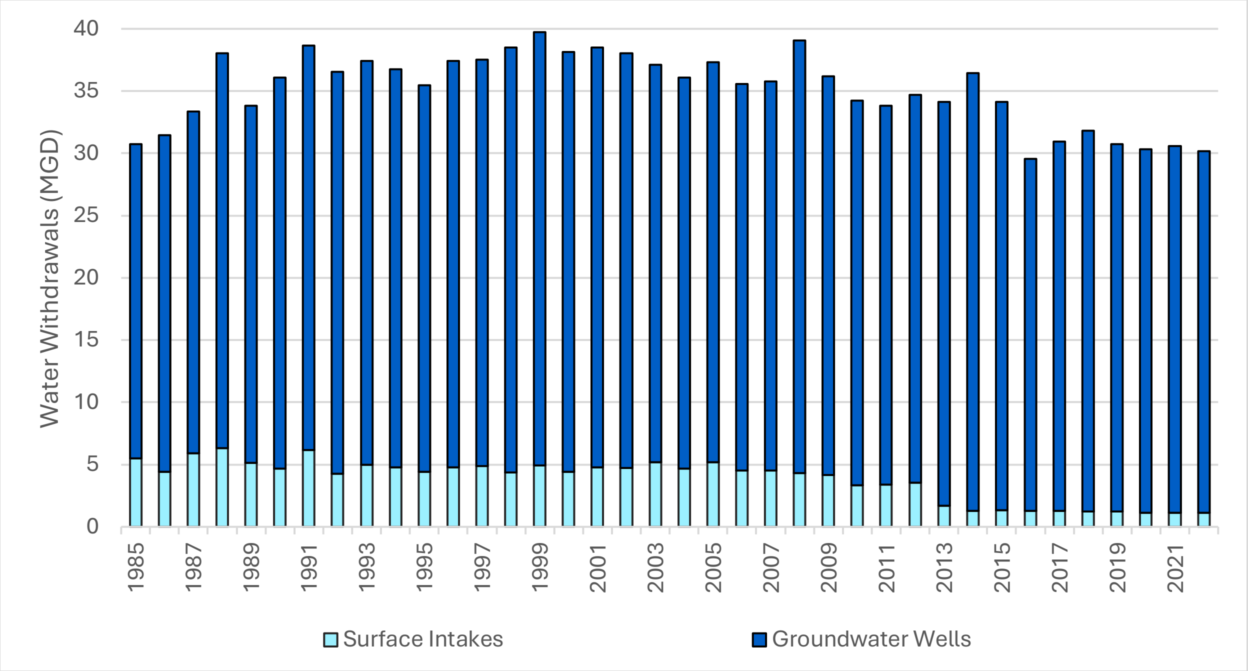


Figure 3-13. Annual Average Daily Withdrawals for Public Supply by Source Water Type (1985 through 2022)

Table 3-1. Public Water Utilities in the Upper Wabash Headwaters Region

Utility Name	Population Served	Service Connections	Principal County	Principal City	Primary Water Source[1]
Fort Wayne City Utilities [2]	266,000	106,362	Allen	Fort Wayne	SW
Indiana American Water – Kokomo[2]	55,813	22,325	Howard	Kokomo	SW
Marion City Water Works	28,363	10,763	Grant	Marion	GW
Ohio Public Water Utilities	26,485	10,250	Mercer, Drake, and Auglaize	Multiple	GW
Logansport Municipal Utility-Well Field	18,369	7,330	Cass	Logansport	GW
Huntington Water Department	17,300	7,416	Huntington	Huntington	GW
Peru Water Department	11,417	4,843	Miami	Peru	GW
Indiana American Water - Wabash	11,190	4,476	Wabash	Wabash	GW
Bluffton Utilities Water Department	10,298	4,100	Wells	Bluffton	GW
Columbia City Water Department	9,892	4,124	Whitley	Columbia City	GW
Huntertown Utilities [2]	7,400	4,100	Allen	Huntertown	GW
Rochester Water Department	6,218	3,661	Fulton	Rochester	GW
Portland Municipal Water Plant	6,209	2,712	Jay	Portland	GW
North Manchester Water Department	6,100	2,200	Wabash	North Manchester	GW

Utility Name	Population Served	Service Connections	Principal County	Principal City	Primary Water Source[1]
Gas City Water Department	6,000	2,600	Grant	Gas City	GW
Hartford City Water Works	5,600	2,400	Blackford	Hartford City	GW
Berne Water Department [2]	4,388	1,823	Adams	Berne	GW
Union City Water Works [2]	3,513	1,600	Randolph	Union City	GW
Town of Upland	3,308	859	Grant	Upland	GW
Ossian Municipal Water Department	3,289	1,329	Wells	Ossian	GW
Delphi Water Works	3,200	1,200	Carroll	Delphi	GW
Fairmount Water Works	2,756	1,156	Grant	Fairmount	GW
Dunkirk Water Department	2,305	967	Jay	Dunkirk	GW
Albany Water Department	2,165	940	Delaware	Albany	GW
Jonesboro Water Department	2,034	967	Grant	Jonesboro	GW
Churubusco Water Department	1,803	869	Whitley	Churubusco	GW
Montpelier Water Works	1,800	713	Blackford	Montpelier	GW
Roanoke Water Works	1,722	819	Huntington	Roanoke	GW
South Whitley Municipal Water	1,709	900	Whitley	South Whitley	GW
Eaton Water Works	1,595	630	Delaware	Eaton	GW
Town of Geneva	1,359	649	Adams	Geneva	GW
Redkey Water Plant	1,323	553	Jay	Redkey	GW
Farmland Municipal Water Works	1,301	660	Randolph	Farmland	GW
Town of Converse	1,265	473	Miami	Converse	GW
Galveston Water Works	1,258	639	Cass	Galveston	GW
Warren Municipal Water Works	1,237	639	Huntington	Warren	GW
Andrews Water Department	1,149	447	Huntington	Andrews	GW
Markle Water Utility	1,095	474	Huntington	Markle	GW
Walton Water Works	1,040	440	Cass	Walton	GW
Silver Lake Water Works	1,030	454	Kosciusko	Silver Lake	GW
Swayzee Water Utility	975	430	Grant	Swayzee	GW
Lafontaine Water Company	906	396	Wabash	La Fontaine	GW
Bunker Hill Water Works	900	385	Miami	Bunker Hill	GW
Ridgeville Water Department	890	360	Randolph	Ridgeville	GW
Gaston Water Works [2]	871	323	Delaware	Gaston	GW
Van Buren Municipal Utilities	864	381	Grant	Van Buren	GW
Pennville Water Company	706	265	Jay	Pennville	GW
Town of Camden	611	282	Carrol	Camden	GW
Norwood Regional Water and Sewage	486	194	Huntington	Huntington	GW
Lagro Municipal Water Department	438	200	Wabash	Lagro	GW

Utility Name	Population Served	Service Connections	Principal County	Principal City	Primary Water Source[1]
Indiana American Water - Somerset	233	93	Wabash	Somerset	GW

Source: IDEM, 2024b

[1] *SW = Surface Water, GW = Groundwater*
[2] *Public water utilities whose service areas are partially located within our study area.*

Note: Table is organized by the size of the population served, from largest to smallest.

3.1.3 Self-Supplied Residential

Self-supplied residential water demand reflects the water usage of households that withdraw their own water rather than relying on a municipal public water supply. A spatial analysis was conducted to calculate the number of households within the study area that have their own wells. Key spatial features used for this analysis include sub-basin, county, and water utility service area boundaries, as well as address point data from the National Address Database (NAD) (U.S. Department of Transportation NAD, 2024). Proper association of data with each service area required spatial analysis of address distributions, as described in Appendix A. The address point analysis determined how many households are served by public water utilities and how many are likely self-supplied. Table 3-2 shows the estimated self-supplied residential population and water demand per sub-basin for year 2022.

Table 3-2. Self-Supplied Residential Population and Water Demand Estimated for 2022

Sub-basin	Sub-basin Population (2022)	Publicly Supplied Population	Self-supplied Residential Population	Self-supplied Residential Population (%)	2022 Self-supplied Residential Water Demand (MGD)
1 Mississinewa-Marion	88,966	62,382	26,584	30	2.02
2 Salamonie-Warren	22,251	12,701	9,550	43	0.72
3 Wabash-Linn Grove	52,743	22,688	30,055	57	2.26
4 Little-Huntington	67,804	55,385	12,419	18	0.95
5 Wabash-Wabash	54,546	37,154	17,392	32	1.32
6 Wabash-Peru	29,920	20,822	9,098	30	0.69
7 Eel-North Manchester	46,919	24,490	22,429	48	1.71
8 Wabash-Logansport	60,893	32,907	27,986	46	2.12
9 Deer Creek-Delphi	14,108	3,992	10,116	72	0.77
10 Wabash-Ungauged	17,705	7,207	10,498	59	0.80

Approximately 25% of the total Indiana population relies on self-supplied residential water use (Dieter et al., 2018). Self-supplied residential water withdrawals in Indiana come from groundwater and total approximately 127 MGD (Dieter et al., 2018). For the study region, which includes a portion of Ohio, 39% of the population relies on self-supplied groundwater wells with a total water demand of 13.4 MGD in 2022 calculated using a per-person estimate of 76 gallons per day (Dieter et al., 2018). The largest concentration of self-supplied users is in Sub-basin 3 Wabash-Linn Grove. A large section of Sub-basin 3 Wabash-Linn Grove is in Ohio, where most of the self-supplied population within that watershed resides. The smallest self-supplied population was calculated for Sub-basin 4 Little-Huntington where the Fort Wayne City Utilities' service area covers a large portion of the basin. Consumptive use for self-supplied residential shows a seasonal variation where consumptive use is highest in the summer (19%) and zero during the winter months (Shaffer, 2009).

3.1.4 Irrigation

Self-supplied irrigation users comprise a significant water use sector that largely supports agricultural production in the study area, but also includes golf courses. Water demand for irrigation users fluctuates throughout the year due to climate, growing season length, and crop requirements Withdrawals typically occur and peak in summer months due to crop production requiring irrigation and landscape maintenance to counteract high temperatures and evapotranspiration rates during the season. The study area is a significant region for agricultural production, evidenced by the numerous farms and rural composition of the region. The two key cultivated row crops are corn and soybeans.

Based on an analysis of historical data between 1985 and 2022, the irrigation sector withdrew an average of 2.69 MGD. Sub-basin 8 Wabash-Logansport had the majority of irrigation withdrawals (approximately 35%), and this water was sourced from both groundwater wells and surface water intakes (Figure 3-14). Water withdrawals peaked in 2012, a drought year, averaging 6.35 MGD. Within the self-supplied irrigation sector, agricultural production accounted for 73% of total irrigation withdrawals, averaging 1.9 MGD, while golf courses averaged 0.59 MGD (Figure 3-15). Most of the water used for irrigation is considered consumptive use from evapotranspiration. Return flows after irrigation usually occurs through groundwater recharge and surface water runoff. For this study, a constant consumptive use of 80% was assumed for all types of irrigation (Schaffer, 2009).

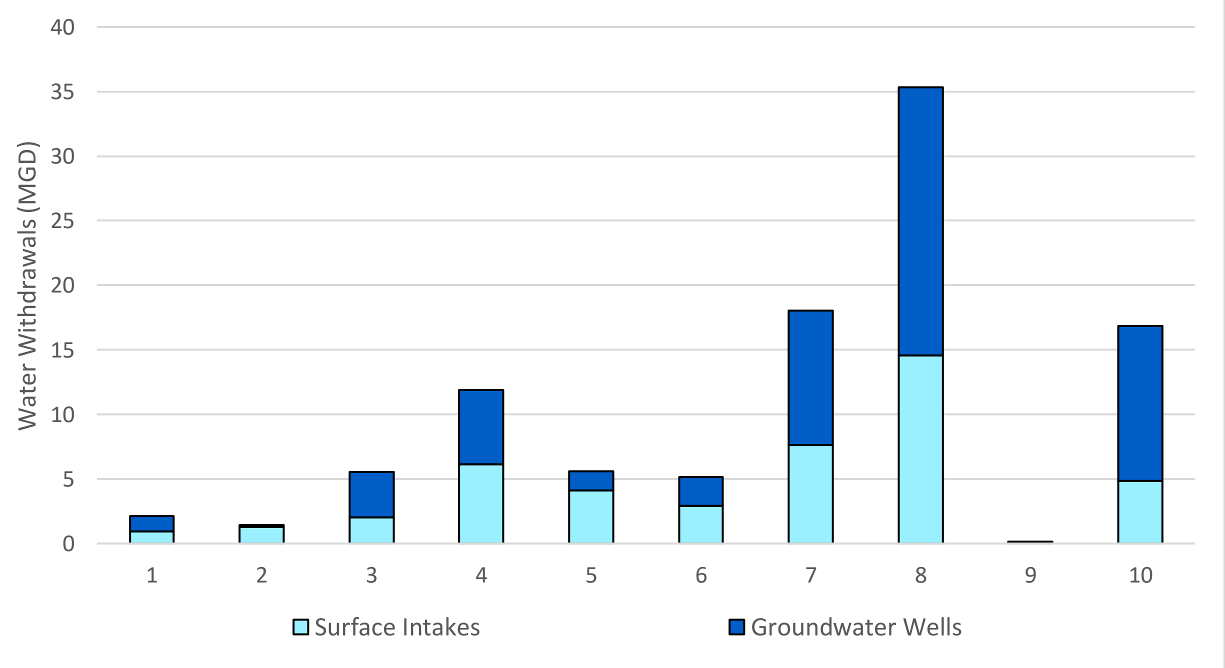


Figure 3-14. Annual Average Daily Withdrawals for Self-supplied Irrigation Users by Source per Sub-basin (1985-2022)

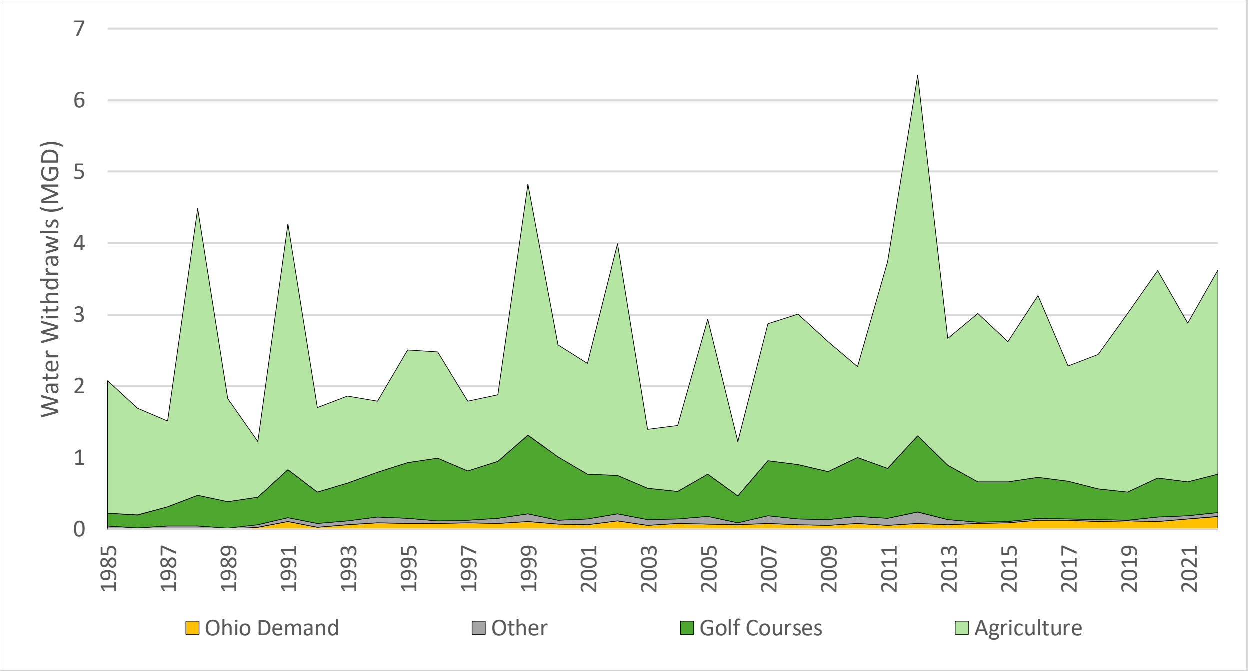


Figure 3-15. Annual Average Daily Withdrawals by Irrigation Facility Classification

3.1.5 Rural Use and Livestock Operations

In 2022, rural use facilities and livestock operations accounted for 3% of the Wabash Headwaters total water use, that is, 2.3 MGD annual average daily demand. Water use for rural use includes the registered rural use facilities (livestock and aquaculture) listed in the SWWF database within the Wabash Headwaters study area. The SWWF database summarized monthly withdrawals per user from 1985 to 2022. However, not all livestock operations (CAFO and CFO) in the region are registered in the SWWF database and record their water use. Therefore, these livestock operations were evaluated differently. Two datasets were utilized to develop a historical timeseries for livestock operations, the USDA census records and IDEM's Pending and Issued CFO Permits database (IDNR, 2022). The USDA agricultural census is recorded in 5-year increments, where the 2007, 2012, 2017, and 2022 records were pulled for all Indiana and Ohio counties within the Wabash Headwaters region. In 2008, USDA updated the approach to conducting the agricultural census, so data preceding the 2007 census was not incorporated. Where the census data provided historical records for general livestock operations, the IDEM dataset lists registered CFO discharges as of August 2023. Each registered feeding operation's animal manure units are described as "animal head count" for calculating water demand. Appendix A describes the livestock operation's historical timeseries methodology in detail. Water withdrawals in 2022 for rural use facilities accounted for 69% (1.6 MGD) of the combined total water demand for rural use and livestock operations, while livestock operations accounted for 31% (0.7 MGD).

Based on the rural use water withdrawal data and the estimated livestock operations water usage, the annual daily demand for the rural category ranges from 0.5 to 2.5 MGD in the Wabash Headwaters study area, from 2007 to 2024. Estimates for the rural use subcategory from 1985 to 2007 are not included in this average. Reported rural water withdrawals from 2007 through 2022 are from groundwater sources (Figure 3-16).

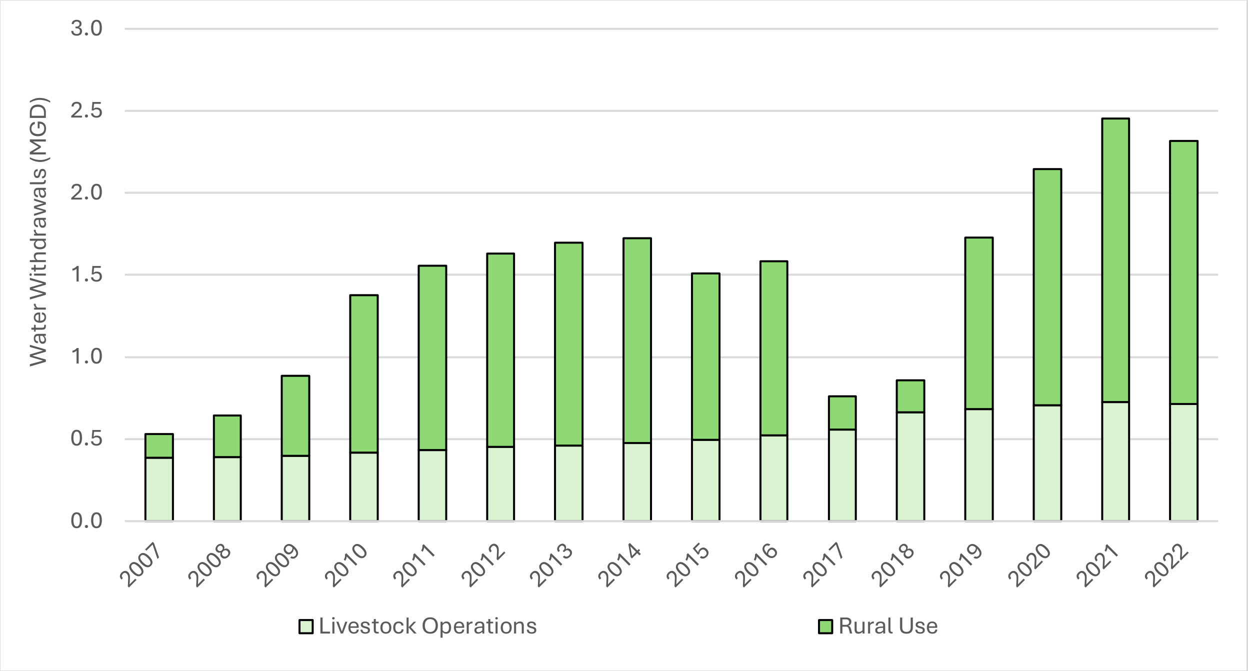


Figure 3-16. Annual Average Daily Withdrawals for Rural Use and Livestock Operations

The rural use registered facilities collectively consumed more water than livestock operations in every year since 2008 other than 2017 and 2018 (Figure 3-16). Rural use is highly concentrated in Sub-basin 1 Mississinewa-Marion (Delaware County), with 56% of the total rural facilities usage from 2007 to 2022. Aquiculture is the most prominent water use and 88% of the water demand for rural use in 2022. Since 2007, water demand for rural use has been increasing but seems more volatile compared to livestock operations (Figure 3-16).

Water demand for livestock operations make up one third of the of the combined total water demand for rural use and livestock operations. For this report, livestock operations are feeding operations regulated under the state's Confined Feeding Control Law and registered as livestock discharges. These facilities are CFOs, which maintain and feed livestock in a confined area. Facilities must apply for a permit and are regulated under this law if they meet the minimum animal headcount for any of the two categories listed in Table 3-3. Some CFOs are further designated as CAFOs if they meet the size requirement based on Indiana's definition of a CAFO. This designation is determined based on whether the CFO meets or exceeds the minimum number of animals for any individual category listed in Table 3-3. For example, even if a CFO does not raise any swine, if it has 700 or more mature dairy cows, it will be designated as a CAFO in Indiana (IDEM, 2024c). Indiana commenced CFO registrations in 2018, and not all facilities listed in the 2022 database historically met the requirements. Many livestock operations began smaller and grew to CFO-size with time. To account for this in the historical timeseries development, the USDA agricultural census provided recorded farm and animal counts for the CAFO/CFO water demand calculations.

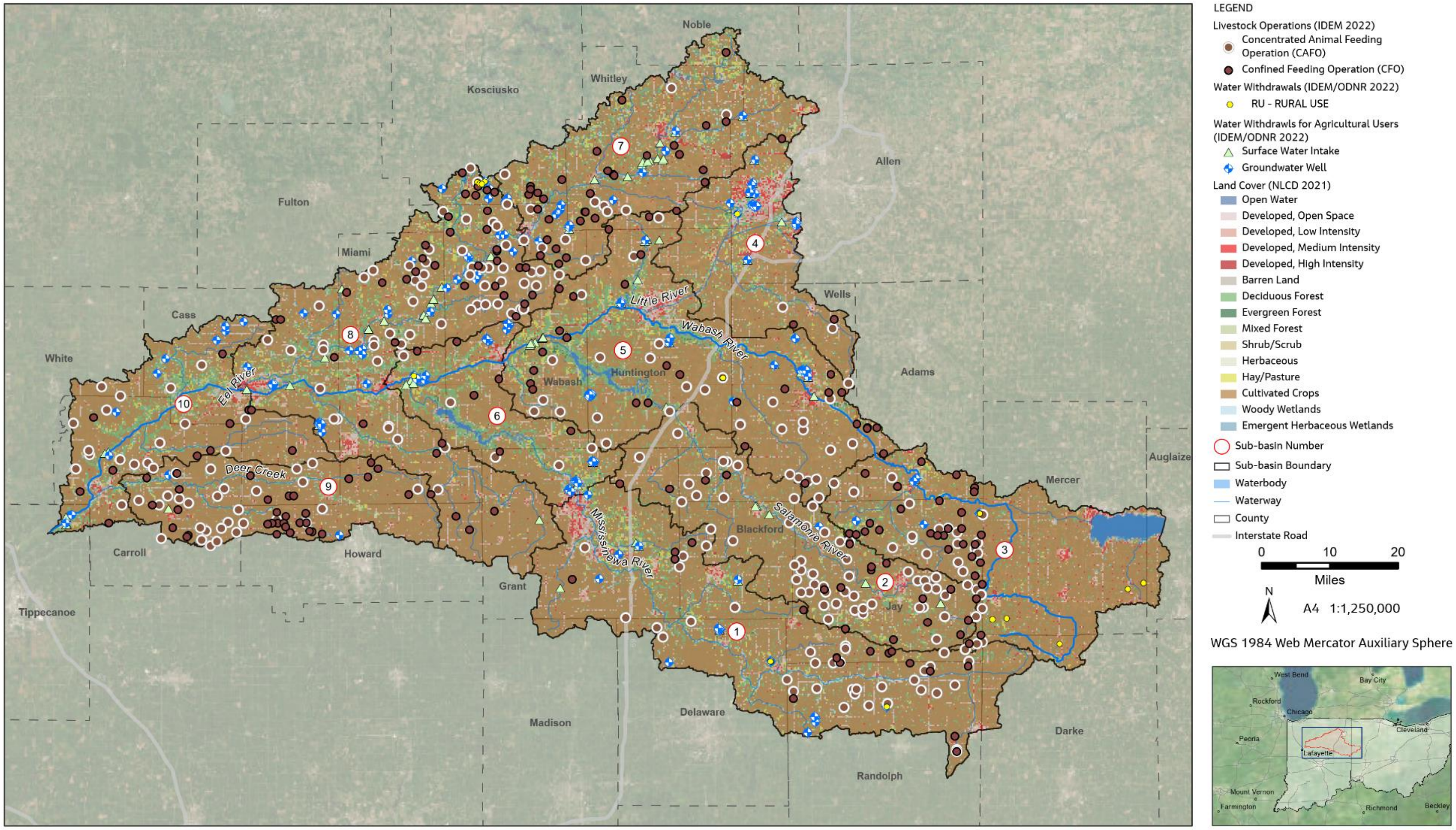
Table 3-3. Minimum Animal Headcount for Livestock Operation in Indiana

Designation	Livestock	Minimum Headcount
CFO	Cattle	300
	Swine or sheep	600
	Poultry (such as chicken, turkey, or ducks)	30,000
	Horses	500
CAFO	Mature dairy cows	700
	Veal calves	1,000
	Cattle other than mature dairy cows	1,000
	Swine above 55 pounds	2,500
	Swine less than 55 pounds	10,000
	Horses	500
	Sheep or lambs	1,0000
	Turkeys	55,000
	Laying hens or broilers with a liquid manure handling system	30,000
	Broilers with a solid manure handling system	125,000
	Laying hens with a solid manure handling system	82,000
	Ducks with a solid manure handling system	30,000
	Ducks with a liquid manure handling system	5,000

Source: DEM, 2024c.

Water demand for livestock operations increased steadily from an annual average daily demand of 0.4 MGD in 2007 to 0.7 MGD in 2022. The only year annual average daily demand decreased was from 2021 to 2022, when it fell slightly from 0.74 to 0.73 MGD. Water demand varies throughout the year because livestock use significantly more water during the warmer months, resulting in cyclical peaking in August and lowest monthly average daily demand in January for livestock operations.

Hog and pig farms account for the highest number of CFOs in the Indiana portion of the study area and are concentrated heavily in Jay, Carroll, and northern Wabash counties. However, there are also high concentrations of poultry farms, many with more than 100,000 animals, in northern Wabash County and eastern Jay County. In addition, cattle farms are found within every sub-basin but are most common in northern Wabash County. Figure 3-17 shows the distribution of rural use and livestock operations in the study area, as well as their relative size based on animal head count. A constant consumptive use of 80% was assumed for rural use and livestock operations (Shaffer, 2009).



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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Figure 3-17. Rural Facilities in the Wabash Headwaters Region

3.1.6 Energy Production

Between 1988 and 2021, there were three active power plants in the Wabash Headwaters study area: the City of Peru Utilities in Sub-basin 6 Wabash-Peru, Logansport Municipal Utilities in Sub-basin 8 Wabash-Logansport, and the Montpelier Generating Station, LLC in Sub-basin 1 Mississinewa-Marion. The Peru power plant was decommissioned in 2012 and demolished in 2017 (Gerber, 2016). They phased out into a solar power utility that is currently owned by the Indiana Municipal Power Authority, as noted in Table 2-3. The Logansport Generating Plant was decommissioned in 2015 and razed in 2022 (Paul, 2022). Both facilities were coal-fired power plants that had been in service for more than 100 years. The natural gas power plant, Montpelier Electric Generating Station, came online in 2001 and is still active.

Before being decommissioned, the two coal-fired power plants used a large amount of surface water for cooling, cleaning, and processing fuel, as well as for emission control. Between 1988 and 2012, both plants averaged withdrawals of 12.3 MGD, peaking at 43.5 MGD in 2005. Since coming online, Montpelier Electric Generating Station has averaged 0.018 MGD of withdrawals from the local aquifer but has not reported any significant water withdrawals after 2021 (Figure 3-18). The traditional energy power plants consumed a ton of surface water, resulting in the transition to newer. These new power plants utilize solar power and are generally low-demand and non-consumptive making them more efficient.

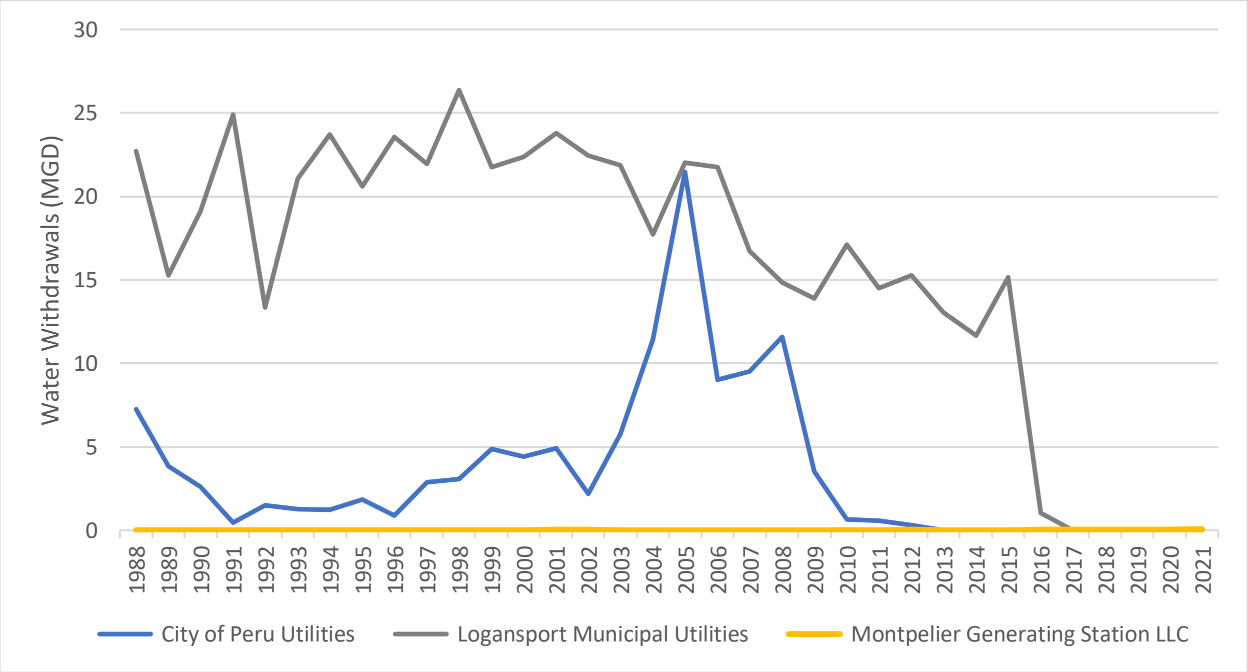


Figure 3-18. Annual Average Daily Withdrawals for Energy Production Users

3.1.7 Miscellaneous Uses

Self-supplied miscellaneous registered users include fire protection, amusement parks, construction dewatering, dust control, pollution abatement, hydrostatic testing, and recreational field drainage. Their withdrawals do not occur with regularity, and they lack a consistent pattern. Between 1985 and 2022, the number of active miscellaneous facilities in the study area has varied, peaking in 1995 with 19 miscellaneous facilities. Figure 3-19 displays the miscellaneous water withdrawals in the study area.

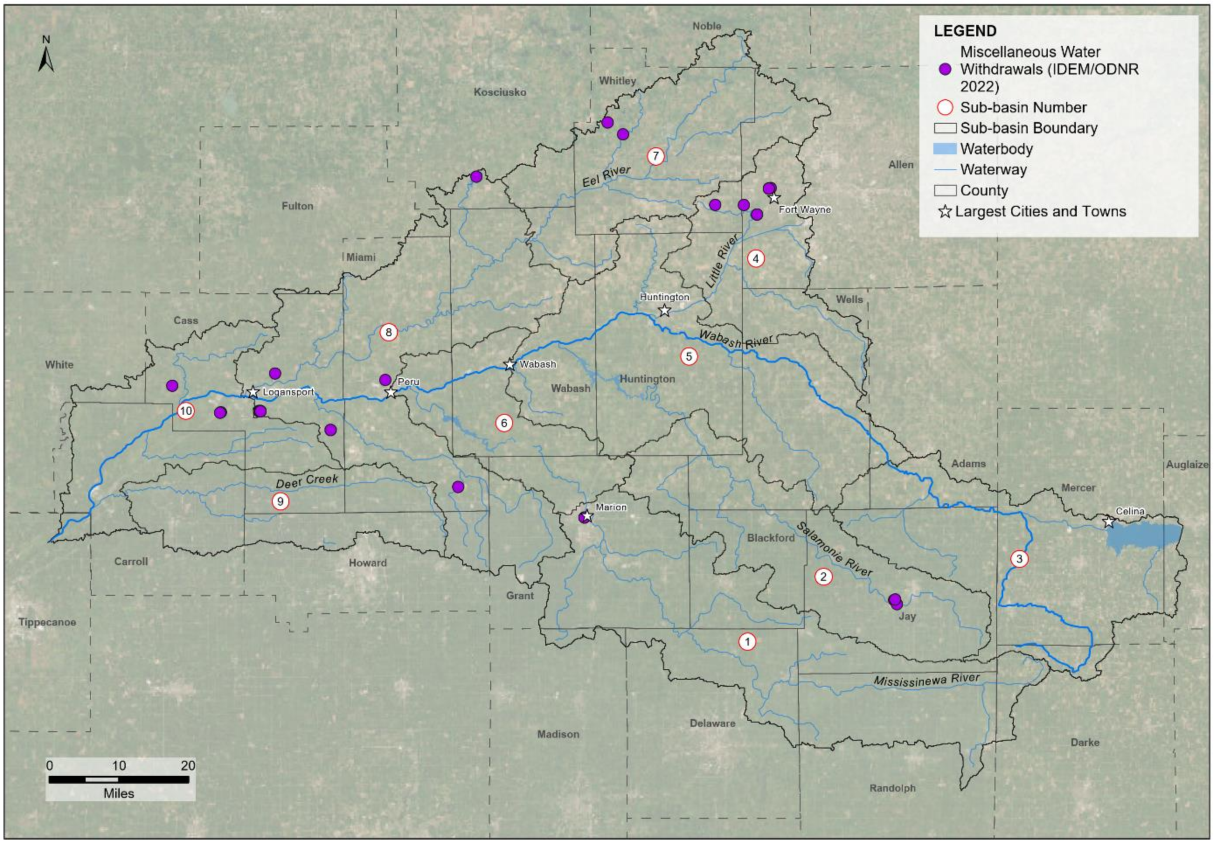


Figure 3-19. Miscellaneous Users in the Wabash Headwaters Region

Daily withdrawals for miscellaneous facilities average 0.049 MGD during the study period. The largest withdrawal recorded occurred in 1989 for the Griffin Dewatering Corporation, which averaged 0.630 MGD from July through December 1989. Sub-basin 4 Little-Huntington has highest quantity of miscellaneous users and annual average daily withdrawal (Figure 3-20).

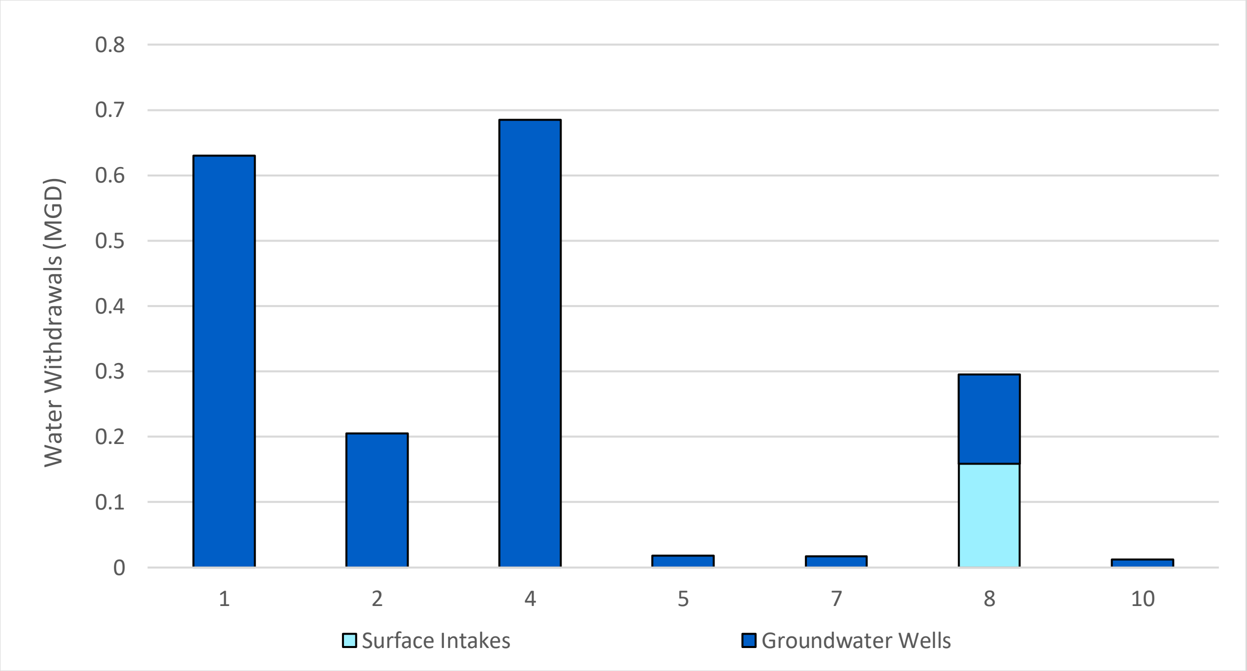


Figure 3-20. Annual Average Daily Withdrawals for Miscellaneous Users by Source per Sub-basin

3.1.8 Consumptive Use

The water demand forecast was based on the reported monthly water withdrawals from surface water or groundwater sources. However, water withdrawals are not equivalent to consumptive use; a significant portion of withdrawals is not consumed and returns to the system. Consumptive water use refers to the water withdrawn from an available water source that does not return to the immediate water source because it is evaporated or transpired (that is, by irrigated crops or landscapes), or was consumed by humans or livestock (Shaffer, 2009). In this study area, where 70% of water is withdrawn from groundwater sources, the water discharged is often returned to a different location from where it was extracted. For this study, the consumptive use is considered by introducing return flows into the water availability analysis (Section 4). As part of the demand analysis, withdrawals occurring in the study area – but being used outside the watershed – were quantified to show the removal of that volume from the watershed. On the other hand, withdrawals that occur outside the study area – but are discharged inside the watershed – were modeled within the water availability analysis to estimate the corresponding return flows. The return flows assumptions for the sectors that dominate water demand in the region (public water utilities and industrial users) are further discussed in the water availability section (Section 4) and Appendix D.

3.1.9 Water Demand Seasonality

Seasonal variations were evaluated for all sectors during data gathering and model testing phases using the IDNR SWWF (2022) monthly water withdrawal data. The public supply and irrigation sectors showed the most pronounced seasonal fluctuations. Seasonal variation in water demand can be significantly impacted driven by changes in weather patterns. As a result, higher temperatures and drier months have historically resulted in higher demands. The seasonal variation of per capita public supply usage for the Wabash Headwaters Region in 2022 is shown on Figure 3-21.

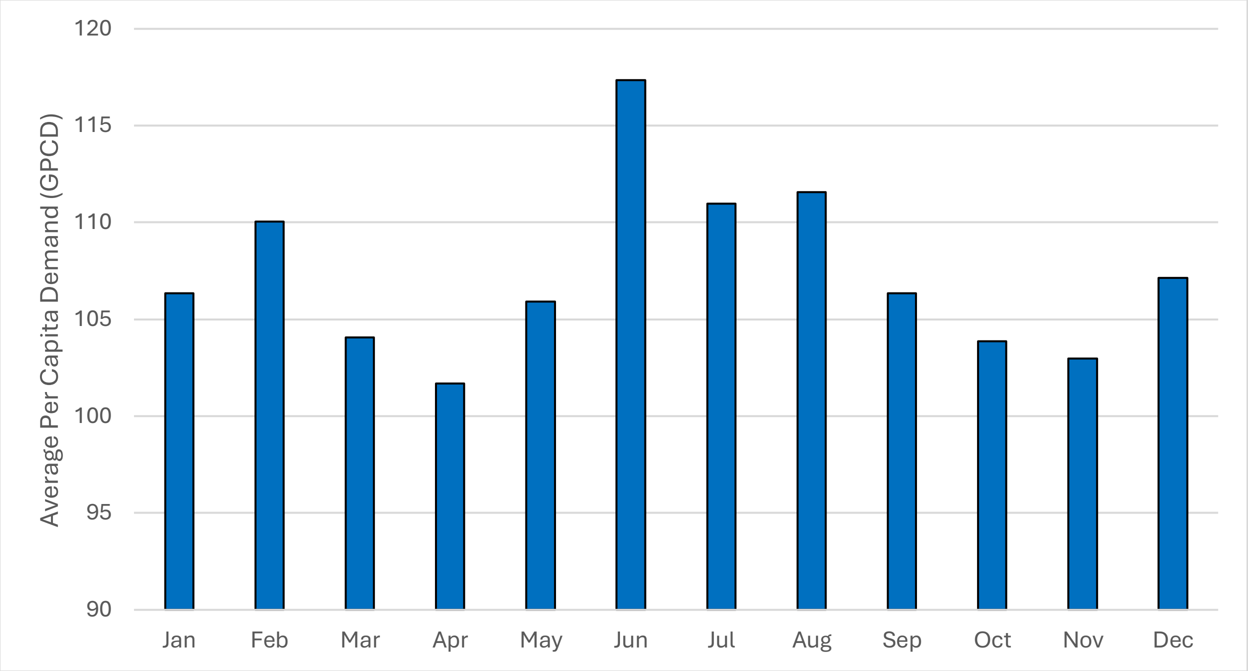


Figure 3-21. Monthly Average Water Demand per Capita for the Public Supply Sector in the Wabash Headwaters Region (2022)

The average water use was 107 gallons per capita per day (GPCD). Higher demands were observed in summer months, with June having the highest demand at 117 GPCD. April had the lowest water demand with 102 GPCD. The data show water demands during the winter months have an average use of 108 GPCD. A review of the largest public water utilities in the region shows a seasonal water usage pattern consistent with Figure 3-21. The reported water loss audits for this region show an average (weighted average) percent by volume of water supply of 24%, with losses ranging from 1% to 62% (IFA, 2022). Increased water demands in the winter months can be attributed to the use of indoor heating systems such as boilers and radiators used to generate heat, increased water use for hot showers and baths, faucets left dripping to prevent pipes from freezing and may in part be due to losses caused by leaks and waterline breaks during cold weather.

The irrigation sector has a more pronounced seasonal water usage pattern, with significant increases in use during the summer months and little-to-no use during the winter months. The irrigation sector has two main categories: agricultural irrigation and golf courses. Figure 3-22 shows the average monthly water use for both categories in the Wabash Headwaters Region.

For agricultural irrigation, water use typically increases during the summer months because crops need more water during the growing season when precipitation is inadequate. During the winter, crops are either already harvested or are dormant (for example, winter wheat), and the fields are not typically irrigated. For this region, agricultural irrigation was not reported from December through March.

For golf courses, the water use pattern similarly increases during the summer months to maintain the greens and fairways. In contrast, during the winter months, water use drops significantly as the grass enters a dormant phase and requires far less maintenance.

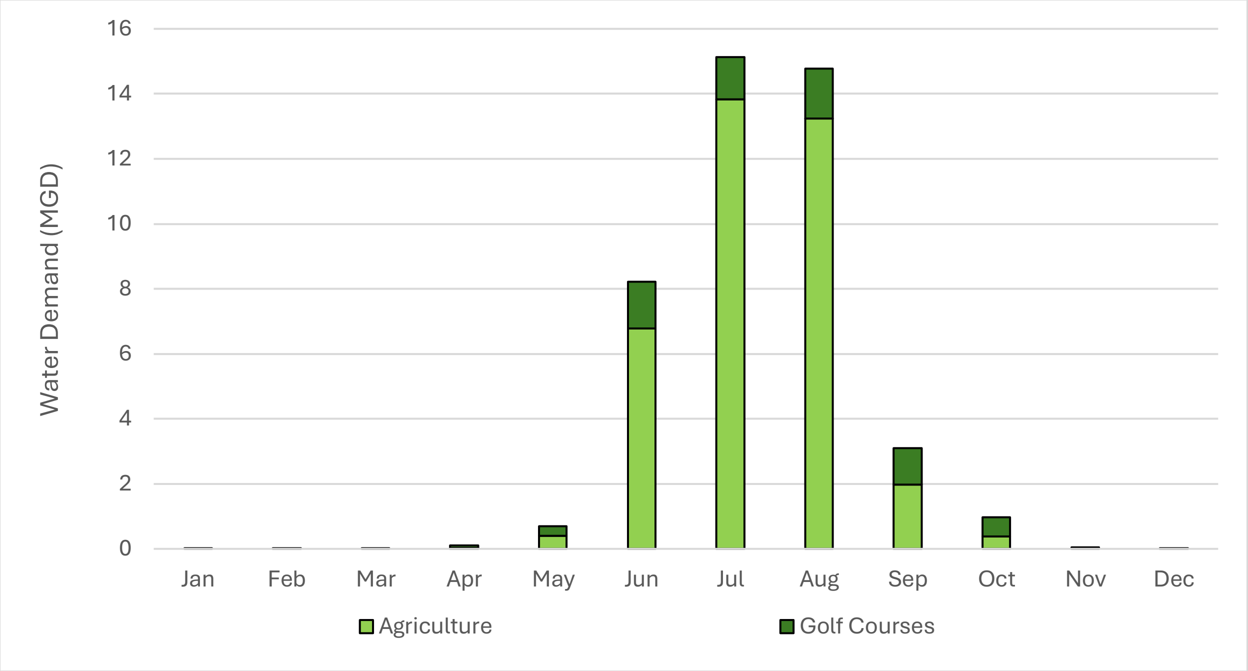


Figure 3-22. Monthly Average Water Demand for Irrigation Sector in the Wabash Headwaters Region (2022)

3.2 Future Water Demand (2023 through 2070)

When forecasting water demand, explanatory variables (such as population, climate, and economic factors) were considered to understand water use patterns and to inform forecasting. Separate water demand models were developed for most individual registered facilities, excluding agricultural irrigation, enabling us to fine-tune each model to specific user patterns. The historical water use was compiled for each facility and served as the basis for the forecasting models. The historical data were analyzed, and different model types were evaluated. The aim was to develop multivariate linear regression models that can capture both temporal and seasonal trends while responding to changes in the input variables. However, in cases when this was not achievable due to limited available data or changes in the consumption patterns, a linear temporal trend or seasonal trend were used to project future demand. Based on the data quality and availability, a flexible programming framework was developed to use various time windows for modeling. When possible, a portion of the historical data was used to fit the model, while a more recent portion was used to validate the model and make sure the predicted demand matched observed demands. During the testing phase, time windows that did not appear to be representative of the most current use pattern were excluded to stabilize the model output. Once the forecasting exercise was completed for each user, the cumulative historical water withdrawal volume of the past 10 years was used to allocate the demand prediction of already modeled users to specific sub-basins or counties as well as surface and ground water for the users who might have withdrawal points in multiple locations. If there was a significant change in the source, like when a user’s main withdrawal points change sub-basin or it switches from predominantly using surface water to ground water, the number of years used to allocate the demand was then adjusted based on when the change occurred, while keeping the overall predictions intact.

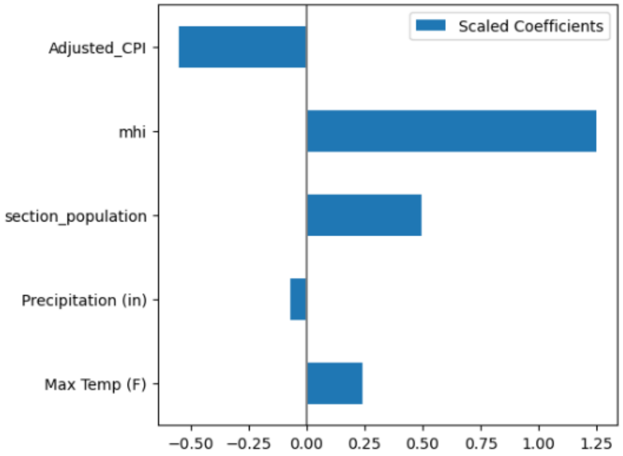
The regression analysis used for most of the facilities relied on explanatory variables to guide future growth and demand projections. Different combinations of population, precipitation, temperature (for example, average, minimum, maximum), Palmer Drought Severity Index, Consumer Price Index (CPI), and median household income (MHI)- were evaluated as input variables to the prediction models, but only a few variables were used consistently in model testing results. Temperature, population, precipitation, MHI, and inflation-adjusted CPI were the variables used most for public water utilities. Figure 3-23 shows the testing results for Gas City Water Department as an example of model results. Like public water utilities, industrial water use is mainly influenced by temperature, precipitation, population, and inflation-adjusted CPI, and is reflected in the explanatory variables for their future projections. Seven industrial users in Indiana were projected using either a trendline or a constant value projecting the average consumption of the last few years because their water use patterns were insensitive to the predictor variables.

For agricultural irrigation, water withdrawal for users with active registrations were aggregated per county and modeled together. Golf courses were modeled separately as individual users because they showed different use patterns. Both user types were modeled based on the yearly peak consumption and using maximum temperature and average precipitation as their explanatory variables.

The model assumed that the seasonal distribution of water demand remained constant year-to-year throughout the modeling period, while annual peak values were allowed to fluctuate. Annual peak values were simulated through multivariate linear regression, predominantly using temperature and precipitation. The seasonal distribution for each user was determined by historical monthly mean values for each month. The modeled annual peak was then combined with the seasonal distribution to generate a complete water demand time series. To maintain consistency with the water availability analysis, the water demand forecast per user type was aggregated for each sub-basin. Future water demand aggregated by county within the study region can be found in Appendix C.

The historical data for all sectors were reviewed, cleaned, and organized to be used as the base for the forecasting exercise. Once the models were fitted and evaluated, a water demand forecast was produced for each user through 2070. Appendix C summarizes regression performance metrics for public water utilities (aggregated by county) applied to future demand projections.

The line graph displays the model training for Gas City Water Department, where the historical water use data from 1985 to 2020 (blue line) was used to train the model using the variables shown in the bar chart on the right. The predicted water use (yellow line) was the developed by the trained model using the explanatory variables and extends from 2020-2022 (red line). The period after 2020 was used to compare the results of the trained model (red line) with the most current historical data available (green line) and determine if the model successfully predicted future use. The bar chart shows the explanatory variables used as inputs to the model for when water use is scaled between 0 to 1 (unitless) and is meant to depict the influence each variable has on the model prediction. In this case, the model is strongly and positively correlated to MHI and to population. It is negatively correlated to CPI and shows a small negative correlation to precipitation.



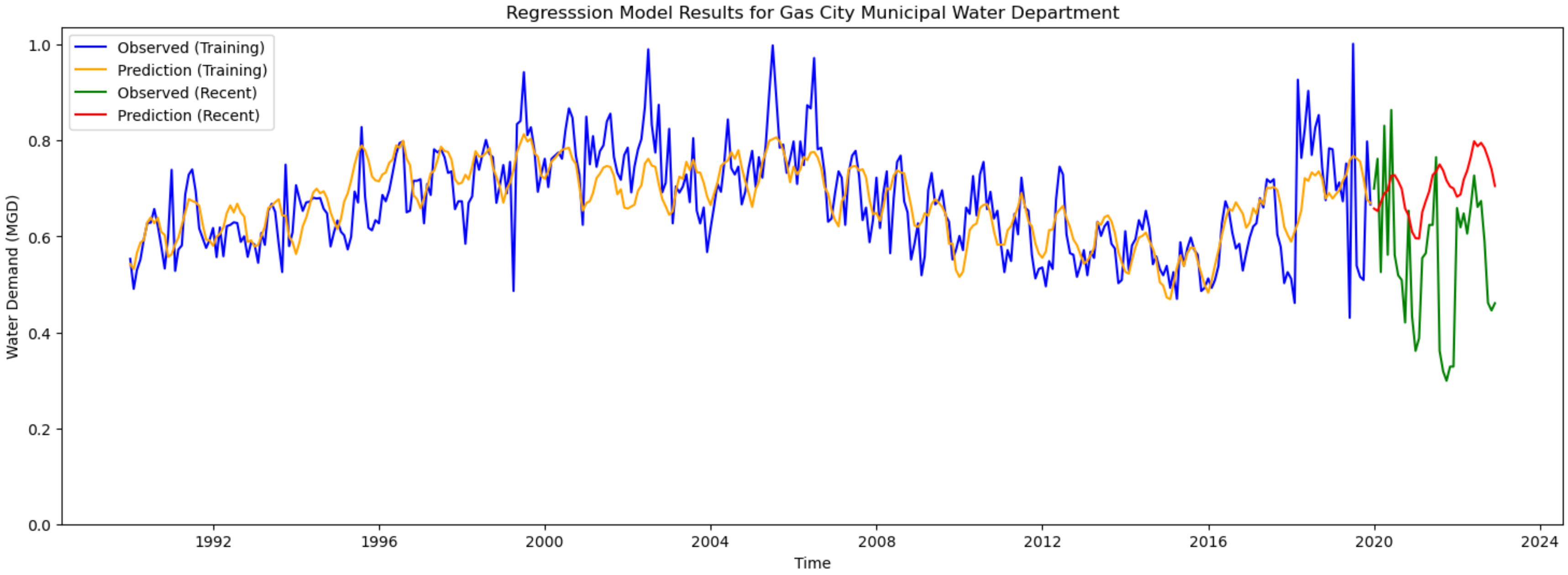


Figure 3-23. Model Testing Results for Gas City Water Department

3.2.1 Baseline Water Demand Forecast Scenario

Prior to forecast modeling, the most dominant explanatory variables were evaluated to determine which variables have the most significant impact on water demand. Careful consideration was given to the baseline scenario because of the characteristics of the study area. The counties within our study region have experienced a general decline in population and loss of industrial users. Table 3-4 shows the historical and projected population projections for the 10 counties within the Wabash Headwaters Region. Overall population declined by 6% between 1980 and 2020, and it is expected to further decline 9% between 2020 and 2050 (STATS Indiana, 2024). Wells County in Sub-basins 2, 4, and 5 is the only county expected to grow over the next 50 years (Strange, 2024). Population numbers through 2070 were modeled as described in Appendix A for the purposes of this analysis.

Table 3-4. Historical and Projected Population from STATS Indiana (2024)

County	Historical Population[a]					Projected Population[a]			Modeled Population Projection	
	1980	**1990**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Blackford	15,570	14,067	14,048	12,766	12,112	11,403	10,560	9,618	8,682	7,746
Carroll	19,722	18,809	20,165	20,155	20,306	20,505	20,000	19,136	18,242	17,348
Cass	40,936	38,413	40,930	38,966	37,870	37,314	35,570	33,304	32,416	32,302
Grant	80,934	74,169	73,403	70,061	66,674	64,711	61,570	59,052	56,698	54,344
Huntington	35,596	35,427	38,075	37,124	36,662	36,461	35,291	33,581	32,809	32,677
Jay	23,239	21,512	21,806	21,253	20,478	18,999	17,300	15,506	13,773	12,039
Miami	39,820	36,897	36,082	36,903	35,962	34,058	31,699	29,029	26,371	23,713
Wabash	36,640	35,069	34,960	32,888	30,976	29,641	27,788	26,066	24,400	22,734
Wells	25,401	25,948	27,600	27,636	28,180	29,242	29728	29,991	30,275	30,560
Whitley	26,215	27,651	30,707	33,292	34,191	35,333	35,187	34,285	33,347	32,410

[a] *Source: STATS Indiana (2024).*

Interviews were conducted with various economic development organizations to determine if new known user(s) are expected within their region, but these did not provide specific guidance on any significant changes in growth, conservation, and water supply needs. With that in mind, the selected baseline scenario considers the available population projections, MHI, and adjusted CPI for the future period. Climate variables, such temperature and precipitation, had a wider range of possibilities. The baseline climate scenario (CESM1-CAM5. RCP8.5) assumes significant warming and increases in winter and spring precipitation. Additional details on the climate models can be found in Appendix B.

The forecasting methodology used in this study relied on existing historical and predicted data that provide a solid foundation, but modeling comes with some limitations associated with data quality, assumptions, unpredictable variables, and model limitations. Multivariate linear regression models are great for identifying general trends and seasonal patterns, especially when dealing with variables like temperature that have predictable fluctuations. However, they cannot capture anomalies or unexpected peaks and troughs or match trends that cannot be predicted by the explanatory variables.

The combination of actual MHI and inflation-adjusted CPI introduces the temporal effects of inflation and economic factors that influence water use into the model, capturing some shifts in consumption patterns. This tends to capture usage shifts driven by technological advancements, such as water-efficient toilets causing usage decreases for public utilities. However, potential changes in consumption patterns over the next 50 years remain uncertain, especially for other sectors, where the complexity of influencing factors makes long-term forecasts even more challenging.

Future water demands were allocated to a source (groundwater or surface water) after the forecast was estimated for each user. For that purpose, the forecast for a given user was disaggregated and allocated based on the historical withdrawal ratio for each source, groundwater or surface water. The past 10 years of data were used to determine the average use per source, unless a recent shift in the water source occurred. This assumes the current water sources will provide the same ratio of water demand for a specific facility in the future as they have provided for the past 10 years. This static method for disaggregating demand may not correspond or reflect future conditions.

Industrial use constitutes a significant portion of overall demand in the region and as such careful consideration was given to each user. The region has seen an increase in biofuel facilities and experienced a loss of manufacturing facilities. Although active users were modeled based on historical usage patterns, it does not account for new users that may enter the market or current users that may shut down, which could impact future demand projections. The stakeholders interviewed as part of the study highlighted the desire to attract more industrial customers but did not have any specific projects under construction or in the planning phases that could be added to the forecast. The same can be said for irrigation, rural use, and other livestock operations.

3.2.2 Future Water Demand Forecast per Sub-basin and Sector

Even with a declining population, water demand in the region is expected to increase by 8.9% between 2022 and 2070 (81.8 to 89.8 MGD). Table 3-5 and Figure 3-24 show historical and future average water demands in 5-year increments for each study area sub-basin. Showing water demand in 5-year increments instead of annual results helps smooth out short-term variations, providing a clearer long-term trend. Not all sub-basins show the same growth. Water use in sub-basins in the upper watershed are expected to increase between 1% and 32%, with the largest demand expected in Sub-basin 4 Little-Huntington. This growth is led by the industrial sector that has seen an increase in water demand since 2020. Figure 3-25 shows a map of the sub-basins within the study region to be a used as reference as results are summarized, the sub-basin numbers are circled in red.

Sub-basins at downstream end of watershed (Sub-basins 8, 9, and 10) show a decrease in future water demand ranging from 4% to 26% calculating using the 5-year average incremental results. The region with highest decrease in water demand is Sub-basin 10 Wabash-Ungauged (east of Lafayette, Indiana) showing decrease of 3.5 MGD. This may be attributed to the diminishing demand in all sectors but most notably in industrial and public supply demand. In 2019, Sub-basin 10 Wabash-Ungauged experienced the highest increase in industrial use (10.8 MGD), led by mining and ethanol facilities, followed by a steep decline in 2021 (3.8 MGD), during the pandemic. The industrial sector has seen a steady recovery and increased water demands but has not yet reached demands reported in 2019. The water demand in the public sector is expected to slightly decline due to the projected decrease in population.

Table 3-5. Historical and Future Average Water Demand per Sub-basin in 5-Year Increments for 2007 through 2070 (MGD)

Sub-basin Number and Name	2007 to 2010	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2031 to 2035	2036 to 2040	2041 to 2045	2046 to 2050	2051 to 2055	2056 to 2060	2061 to 2065	2066 to 2070
1 Mississinewa-Marion	14.4	15	12.7	12.2	13.3	13.1	12.8	12.8	12.7	12.7	12.8	12.8	12.8
2 Salamonie-Warren	3.5	3.8	3.9	3.7	3.8	3.9	4.0	4.0	4.1	4.2	4.3	4.4	4.4
3 Wabash-Linn Grove	8.9	8.3	8.8	9.1	9.5	9.6	9.8	10.1	10.3	10.4	10.7	10.8	11
4 Little-Huntington	10.3	9.2	5.6	6.8	7.5	7.5	7.4	7.5	7.5	7.5	7.5	7.4	7.4
5 Wabash-Wabash	10.4	11.1	10.7	11.8	12.1	12	11.9	11.9	11.8	11.8	11.8	11.8	11.8
6 Wabash-Peru	25.8	15.4	10.4	11.7	11.7	11.3	11.1	11.1	11	11.1	11.2	11.3	11.5
7 Eel-North Manchester	5.1	5.4	6.3	6.4	6.5	6.6	6.7	7.0	7.1	7.3	7.5	7.6	7.9
8 Wabash-Logansport	28.6	25.8	10.5	10.0	10.5	10.4	10.4	10.4	10.3	10.1	10.2	10.1	10.1
9 Deer Creek-Delphi	2.2	2.3	2.1	2.03	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6
10 Wabash-Ungauged	8.9	13.0	15.4	13.3	14.3	13.9	13.4	13.4	12.7	12.2	12.2	11.9	11.9

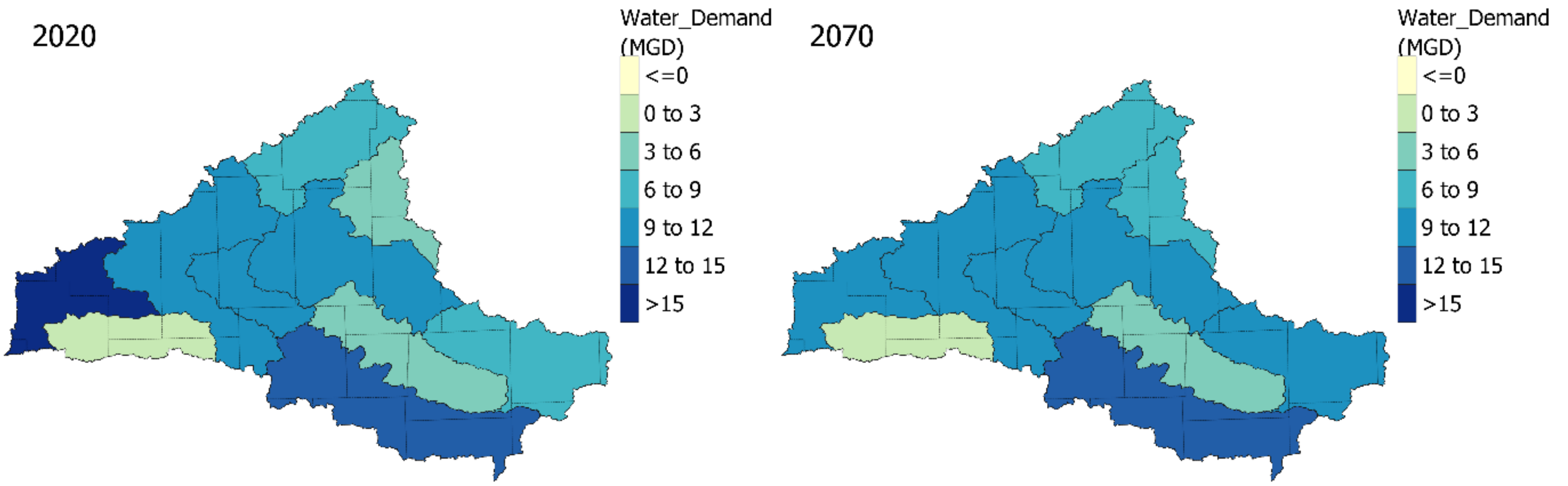


Figure 3-24. Historical (2016 to 2020, left) and Future (2066 to 2070, right) Average Water Demand per Sub-basin (MGD)

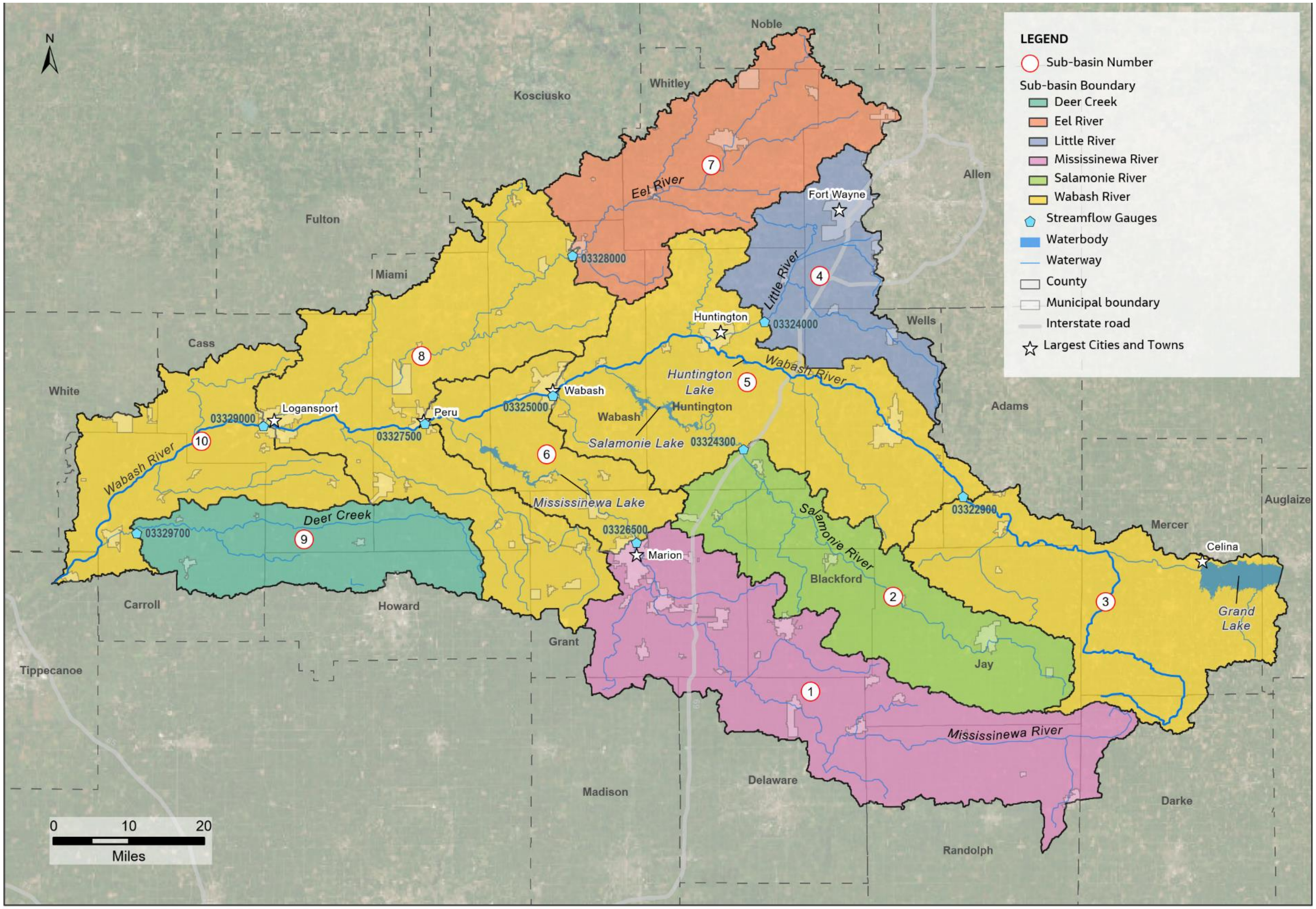


Figure 3-25. Wabash Headwaters Region Study Area and Sub-basins

Figure 3-26 shows the historical and future average water demand in 5-year increments for each sector. Industry and public supply are projected to continue to be the largest users, with industrial demand projected to grow by 15% between 2016-2020 and 2066-2070. Public supply is projected to decrease by 5% during the same period. Irrigation (from 2.9 MGD to 4.2 MGD) and rural use (from 1.4 MGD to 2.4 MGD), including livestock operations, are expected to grow 44% and 69%, respectively.

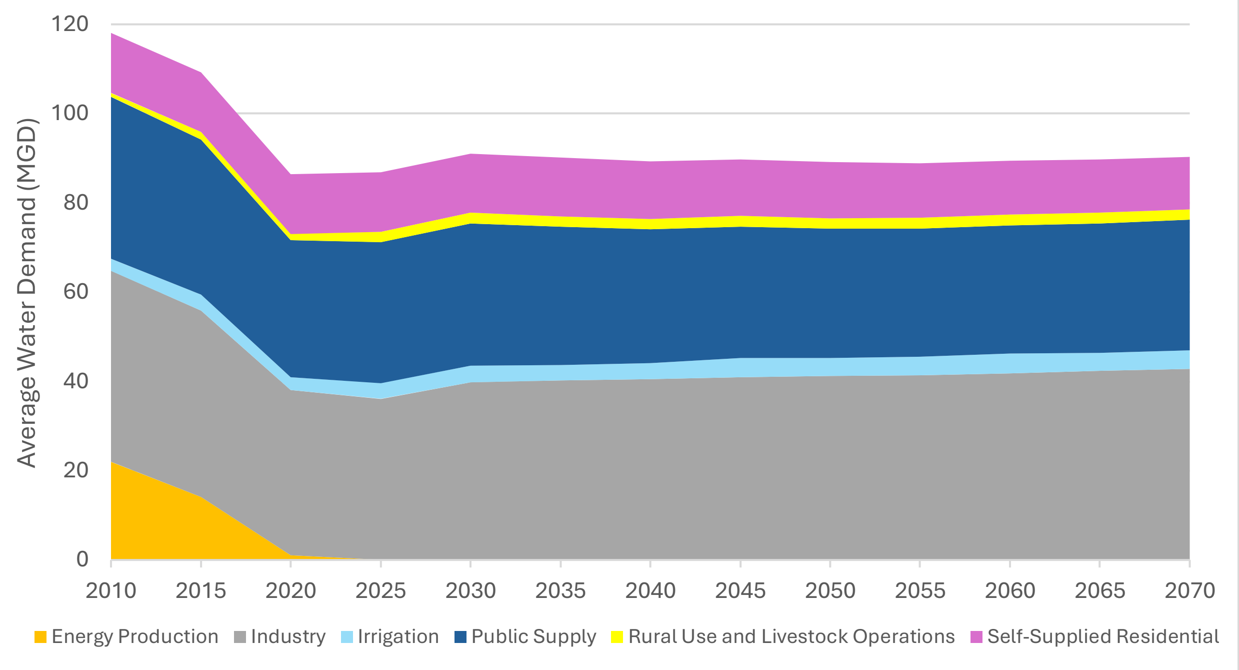


Figure 3-26. Historical and Future Average Water Demand per Sector in 5-Year Increments (2007 through 2070) (MGD)

Note: Miscellaneous registered facilities are not shown in the figure because their demand has not exceeded 1% of the total water demands in the region.

Based on interviews with public water utilities and local stakeholders, it was assumed that the sources of water would not change in the future. That is, if a user or facility currently pumps a groundwater source, it will continue to do so in the future. If a facility has both groundwater and surface water withdrawals, future demands were split based on the most current (2022) usage-ratio (IDNR SWWF) at the facility. Figure 3-27 shows the current and future water demand per source and sub-basin.

The largest increase (greater than 100%) in surface water use is projected to occur in Sub-basin 1 Mississinewa-Marion, mainly because of an increase in industrial demands. Sub-basin 6 Wabash-Peru shows a slight decrease in surface water demand (-1%). Groundwater is projected to remain overall the primary source of water for the region, but a small shift (5%) can be expected from groundwater to surface water. Sub-basin 3 Wabash-Linn Grove is projected to experience an increase in groundwater use because of the increases in water demand from livestock operations, industrial users, and public water utilities. Sub-basin 10 Wabash-Ungauged shows the largest decrease in groundwater use between 2022 and 2070 because of the projected decrease in water demand from public supply and self-supplied residential.

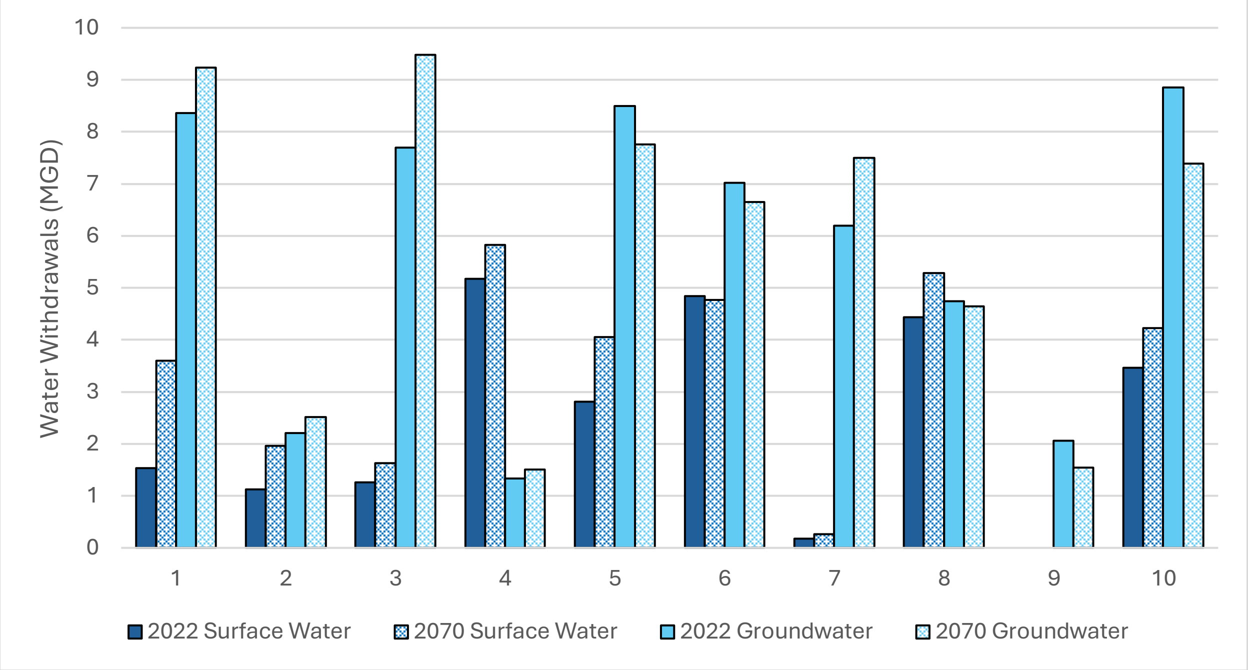


Figure 3-27. Current and Future Water Withdrawals by Source per Sub-basin

Table 3-6 summarizes the historical and future average water demand for public supply in 5-year increments for each sub-basin. The projected declining population in the region heavily influences future water demand for public supply which is expected to experience a 4 % decrease in the next 50 years (2020-2070). Sub-basin 8 Wabash-Logansport shows a 73% decrease in demand between 2010 and 2020 due to a shift in the location of the water source for Logansport Municipal Water Department from Sub-basin 8 to Sub-basin 10 Wabash-Ungauged. Fort Wayne also experienced a shift in source location in 2015 from Sub-basin 4 Little-Huntington to a surface water intake located outside the study area. The tables below show the expected water demand for the portion of the Fort Wayne service area that is located within the Wabash Headwaters region even though it is supplied by a source outside the watershed. The Fort Wayne service area water demand makes up approximately 90% of Sub-basin 4 Little-Huntington total average water demand.

Table 3-7 and Table 3-8 summarizes the historical and future maximum (peak) and the summer maximum (peak) water demand for public supply in 5-year increments for each sub-basin. Historically, maximum (peak) daily demand has been recorded in the summer (Jun-Aug) and in the winter months (Dec-Feb) for some of the sub-basins; therefore, the historical maximum daily demand peaking factor for the region (1.25) is slightly higher than the historical summer peak daily demand (1.24). The maximum daily demand factor for future demand ranges between 1.05 and 1.20 depending on the customer base served by the public supply facilities located within each sub-basin.

Table 3-6. Historical and Future Average Water Demand for Public Supply per Sub-basin in 5-Year Increments for 2007 through 2070 (MGD)

Sub-basin	2007 to 2010	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2031 to 2035	2036 to 2040	2041 to 2045	2046 to 2050	2051 to 2055	2056 to 2060	2061 to 2065	2066 to 2070
1 Mississinewa-Marion	5.6	4.6	5.0	5.0	5.3	5.0	4.8	4.7	4.7	4.6	4.6	4.7	4.7
2 Salamonie-Warren	1.4	1.5	1.5	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7
3 Wabash-Linn Grove	3.2	3.2	3.4	3.2	3.4	3.5	3.5	3.6	3.7	3.8	3.8	3.9	4.0
4 Little-Huntington	3.8	3.3	3.6	3.6	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6
5 Wabash-Wabash	5.3	5.3	5.2	5.5	5.2	5.1	4.9	4.8	4.7	4.6	4.5	4.5	4.4
6 Wabash-Peru	5.2	5.4	4.2	4.9	5.0	4.6	4.3	4.2	4.1	4.2	4.3	4.4	4.5
7 Eel-North Manchester	2.1	2.2	2.9	2.9	2.8	2.8	2.8	2.9	2.9	3.0	3.1	3.2	3.3
8 Wabash-Logansport	3.8	2.0	1.0	0.9	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2
9 Deer Creek-Delphi	1.4	1.5	1.3	1.2	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.9
10 Wabash-Ungauged	4.4	5.7	5.9	6.1	6.2	5.9	5.5	5.2	4.7	4.4	4.3	4.2	4.2

Table 3-7. Historical and Future Maximum Water Demand for Public Supply per Sub-basin in 5-Year Increments for 2007 through 2070 (MGD)

Sub-basin	2007 to 2010	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2031 to 2035	2036 to 2040	2041 to 2045	2046 to 2050	2051 to 2055	2056 to 2060	2061 to 2065	2066 to 2070
1 Mississinewa-Marion	8.5	6.6	6.2	5.9	5.7	5.4	5.1	5.0	4.9	5.0	5.0	5.0	5.0
2 Salamonie-Warren	1.5	1.7	1.8	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9
3 Wabash-Linn Grove	3.9	3.8	4.1	3.7	3.7	3.8	3.9	3.9	4.0	4.1	4.1	4.2	4.3
4 Little-Huntington	5.6	6.2	4.0	4.0	4.0	4.1	4.0	4.2	4.1	4.1	4.1	4.2	4.1
5 Wabash-Wabash	13.4	10.0	6.1	6.3	5.5	5.4	5.2	5.1	5.0	4.9	4.8	4.7	4.7
6 Wabash-Peru	7.3	7.4	6.5	6.2	5.3	5.0	4.6	4.5	4.4	4.4	4.5	4.7	4.8
7 Eel-North Manchester	2.5	3.1	3.6	3.5	3.2	3.1	3.2	3.3	3.3	3.4	3.5	3.5	3.7
8 Wabash-Logansport	5.0	4.7	1.3	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.3
9 Deer Creek-Delphi	2.2	2.3	1.8	1.6	1.3	1.2	1.1	1.1	1.1	1.0	1.0	1.0	0.9
10 Wabash-Ungauged	5.5	7.8	6.5	7.0	7.0	6.7	6.4	6.2	5.6	5.3	5.1	5.0	5.1

Table 3-8. Historical and Future Summer Peak Water Demand for Public Supply per Sub-basin in 5-Year Increments for 2007 through 2070 (MGD)

Sub-basin	2007 to 2010	2011 to 2015	2016 to 2020	2021 to 2025	2026 to 2030	2031 to 2035	2036 to 2040	2041 to 2045	2046 to 2050	2051 to 2055	2056 to 2060	2061 to 2065	2066 to 2070
1 Mississinewa-Marion	6.6	5.9	6.0	5.9	5.6	5.3	5.1	5.0	4.9	4.9	4.9	4.9	4.9
2 Salamonie-Warren	1.5	1.7	1.8	1.6	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.8
3 Wabash-Linn Grove	3.9	3.8	4.1	3.7	3.7	3.8	3.9	3.9	4.0	4.1	4.1	4.2	4.3
4 Little-Huntington	5.6	6.2	4.0	4.0	4.0	4.1	4.0	4.2	4.1	4.1	4.1	4.2	4.1
5 Wabash-Wabash	13.4	7.9	5.9	6.3	5.5	5.4	5.2	5.1	5.0	4.9	4.8	4.7	4.7
6 Wabash-Peru	7.0	6.9	6.4	5.3	5.3	5.0	4.6	4.5	4.4	4.4	4.5	4.7	4.8
7 Eel-North Manchester	2.5	3.1	3.6	3.5	3.2	3.1	3.2	3.3	3.3	3.3	3.5	3.5	3.7
8 Wabash-Logansport	5.0	4.7	1.3	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.3
9 Deer Creek-Delphi	2.2	2.3	1.8	1.6	1.3	1.2	1.1	1.1	1.1	1.0	1.0	1.0	0.9
10 Wabash-Ungauged	5.4	7.4	6.4	7.0	7.0	6.7	6.4	6.2	5.6	5.3	5.1	5.0	5.1

4 Water Availability

In this section, historical and future water availability in the region is assessed and quantified, building on methodologies developed during previous regional water studies in Indiana (IFA, 2021; Letsinger and Gustin, 2024). This analysis aims to characterize monthly water availability based on local hydrology, stream hydraulics, instream flow requirements, flood control reservoir operations, and anthropogenic uses of water as defined by the water demand analysis discussed in Section 3. This analysis is a watershed-based inventory of current (2007 through 2022) and future (2023 through 2070) water availability to support ongoing and future water resources planning and management efforts in the region. The watersheds used in the analysis correspond to the sub-basins presented on Figure 2-1 and described in Appendix A. This section describes the water availability analysis methodology, discusses historical and future water availability results, and summarizes key findings used to develop recommendations in Section 6. In this section, results are presented at the regional level with some sub-basin examples and in Appendix D, results are summarized annually and seasonally by sub-basin.

4.1 Methodology

Historical measured data and analytical techniques were used to characterize, quantify, and evaluate components of water availability for each sub-basin in the Wabash Headwaters Region. Three metrics are used for this analysis: (1) water availability, (2) excess water availability, and (3) cumulative excess water availability. The first two metrics are estimated at the sub-basin level and the last term at the sub-basin level but accounting for the effect of upstream sub-basins. The following provides a brief description of these metrics.

Water availability is characterized as the net natural baseflow remaining in the stream after net instream flow requirements are met, and sub-basin reservoir operations are accounted for. The sub-basin's water availability is an estimate of reliable supplies that are available while ensuring that net minimum instream flow requirements and flood control factors are prioritized. Monthly water availability is quantified using net terms[1] to perform the water availability assessment at the sub-basin level using Equation 1:

Water availability = net natural baseflow – net minimum instream flow requirement + sub-basin net reservoir release (Equation 1)

Where,

Net natural baseflow = Total groundwater contributions to streamflow within sub-basin; these contributions are estimated as portion of natural streamflow, which is streamflow that would be measured if anthropogenic (man-made) effects of surface-water and groundwater withdrawals and wastewater return flows were removed.

Net minimum instream flow requirement = Streamflow required to remain within the sub-basin stream to support ecological function of the stream

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[1] In sub-basins without upstream sub-basins, net natural baseflow, net minimum instream flow requirement, sub-basin net reservoir releases and sub-basin net return flows are the same as the corresponding cumulative terms.

Sub-basin[2] net reservoir release	=	Difference between reservoir outflows and reservoir inflows to characterize whether reservoir located within the sub-basin is storing or releasing water downstream

The estimation of net natural baseflow and net minimum instream flow requirement is first conducted as a cumulative term and then, the flows corresponding to upstream sub-basin portions are subtracted.

Excess water availability is quantified to evaluate the water supply remaining after consumptive water uses are considered. The non-consumptive proportion of water use factors in the portion of the surface water and groundwater withdrawals that is returned to the system. The excess water availability provides an evaluation of whether supplies are sufficient to meet water use demands within a sub-basin. Monthly excess water availability is quantified for each sub-basin using Equation 2:

Excess water availability = water availability – withdrawals + return flows (Equation 2)

Where,

Withdrawals	=	total surface water and groundwater extracted to meet water use demands within the sub-basin
Return flows	=	total return flows discharged back to streams within the sub-basin; this is how the non-consumptive portion of water used in the sub-basin is integrated back into the water availability analysis

The difference between *withdrawals* and *return flows* is also known as *net return flows*. Since the *withdrawals* and *return flows* correspond to those taking place at the sub-basin level, the water availability and excess water availability metrics are estimated at the sub-basin level. If excess water availability is a negative value, it suggests that the sub-basin water resources are being strained, and a closer look should be taken to evaluate potential water shortages. If the excess water availability is positive, expansion of water use within the sub-basin could occur. Both positive and negative excess water availability can occur on a seasonal basis within a given year depending on climate and hydrology. Thus, the evaluation of excess water availability is transient and whether water shortage or excess water occurs will depend on seasonal and annual conditions.

While it is possible for excess water availability to occur in any sub-basin, it is important to recognize the hydraulic connectivity of sub-basins to account for upstream excess water availability where water in excess in upstream sub-basins could be made available to downstream sub-basins. Therefore, an additional metric called *cumulative excess water availability* is quantified to account for regional water availability within the study area. It is estimated same as excess water availability but using the cumulative terms: cumulative natural baseflow, cumulative minimum instream flow requirements, cumulative withdrawals, and cumulative return flows. This metric is especially important for the water supply assessment of the downstream study area, the North Central Indiana region.

The following sections, 4.1.1 and 4.1.2, describe each individual terms used in the evaluation of water availability and excess water availability for the historical and future periods. Appendix A provides additional details on the approach and tools used as part of the study.

4.1.1 Historical Water Availability

To evaluate historical water availability using the methodology described in Section 4.1, data associated with each sub-basin in the study area were collected and evaluated. Post-processing of data and

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[2] "Sub-basin" word is added to the term to differentiate between the net reservoir releases calculated for the sub-basin versus the cumulative net reservoir releases that include the net reservoir releases from upstream sub-basins.

assumptions were required to conduct the historical water availability assessment. Table 4-1 summarizes water availability term definitions, relevant data sources, and historical data availability.

Table 4-1. Water Availability Term Definitions, Data Sources, and Historical Data Availability

Component	Term Definition	Historical Data Source	Historical Data Availability
Natural streamflow	Streamflow that would occur naturally based on hydrologic conditions without human influence (for example, streamflow in absence of reservoir storage, or diversions from streams).	Estimated by removing water-withdrawal and reservoir influences and adding back return flows from measured streamflow at USGS stream gauging stations.	Daily streamflow is available for each USGS stream gauge associated with sub-basin outlets. Natural streamflow is estimated from measured streamflow for January 2007 through December 2022.
Natural baseflow	Groundwater contributions to streamflow. In this study, this term is also referred as Cumulative natural baseflow to differentiate from Net natural baseflow which corresponds to portion contributed by a sub-basin.	Estimated based on natural streamflow estimates at USGS gauging stations using the USGS HYSEP-Slide program (Sloto and Crouse, 1996).	Daily and monthly estimates for the historical period (January 2007 through December 2022).
Minimum instream flow requirement	Streamflow required to remain within the stream to support ecological function of the stream.	Estimated based on measured streamflow data at USGS stream gauging stations.	Used 30-year period of 1990 through 2020 to evaluate instream flow statistics.
Net reservoir release	Difference between reservoir outflows and reservoir inflows: Positive (+) values represent a net release of water from the reservoir to the stream; negative (-) values represent a net storage of water in the reservoir.	Historical reservoir inflows and outflows provided by USACE.	Required historical period (2007 through 2022) data set of 6-hour increments for measured inflow and outflow from reservoirs provided by USACE - Chicago District. Data presented in cfs.
Withdrawals	Surface water and groundwater extracted to meet water use demands.	IDNR SWWF data (IDNR, 202). Data sources for the estimation of self-supplied residential and small livestock operations are summarized in Appendix B.	SWWF data are available from 1985 through 2022.
Return flows	Extracted water returned to system after use and treatment	NPDES monitoring data (EPA, 2024) and fractions of consumptive use associated with various water uses.	2007 through 2022.

cfs = cubic feet per second
USACE = U.S. Army Corps of Engineers

Based on data availability, the period from January 2007 through December 2022 was used to quantify historical water availability; this period was selected because of availability of return flow data started in January 2007 from the U.S. Environmental Protection Agency (EPA) NPDES. Details on data processing and methodology assumptions associated with each water availability term are discussed in further detail in Section 4.2.1 and in Appendix A.

4.1.2 Future Water Availability

Forecasted (future) water availability was estimated to extend the historical water availability analysis and reflect a possible future condition that can be used as a future baseline scenario. Other potential future scenarios are discussed in Appendix B. The water availability, excess water availability, and cumulative excess water availability metrics were calculated for the future period using equations 1, 2, and 3 as described in Section 4.1. To perform this analysis for the future baseline scenario, assumptions were made for each water availability component to extended them into the future to reflect potential future conditions for this scenario. The following section discusses assumptions used to develop future conditions for each water availability component.

Future climate scenarios used in this study were adapted from two previous studies that evaluated projected changes in climate and streamflow over the Midwest and Great Lakes Region (Byun and Hamlet, 2018) and the state of Indiana (Hamlet et al., 2019). Future estimates of streamflow, based on the climate scenarios evaluated in these previous studies, were adapted from simulated streamflow from an application of the Variable Infiltration Capacity (VIC) model applied over the state of Indiana (Cherkauer et al., 2021). Future climate and streamflow datasets were available covering the state of Indiana for a suite of Coupled Model Intercomparison Project Phase 5 Global Circulation Models. These datasets were leveraged to develop future baseline conditions and evaluate future water availability. Table 4-2 presents a high-level summary of the assumptions for each water availability term used to generate future conditions. Appendix A provides additional details on the approach and tools used to predict the future water availability terms.

Table 4-2. Water Availability Model Term Definitions, Data Sources, and Future Assumptions

Water Availability Term	Future Assumptions
Natural streamflow	Historical natural streamflow estimates repeated into the future using a climate-based year-type indexing approach. Monthly factors were applied to this dataset that reflect potential changes to streamflow due to changes in climate.
Natural baseflow	Estimated based on future natural streamflow estimates at USGS gauging stations using the USGS HYSEP-Slide program (Sloto and Crouse, 1996).
Minimum instream flow requirement	Instream flow requirements are assumed to remain the same as in the historical period.
Net reservoir releases	Historical net reservoir releases repeated into the future using a climate-based year-type indexing approach. Reservoir operations are assumed to be consistent with historical operations.
Withdrawals	Full detail on future water demand discussed in Section 3. Projected demands are assumed to represent total surface water and groundwater withdrawals within a sub-basin.
Return flows	The proportion of non-consumptive water returned to each sub-basin at rates based on that which was reported in the past. Historical monthly water use trends were developed for those users with NPDES and consumptive use fractions assumed the same as historical.

4.2 Historical Water Availability

In this section, the sub-basin analysis for the water availability components is first presented to provide the basis for the interpretation of the historical water availability results. Then, water availability results are presented annually and seasonally. In Appendix D, additional components analysis results are included as well as historical water availability results summaries by sub-basin.

4.2.1 Components Analysis

In this section, an individual analysis for the water availability components is presented to support the understanding of the water availability results. The order in which these are presented follows the order of the methodology steps (see Appendix B). The individual analysis of the withdrawals is not included because it was performed as part of the historical demands and is presented in Section 3. The estimation of net natural baseflow and net minimum instream flow requirement used in the sub-basin Water availability estimates, are first conducted as a cumulative term and then, the flows corresponding to upstream sub-basin portions are subtracted. The information presented in this section correspond to cumulative values, accounting for upstream flows in addition to what is happening at the sub-basin level.

4.2.1.1 Cumulative Natural Streamflow

The natural streamflow is obtained by estimating and removing the anthropogenic impact in measured streamflow data. Natural streamflow is the amount of water that would be flowing in a river if humans were not using or managing its waters. As an introduction to this component, Figures 4-1 and 4-3 show the estimated historical natural streamflow for two sub-basins in the region as examples to highlight the impact of the anthropogenic influence due to withdrawals and reservoirs. Figures 4-1 and 4-2 show historical values for Sub-basin 3 Wabash-Linn Grove as an example of a sub-basin with small, measured streamflow, because it is located at the headwater of Wabash River, with only withdrawals; and Figure 4-3 shows historical values for Sub-basin 6 Wabash-Peru as an example of a sub-basin with large measured streamflow, because it is further downstream, with the largest cumulative net reservoir releases in the region.

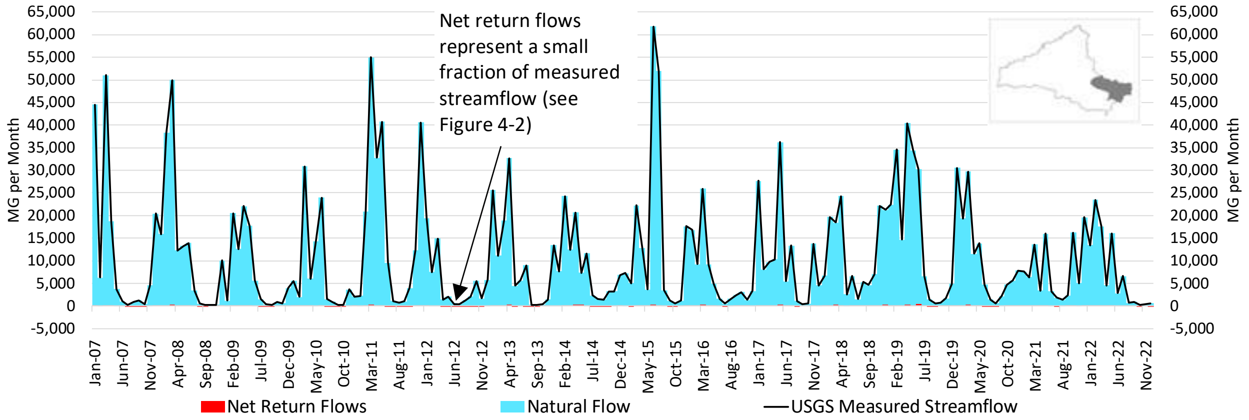


Figure 4-1. Estimated Cumulative Monthly Natural Streamflow, USGS Measured Streamflow, and Cumulative Net Return Flows (also shown in Figure 4-2) for Historical Period 2007 through 2022 for Sub-basin 3 Wabash-Linn Grove

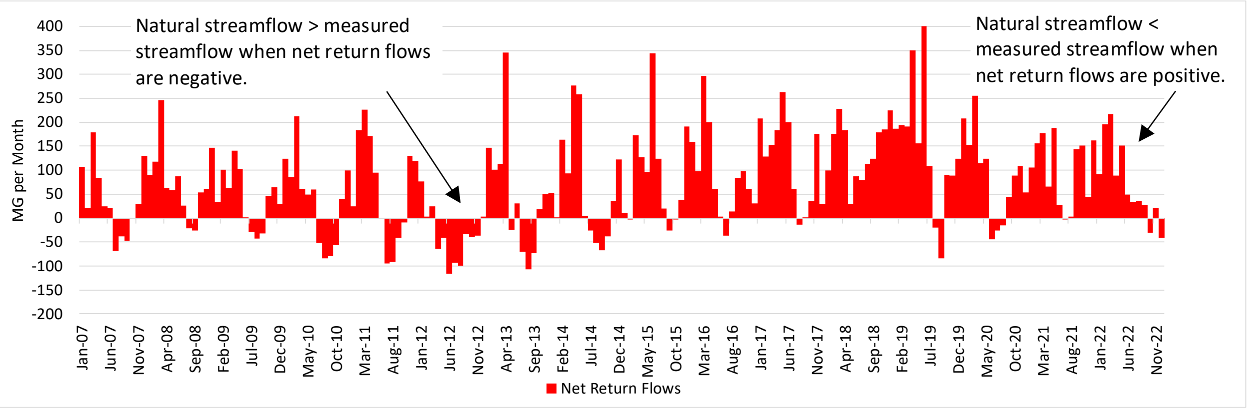


Figure 4-2. Estimated Monthly Net Return Flows for Historical Period 2007 through 2022 for Sub-basin 3 Wabash-Linn Grove.

Note: values shown in a smaller scale than Figure 4-1 to make them visible.

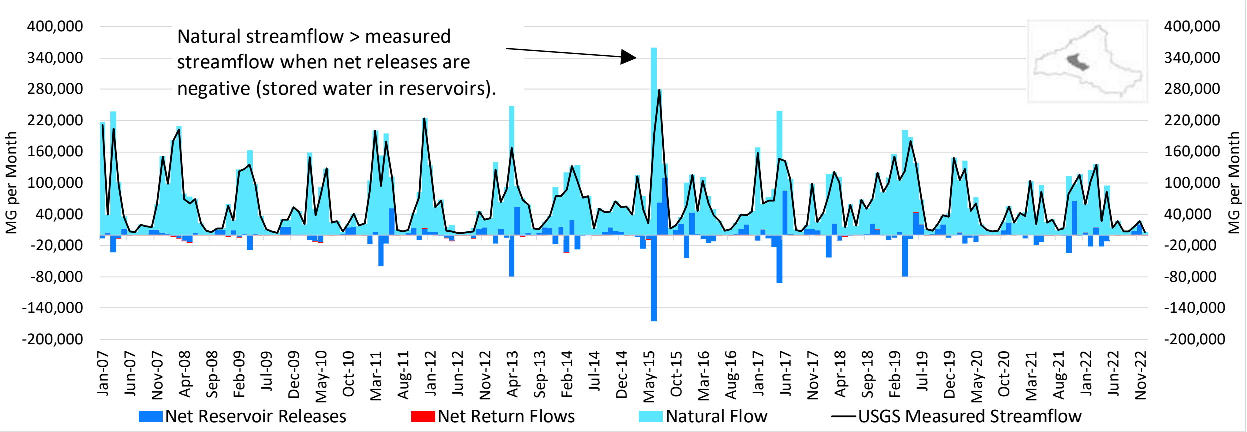


Figure 4-3. Estimated Monthly Natural Streamflow for Historical Period 2007 through 2022 for Sub-basin 6 Wabash-Peru

Cumulative Net Return Flows

The net return flows are estimated as the difference between withdrawals (from groundwater and surface water) and the return flows to the system, either as direct flows returning to the river from external outflows monitored by the NPDES permitting program, or by indirectly infiltrating back to the water table from within the watershed. Net return flows reflect non-consumptive uses of water that eventually return to nearby rivers and streams. The cumulative net returns at each sub-basin represent the upstream net return flows plus the sub-basin net return flows.

Positive cumulative net return flows represents a source of water contributing to streamflow which is especially relevant during periods of low streamflow. Positive cumulative net return flows occur when more water is returning to the system than is extracted at a sub-basin, creating additional supply flowing into the river stream. The differences in cumulative net return flows within the sub-basins in the study area are mainly associated with the withdrawals and consumptive use taking place in the sub-basin or upstream of that sub-basin: **the lower the consumptive use from the extracted water volume, the more water that can be returned to the system.**

While the post-processing of the NPDES data included the removal of runoff entering into and discharging from large water treatment plants (those with a capacity larger than 1 MGD), some peaks in return flows during rain events were still observed in the estimated flows. This indicates direct storm drainage coming into the plant through combined sewage systems and some potential presence of inflow/infiltration in the sewage system coming into the wastewater treatment plants.

The consumptive water use in the region is generally low because the main uses are municipal public supplies and industrial. The irrigation and livestock-operation water use sectors, which have the highest consumptive proportions (estimated as 80% for this study), represent approximately 10% of total withdrawals during the summer period. While the withdrawals and returns show a similar pattern across the region, there are three common cases within sub-basins in the region that are described as follows and presented on Figure 4-4:

- **Cumulative net returns are mostly positive, where more water is returned to the system than the amount of withdrawals that occurred at the sub-basin.** In these sub-basins, the water use is predominantly non-consumptive, there are potentially return flows coming from areas outside of the sub-basins and/or infiltrated stormwater. Further refinement could be conducted to investigate sources of return flows; this is the case of Sub-basin 3 Wabash-Linn Grove (Figure 4-4 top).
- **Cumulative net returns are both positive and negative, where withdrawals and return flows are generally equivalent but show seasonal variability.** Normally, this occurs in a sub-basin with larger water withdrawals and drainage areas, which is the case for Sub-basin 6 Wabash-Peru (Figure 4-4 middle).
- **Cumulative net returns are mostly negative, where sub-basins have small drainage areas, low water use, and relatively high water-consumption rate.** This is the case for Sub-basin 7 Eel -North Manchester (Figure 4-4 bottom).

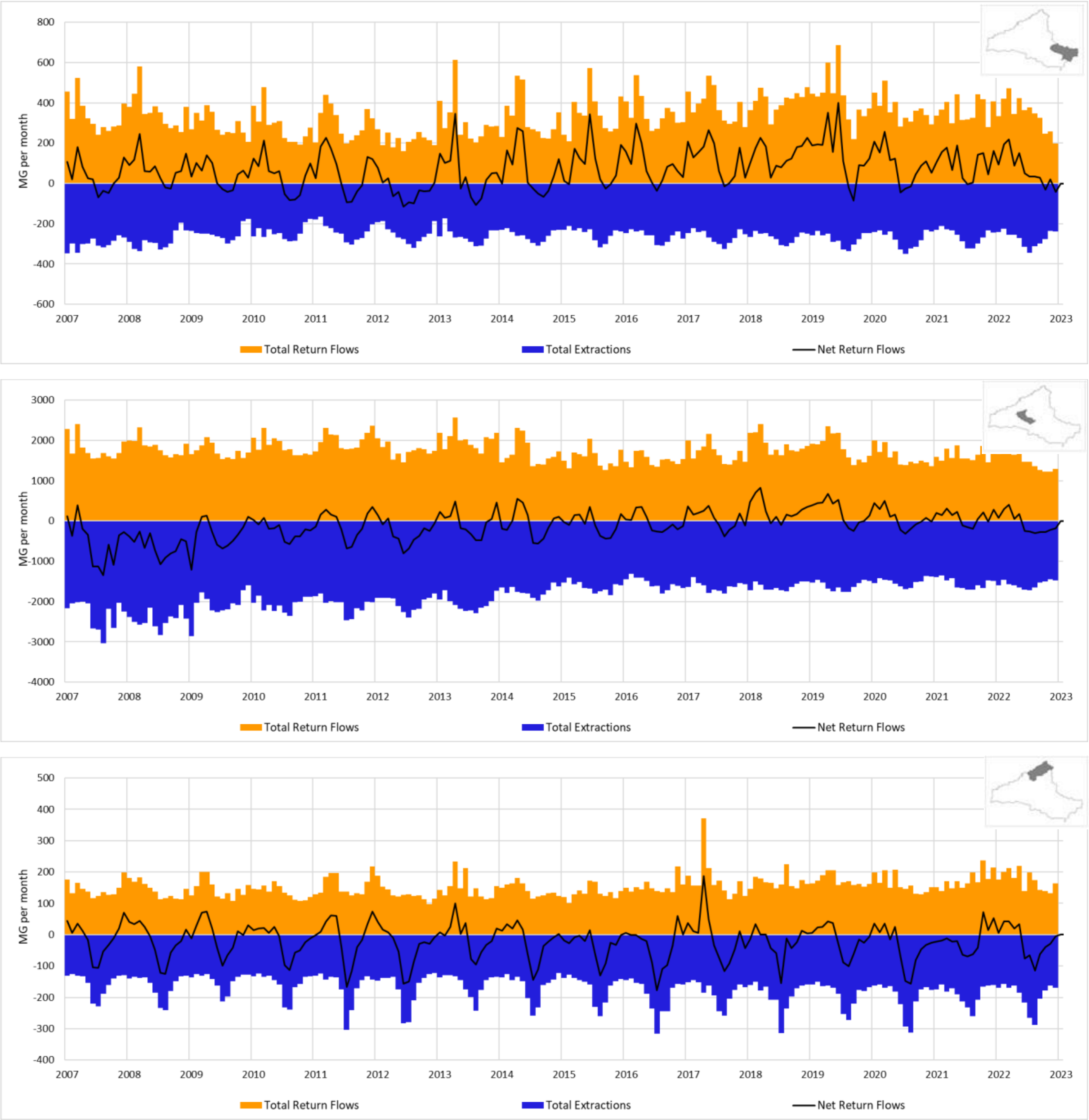


Figure 4-4. Estimated Monthly Net Return Flows for Historical Period 2007 through 2022 for Sub-basins 3 Wabash-Linn Grove (top), 6 Wabash-Peru (middle), and 7 Eel -North Manchester (bottom)

Additionally, two sub-basins (Sub-basins 4 Little-Huntington and 8 Wabash-Logansport) show mostly negative cumulative net return flows during the early portion of the historical period, with a shift to mostly positive net return flows, after year 2015, mostly due to shift in the location of withdrawals in Sub-basin 4 and reduction in water withdrawals in Sub-basin 8.

All sub-basins have Cumulative net return flows with some seasonal variability. During winter and spring, higher net return flows occur as more precipitation infiltrates and the consumptive use is lower.

Alternatively, during the summer, net return flows are lower because of increased irrigation and higher consumptive use. The net return flows for all sub-basins and additional discussion are presented in Appendix D.

There are two main limitations of net return flow estimates in this study. First is the assumption that groundwater withdrawals from self-supplied systems (representing approximately 20% of all withdrawals) return to the system without a time lag and at a high ratio. Second is the challenge of calculating the removal of precipitation runoff volumes from return flows to avoid double counting runoff already reflected in streamflow gauge data (hydrographs). The presence of combined sewage outflows feeding wastewater treatment plants and the lack of easily available information related to the breakdown of sewage sources being treated in the same wastewater treatment plant (for example, industrial and public supply sewage treated in same wastewater treatment plant) makes it difficult to piece apart the contribution of runoff to the uncertainty in the net return flow estimates. The above-mentioned limitations are also discussed in an assessment of water use and reuse conducted in the Wabash River as a case study (Wiener et al., 2015): several circumstances may lead to some sub-basins having a ratio of annual average wastewater discharges to annual withdrawals greater than 1.This will occur in sub-basins that have numerous small self-supply withdrawals that are ultimately discharged to a permitted Publicly Owned Treatment Plants. It also will occur in sub-basins with significant combined sewer systems (Marsalek et al., 1993). In addition, the article points out as that because the SWWF water use classification categories do not map directly to the NPDES SIC Codes, it is often impossible to directly compare withdrawal and discharge volumes among related facilities.

Cumulative Net Reservoir Releases

Net reservoir releases are the difference between reservoir outflows and reservoir inflows. These flows are estimated to quantify the net changes in the river streamflow caused by the reservoirs. Several reservoirs are in the Wabash Headwaters Region but only three, presented in Table 4-3, are considered for this analysis given their impact on natural streamflow (reservoir locations are shown on Figure 2-12).

Table 4-3. Flood-control reservoirs in the Wabash Headwaters Region

Reservoir		J. Roush (Huntington)	Salamonie	Mississinewa
Sub-basin location		5 Wabash-Wabash	5 Wabash-Wabash	6 Wabash-Peru
Storage capacity (TAF)		153.1	263.6	368.4
Elevation (feet mean sea level)	Winter pool	737	730	712
	Summer pool	749	755	737
	Flood pool	798	793	779
Operating purpose		Flood Control (PL 85 500), Recreation (PL 78 534) and Water Quality (PL 92 500)		

These reservoirs are part of the Upper Wabash Projects (constructed between 1966 and 1968) consisting of the Mississinewa Lake, Salamonie Lake, and J. Edward Roush Lakes (also known as the Huntington Lake). These reservoirs operate as a unit to reduce flooding in the Upper Wabash Basin. Huntington Lake was built along the Wabash River within Sub-basin 5 of the Study Area. Salamonie Lake was built along the Salamonie River and is downstream of Huntington Lake within Sub-basin 5 of the Study Area. Mississinewa Lake was built along the Mississinewa River in Sub-basin 6 of the Study Area. Releases from Mississinewa Lake flow to the Wabash River downstream of both Huntington and Salamonie Lakes. The combined storage capacity of Huntington and Salamonie Lakes in Sub-basin 5

Wabash-Wabash is 417.7 thousand acre-feet (TAF) while the storage capacity of Mississinewa Lake in Sub-basin 6 Wabash-Peru is 368.4 TAF. USACE Chicago District operates the reservoirs and has developed a partnership for the management of the public lands surrounding the three lakes. Under lease agreements, IDNR operates and maintains the recreation facilities and wildlife areas at the lakes, with a few exceptions where USACE still maintains and operates some infrastructure.

A reservoir's operation is driven by reservoir target levels (pool [water level elevation] zones) as well as hydrologic and climatological conditions; that is, flow coming into the reservoirs, precipitation and evapotranspiration, and climate and operation targets. As an example, daily operation for Mississinewa reservoir is shown on Figure 4-5 for calendar year 2015.

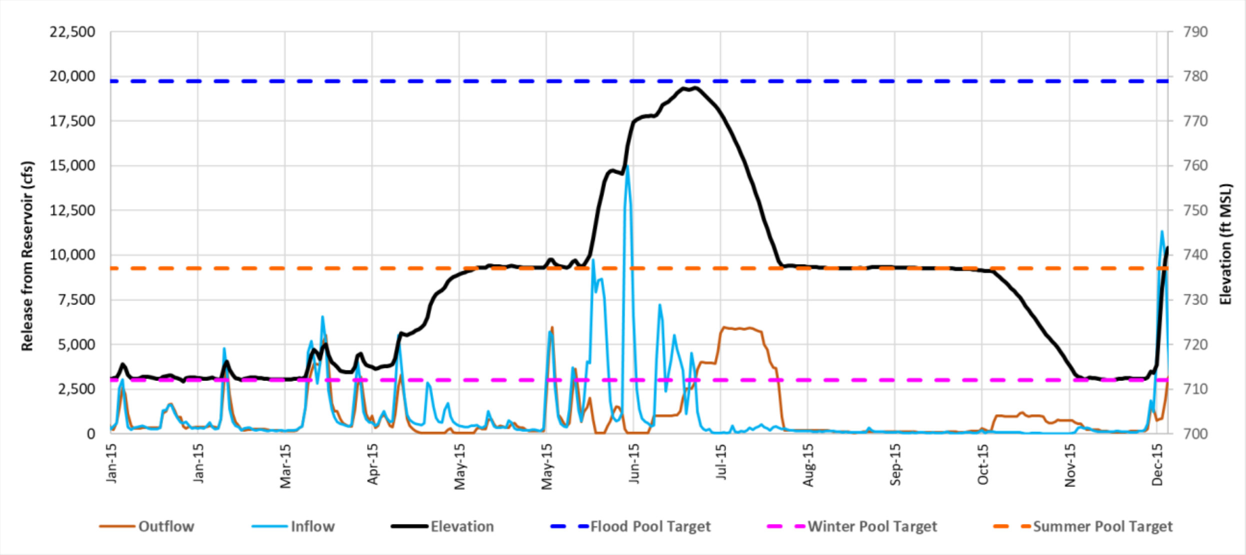


Figure 4-5. Calendar Year 2015 Daily Operations for Mississinewa Lake: Water Level Operation Targets, Inflows, and Outflows

The inflow to the reservoir (refer to light blue line) follows the river streamflow pattern mostly driven by precipitation runoff showing the largest peak flows during June. During the winter and spring months, the flows coming in and out of the reservoir are very similar. Around May, in anticipation of the summer, the outflows (releases) are reduced (refer to the dashed orange line) to allow the inflows to fill the reservoir and reach the summer pool target for recreational purposes. The outflows from the reservoir (refer to the solid orange line) are larger than the inflows (refer to the solid light blue line) when flow releases are required to drawdown the storage level, either when the stored water is reaching the flood pool (dashed dark blue line) or after the summer months when the storage level requirement drops from the 737 feet summer-pool target to the 712 feet winter-pool target.

Historical net reservoir releases, estimated as outflow minus inflow, are shown on Figure 4-6 for each reservoir. Positive values mean stored water is being released from reservoirs, and negative values mean reservoirs are being filled. The more significant releases take place before winter (net positive reservoir releases), and reservoirs are filled prior to summer (net negative reservoir releases). The monthly values range between plus or minus 96,000 MG. In this assessment, the reservoir evaporation and infiltration are not considered. Also, travel time from the reservoir to the measuring point at the basin outlet was not calculated in this analysis.

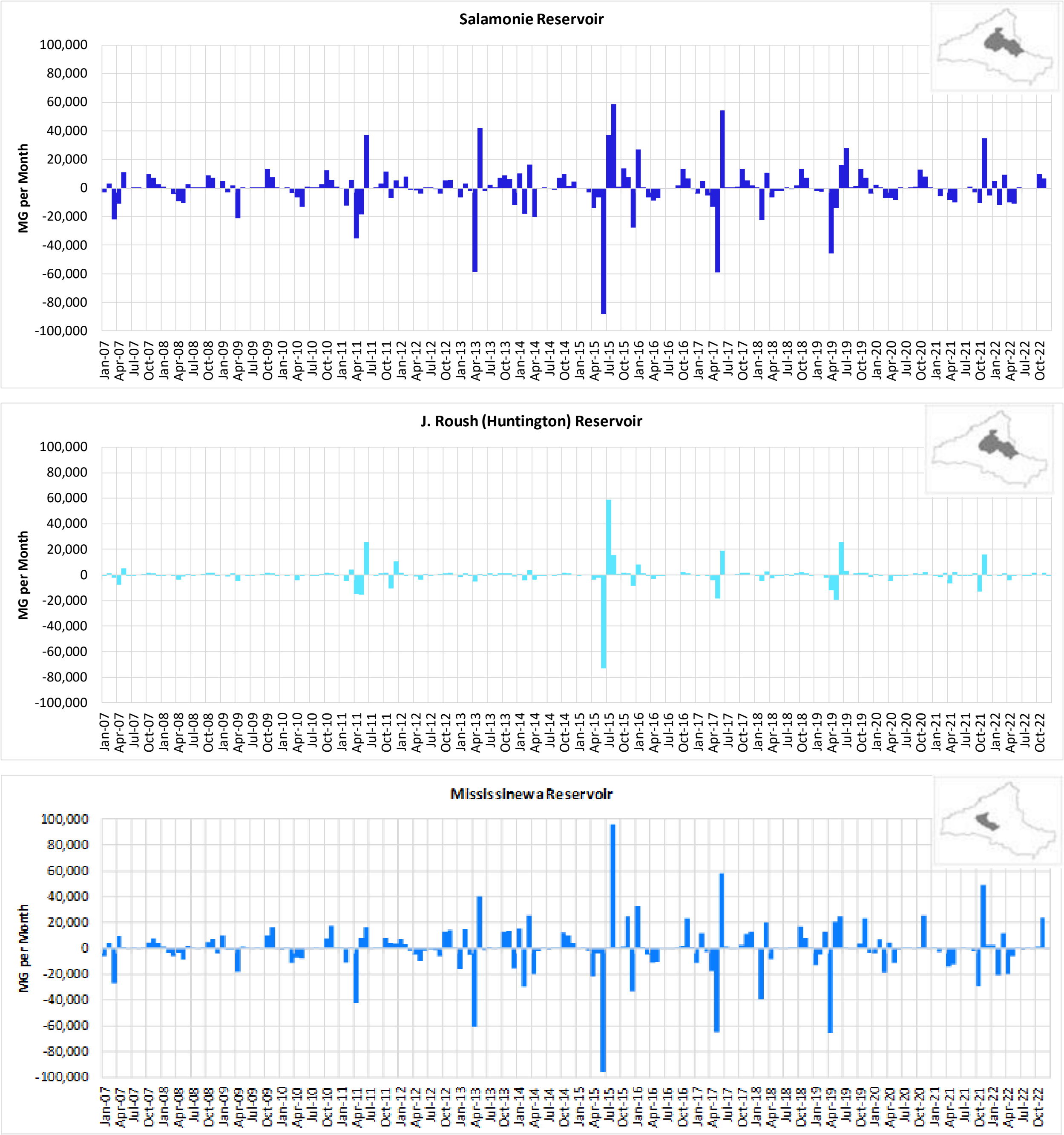


Figure 4-6. Estimated Monthly Net Reservoir Releases for Historical Period 2007 through 2022 for Salamonie Reservoir (top) and J. Roush (Huntington) Reservoir (middle) in Sub-basin 5 Wabash-Wabash and Mississinewa Reservoir (bottom) in Sub-basin 6 Wabash-Peru

The cumulative net reservoir releases are shown for Sub-basins 5 Wabash-Wabash and 6 Wabash-Peru are shown on Figure 4-7. Downstream Wabash River from Sub-basin 6, there is not any other reservoir and the cumulative net reservoir releases for Sub-basin 8, Wabash-Logansport and Sub-basin 10, Wabash-Ungauged are, therefore, the same as Sub-basin 6 which aggregates all three reservoirs in the study area.

Figure 4-7. Cumulative Net Reservoir Releases in Sub-basins 5 (top) and 6 Wabash-Peru (bottom)

4.2.1.2 Cumulative Natural Baseflow

Hydrograph separation is the process of mathematically estimating the proportion of baseflow and surface runoff from streamflow data collected at stream gauges. In this study, the estimated cumulative natural streamflow was used as the hydrograph input data in the hydrograph-separation method to estimate the portion corresponding to cumulative natural baseflow. This portion of the streamflow is generally recognized as the groundwater discharge component of streamflow. Following the computation of the cumulative natural streamflow (Section 4.2.1.1), cumulative natural baseflow (was estimated for each basin using the HYSEP-Slide methodology developed by the USGS (Sloto and Crouse, 1996) and incorporated into the USGS Hydrologic Toolbox (Barlow et al., 2022). For more detail on the methodology, refer to Appendix D.

Figure 4-8 shows the monthly streamflow for Sub-basin 6 Wabash-Peru (previously shown on Figure 4-3) with the estimated monthly cumulative natural baseflow. Monthly cumulative natural baseflow rates spike (representing groundwater recharge events) during high streamflow events and decrease during low flows.

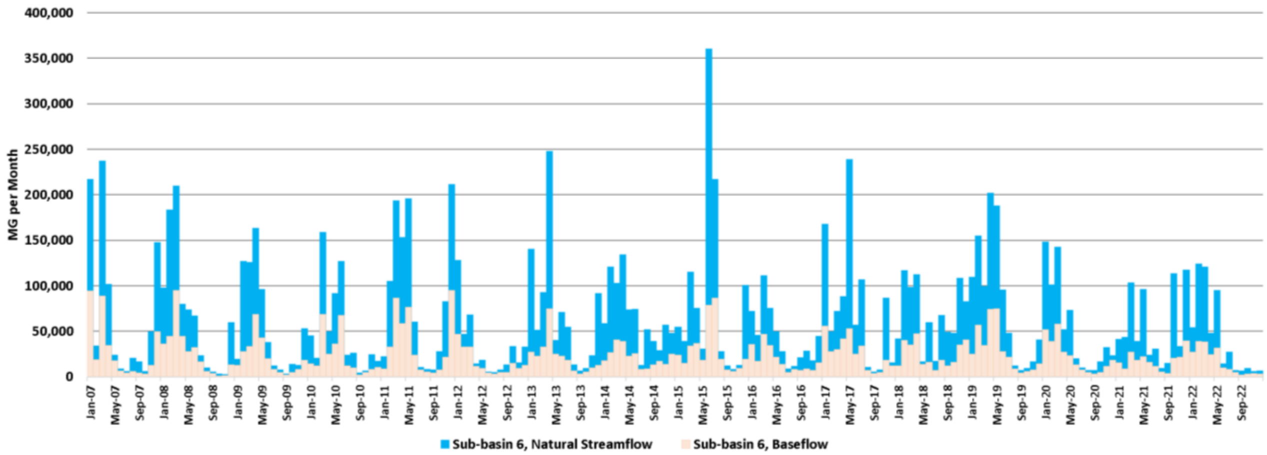


Figure 4-8. Estimated Monthly Cumulative Natural Streamflow and Cumulative Natural Baseflow for Historical Period 2007 through 2022 for Sub-basin 6 Wabash-Peru

Note: Cumulative natural baseflow follows similar trends as cumulative natural streamflow where cumulative natural baseflow increases and decreases with seasonal pulses in natural streamflow. Cumulative natural baseflow tends to be a larger component of streamflow during low-flow periods.

A more detailed overview is provided on Figure 4-9 with an example of the separation of natural baseflow from streamflow using the HYSEP-Slide method (Sloto and Crouse,1996) for year 2015. The figure shows daily and monthly values for streamflow and baseflows (primary y-axis) and the baseflow index (secondary y-axis), which is the ratio of baseflow to streamflow, representing the relative proportion of natural streamflow that is derived from natural baseflow. The baseflow index metric gives an indication on the dynamics of natural baseflow and can be helpful in highlighting seasonal patterns and spatial differences in natural baseflow conditions throughout the study area. Since natural baseflow is the primary source of supply in the water availability analysis, it is important to evaluate natural baseflow conditions and the baseflow index provides a simplified metric in this evaluation.

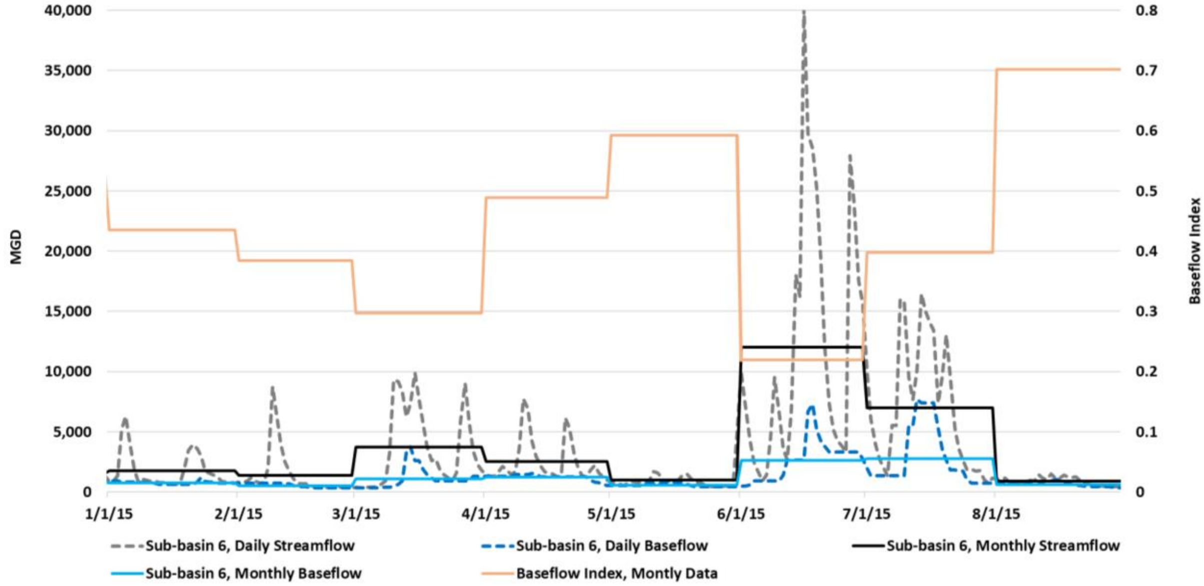


Figure 4-9. Separation of Baseflow from Natural Streamflow at Sub-basin 6 Wabash-Peru: Daily and Monthly Values for year 2015

On Figure 4-8, the baseflow index changes substantially month-to-month, where the baseflow index typically decreases during high streamflow events, when runoff becomes a larger contributor to natural streamflow, and increases during low flow periods when little to no surface runoff occurs. Figure 4-10 shows the average baseflow index for the sub-basins during the Historical period (2007 through 2022). The overall average baseflow index value for all sub-basins is 0.39. The baseflow index values for the tributaries to the Wabash River (Sub-basins 1, 2, 4 and 9) display a wider range than those in the sub-basins along the mainstem of the Wabash River (Sub-basins 3, 5, 6, 8 and 10). The baseflow values along the Wabash River exhibit an increasing trend moving downstream, outside of the headwaters (Sub-basin 3 Wabash-Linn Grove). For additional discussion of baseflow index and estimates of Net natural baseflow Appendix D.

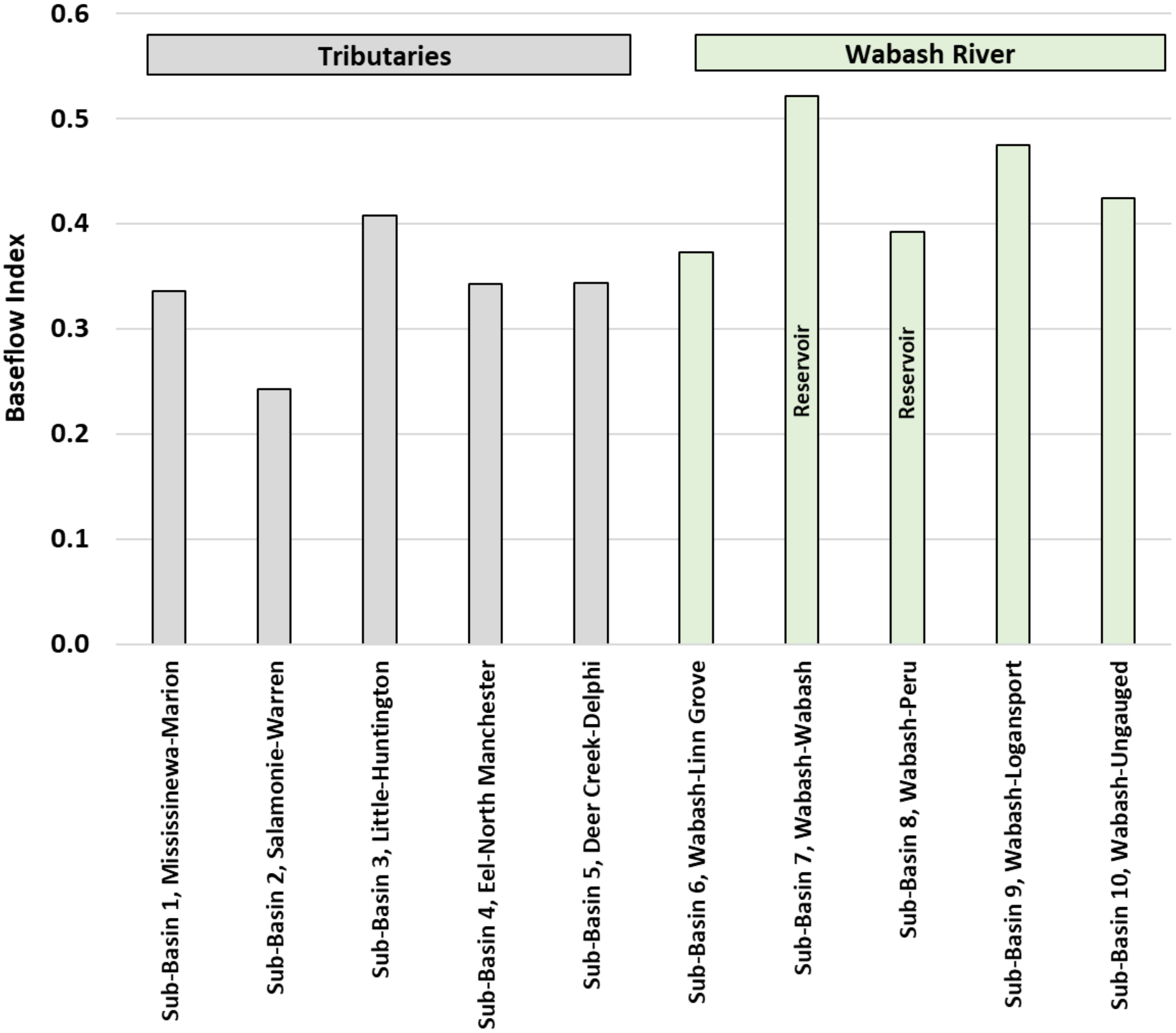


Figure 4-10. Baseflow Index for Natural Streamflow (2007 through 2022) for each Study Area Sub-basin

Note: The baseflow index represents the relative proportion of natural streamflow that is derived from natural baseflow; the overall average baseflow index value for all sub-basins is 0.39, but values for Wabash River tributaries display a wider range than those in the sub-basins along the Wabash River mainstem, which exhibit an increasing trend moving downstream, outside of the headwaters.

Overall, natural baseflow follows similar patterns as natural streamflow when using the baseflow hydrograph separation method. As natural streamflow increases, the baseflow index decreases, and conversely, the baseflow index increases while the natural streamflow decreases. Natural baseflow comprises a larger component of natural streamflow during lower-flow months. Sub-basins are categorized to reflect tributary streams and the Wabash River. A slight increasing trend in baseflow index can be observed in the downstream direction (right to left on Figure 4-10), suggesting that natural baseflow contributions comprise a larger portion of streamflow along the Wabash River.

4.2.1.3 Cumulative Minimum Instream Flow Requirements

Minimum instream flows are required for riverine ecosystem health and water quality. Two metrics are used to determine the value of monthly instream flows in the Wabash Headwaters Region's rivers for this study:

- 7Q10, defined as the lowest 7-day average flow in a stream that occurs once every 10 years. IDNR recommends this as the minimum value during low-flow periods (IDNR, 2015). This value is used to define minimum flows during the summer and fall months (June through November) when streamflow is typically lower.
- Q90, defined as the minimum flow that is present 90% of the time in a stream. Flows are expected to be lower than this value 10% of the time. This value is used to define minimum flows during the wetter months (December through May) when streamflow is typically higher.

Figure 4-11 presents the computed cumulative minimum instream flow requirement for Sub-basin 6 Wabash-Peru, along with the previously presented natural streamflow and baseflow. Note that the y-axis scale on Figure 4-11 truncates the high flows to better view the details of the instream requirement values.

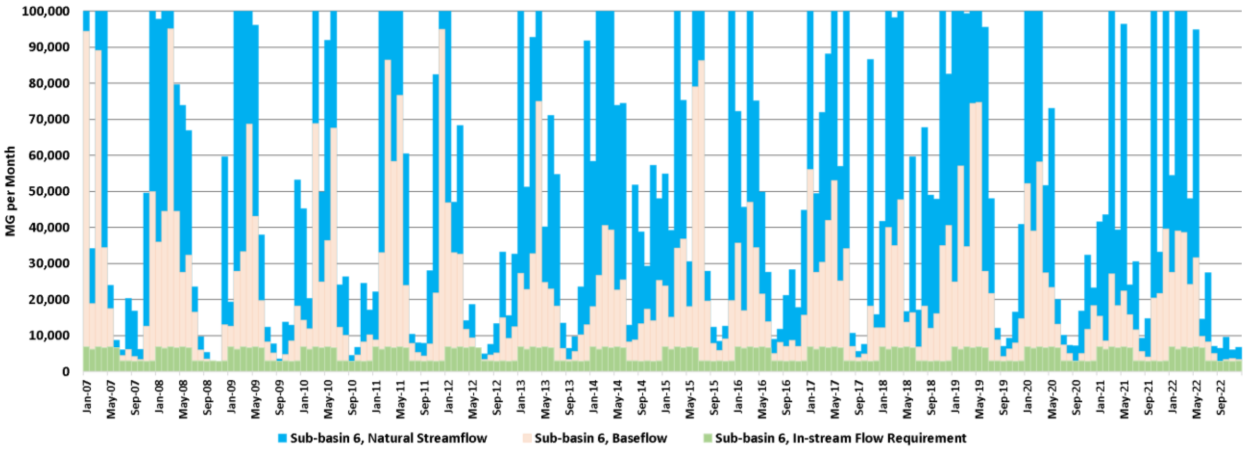


Figure 4-11. Estimated Cumulative Monthly Minimum Flow Requirement, Natural Streamflow, and Natural Baseflow for Historical Period 2007 through 2022 for Sub-basin 6 Wabash-Peru

Note: Instream flow requirements vary seasonally using based around the 7Q10 and Q90 metrics and are typically less than the natural baseflow conditions on a monthly basis. Y-axis is truncated for better visibility of smaller values.

The cumulative instream flow requirement metrics were computed on measured streamflow data (not the cumulative natural streamflow discussed earlier in this section) for the period 1990 through 2020. A 30-year period was deemed adequate for use in calculating the instream flow requirements. Because only guidance (IDNR, 2015), but no regulatory statutes define the determination of minimum instream flows requirements, a similar protocol used by the Central Indiana Water Study (IFA, 2021) is implemented herein. The annual Q90 is used to specify minimum flow during winter and spring months (December through May) when streamflow is typically higher, and the 7Q10 during summer and fall months (June through November) when streamflow is typically lower.

The flow rates defined by these metrics vary depending upon the size of the stream and watershed, the hydrology of the watershed, local geology, and water use patterns. Typically, as stream flow rates increase in a downstream direction, so will the instream flow requirements. Table 4-4 presents the estimated minimum flow metrics computed for all sub-basins in the Wabash Headwaters Region. The Net Minimum Instream Flow Requirements for each sub-basin were calculated to be used in the sub-basin Water availability estimates. The values and additional discussion are presented in Appendix D.

Table 4-4. Computed Cumulative Minimum Instream Flow Requirements for Period 1990 through 2020 in the Wabash Headwaters Region in cfs and MGD.

Sub-basin Number and Name	December through May		June through November	
	Q90 (cfs)	Q90 (MGD)	7Q10 (cfs)	7Q10 (MGD)
1 Mississinewa-Marion	61.0	39.5	30.2	19.5
2 Salamonie-Warren	21.0	13.6	6.7	4.3
3 Wabash-Linn Grove	17.8	11.5	6.1	3.9
4 Little-Huntington	26.6	17.2	17.0	11.0
5 Wabash-Wabash	189.0	122.2	74.2	48.0
6 Wabash-Peru	342.4	221.3	147.5	95.3
7 Eel-North Manchester	84.6	54.7	57.3	37.0
8 Wabash-Logansport	685.0	442.8	321.6	207.9
9 Deer Creek-Delphi	32.0	20.7	14.0	9.0
10 Wabash-Ungauged	901.0	582.4	346.7	224.1

4.2.2 Annual Water Availability

Historical monthly water availability across all sub-basins was summarized to characterize annual water availability in the study area. In this section, annual water availability will be discussed for the study area with more detailed evaluations presented for a few sub-basins to highlight specific general trends and dynamics that can be seen in different sub-basins throughout the study area. Evaluation of annual water availability for all sub-basins is provided in Appendix D.

Table 4-5 presents annual average water availability, excess water availability, and cumulative excess water availability across all sub-basins in the study area. In general, water availability and excess water availability are relatively similar because overall water withdrawals and consumptive use are low compared to groundwater (natural baseflow) conditions and minimum instream flow requirements throughout the study area. Water availability and excess water availability are positive for all sub-basins on an annual average basis for the historical period. Seasonality in natural baseflow conditions can however cause negative water availability in some sub-basins in certain years. Additional discussion on seasonality of water availability will be discussed in Section 4.2.3.

Table 4-5. Historical Annual Average Water Availability by Sub-basin

Sub-basin Number and Name	Historical Annual Average		
	Water Availability (MGD)	Excess Water Availability (MGD)	Cumulative Excess Water Availability (MGD)
1 Mississinewa-Marion	151	149	149
2 Salamonie-Warren	72	72	72
3 Wabash-Linn Grove	134	137	137
4 Little-Huntington	53	53	53
5 Wabash-Wabash	116	112	374
6 Wabash-Peru	88	88	610
7 Eel-North Manchester	117	116	116
8 Wabash-Logansport	81	79	805
9 Deer Creek-Delphi	80	79	79
10 Wabash-Ungauged	131	136	1,010

The Wabash River, within a large river system, is the primary river flowing through the study area, accumulating streamflow volumes downstream as the drainage area increases. Therefore, the instream flow requirements also increase in a downstream direction. Overall, cumulative excess water availability is positive across all sub-basins, suggesting the potential for expansion of water use on a regional basis. Further analysis on the downstream effect on potential water use expansion to the North Central region needs to be considered.

The upstream conditions as well as the specific characteristics of the sub-basin influence the water availability results. The breakdown of the water availability components for two sub-basins are presented to portray the effect of upstream sub-basins: Sub-basin 1 Mississinewa-Marion has no upstream sub-basin inflows, while Sub-basin 5 Wabash-Wabash has inflows coming from the Salamonie River (Sub-basin 2), the Little River (Sub-basin 4 Little-Huntington), and from the upstream Wabash River (Sub-basin 3 Wabash-Linn Grove).

Table 4-6 summarizes annual water availability terms and water availability for Sub-basin 1 Mississinewa-Marion for the historical period of 2007 through 2022. Sub-basin 1 Mississinewa-Marion is in the upper portion of the study area and does not have upstream sub-basins that contribute flow to it. In this sub-basin, water availability and excess water availability are positive throughout the historical period on an annual basis. Variability in water availability and excess water availability are generally driven by annual variability of baseflow in Sub-basin 1 Mississinewa-Marion, which results from differences in total precipitation from year-to-year. Cumulative excess water availability for Sub-basin 1 Mississinewa-Marion is equal to the excess water availability because there are no upstream sub-basins that contribute flow.

Table 4-6. Sub-basin 1 Mississinewa-Marion Annual Average Water Availability

Year	Baseflow (MGD)	Return Flow (MGD)	Withdrawals (MGD)	Net Reservoir Release (MGD)	Instream Flow (MGD)	Water Availability (MGD)	Excess Water Availability (MGD)	Cumulative Excess Water Availability (MGD)
2007	188	11	15	0	29	158	154	154
2008	179	11	14	0	29	149	146	146
2009	151	12	15	0	29	121	118	118
2010	175	12	14	0	29	145	143	143
2011	241	13	14	0	29	212	211	211
2012	136	12	14	0	29	106	104	104
2013	166	14	16	0	29	136	134	134
2014	182	13	17	0	29	153	149	149
2015	216	12	15	0	29	187	184	184
2016	173	12	14	0	29	144	141	141
2017	202	12	13	0	29	172	171	171
2018	205	11	13	0	29	176	174	174
2019	210	11	13	0	29	180	179	179
2020	172	8	10	0	29	143	140	140
2021	153	8	11	0	29	124	121	121
2022	143	6	10	0	29	114	110	110

Table 4-7 summarizes annual water availability terms and water availability for Sub-basin 5 Wabash-Wabash for the historical period of 2007 through 2022. Sub-basin 5 Wabash-Wabash is relatively central to the study area and contains two flood-control reservoirs that influence streamflow in the sub-basin. Water availability for Sub-basin 5 Wabash-Wabash is positive throughout the historical period on an annual basis. Excess water availability is positive in all years except 2022. Instream flows have a large influence on water availability but remain constant on an annual average basis with the variability in water availability mainly being driven by fluctuations in natural baseflow. Net reservoir releases have a small influence on water availability on an annual basis, as seasonal reservoir operations are not captured at the annual scale. Cumulative excess water availability for Sub-basin 5 Wabash-Wabash is larger than the excess water availability throughout the historical period because of contributions of excess available water from the sub-basins that are upstream.

Table 4-7. Sub-basin 5 Wabash-Wabash Annual Average Water Availability

Year	Baseflow (MGD)	Return Flow (MGD)	Withdrawals (MGD)	Net Reservoir Release (MGD)	Instream Flow (MGD)	Water Availability (MGD)	Excess Water Availability (MGD)	Cumulative Excess Water Availability (MGD)
2007	241	5	9	-4	54	184	180	472
2008	213	6	12	-7	54	151	146	449
2009	163	5	10	7	54	115	110	305
2010	176	6	11	0	54	122	117	316
2011	277	6	11	-24	54	199	194	681
2012	104	6	10	19	54	68	64	210
2013	150	6	11	-24	54	72	67	294
2014	150	10	11	13	54	109	108	333
2015	198	8	13	-63	54	81	77	461
2016	139	7	10	61	54	145	142	323
2017	184	7	11	6	54	135	132	413
2018	168	11	11	-8	54	106	106	411
2019	216	8	11	-10	54	152	149	518
2020	173	7	11	5	54	124	120	361
2021	128	7	11	-17	54	57	52	228
2022	95	7	11	-8	54	33	28	210

4.2.3 Seasonal Water Availability

In addition to annual evaluation of water availability, a seasonal approach to summarizing monthly water availability was employed to characterize seasonal variability in supplies and demands that can have an impact on water availability. For the seasonal water availability analysis, seasons have been defined as follows:

- Winter is represented by December through February
- Spring is represented by March through May
- Summer is represented by June through August
- Fall is represented by September through November

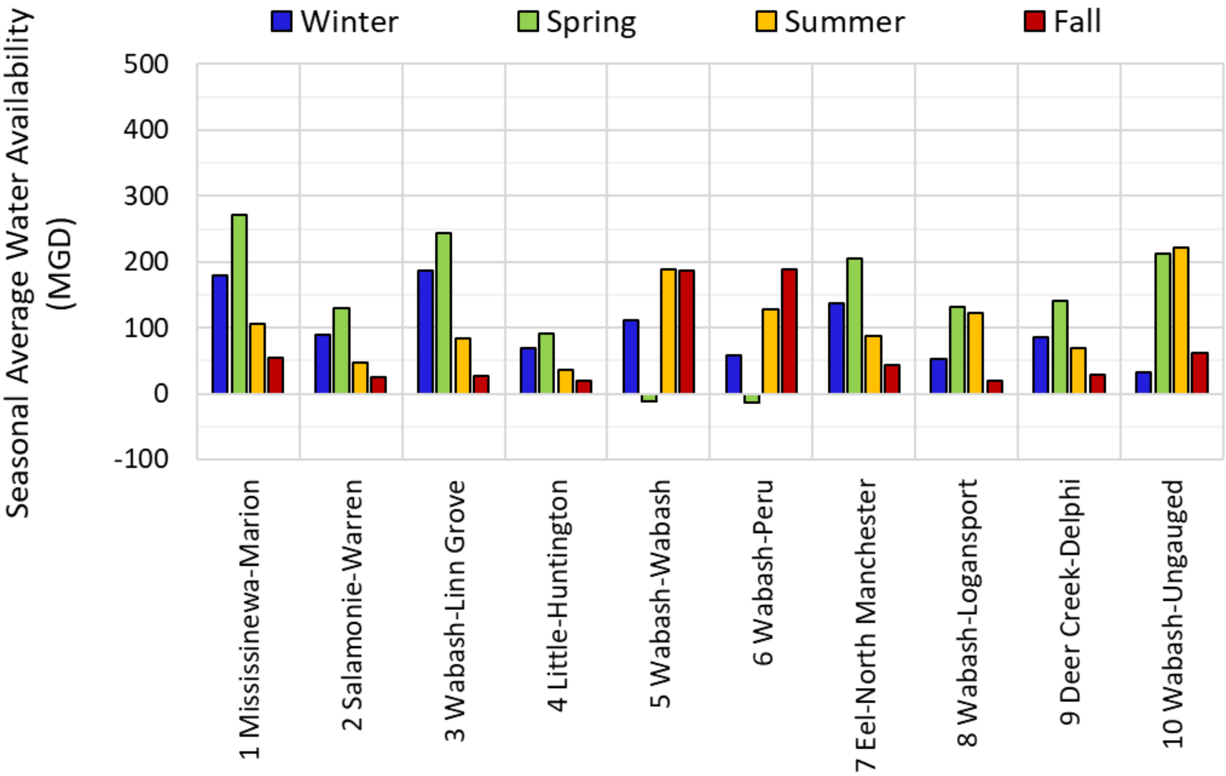


Figure 4-12. Historical Seasonal Average Water Availability by Sub-basin

Figure 4-12 compares seasonal average water availability for all sub-basins in the study area. All Sub-basins except 5 and 6, have positive seasonal average water availability throughout all four seasons, with more water availability during the winter and spring months and less during summer and fall months. The water availability drop from summer to fall is also relevant and requires special attention in those sub-basins the baseflows are the lowest which is normally the case in sub-basin crossed by tributary rivers. As an example, Figure 4-13 shows the contrast of stream flows during mid-July (summer) and end of September (fall) in the Eel River and Deer Creek .

Sub-basin 5 Wabash-Wabash contains the Huntington and Salamonie flood-control reservoirs, and as a result of reservoir operations it has negative water availability in the spring when the reservoirs tend to store more water than they release. Conversely, the summer and fall seasons in Sub-basin 5 Wabash-Wabash have the largest water availability, on average, as compared to all other sub-basins, due to the reservoirs releasing water during summer and fall months.

Sub-basin 6 Wabash-Peru also includes a flood-control reservoir (Mississinewa) that influences seasonal water availability, as the reservoir tends to store more water than it releases during spring, resulting in negative water availability; and subsequently releases water during the summer and fall to create an increase in water availability during these seasons when streamflow would otherwise be generally low.

Figure 4-13. Summer and Fall Streamflow Contrast at Eel River at Longport (top) and Deer Creek (bottom)

Note: Location of these pictures is upstream the confluence of the Wabash River. The Eel River joins the Wabash River at Longport in Sub-basin 8 and Deer Creek joins the Wabash River downstream of Delphi in Sub-basin 10

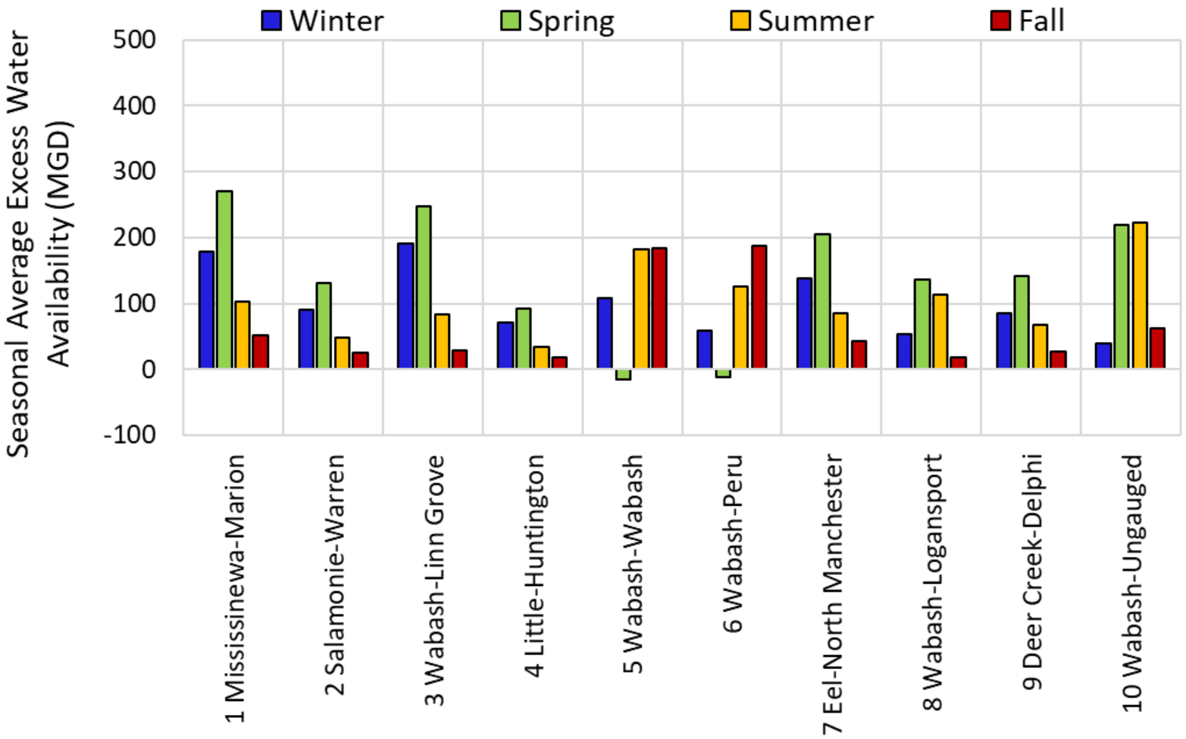


Figure 4-14. Seasonal Average Excess Water Availability by Sub-basin

Figure 4-14 shows seasonal average excess water availability across all sub-basins in the study area. In general, the trends across each sub-basin are consistent with the trends previously discussed for water availability. Water withdrawals and consumptive use are relatively small in comparison to the other water balance components (baseflow, instream flow, and net reservoir releases), causing water availability and excess water availability to be similar across all four seasons for each sub-basin.

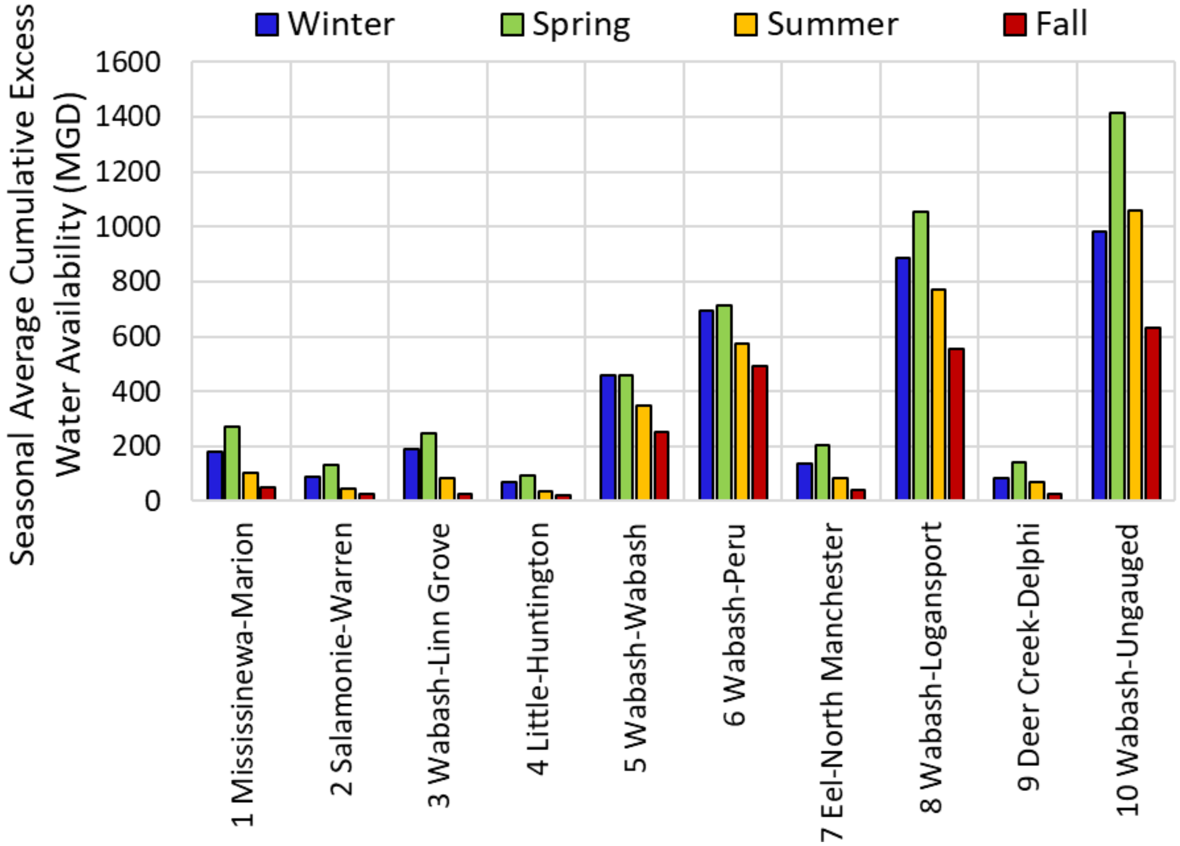


Figure 4-15. Seasonal Average Cumulative Excess Water Availability by Sub-basin

Figure 4-15 shows seasonal average cumulative excess water availability across all sub-basins in the study area. Overall, cumulative excess water availability is positive for all sub-basins throughout all four seasons. In general, sub-basins that contain tributaries to the Wabash River (Sub-basins 1 through 4, 7, and 9) show a similar pattern across seasons with maximum cumulative excess water availability occurring in spring, followed by winter and summer and minimum cumulative excess water availability occurring in fall. In Sub-basins 5, 6, 8, and 10, net reservoir releases in summer and fall can sustain cumulative excess water availability through the drier, low baseflow months.

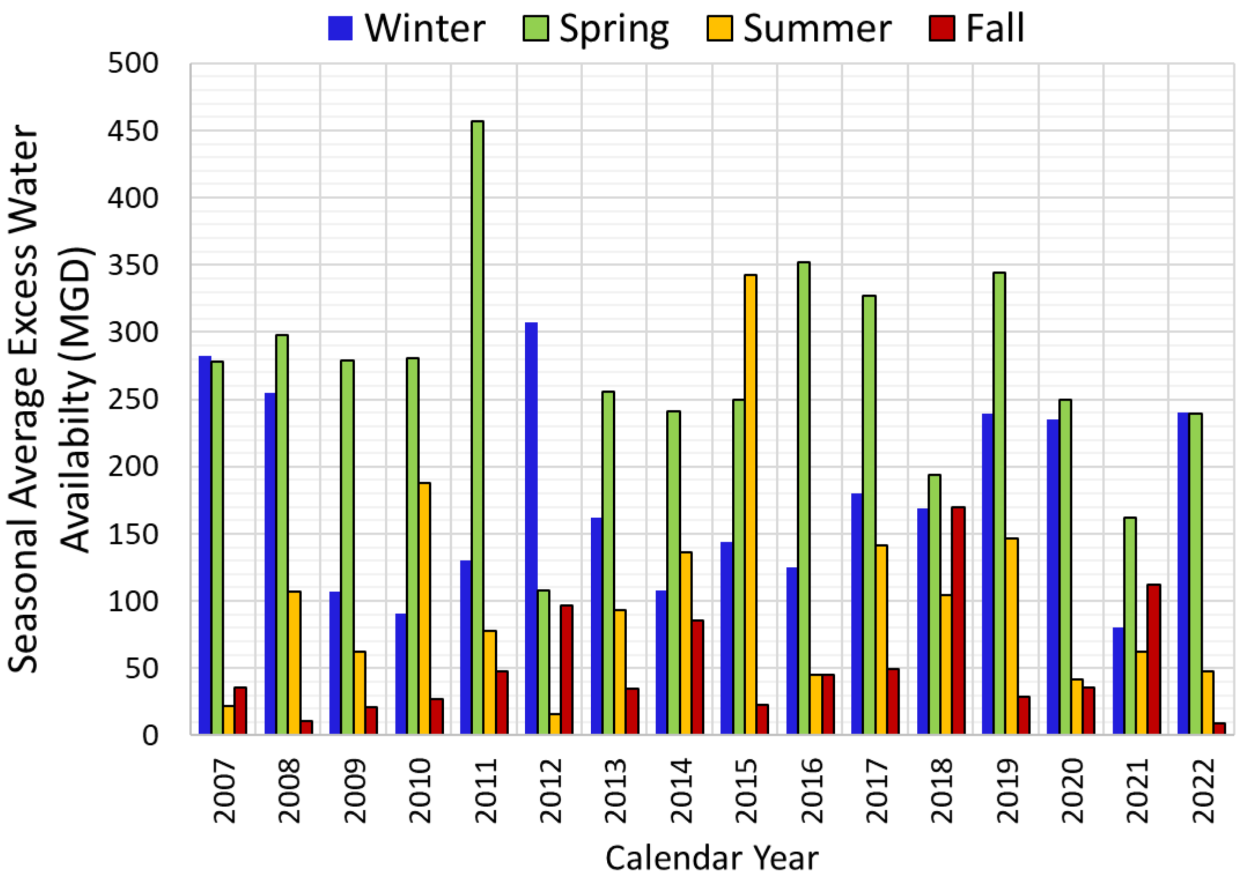


Figure 4-16. Seasonal Average Excess Water Availability for Sub-basin 1 Mississinewa-Marion

Figure 4-16 shows seasonal average excess water availability for every year within the historical period at Sub-basin 1 Mississinewa-Marion as an example of conditions in one of the sub-basins that contains a tributary to the Wabash River. Throughout the 16-year historical period from 2007-2022, excess water availability is positive for all seasons. In general, the spring shows the largest magnitude of excess water availability, followed by winter, summer, and fall. Variability in magnitudes is observed for all seasons during the historical periods because of the variability in baseflow conditions.

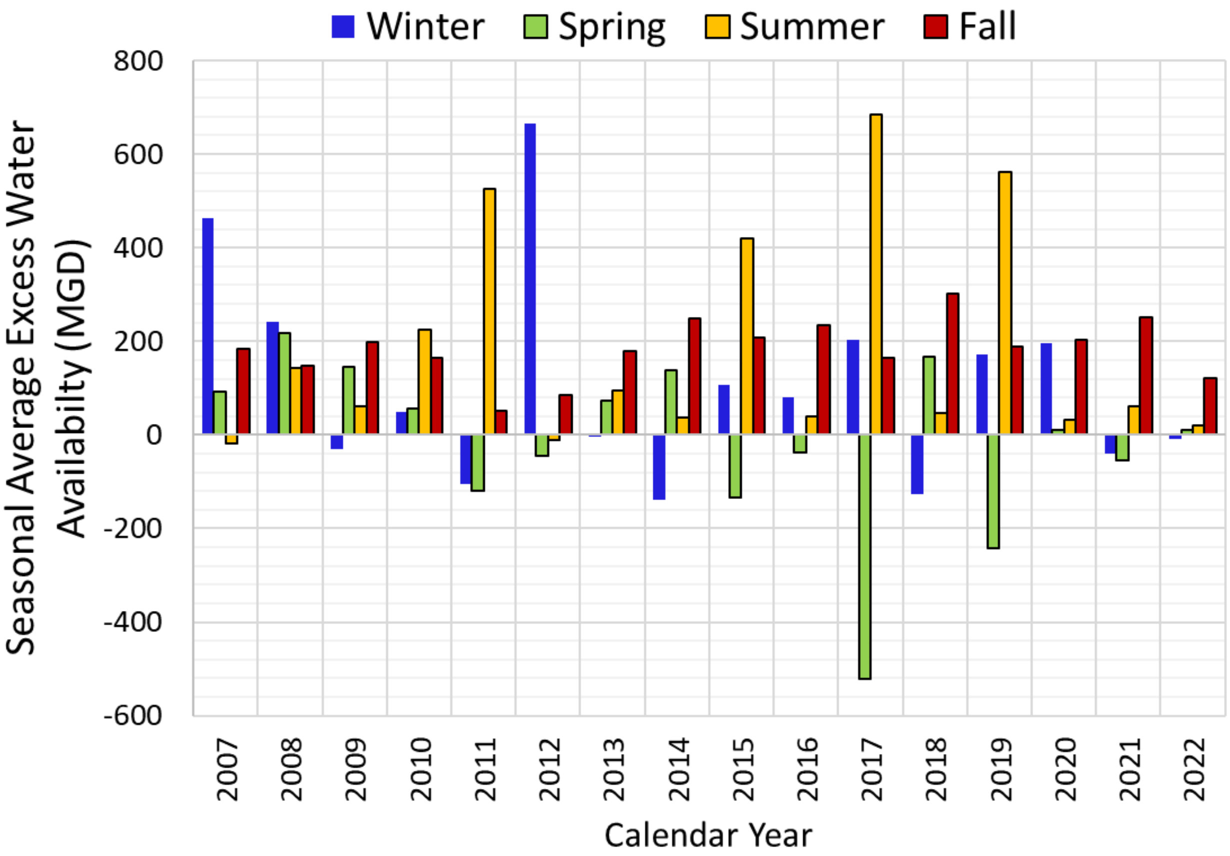


Figure 4-17. Seasonal Average Excess Water Availability for Sub-basin 5 Wabash-Wabash

Another sub-basin example is presented on Figure 4-17. This figure shows seasonal average excess water availability for every year within the historical period at Sub-basin 5 Wabash-Wabash as an example of conditions in one of the sub-basins that the Wabash River flows through. Overall, excess water availability varies across the years in both the positive and negative directions. Most notably, in 2017 the excess water availability is largely negative during the spring season because of water storage occurring in the reservoirs in Sub-basin 5 Wabash-Wabash. This large deficit in water availability is followed by a surplus of available water during the summer season when the stored flows were released from the reservoirs. In addition, fall excess water availability is consistently positive throughout the historical period due to reservoirs releasing water in the summer and fall months to sustain flows along the Wabash River. Further discussion related to seasonal water availability is available for all sub-basins in Appendix D.

4.3 Future Water Availability

Future water availability has been projected using the selected potential climate conditions model (CESM1-CAM5. RCP8.5) through the year 2070, which has been established as the future baseline for this study. Details on the development of the future baseline scenario were presented in Section 4.1.2 and additional discussion on the development of each component of the projected water availability methodology can be found in Appendix A.

4.3.1 Analysis Approach Overview

Monthly water availability, excess water availability, and cumulative excess water availability were calculated from January 2023 through December 2070. Each water availability term was projected into this time frame to account for future changes in demand, seasonal changes to the timing and magnitude of streamflow, and continued operation of the three flood-control reservoirs present in the study area. Evaluation of future projected water availability is provided in the following section by comparing the 16-year Historical (2007 through 2022) period to a selection of hydrologically similar years from a future period centered around the 2060s (2043 through 2071). Selecting future years with representative hydrology allows comparisons to be made against Historical conditions to evaluate the influence of changes in future projected baseflow, return flows, withdrawals, and reservoirs reasons on water availability for each sub-basin. Further discussion on the development of future water availability can be found in Appendix A.

4.3.2 Projected Changes in Water Availability

As described in Section 4.3.1, projected changes in water availability, as compared to historical conditions were calculated for a period centered around 2065. Table 4-8 shows a breakdown of historical and future winter and spring seasonal average cumulative excess water availability for each sub-basin in the study area. In general, winter and spring cumulative excess water availability is projected to increase across all sub-basins, except for Sub-basin 9 Deer Creek-Delphi where there is a small decrease in winter cumulative excess water availability. Winter increases in cumulative excess availability range from 3% to 21%. Similarly, spring cumulative excess water availability is projected to increase across all sub-basins, with values ranging from an increase of 14% to 39%.

Table 4-8. Winter and Spring Cumulative Excess Water Availability by Sub-basin for Historical and Future Period

Sub-basin	Winter Cumulative Excess Water Availability			Spring Cumulative Excess Water Availability		
	Historical Period (MGD)	2060's Future (MGD)	% Change	Historical (MGD)	2060's Future (MGD)	% Change
1 Mississinewa-Marion	178	178	0	270	320	18
2 Salamonie-Warren	91	93	3	131	159	21
3 Wabash-Linn Grove	191	196	3	248	283	14
4 Little-Huntington	70	78	12	93	115	24
5 Wabash-Wabash	459	498	8	456	651	43
6 Wabash-Peru	696	744	7	713	993	39
7 Eel-North Manchester	138	167	21	205	236	15
8 Wabash-Logansport	888	949	7	1,054	1,419	35
9 Deer Creek-Delphi	84	79	-6	141	170	20
10 Wabash-Ungauged	982	1,039	6	1,413	1,892	34

Table 4-9 shows a comparison of historical and future summer and fall seasonal average cumulative excess water availability for each sub-basin in the study area. In general, summer cumulative excess water availability is projected to decrease across all sub-basins, except for Sub-basin 4 Little-Huntington and Sub-basin 9 Deer Creek-Delphi, which exhibit a small increase in summer cumulative excess water availability. Summer decreases in cumulative excess water availability range from -3% to -20%. Fall cumulative excess water availability is projected to decrease across all sub-basins ranging from -11% to -32%

Table 4-9. Summer and Fall Cumulative Excess Water Availability by Sub-basin for Historical and Future Period

	Summer Cumulative Excess Water Availability			Fall Cumulative Excess Water Availability		
Sub-basin	Historical Period (MGD)	2060's Future (MGD)	% Change	Historical (MGD)	2060's Future (MGD)	% Change
1 Mississinewa-Marion	102	92	-10	52	37	-28
2 Salamonie-Warren	47	41	-13	25	18	-26
3 Wabash-Linn Grove	84	67	-20	28	22	-22
4 Little-Huntington	34	37	8	19	14	-23
5 Wabash-Wabash	347	313	-10	254	227	-11
6 Wabash-Peru	575	524	-9	491	429	-13
7 Eel-North Manchester	84	79	-7	42	29	-32
8 Wabash-Logansport	770	726	-6	552	470	-15
9 Deer Creek-Delphi	68	75	9	27	19	-28
10 Wabash-Ungauged	1,059	1,025	-3	631	526	-17

Figure 4-18 presents a graphical version of Tables 4-8 and 4-9 highlighting the changes in cumulative excess water availability throughout the Study Area. The largest changes in cumulative excess water availability are focused on the Wabash River in the central portion of the Study Area due to contributions of tributary creeks to the Wabash River. Larger decreases, on a percentage-basis, can be observed in the tributary creeks which do not have upstream contributions to help offset reductions in natural baseflow during the Summer and Fall months. While these reductions may appear significant (that is, larger percentage reduction), it is important to recognize that the change is may be relatively smaller from a volume perspective in the sub-basins tributary to the Wabash River.

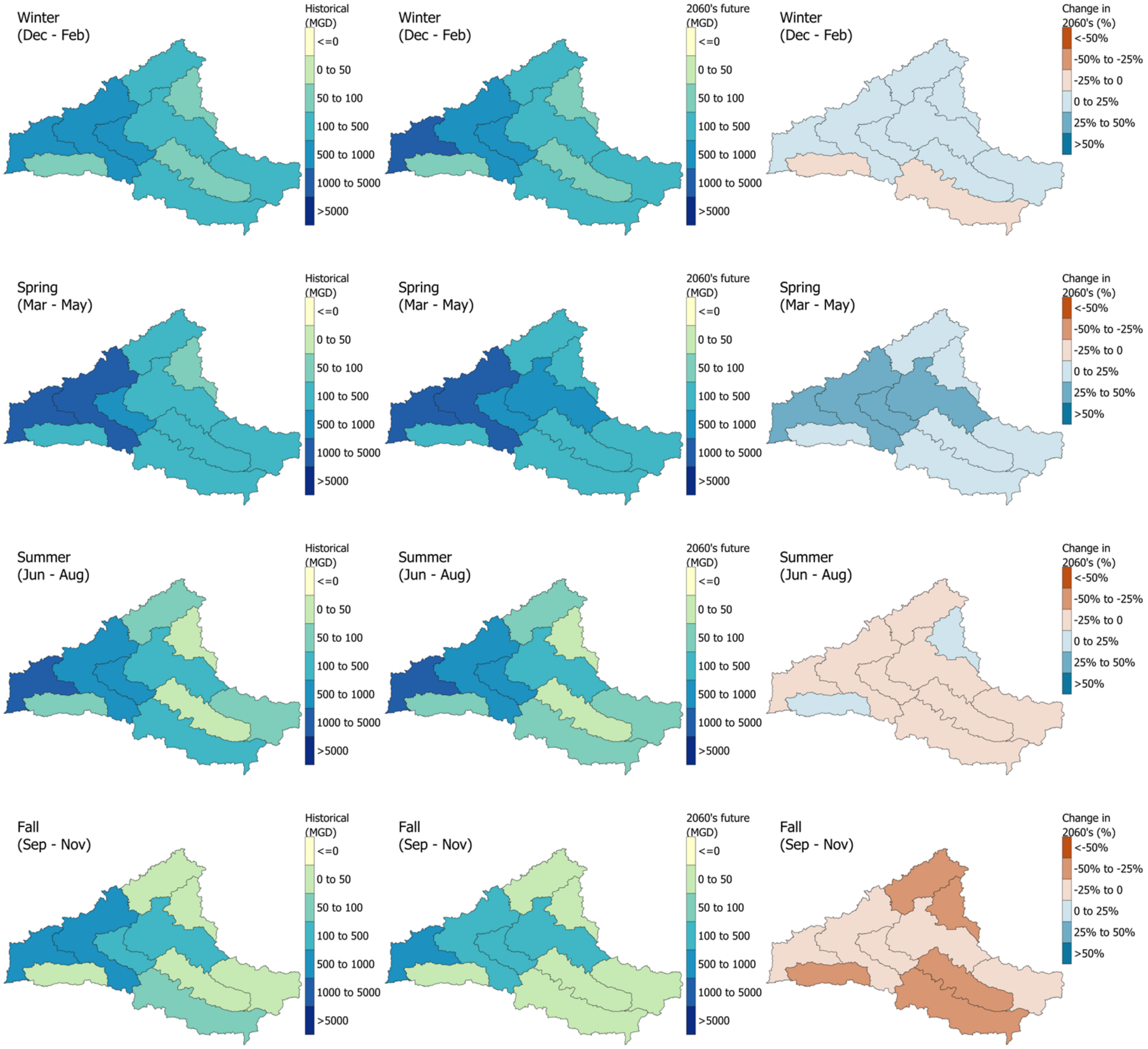


Figure 4-18. Historical and Projected Future Cumulative Excess Water Availability and Projected Future (2060s) Changes in the Wabash Headwaters Region

Note: Winter and spring cumulative excess water availability are projected in increase in the future while Summer and Fall cumulative excess water availability are projected to decrease.

4.4 Water Availability Assessment Summary

In this section, the water availability, excess water availability, and cumulative excess water availability assessment is summarized for the historical and future periods. Key findings are highlighted (bold text) with additional discussion to provide context.

4.4.1 Historical Water Availability

The following key findings summarize the most relevant insights and observations from the historical availability assessment:

- **The upstream conditions as well as the specific characteristics of the sub-basin influence the water availability results.** In this region, there are two distinct groups:
  - Sub-basins crossed by tributaries to the Wabash River (Sub-basins 1, 2, 4, 7, and 9) and the headwaters of Wabash River (Sub-basin 3). In these sub-basins, cumulative excess water availability is lower as there are no other upstream sub-basins that contribute with additional flow to them and streamflows are smaller.
  - Sub-basins crossed by the Wabash River and with flood control reservoirs influence (Sub-basins 5, 6, 8 and 10). In these sub-basins, cumulative excess water availability is higher and excess water availability seasonal pattern is modified by the reservoirs operations.
- **Water availability, excess water availability, and cumulative excess water availability are all positive on an annual basis.** Positive water availability and excess water availability during the historical period suggests that water demands are generally smaller than the available water supply in all sub-basins throughout the Study Area on an annual basis. Sub-basins' water availability and excess water availability are relatively similar because overall water withdrawals and consumptive use are low compared to groundwater contributions to streamflow (natural baseflow) and minimum instream flow requirements throughout the study area. Cumulative excess water availability is also positive throughout the Study Area (see Sub-basin 10 values), highlighting the interconnection of sub-basins and the availability of water supply as a region.
- **While there may be opportunities for expansion of water use in the Wabash Headwaters Region, further evaluation should be considered to characterize "negative water availability" at the individual sub-basin level, at a seasonal level and downstream effect to North Central Region.** Both positive and negative excess water availability can occur on a seasonal basis within a given year depending on climate and hydrology. Thus, the evaluation of excess water availability is transient and whether water shortage or excess water occurs will depend on seasonal and annual conditions. Also, further analysis on the downstream effect on potential water use expansion to the North Central region needs to be considered.
- **Variability in water availability and excess water availability are generally driven by variability in natural baseflow conditions.** Natural baseflow conditions vary both seasonally and from year to year causing similar variability in water availability and excess water availability. During summer and fall months, and in drier years, when natural baseflow conditions are lower, the balance between supply and demand within the Study Area exhibits a much narrower margin creating negative water availability or water shortages in some sub-basins during some months. This variability is especially relevant in sub-basin crossed by tributary rivers (sub-basins 1,2, 4, 7 and 9) and at the headwaters of Wabash River (sub-basin 3).
- **During summer when river flows are low and water demand is high, the net return flows can represent a significant source of additional instream flows.** For example, in Sub-basin 4 Little-Huntington, the smallest sub-basin in the region, and in Sub-basin 3 Wabash-Linn Grove, the estimated net return flows represent in some months more than 40% of the observed streamflow. A case study for the Wabash River, indicated that during months of reduced flows, the upstream

volumetric flow of treated wastewater discharge is approximately equivalent to or greater than the entire volumetric flow of the Wabash River (Wiener et al., 2015).

- **Reservoir operations have a significant influence on seasonal water availability within the sub-basins that contain these reservoirs.** Flood-control reservoirs operated in Sub-basins 5 and 6 have a significant influence on seasonal water availability in these sub-basins due to the storage and release of water to meet reservoir operational criteria. Winter and Spring water availability tend to be lower in Sub-basin 5 and 6, as compared to other sub-basins, due to the reservoirs primarily storing water which negatively influences the water availability balance. Conversely, water stored during the Winter and Spring is generally released during the Summer and Fall months causing the water availability in sub-basins 5 and 6 to be relatively larger than other sub-basins.
- **Reservoir operations increase cumulative excess water availability in Summer and Fall seasons in downstream sub-basins.** Flood-control reservoirs in Sub-basins 5 and 6 sustain summer and fall season flows in downstream sub-basins increasing the cumulative excess water availability in these sub-basins.

4.4.2 Future Water Availability

The following key findings summarize the most relevant insights and observations from the future availability assessment:

- **Future cumulative excess water availability is generally positive in the future in all sub-basins.** Projected water demands are not expected to increase significantly throughout the study area into the future. Thus, the cumulative excess water availability is expected remain similar to historical conditions with some changes in seasonality due to changes in climate and hydrology.
- **Future cumulative excess water availability is projected to increase during winter and spring months and decrease during summer and fall months mostly driven by changes in natural baseflow conditions.** Due to changes in seasonal climate and hydrology, the summer and fall months are projected to exhibit less natural baseflow conditions throughout the study area. Decreases in summer and fall natural baseflow, during already low flow periods, presents the largest potential challenge in balancing water demands when water demands can make up a large percentage of streamflow during these periods. However, with the increase in winter and spring natural baseflow, there may be opportunities to better utilize reservoirs in the Study Area to help offset reductions in natural baseflow during the Summer and Fall months.
- **Winter and spring cumulative excess water availability is projected to increase across all sub-basins, except for Sub-basin 9 Deer Creek-Delphi where there is a small decrease in winter cumulative excess water availability.** Winter increases in cumulative excess availability range from 3% to 21%. Similarly, spring cumulative excess water availability is projected to increase across all sub-basins, with values ranging from an increase of 14% to 39%.
- **Summer cumulative excess water availability is projected to decrease across all sub-basins, except for Sub-basin 4 Little-Huntington and Sub-basin 9 Deer Creek-Delphi, which exhibit a small increase in summer cumulative excess water availability**. Summer decreases in cumulative excess water availability range from -3% to -20%. Fall cumulative excess water availability is projected to decrease across all sub-basins ranging from -11% to -32%

5 Water Quality

Water quality in the Wabash Headwaters study area is regulated federally by the EPA, and also by the states of Indiana and Ohio within which the region lies. The focus of this study is Indiana The, with EPA regulating treated drinking water quality through the National Primary Drinking Water Regulations, which looks for constituents grouped into six categories (Microorganisms, Disinfectants, Disinfection Byproducts, Inorganic Chemicals, Organic Chemicals, and Radionuclides) and has treatment rules for surface water and groundwater independently (Code of Federal Regulations Title 40, Section 141). These regulated constituents have a maximum contaminant level (MCL) and/or a treatment technique that public water utilities must implement to reach a level below the MCL. DEM uses EPA regulations as a basis for treated drinking water but has their own set of regulations around source water quality that is outlined in Title 327 of the Indiana Administrative Code (IAC). IAC standards and implementation are divided into three distinct categories: waters within the Great Lakes system, waters not within the Great Lakes system, and waters contributing to the mainstem of the Ohio River.

The EPA also oversees the Assessment, Total Maximum Daily Load (TMDL) Tracking and Implementation System (ATTAINS) program for evaluating and tracking the nation’s surface water resources. This program facilitates stream-segment assessments based on set criteria (such as *E. coli* and dissolved oxygen [DO] content) and classifies segments based on contamination in a ranking from 1 to 5 (305b, 303d, 314 CWA). Segments classified higher than 4 undergo a TMDL reduction process to improve water quality in the respective waterbody. IDEM developed a 2022 to 2026 Water Quality Monitoring Strategy per these federal requirements (IDEM, 2024a). This report describes state programs, such as the NPDES wastewater compliance program and the Nonpoint Source Pollution Program, and additionally outlines statewide maximum levels for contaminants in surface water and groundwater (Appendix A; IDEM, 2009). EPA requirements spearheaded the IDEM Watershed Management Plan program for handling TMDL requirements and addressing water quality concerns. The 2009 checklist developed water quality targets based on previous stream assessments for parameters of concern statewide, and can be found on IDEM’s website (IDEM, 2009). IDEM office of Water Quality also enhanced the groundwater monitoring program in 2016 with the Groundwater Monitoring Network (GWMN) program’s report, providing further insight into aquifer quality by testing existing wells.

Historically, the Wabash Headwaters Region has had water quality concerns related to the region emphasis on industrial and agricultural sectors. The Upper Mississinewa River previously had a TMDL violation in 2017 for *E. coli* and impaired biotic communities, and the Wabash River also had a violation in 2006 for *E. coli*, nutrients, impaired biotic communities, DO, and pH. The Wabash River TMDL established nitrate + nitrite and phosphorus targets for Indiana and Ohio (TMDL, 2006), though segments of the river still appear on the 303d impaired waterbodies list for Indiana.

5.1 Water Quality Characterization

Water contamination often starts on the land or in surface water bodies and travels through permeable surfaces to reach groundwater sources, making surface water and alluvial aquifers more susceptible to contamination than deeper aquifers. The study area has significant rivers, such as the Wabash River and Eel River, that are surrounded by freshwater emergent and forested wetlands (USFWS, 2024), specifically on the northern and southern regional borders. This increases the potential for, and intensity of, contamination impact.

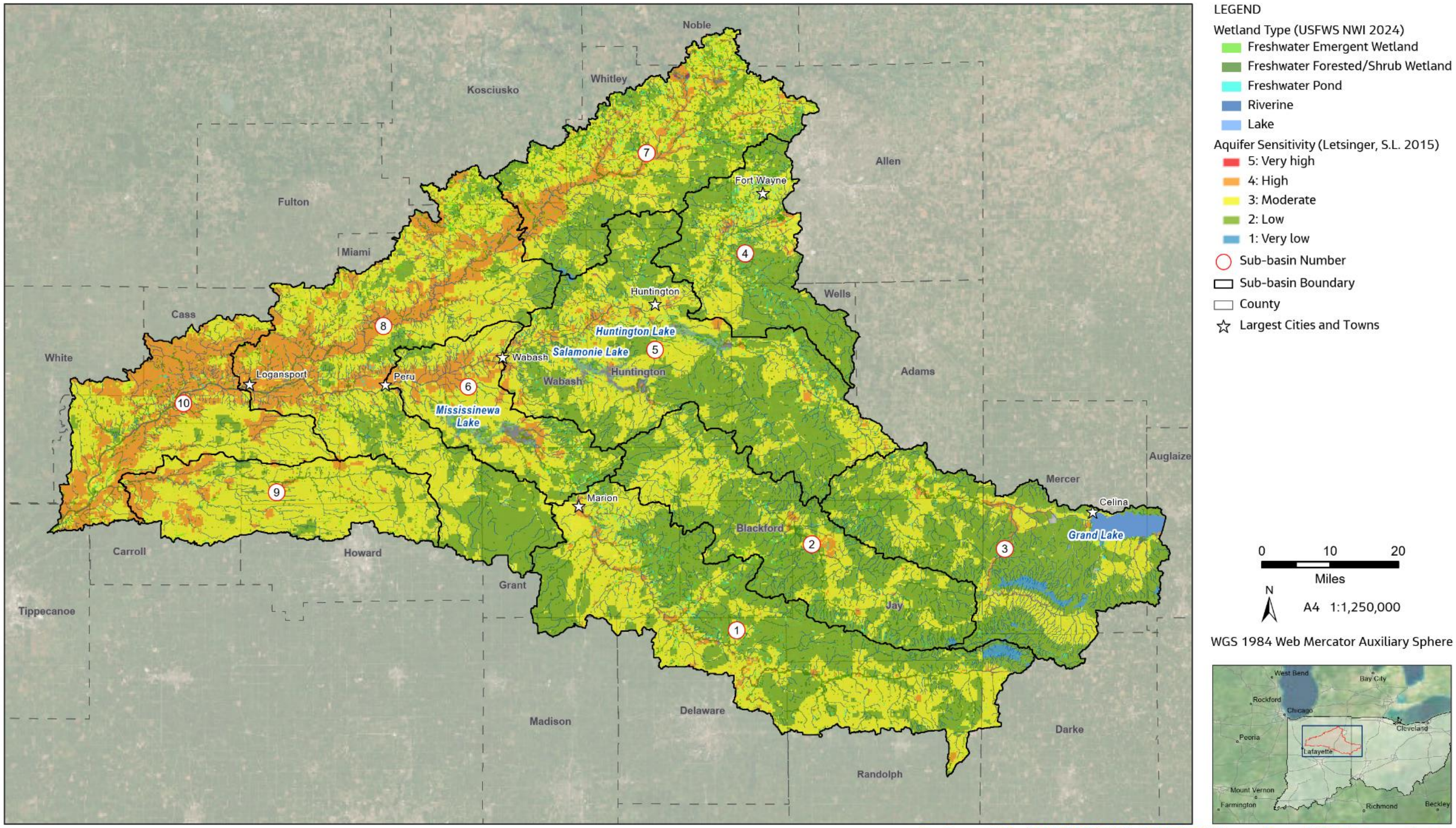
Sensitivity to groundwater contamination is related to the thickness and composition of the aquifer and any overlying material. Aquifers comprised of silts, sands, sandy clay, and sand and gravel materials can be vulnerable to contamination depending on the composition and thickness the overlying deposits and potential contaminant sources. Where thick deposits of clay-rich till overlay the aquifer, the recharge permeability is generally lower owing to this geologic barrier. Hydrogeologic settings corresponding to a shallow water table and highly permeable materials generally correspond to higher aquifer recharge and potential sensitivity to contamination.

Hydrogeologic settings such as surficial glacial outwash deposits, river or stream sediments, and natural lakes have a higher sensitivity to contamination because they tend to have a higher hydraulic conductivity and minimal confining units above to protect from pollution sources. barrier to migration of contaminants from the surface. Vulnerability may be correlated to aquifer recharge, or the rate of water per unit area infiltrating the aquifer from the land surface. Hydrogeologic settings, aquifer vulnerability, and sensitivity were evaluated throughout the study area to compare with contamination sources and potential risks for the Wabash Headwaters. Aquifer sensitivity was visualized for the study area according to aquifer recharge in inches per year and is displayed on Figure 5-1.

The near-surface unconsolidated and bedrock aquifers in the region range in aquifer sensitivity risk to contamination range from moderate to high, and from low to moderate, respectively. Where unconsolidated aquifers have a thick upper barrier or clay-rich confining layer, like in the eastern portion of the study area, sensitivity decreases. The western portion of the study area has shallower aquifers and greater river connectivity, which corresponds to an overall higher sensitivity. Bedrock aquifers in the region vary in terms of sensitivity depending on their depths and confined status, which correlates to the thickness of overlying sand and gravel deposits and local aquifer recharge characteristics but tend to be on the lower side of the sensitivity index.

5.2 Water Quality Sampling and Testing Results

Surface waterbodies were recently evaluated in the 2024 EPA ATTAINS assessment. In Indiana, this resulted in numerous “impaired waterbodies” based on elevated levels of various constituents. Specifically, stream segments in the study area received categories 4A, 4C, and 5 (most impaired or contaminated) for ammonia, biological integrity, chloride, DO, nutrients, phosphorus, and zinc (EPA, 2024). Habitat alteration, as well as the presence of sulfur, pesticides, sedimentation, and selenium in fish tissue were not detected during the surface water assessment. The mainstem of the Eel River running from western Sub-basin 10 Wabash-Ungauged to northeastern Sub-basin 7 Eel -North Manchester was classified as a Category 5 (significantly impaired). Mainstems of the Wabash River, Salamonie River, and Mississinewa River were also found to be significantly impaired. Figure 5-2 shows all the assessed surface waterbodies and their respective 303d listing categories.



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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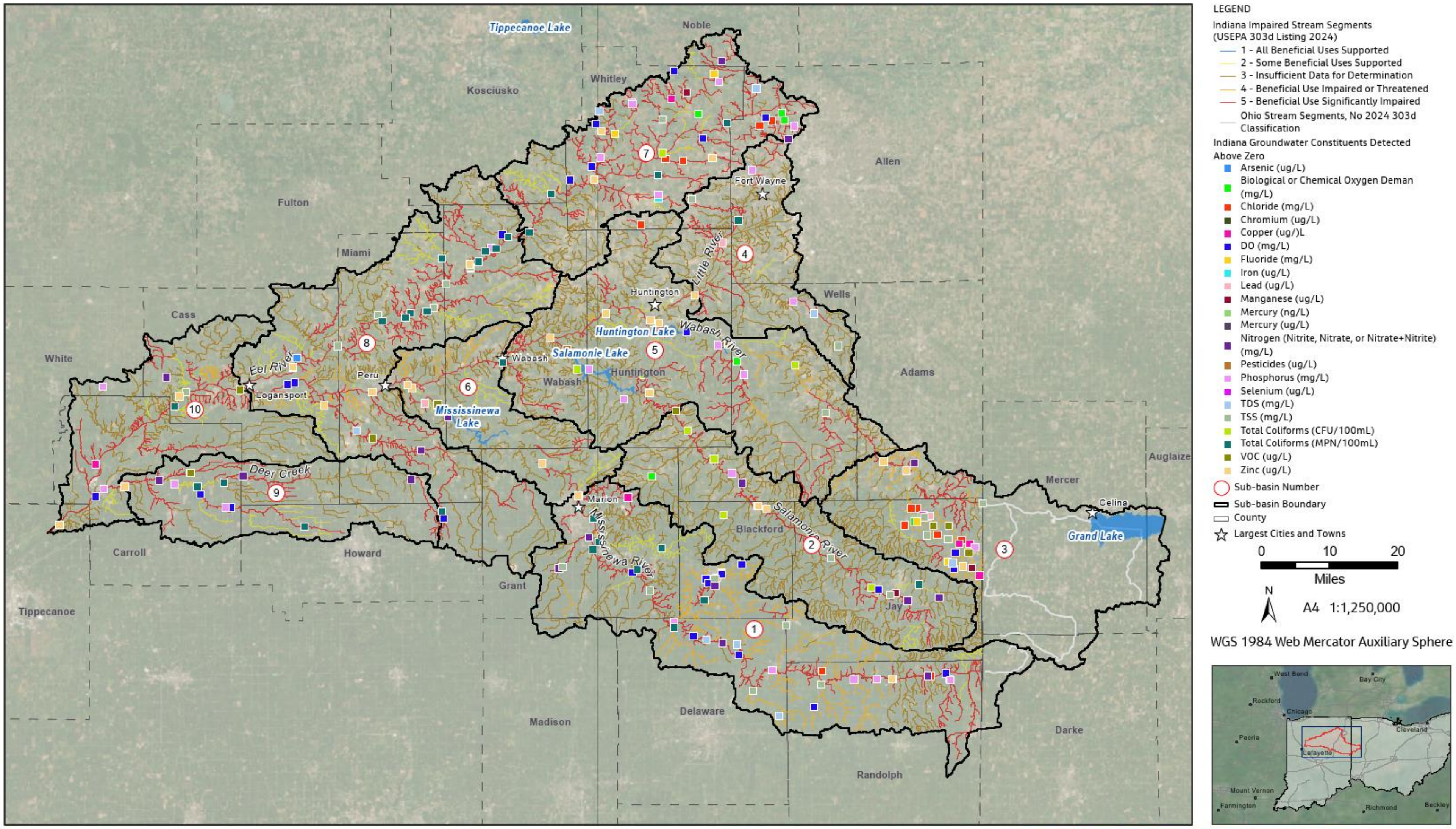
Figure 5-1. Aquifer Sensitivity and Wetlands



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\\ausyd0vs01\GISProj\US_Wabash\Apps\Wabash_Mapping_v3.aprx/EEXM100_Wabash_F021_WQImpairedWaterbodiesAndContamLocs_v05 | Date: 19/12/2024

Figure 5-2. Impaired Surface Waterbodies and Detected Groundwater Constituents in the Wabash Headwaters Region

Findings are summarized as follows:

- **Biological Integrity:** 119 counts of impaired segments ranging across 10 counties in the study area and majority of the major river systems. This is likely due to other constituents causing a risk to biological integrity. Rivers include the Blue, Eel, Mississinewa, Salamonie, and Wabash and many associated creeks and lakes.
- **Chloride:** Three counts of impaired segments in Grant County, including a specified drainage ditch and two segments of the Salamonie River.
- **DO:** 27 counts of impaired segments across six counties in various ditches and unnamed tributaries. There are no main rivers or lakes, so this likely corresponds to wastewater outfalls and drainage creeks.
- **Nutrients:** 97 counts of impaired segments across nine counties, including Huntington Lake, Mississinewa River, Salamonie River, Wabash River, and various unnamed tributaries and drainage creeks. This corresponds to nitrogen content in the waterbody, likely related to agricultural operations.
- **Phosphorus:** 14 counts of impaired segments, all in Carroll County and all are for lakes or reservoirs.
- **Zinc:** Two counts of impaired segments on the Mississinewa River and Wabash River in Wabash and Huntington counties, respectively.

Groundwater is routinely evaluated through Indiana's GWMN through random sampling of residential drinking water wells and a small portion of non-community public water supply. Data was collected from 2008 to 2021 and evolved to focus on specific areas of the state with known contamination issues, like arsenic. The GWMN program no longer functions as an ambient groundwater assessment tool for discovering new contaminants, and currently works as a project-based sampling program. The 2016 GWMN results indicated the region has water quality issues with arsenic, iron, nitrogen (nitrate-nitrite), and pesticides (IDEM, 2016). Pesticides included are as follows: acetochlor ethane sulfonic acid (ESA), acetochlor oxanilic acid (OA), alachlor ESA, alachlor OA, metolachlor ESA, and metolachlor OA, which must be below EPA's MCL of 10 micrograms per liter (µg/L). Table 5-1 displays key 2016 and historic GWMN results compared to regulatory limitations. Figure 5-2 displays the sampled and tested constituents within the project area for the GWMN sampling (2008-2021).

Table 5-1. Indiana Department of Environmental Management Groundwater Monitoring Program Results

Constituent (Unit)	EPA Drinking Water MCL	2016 Indiana GWMN Results	Historic Range of Indiana GWMN Results
Arsenic (µg/L)	10	1 to 53.70	1.0 to 8.60
Iron (µg/L)	300 [a]	0.02 to 9.80	59 to 29,400
Lead (mg/L)	0.015	1.0 to 43.10	1.04 to 8.0
Manganese (µg/L)	N/A	0.01 to 75.0	39 to 500
Nitrogen, nitrate-nitrite (mg/L)	10	0.01 to 6.40	0.012 to 21.40
Pesticides (ug/L)	10	0.1 to 1.80	0.1 to 8.10
Phosphorus (mg/L)	0.3[a]	N/A	0.03 to 7.34
VOCs (µg/L, ppb)	0.3	0.01 to 7.50	0.1 to 7.40

[a] Limits from Indiana Department of Environmental Management 2009 water quality targets for source water, not EPA drinking water limitations (IDEM, 2009)

[b] The range represents the lowest and highest values for each parameter from 2008 to 2021.

µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
N/A = not applicable
ppb = part(s) per billion
VOC = volatile organic compound

Utilities in Indiana also conduct sampling and testing for harmful chemicals in treated drinking water supplies and surface waterbodies. Per- and polyfluoroalkyl substances (PFAS) are a class of synthetic organic chemicals containing fluorine that may have adverse health effects. IDEM completed a four-phase sampling and testing campaign of PFAS in public water utilities throughout the state from March 2021 to April 2024 (IDEM, 2024d). The phases were divided based on population served, with the final phase testing surface waterbodies. Refer to the results in Table 5-2 within sub-basins within the study area.

Public water utilities have expressed water quality concerns other than PFAS, such as biological oxygen demand (BOD) loading, iron, and manganese in surface waterbodies. Generally, these water-quality issues are removed during the drinking water treatment process; however, utilities in Grant County, have noted challenges in treating for elevated levels of iron and manganese in the source water in their respective Preliminary Engineering Reports or PERs (Commonwealth, 2023; Wessler, 2019). Other utilities in counties, such as Huntington, Howard, Jay, Wabash, and Wells, have noted higher BOD loading corresponding to groundwater contamination. Huntington and Howard Counties, in particular, have many industrial dischargers, and this industrial wastewater effluent may have higher BOD loading discharge from other users. Utilities in Wabash and Wells Counties have noted that combined sewer overflows and failing septic systems have an adverse impact on groundwater contamination and BOD loading. A utility in Jay County noted NPDES permit violations of BOD loading. And challenges in Huntington County regarding an industrial chemical spill have resulted in a search for collaborative regional solutions. These examples, combined with the 2024 Impaired Waterbodies List results and groundwater monitoring sampling results, help to identify multiple potential sources of contamination.

Table 5-2. Public Water Service Utility PFAS Sampling Results in the Wabash Headwaters

Sub-basin	Sample Collected (Date)	PFAS Detected in Surface Water	PFAS Detected in Treated Water	PFAS Results above EPA Health Advisory Level
1	6/16/2021	Yes	No	No
	7/28/2022	Yes	No	No
5	5/9/2022	Yes	No	No
7	9/14/2021	Yes	Yes	No
8	6/13/2022	Yes	Yes	No
8	5/8/2023	Yes	Yes	Yes
	2/26/2024	Yes	Yes	Yes
9	6/19/2023	Yes	No	No
10	2/14/2022	Yes	Yes	Yes
	6/5/2023	Yes	Yes	Yes
10	2/15/2022	Yes	Yes	Yes

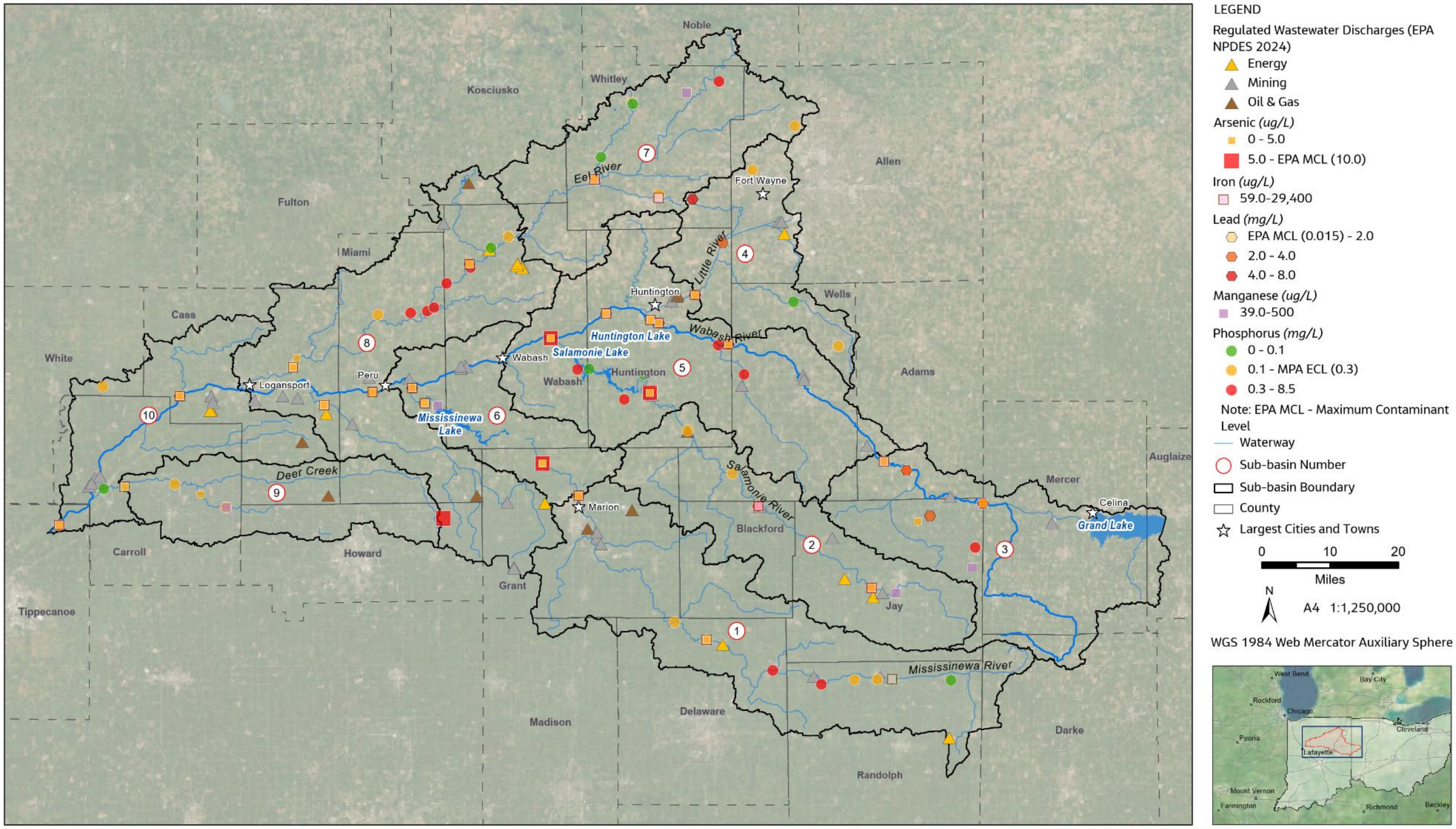
5.2.1 Sources of Contamination

According to the 2024 State Water Monitoring Report, human-generated wastes, including failing septic systems and landfills, can cause spikes in nitrate levels. The report also indicates that man-made activities and substances, such as underground injection wells, industrial activities, CFOs, oil spills, road salts, and fertilizers, are the main sources of groundwater contamination (IDEM, 2024a). Contamination in the Wabash Headwaters study area may be classified into three categories: pollution from natural and anthropogenic processes, human-generated waste streams and products, and agricultural waste streams.

Some natural and anthropogenic sources of surface water and groundwater contamination are natural sediment erosion and deposition due to changing geography, oil and gas production, and mining operations. These processes can correspond to elevated levels of arsenic, iron, and manganese. Arsenic may be caused by natural infiltration of water, the dissolution of minerals from clay soils which naturally occur in aquifers, the erosion of rocks, or as byproducts of industrial activities (such as wood preservation, mining, and smelting). Other constituents, such as manganese and phosphorus, are often byproducts of industrial activities and can form in water sources downstream from respective industrial activities. Figure 5-3 displays the regulated wastewater outfalls (EPA, 2024) for oil and gas, energy production, and mining with respect to various constituents from the historic IDEM GWMN data. Downstream of the outfalls on numerous waterbodies, such as Mississinewa River, Eel River, and Wabash River, there are elevated levels of phosphorus, lead, and arsenic.

Human-generated waste streams and products may cause increases in *E. coli* bacterial concentrations, higher BOD loading, and nitrogen spikes in some source waters. Wastewater effluent from combined sewer overflows, wastewater treatment plants (WWTPs), water treatment plants, wastewater retention ponds or waste stabilization ponds, and biosolids/landfill-application facilities, can infiltrate or migrate into the subsurface as groundwater and cause elevated levels of these constituents. Many of the surface waterbodies listed on the 303d impaired waterbodies list have elevated nitrate-nitrite levels and VOCs, as displayed on Figure 5-4. Nitrate-nitrite could be caused by runoff from agricultural fertilizers, septic tank leakage, insufficiently treated sewage, or naturally from the erosion of natural geologic deposits. These constituents can cause serious harm to the native ecosystem and the biological integrity of the systems if levels are allowed to remain elevated without restrictions or remediation.

Agricultural sources of contamination include livestock operations, such as CAFOs and CFOs, as well as pesticide usage. Pesticides are used to control broadleaf and grassy weeds in corn and soybean production in the study area (IDEM, 2016). Figure 5-5 displays the feeding operations and pesticide levels in the project area.



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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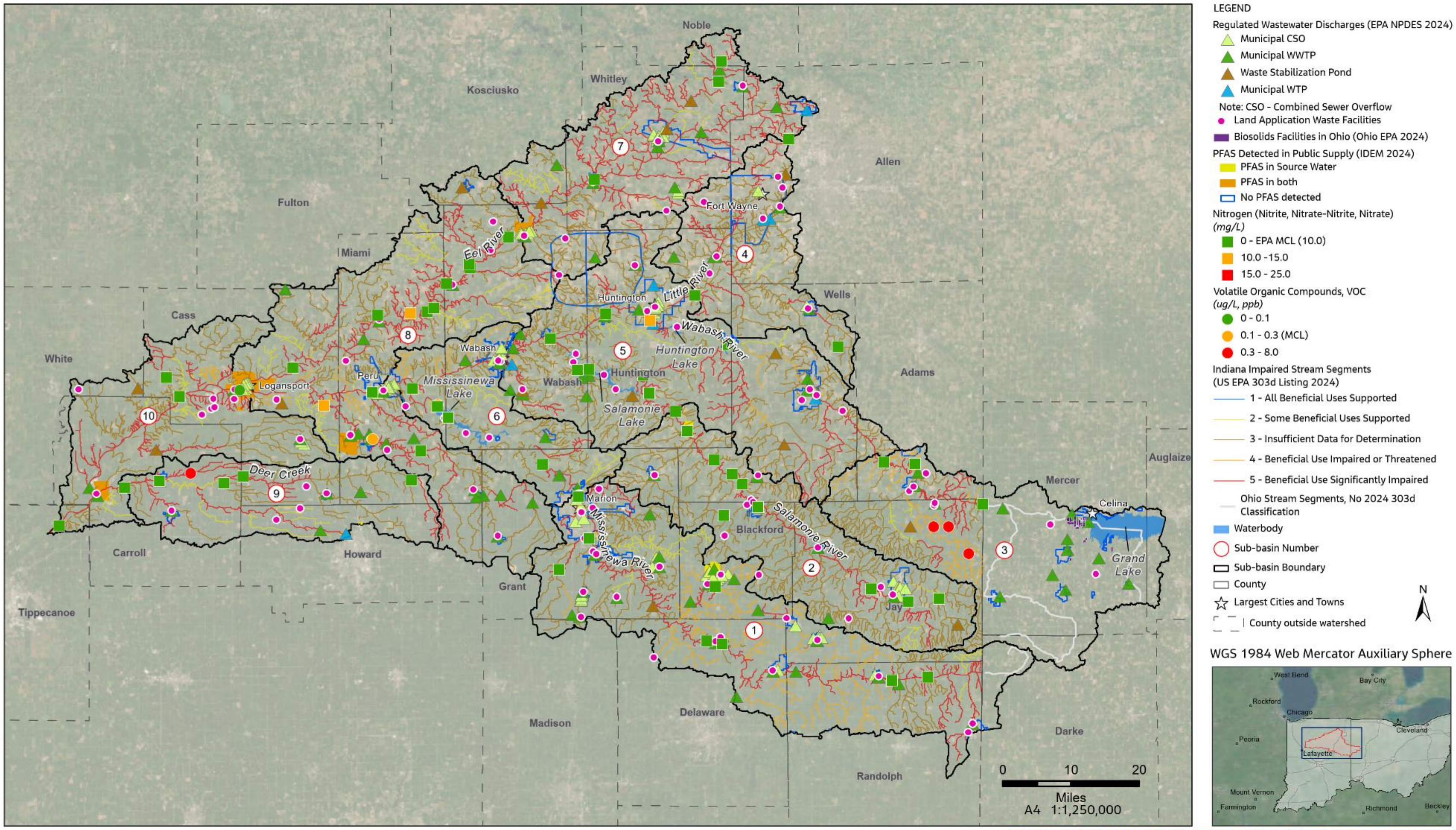
Figure 5-3. Natural and Anthropogenic Sources of Contamination in the Wabash Headwaters Region



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
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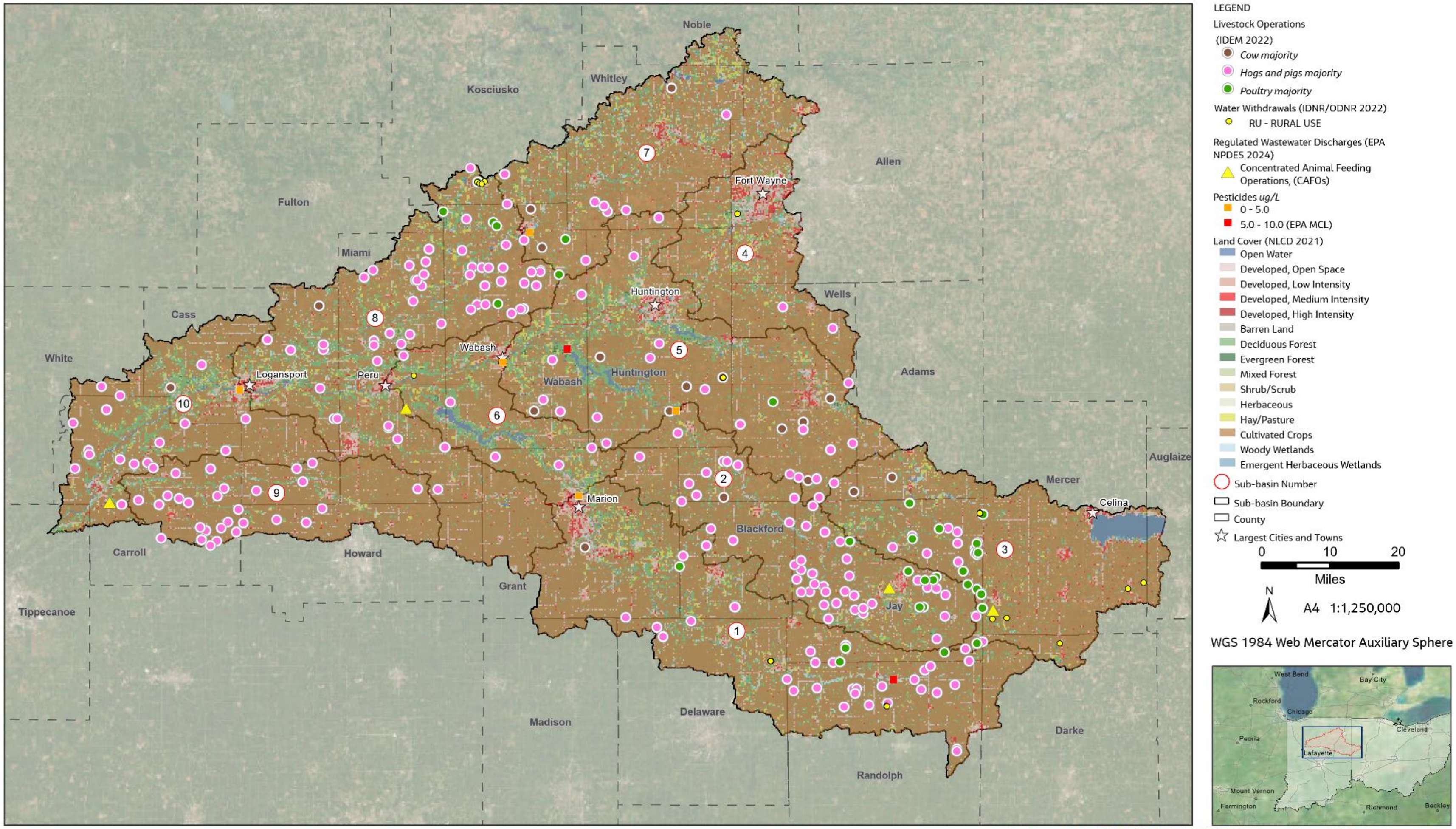
Figure 5-4. Waste Sources of Contamination in the Wabash Headwaters Region



Data Sources: IN Gov (2024), TIGER (2024), JACOBS (2024); Imagery Sources: ESRI Online Imagery Services
\\ausyd0vs01\GISProj\US_Wabash\Apps\Wabash_Mapping_v3.aprx/EEXM100_Wabash_F024_WQAgriculturalSourcesOfContamination_v06 | Date: 28/11/2024

Figure 5-5. Agricultural Sources of Contamination in the Wabash Headwaters Region

5.2.2 Water Quality Monitoring Programs

The state of Indiana is actively engaged in the EPA's Nutrient Scientific Technical Exchange Partnership & Support (N-STEPS) program, aimed at to reducing nitrogen content in source waters, as well as the dissolved reactive phosphorus and continuous DO programs, aimed at reducing these constituents statewide (IDEM, 2024a). In addition to the surface water and groundwater monitoring programs discussed in the section overview, the state has the following active contamination control programs:

- NPDES Wastewater Permitting Program
- Stormwater Permitting
- Total Maximum Daily Load Program and Watershed Characterization Program for TMDL development
- Nonpoint Source Pollution Program
- Monitoring: Probabilistic, Fixed Station, Contaminants, Performance Measures
- Wetlands Program

Indiana has identified the Wabash Headwaters as a priority area to reduce nutrients loads, per Section 319 of IDEM office of Water Quality watershed priorities. The Indiana State Department of Agriculture also outlined a nutrient reduction strategy statewide, with localized measures for specific watersheds (ISDA, 2021).

6 Risks, Uncertainties, Opportunities, and Recommendations

This study documents historical and forecasted water demand and supply availability with the Wabash Headwaters study area. Conducing historical analysis and forecasting water demand and supply availability over a 50-year period has inherent risks and uncertainties. In addition, data gaps for which assumptions were made incorporated some degree of uncertainty. While reviewing water availability results, opportunities and recommendations were identified to improve the water supply analysis and water supply forecasts aiming to mitigate risks and reduce uncertainties. The risks and uncertainties, as well as opportunities and recommendations, are presented in this section as follows:

- Overall Risks and Uncertainties
- Water management and planning
- Data and technical considerations

6.1 Overall Risks and Uncertainties

Planning for the future water security and reliability includes inherent risks and uncertainty. Some of major risks and uncertainties include:

- **Water demand increases resulting from future economic and population changes increasing water demand:** This study used rigorous methods to estimate future demand through 2070; however, various factors could influence actual water use in the future such as significant changes to economic influences that could result in increased water demand in the agricultural and industrial sectors or increases in population that could result in increased demand for public water supply and self-supplied residential users. While not analyzed in this study, increased water use could have implications for additional (or expanded) infrastructure.
- **Seasonal source water supply availability:** While the results of the study analyses indicate no significant negative water supply availability generally throughout the region in annual basis, there is the potential for limitations on surface or ground water availability on a seasonal basis, especially during dry years and sub-basins without upstream sub-basins that contribute with additional flow to them and with smaller streamflow. Also, in smaller sub-basin net return flows during summer when river flows are low and water demand is high, the net return flows can represent a significant source of additional instream flows. For example, in Sub-basin 4 Little-Huntington, the smallest sub-basin in the region, and in Sub-basin 3 Wabash-Linn Grove, the estimated net return flows represent more than 40% of the observed streamflow. A case study for the Wabash River, indicated that during months of reduced flows, the upstream volumetric flow of treated wastewater discharge is approximately equivalent to or greater than the entire volumetric flow of the Wabash River (Wiener et al., 2015). Appendix D presents seasonal water availability results by sub-basin.

  The season water supply availability could represent a regional risk if future demand increase beyond what is forecast in this study, supplies are reduced based changing hydrology or if reservoir operations with the study area change to manage potentially different flooding conditions in the future.

- **Climate change**: Observed temperature and precipitation trends are different over the last few decades as compared with longer-term historical trends. This study used results of a climate change scenario for the State of Indiana (Cherkauer et al., 2021) to forecast potential changes in water demand and supply availability. As presented in Appendix B, other climate futures are possible which could change both future water demands and supply availability.
- **Water quality:** The Wabash Headwaters Region includes many impaired surface water resources (those with water quality below minimum standards). If the water quality trends continue, costs of water treatment could increase and requirements for effluent discharge quality standards could become more stringent. Additionally, there are localized public water systems within the study area that are currently unable to meet drinking water quality standards with their existing treatment plants.

6.2 Water Management and Planning

Considerations water management include opportunities for water use efficiency (conservation), seasonal water availability, existing reservoir operations, water quality and climate variability.

6.2.1 Water Demand Projections and Water Use Efficiency (Conservation)

As presented in detail in Section 3, water demand is influenced by many factors, including the type of use, weather conditions, changes in the population and economy, and water use efficiency. Understanding the influence that each factor has on water demand and consumptive use represents an opportunity to increase water use efficiency in the region.

Demand forecasts presented in this study rely on data, assumptions, and analysis regarding future conditions. As presented in Appendix C, future demand will be influenced by long-term and annual rainfall and temperature variations; however, exactly what climate conditions will exist in the future is unknown. Other uncertainties include the actual rate of population change which generally is forecasted to decrease throughout most of the study area, and the potential for development of new water-intensive industries and increases in agricultural irrigation and livestock production. Based on the demand model results, the population growth rate showed the highest influence on the demand projections for public water supply which is one of the top two water demand sectors in the study area.

Some considerations related to water demands:

- <u>Water Loss and per person (gallons per person er day water use:</u>
    - Considering the USGS per person estimates for water use within the study area of 76 GPCD (Dieter et al., 2018), water use for self-supplied water users is on the lower end of water demand when compared to the national average.
    - Review of preliminary engineering reports (PERs) that were submitted as part of state-revolving fund loan applications indicates per capita water uses higher than USGS estimates in many of the public water system. That would be expected as public water supply systems often serve commercial and industrial customers in addition to residential users. Utility water audits are required in Indiana, which is an important step in understanding water use and opportunities for improvement. A review of water loss audits obtained from IFA for this study (IFA, 2022) indicates that public water systems are losing between 8% and 66% of their water supply to system losses.

  - Many utilities in the region would benefit from a water loss prevention program to increase system efficiency. The differences between water produced (either raw water at the source or treated water at the plant) and water sold to customers could be a result of real losses through leaks or apparent losses, such as data errors or unmetered water use. Water loss programs that focus on finding and fixing leaks, as well as enhancing customer metering and billing, can reduce utility expenses for items such as power and treatment chemical costs. These programs often increase revenues due to more accurate metering.
  - While water withdrawals and consumptive use for public systems, irrigation, and other uses are relatively small in comparison to baseflow, instream flow, and net reservoir releases within the study area, most utilities have increased water use during the summer resulting from outdoor watering. Better characterization of seasonal water use trends associated with public utilities can help to anticipate seasonal water availability and identify potential water shortages on a seasonal basis.

Recommendations regarding water demand and water use efficiency include the following:

- Expand funding and technical assistance for water loss prevention programs to include main replacement, advanced metering, and similar investments, especially for small utilities.
- Consider local policies and programs to reduce outdoor water use, including lawn watering sprinkler ordinances or incentives for installation of low water using landscapes and irrigation systems.

6.2.2 Seasonal Water Availability and Additional Storage

Water withdrawals and consumptive use are relatively small in comparison to baseflow, instream flow, and net reservoir releases throughout the study area. The seasonal water supply balance within some sub-basins shows negative water supply availability (deficit); however, this does not mean that there is no water in the rivers and creeks. Rather, it means that the sum of demands (water withdrawals for human needs and minimum instream flows to meet environmental needs) is greater in some sub-basins than supply availability within that sub-basin. When inflows from upstream basins are added to those generated within a sub-basin, seasonal average excess availability (referred to as cumulative excess water availability) occurs in all of the sub-basins, except from sub-basin 5 and sub-basin 6.

In smaller sub-basin net return flows requirement play an important role in the water supply water balance. Even though the net return flows represent a small portion of water availability, during summer when river flows are low and water demand is high, the net return flows can represent a significant source of additional instream flows.

Average annual deficits are not forecast for future human water demand but some potential deficit during drought years. Risks associated with seasonal water availability and drought years appear to be manageable. If they occur in the future as a result of changed conditions, small storage alternatives could be constructed to supplement seasonal needs.

Recommendations regarding seasonal water availability and storage include the following:

- Consider measures to reduce seasonal consumptive use for outdoor watering within public supply systems and for large irrigation users as an initial first step to reduce seasonal use.
- Evaluate the potential for aquifer storage and recovery near water demand centers in the event that additional storage is needed in the future.

- Refinement of net return flows to gain additional insight for potential mitigation measures in small sub-basins for seasonal and drought potential negative excess water availability.

6.2.3 Existing Reservoir Operations

Operation of stored and released water from the three reservoirs included in this study (Mississinewa, Salamonie, and J. Edward Roush Lakes) influence water availability in the mainstem of the Wabash River within the study area, as well as the downstream region known as the North Central Indiana Water study area. During fall and winter seasons, water is released from the reservoirs to provide storage capacity to capture flood flows, resulting in flows being available for water use diversion and for meeting instream flow needs. During the spring and summer seasons, water generally is kept in the reservoir to maintain lake levels and support recreation.

Water supply availability is sensitive to reservoir operations. Given the influence of net reservoir releases on flows throughout the mainstem of the Wabash River, any change in operations could have a positive or negative effect on surface water supply availability to meet human and environmental needs. For example, if significant volumes were to be diverted from the reservoirs to provide water supply for utilities, industries, or other uses, downstream flows would be affected. The significance or impact of such a reduction has not been evaluated.

The reservoir net flow releases have a significant influence on the timing and magnitude of streamflow. The current approach for the net flow releases may not accurately consider reservoir evaporation, direct water deliveries from the reservoir (if applicable), and infiltration through channel losses. Also, the travel time from the reservoir to the measuring point at the basin outlet was not taken into consideration.

In addition, if the frequency, intensity, or duration of flooding increases over time because of climate change, the historical patterns of storage and releases will change to meet the authorized purposes of the reservoirs for flood management and recreation. The significance or impact of altered future operations to manage changes in flood conditions have not been evaluated.

Recommendations regarding reservoir operations include the following:

- Develop a reservoir operations model to perform a comprehensive reservoir water balance to incorporate evaporation, precipitation in the reservoir, and other losses to improve accuracy as well to facilitate analysis impact of climate change and optimization scenarios that affect flooding and the volume, rate, and timing of downstream releases.
- Assess the condition and design of the existing dams to determine the potential of storing additional water during some seasons or conditions. If the dams can accommodate a potential change of operations, study the potential reallocation of the stored water to meet future downstream demand and instream flow needs.
- Evaluate variations of operating rules and forecast-informed reservoir operation regimes to determine the potential for meeting the authorized purposes of the reservoirs and downstream needs throughout the Wabash River basin.

6.2.4 Water Quality

As discussed in Section 5, the study area has significant surface water resources that provide an important resource for drinking water and ecosystems. Groundwater resources in the study area, while seemingly plentiful, are extremely variant in unconsolidated aquifer layer thickness and thus have sensitivity to surface water infiltration, groundwater seepage, and potential contamination. Numerous wetlands occur throughout the study area and allow for high aquifer recharge and access to the regional groundwater table which is at risk of contamination from human-generated waste sources (for example, septic systems, landfills) and agricultural runoff (for example, farming, pesticides).

Elevated nitrogen, BOD, phosphorus, and other constituents may put the biological integrity of foundation water resources at risk long-term. The Salamonie River has already experienced fish decline because of industrial wastewater discharge in areas such as Jay County (Jones & Henry, 2016), and could become more frequent and intense in other rivers and lakes as well without proper regulations.

Other contaminants such as PFAS, VOCs, elevated levels of iron and manganese may require additional investments in drinking water treatment processes. Localized areas within the study area have some water quality concerns that affect drinking water supply. For example, Huntington County has a well-documented case of groundwater contamination that is a public health and economic development concern.

Recommendations regarding water quality include the following:

- Continue water quality monitoring and assessments.
- Conduct pilot tests of various best management practices that reduce need for application of pesticides and fertilizers and reduce run-off throughout the Wabash River Basin.
- Consider incentives to encourage landowners to increase their voluntary participation in watershed management and protection plans.

6.2.5 Climate Variability

Historical data show slightly increasing temperatures for the study area. From 1980 to 2022, daily high temperatures have increased at an average rate of 0.026°F per year, and daily low temperatures have increased at an average rate of 0.042°F per year. Since 1980, an upward trend in precipitation has been observed in the study area. Annual precipitation values by sub-basin for the years 1980 through 1990 ranged from 38 to 39 inches. Since then, annual precipitation has increased to 41 to 42 inches from 1995 to 2005, and then 44 to 45 inches from 2010 through 2020. Modeling indicates that trends could continue, with anticipated changes in the seasonal distribution of rainfall. Furthermore, increased temperatures are expected to increase evaporation from soils which could affect agricultural production and irrigation requirements (Widhalm, 2018).

The baseline scenario used for forecasting water demand and water supply availability for this study included one potential future climate condition. Other climate models were used to assess the potential impact on future demands as presented in Appendix B. While they are helpful to understand potential risks to water supply, these projections include a significant amount of uncertainty and may not show the full range of potential future conditions.

Recommendations regarding climate variability include the following:

- Develop and incorporate high-resolution climate models into future water planning studies with more complete analysis of multiple climate scenarios.
- Consider adaptation strategies to prepare for potential futures and extreme weather events that could increase demands or affect water supply availability.
- Conduct detailed studies on potential changes in floodings and potential effects on reservoir operations that could impact water supply availability throughout the Wabash River basin.

6.3 Data and Technical Enhancement Opportunities

A substantial amount of historical data is available regarding water demands for significant water users, permitted discharges, gauged stream flow and climate data. However, some data gaps were identified that required development of assumptions and calculations. Additionally, water availability estimations could be improved over time with additional field verifications.

6.3.1 Data Collection

As previously noted, Indiana has a significant amount of data regarding water use and discharges that incorporated into this study. Historical demand estimates were prepared for several water use sectors within the region, including self-supplied residential and rural users such as small livestock operations. For example, estimates were generated using assumptions regarding livestock populations and water use per type of animal. Given the rural nature of the study area and the relatively large water demand for rural users, future water demand analyses and forecasts would be improved if more usage data were available. Similarly, data gaps in historical demands of some significant water users were identified requiring the use of assumptions to complete the estimate.

Similarly, general assumptions were made for the fraction of extracted water that is returning to the system to estimate the proportion of consumptive water use. Additional monitoring and studies to validate return flow rates and time lag of those flows, especially for municipal and industrial users that represent over 70% of total water withdrawals would improve future analyses.

Recommendations regarding water demand and water use efficiency include the following:

- Update demand forecasts periodically, perhaps every 5 to 10 years following publication of U.S. Census data, to identify changes between forecasted and actual use.
- Establish policies to require well registration and usage reporting for users beyond those in the Significant Water Withdrawal Facility database would improve the accuracy of demand forecasting and, thus, water supply availability.
- Collect additional information from large wastewater treatment plants to validate assumption of return flows.
- Refine the NPDES database to include information on combined sewage overflows regarding the contribution from rain events that contribute to discharge volumes.

6.3.2 Minimum Instream Flow Requirement Estimates Follow-On Studies

Water availability is estimated by subtracting minimum instream requirements from baseflow. Thus, accurate estimates of the instream flow requirements are not only relevant for maintaining riverine ecosystem health and water quality, but also for obtaining accurate estimates of water availability.

The approach used to estimate minimum instream flow requirements is purely statistical and does not consider physical mechanisms such as magnitude, frequency, timing, and duration of flows regimes critical for biological and ecological function. There are other alternatives that could be considered, such as habitat simulation methods, that model the relationship between flow, habitat availability, and species' needs by integrating hydrologic and biological data. For r example, the Texas Instream Flow Program conducts scientific studies to collect field data to better understand flow and timing requirements for fish and wildlife. Field data were incorporated into a models used to development regulatory requirements for water right administration and planning (TWDB, 2024). These studies and models are data-intensive and time consuming but could be a justified investment in sub-regions where some potential water supply shortage has been identified, where there is a known issue of water quality (impaired water bodies presented in Section 5), or threatened species.

Recommendations regarding instream flows include conducting studies to estimate the biological and ecological requirements for riverine habitats within the study area, including assessment of total, base, and pulse flows needed for the ecological health of the system.

6.3.3 Water Availability Estimation Refinement and Validation

The methodology used for the study resulted in a significant advancement of understanding of the water supply availability for the Wabash Headwaters region and sub-basins' characteristics . However, there are uncertainties associated with each component that could be addressed with additional monitoring or field validation, modeling, and analysis.

Groundwater represents approximately 70% of the region's total water use in 2022, and is the primary source for all water users except for industrial users. Typically, alluvial aquifers are utilized by most users within the study area due to their relatively shallow depths compared with deeper bedrock aquifers. As stream baseflow is derived from groundwater discharge, contributions to streamflow from groundwater could be further assessed to better understanding of groundwater and surface water interactions, and the influence of pumping on this interaction, is crucial for water supply planning efforts at the sub-basin and regional watershed scales.

In this study, the estimated natural baseflow represents groundwater contributions to streamflow and is the primary water supply component of water availability. The natural baseflow is estimated using the hydrograph separation approach which assumes actual surface water and groundwater interactions are accurately captured across the study area and take place instantaneously; where travel time is not considered, and actual contributing volumes are not measured. While this is a reasonable approach given the geology throughout much of the study area, there is a risk for underestimating or overestimating the natural baseflow, not capturing geological differences within sub-basins, and not capturing potential streamflow depletions due to groundwater pumping. The baseflow index (the ratio of baseflow to streamflow), varied from 0.24 to 0.52 within sub-basins, with an average of 0.39.

Additionally, the Wabash River was divided into two planning regions just upstream of the confluence with the Tippecanoe River at an ungauged location. Therefore, several components, including natural streamflow, net return flows, net reservoir release, net baseflows, and instream flows were calculated. Installing a stream gauge just upstream and downstream of the confluence would help to validate the analysis. There may be other localized areas where physical validation of the model would be useful as part of a future study.

Another consideration for future water studies once this cycle of studies is complete could be to develop a multi-year statewide program to develop river basin-wide models to simulate flows stream flows and groundwater recharge. Building on the input data sets developed for this study and other regional studies, additional inputs could be developed such as flow rates and travel times, evaporative losses, and control points where significant discharges, withdrawals or tributaries occur. Including reservoir operations modules would be particularly useful within this study area as well as downstream in the Wabash River basin due to the influence of operations at the existing reservoirs on the surface water hydrology.

Incorporating physical modeling inputs from models such as the Variable Infiltration Capacity model (Hamman et al., 2018) used in the Indiana Climate Change Study (Cherkauer et al., 2021). Such future model enhancements could facilitate simulations of “what-if” scenarios for potential new withdrawals or infrastructure and should be prioritized for those regions expected to have water shortages in the future. Also, historical datasets from this study could be used to calibrate future models and develop a future planning scenarios.

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