

A mesonet station in Howard County, Indiana

# Indiana's Water Monitoring Network A Strategic Path Forward



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A Strategic Path Forward

Prepared for the Indiana Finance Authority by the White River Alliance

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# **Executive Summary**

Indiana's water resources are essential to economic development, public health, and environmental sustainability. The state's water monitoring network is the primary mechanism for understanding these resources and working toward more coordinated water resource management in the future. Commissioned by the Indiana Finance Authority (IFA) and conducted by the White River Alliance, this report evaluates the existing network, identifies key gaps, and proposes strategic improvements to ensure long-term water sustainability and informed decision-making.

#### **Key Findings**

Indiana's water monitoring network has evolved in an ad hoc manner, involving multiple agencies and a variety of technologies. Rather than a single, integrated system, the current network consists of multiple independent networks that collect data on surface water levels and flows, groundwater levels, and limited water quality and meteorological parameters.

Due to its ad hoc nature, the network lacks the capacity to answer critical questions regarding long-term water availability across different regions of the state. Over the past 25 years, disinvestment in water monitoring network has hindered its ability to provide essential data needed for: proactive economic planning, preventative drought and flood response, comprehensive health and safety assurances, environmental protection, and potential future permit review procedures that may require an advanced understanding of the resource.

Addressing these deficiencies is crucial to ensuring a sustainable and resilient water management system for Indiana's future.

#### The Need for a Robust Monitoring Network

A comprehensive water monitoring network is essential to addressing several key challenges in Indiana's water resource management:

- Sustainable water availability: Indiana lacks a sufficient network of monitoring sites to assess
  the long-term sustainability of its shallow and bedrock aquifer systems, which are essential for
  municipal, industrial, and agricultural use.
- **Surface and groundwater interactions:** The impact of groundwater withdrawals on surface water bodies is not adequately represented in existing monitoring networks, limiting effective water management and conservation efforts.
- Stormwater and infiltration rates: Critical data on stormwater runoff, infiltration, and evapotranspiration rates remain scarce, making it difficult to manage the entire water cycle, implement water conservation strategies, and mitigate the risks of droughts and floods.
- Water quality trends: Indiana lacks real-time, widespread monitoring of surface and groundwater quality, which hinders efforts to detect and mitigate pollution, protect drinking water sources, preserve recreational opportunities, and maintain property values.
- Economic development support: A reliable water supply is crucial for attracting and retaining
  industries that depend on consistent water availability. Without a robust monitoring system, the
  state faces challenges in ensuring long-term economic stability and growth.

#### Recommendations

This report outlines six key recommendations to strengthen Indiana's water monitoring network and address existing challenges:

#### 1. Invest in Network Expansion and Maintenance

To enhance Indiana's water resource understanding, state and local leaders must be informed and engaged regarding the limitations of the current network and the benefits of an improved system. A strategic expansion should be initiated with the following guidelines:

- Install a stream gage on every major tributary (HUC 10- or 12-digit watershed)
- Ensure important aquifer systems have at least one continuous monitoring well and/or well cluster uninfluenced by significant water users
- Equip every county with a mesonet (climate) station and pair these stations with the full water balance network
- Enhance drinking water source areas with adequate water quality monitoring

#### Sustaining the Existing Network

Because long-term data sets are invaluable, funding must be secured in perpetuity for:

- Operation and maintenance
- Data archiving, processing, distribution, and availability
- Quality assurance and quality control (QAQC) measures

#### 2. Prioritize and Align Funding

- Review and prioritize the proposed network enhancements locations (see digital appendix
- Identify all potential funding sources that may align with agency objectives
- Develop an implementation timeline for high-priority locations based on funding opportunities

#### 3. Establish Clear Leadership

- Designate a lead agency and personnel to oversee the optimization of the monitoring network
- Ensure leadership is responsible for implementing network enhancements, aligning monitoring strategies with pressing water management needs, and facilitating data sharing across agencies and public officials

#### 4. Engage Academic Institutions

Convene annual meetings with academic professionals to:

- Gather input on network improvements
- Align water monitoring efforts with current research
- Review and update ongoing research involving instrumentation, measurement, and modeling
- Guide future research initiatives to support statewide water management strategies

#### 5. Facilitate Data Sharing

- Improve key databases and establish publicly accessible repositories for water monitoring data
- Explore incentives to encourage data sharing among agencies, utilities, and other water professionals
- Develop systems to collect water use data from irrigation and private domestic sources for comparison with Surface Water Withdrawal Facility (SWWF) reported usage
- Establish an online, publicly-accessible water data hub

#### 6. Expand Staffing for Water Resource Management

Increase staff dedicated to:

- Water resource assessment and interpretation
- Model development and coordination with academic researchers
- Community engagement and cooperation with public officials on water sustainability

#### Conclusion

While Indiana's current water monitoring network provides important data about the state's water resources, it does not provide the comprehensive data necessary to effectively model or manage its water resources into the future. Network gaps as well as reliance on volunteer systems create vulnerabilities, risks, and missed opportunities. Strategic investments in network expansion, funding prioritization, interagency collaboration, and data accessibility are critical to ensuring long-term water sustainability. By implementing the recommendations outlined in this report, Indiana will enhance its ability to proactively manage water resources, support economic growth, and protect public and environmental health.

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## 1. Introduction and Purpose

Data is the key factor in making informed decisions, and a robust water monitoring network is required to provide that crucial data.

This report was commissioned by the Indiana Finance Authority (IFA) for the purpose of understanding where gaps in Indiana's water monitoring exist and how to strategically fill those gaps. This includes understanding two key issues:

- 1. What questions can the current monitoring network answer?
- 2. What do water resources planners and managers need to know that the network cannot currently address?

#### **Questions And Conditions That Can Be Answered**

The current network is able to provide data that answer some important questions about the state's water resources. However, these data are primarily focused on documenting existing conditions and changes in water resources over time at specific locations. They are not widely useful for water management decision-making or the development of robust models. The general conditions that can be ascertained by the existing network include:

- Surface water level (stage) at select instrumented (gaged) locations
- Surface water flow volumes (discharge) at a portion of gaged locations
- Groundwater levels at select locations and depths for a portion of the state's aquifer systems
- Surface and groundwater water quality in even fewer select locations with limited water quality parameters
- Climatic conditions and limited publicly available soil moisture data in select locations

The actual breadth of the state's instrumentation will become clear in Section 3 of this report. Briefly, the density of Indiana's monitoring network has declined as the state has disinvested in it over the last 25 years.

#### **Questions And Conditions That Cannot Currently Be Answered**

Without input data (such as that gathered by a more robust monitoring network) to drive, calibrate, and validate a range of hydrologic models, there are fundamental aspects of Indiana's water resources that cannot currently be answered. These include:

#### Resource assessment

- Seasonal water balance in different hydrogeologic settings across the state, including evapotranspiration (from atmosphere, plants, and soil), infiltration rates, and groundwater recharge
- Groundwater-level trends in all important aquifer systems
- Complex geological layers beneath the surface that contain our aquifers have not yet been comprehensively mapped or characterized

#### Water availability

- Recharge rates of shallow and deep aquifers to inform estimates of sustainable available yields; that is, how much groundwater is reliably available to use to meet expected demand for current and future uses
- Ability to inform economic development efforts, i.e. provide reliable projections of available, sustainable water supplies for industrial and municipal demand

- Effects of pumping by various water users on water levels in nearby aquifers or surface-water bodies
- Stormwater runoff volumes and timing, and implications for both flooding and groundwater recharge

#### Water quality

- Water quality of bedrock aquifers (Note: considerable variation exists even within the same bedrock system; at a certain depth water is not potable due to brine, oil, gas, etc.; yet several areas of the state are dependent on bedrock aquifers)
- Groundwater-quality trends in all important aquifer systems
- · Extensive, real-time surface water quality monitoring

## 2. The Network's History

The current network was established over time in an ad hoc manner without an overall guiding strategy or clear understanding of future needs. While this is typical for how states have approached monitoring in the modern era, many states today have begun to strategically assess and invest in their networks for reasons related to economic development and public health and safety.

Much of Indiana's existing network was established or enhanced in order to answer specific local water resource questions tied to water use conflicts/impacts or as part of larger national research initiatives. For example, while the state has approximately 307 water levelmonitoring wells currently in place, nearly a third of those are funded and maintained to support a

One conclusion that continues to arise from these conversations is that large gaps in the understanding of the state's water resources pose a challenge to the collective ability to make informed decisions about its use.

specific, limited purpose in two locations in the northwestern part of the state. Another 89 have similar limitations. This leaves just 202 funded monitoring wells with the purpose of collecting data for long-term trends and making water availability assessments across the state. Many of these are located in shallow aquifers, and, therefore, no data is collected in deeper, overlapping aquifers.

As questions and conflicts intermittently resolved over the years and state budgets tightened, disinvestment in the monitoring network occurred with the most notable impact occurring in 2003 (removal of support for 54 groundwater observation wells).

Subsequently, when the drought of 2012 caused concerned public officials to ask questions about the sustainability of the state's water resources, the answers were not readily available due to data gaps and a lack of reliable data.

In response, a moderate investment in the Volunteer Monitoring Program (VMP) network was made through House Bill 1319 in 2015. This investment reinstated approximately 20 of the wells that were dropped in 2003. However, most of the remaining wells dropped by 2003 are simply gone, as they were either abandoned (plugged) to eliminate the chance of unintentional contamination to the aquifer system, property ownership changed, or renewed access was not granted. As discussed below, the VMP network has significant limitations and vulnerabilities, and chief among them are changes in property ownership and changes in production near the well.

For years, groups like the Indiana Water Monitoring Council and the Indiana Silver Jackets have tried to elevate and coordinate the needs of the monitoring network with limited success, due mostly to funding challenges and a lack of recognition of the network's importance. This report endeavors to improve those circumstances by tying various aims and associated program alignments to the network's current and future capabilities.

# 3. Methodology

This report is intended to qualitatively characterize the gaps in Indiana's water monitoring network and suggest how those gaps can be filled in order to guide future optimization of the network.

#### STEP 1 - EXPERT CONSULTATION

This plan was developed in close consultation with the state and federal agencies who manage or routinely use the current monitoring system. These include:

- Indiana Department of Natural Resources (IDNR)
- Indiana Department of Environmental Management (IDEM)
- Indiana Geological and Water Survey (IGWS)
- Indiana State Climate Office (ISCO)
- United States Geological Survey (USGS)
- Natural Resources Conservation Service (NRCS)

In addition, individuals and organizations who contributed expertise include:

- Indiana Silver Jackets (an interagency team that facilitates collaborative solutions to state flood risk priorities)
- Indiana Water Monitoring Council's Groundwater Focus Committee
- Sally Letsinger, Hydrogeologist, Indiana University
- Jack Wittman, Vice President of Strategy and Integration, INTERA

#### **STEP 2 - SYSTEM INVENTORY**

The current water monitoring network is a collection of varied and independent networks managed by many different agencies at the local, state, and federal level. These networks have different data collection frequency, types of instrumentation, geographic spread and scale, and were designed with different uses in mind. The types of measurements taken by the instruments in these networks can be roughly divided between three categories: water quality, water quantity, and climate-related (meteorological) data.

Furthermore, data collection frequency varies according to instrumentation and available resources as well.

- Real-Time continuous data collection: Continuous recordings that transmit data hourly
- Continuous data collection: Continuous recordings which require data to be downloaded and posted to the database following site visits
- Non-continuous data collection: Measured during a site visit only. Site visits occur at different frequencies depending on the network and funding.

Non-continuous data collections are also referred to as "periodic" or "non-continuous".

The specific networks analyzed for this report include those below.

#### **Indiana's Water Quantity and Quality Networks**

U.S. Geological Survey (USGS) Surface Water Stream Gage Network (see Fig. 1)

SCOPE: Continuous, near real-time streamflow and surface water-level data from which stream flows are computed and made publicly available online.

SCALE: Nationwide network, 256 stream gages in Indiana.

USE: Planning, forecasting, and warning for floods and drought, water allocations, regulating pollutant discharges, designing reservoirs, roads, bridges, drinking water and wastewater facilities, operating waterways for power production and navigation, monitoring environmental conditions to protect aquatic habitats, and determining safety of recreational activities.

#### USGS Surface Water Quality Super Gage Network (see Fig. 1)

SCOPE: Some gages in the USGS Stream Gage Network have added capacity to test surface water quality parameters, including water temperature, specific conductance, pH, dissolved oxygen, total nitrogen (or nitrate concentration), total phosphorus (or orthophosphate), turbidity, chlorophyll, and/or suspended sediment.

SCALE: Nationwide network, 16 Super Gages (a subset of the 256 stream gages) in Indiana.

USE: Calculate concentration and contaminant loads to understand and address watershed processes and issues such as climate and land use effects, water-related human health issues, algal blooms, or hazardous substance spills.

#### <u>USGS Lake and Reservoirs Gage Network (see Fig. 7)</u>

SCOPE: Instantaneous water surface elevation and reservoir storage (in select locations) data collection system led by USGS and managed in cooperation with local agencies.

SCALE: Nationwide network, 18 lake/reservoir gaging stations in Indiana.

USE: Planning and management of lake/reservoirs for water supply, flood mitigation, industry, and recreation.

#### USGS Groundwater Level Network (see Fig. 2)

SCOPE: The network measures water levels in wells with a range of measurement frequencies and monitoring objectives.

SCALE: Nationwide network, 202 wells in Indiana (49 Real-time, 153 periodically measured).

USE: Includes but not limited to providing long-term groundwater-level data for planning purposes, monitoring conditions during drought and in relation to nearby water production or use, and hydrologic research including aguifer tests and individual, short-term project sites.

#### <u>Indiana Volunteer Groundwater Monitoring Program (VMP, see Fig. 2)</u>

SCOPE: Continuous and non-continuous groundwater level data collected through a cooperative agreement between the IDNR, USGS, and volunteer well owners initiated by HB 1319 in 2015 session year.

SCALE: Statewide network includes 60 wells (57 continuous, 3 intermittent); 53 wells operated and maintained by IDNR, 7 by cooperative partners, and data quality-assured and hosted by USGS.

USE: Track groundwater levels to identify and assess changes in groundwater storage, which may be resulting from water use, changes in groundwater recharge, or climate conditions.

#### Indiana Department of Environmental Management Fixed Station Network (see Figs. 4, 5)

SCOPE: Monthly surface water samples from rivers and streams. Parameters include nutrients, metals, cyanide and general chemistry.

SCALE: Statewide network, 165 sites in Indiana.

USE: Used for long term trend analyses, to identify potential sources of pollution entering a stream, to understand statewide background concentrations of parameters like nutrients, metals and pesticides, and to collect useful data for municipal, industrial, agricultural and recreational decision-making processes. This includes the total maximum daily loads (TMDL) process and National Pollutant Discharge Elimination System (NPDES) permit modeling. These data are also used by IDEM for water quality assessments.

#### Indiana Department of Environmental Management Ground Water Monitoring Network (GWMN)

SCOPE: Random statewide sampling of groundwater quality from private residential wells and non-community public water supplies by hydrogeologic setting using a stratified sampling design.

SCALE: Statewide; samples have been collected from over 1300 unique locations to date.

USE: Establishing statewide groundwater quality; data utilized by Public Water Systems and for regional studies for groundwater resource development; investigating areas with high arsenic concentrations and conducting public outreach to minimize exposure to arsenic in drinking water.

#### **Indiana's Mesonet Network**

Purdue University (see Fig. 3)

SCOPE: Continuous data collection of atmospheric (up to 10 meters high) and shallow soil (within 1 meter depth) data at mesoscale (~1000 sq meters) resolution.

SCALE: Statewide network of 15 stations (as of early 2025) with the goal of at least 1 station per county. All stations monitor winds, temperature, humidity, incoming solar radiation, precipitation, soil temperature and soil moisture collected every 5-minutes.

USE: Monitor real-time weather and long-term climate conditions and impacts to facilitate better weather safety, water management, and economic prosperity throughout Indiana.

#### Indiana Water Balance Network (IWBN, Indiana Geological and Water Survey, see Fig. 3)

SCOPE: Continuous data collection to account for full atmosphere-to-subsurface water balance. Measurements to calculate potential evapotranspiration, precipitation, available soil moisture, and water level fluctuations in aquifers.

SCALE: Statewide network, 24 sites capturing multiple levels of data; 8 sites only monitoring groundwater in wells; 16 capture atmosphere parameters, soil parameters, and multiple groundwater aquifers water levels.

USE: Monitor trends and seasonal variations over time in water loss and gain from atmosphere to subsurface to improve understanding of water budgets in Indiana.

Maps of the existing surface water, groundwater quantity monitoring, mesonet and water balance, and surface water quality monitoring networks mentioned above are shown in Figures 1, 2, 3 and 4 below. The IDEM GWMN is not mapped because monitoring of this network consists of random sampling of private residential wells.

#### **Indiana's Groundwater Quality Databases**

IGWS Groundwater Database

SCOPE: Groundwater characterization and spatial distribution of chemical components from cumulative, one-time sampling events of domestic and monitoring wells within river basins, from regional and county studies, in process of being made publicly available online.

SCALE: State-wide, groundwater database, consisting of over 2,000 wells. Contains major chemical components for characterizing groundwater aquifers, with some minor and trace element data from regional and county studies.

USE: Provide spatial distribution of chemical data for hard water and naturally occurring soft water, concentration levels and spatial distribution of some chemicals monitored for both primary and secondary drinking water.

The database does not provide complete coverage of Indiana as some of the basin studies were never conducted and other recent studies have not expanded into a portion of these basin areas.

#### IGWS Indiana Springs Database

SCOPE: Dynamic database of spatial and temporal chemical characterization, minor and trace element monitoring, and coliform bacteria screening of perennial springs in Indiana in an online, searchable and downloadable database.

SCALE: Currently consisting of bedrock springs in the Uplands region of Indiana, with potential to be expanded to statewide database. Spatially consisting of 149 springs covering 14 counties, with multiple annual samplings for subset of springs covering 2019 – 2024, and new springs added each year.

USE: Provide spring owners with water quality data for determining domestic, agricultural, and commercial needs. Spatial and temporal data available for environmental monitoring of aquifer quality and contamination, land use changes, and watershed chemical component sources.

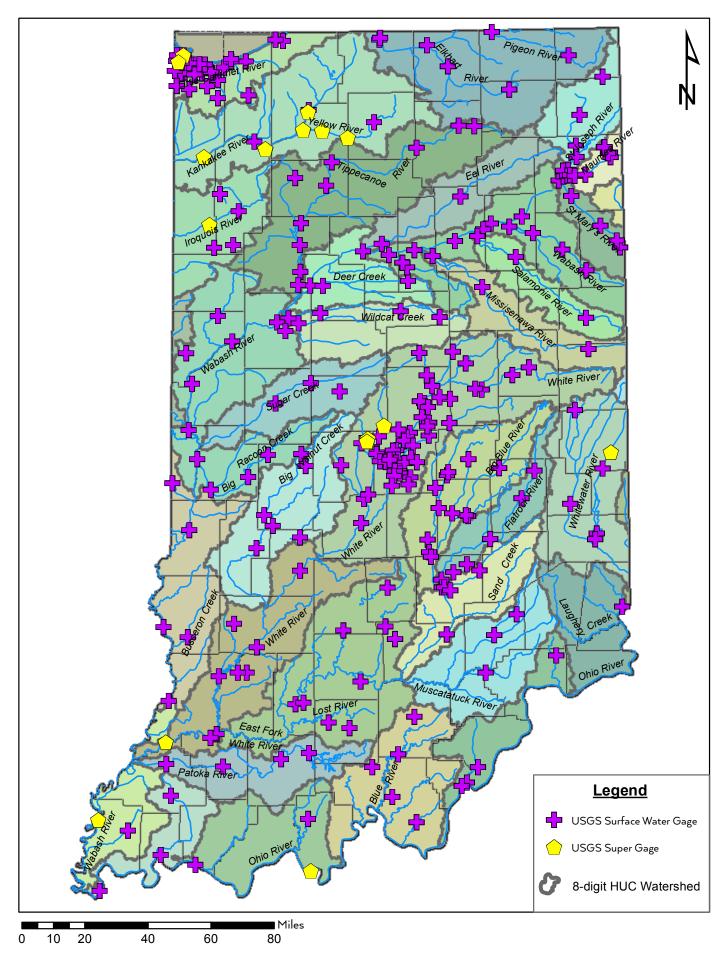


Fig. 1: Indiana HUC 8 watersheds and stream gages

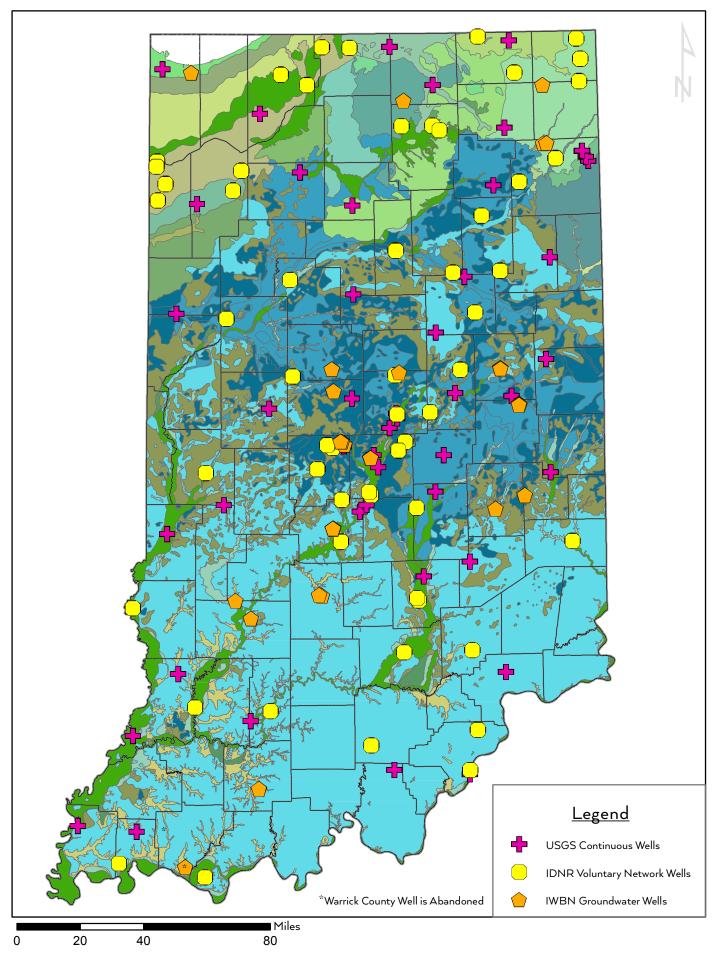


Fig. 2: Unconsolidated aquifer systems and groundwater wells | See Appendix A for aquifer legend

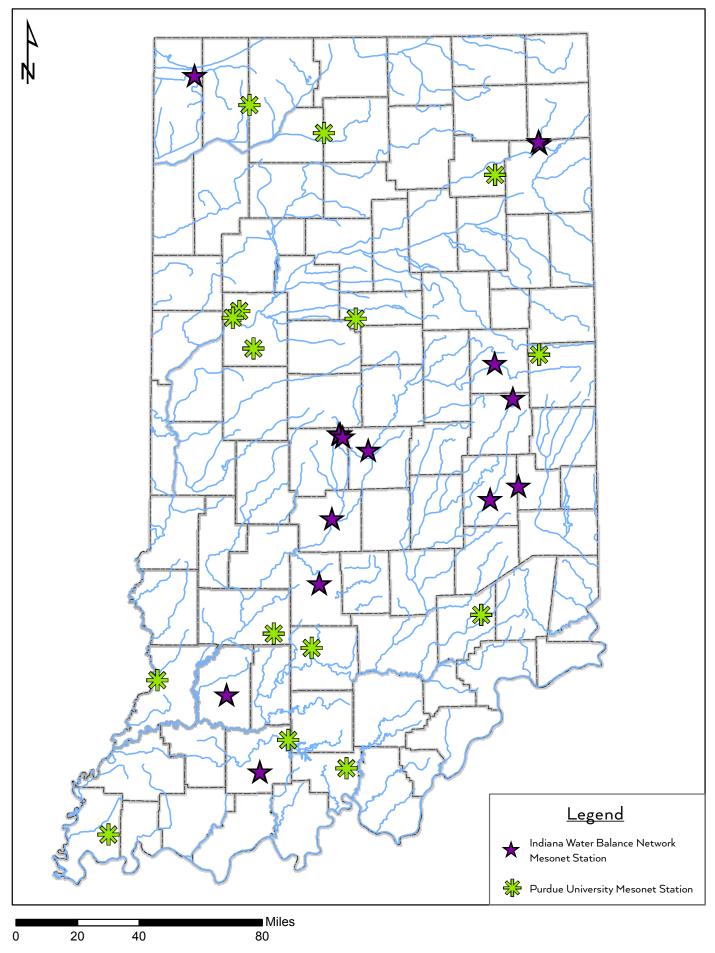


Fig. 3: Existing mesonet network (note: due to scale, not all of the instrument locations can be seen as the symbols overlap)

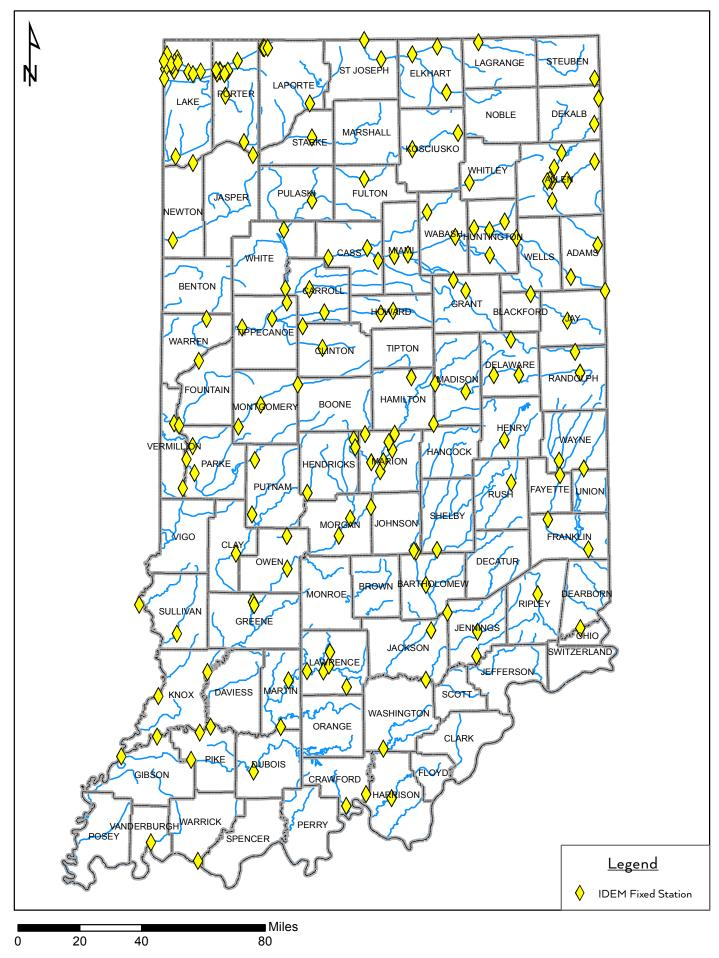


Fig. 4: IDEM Fixed Station water quality locations

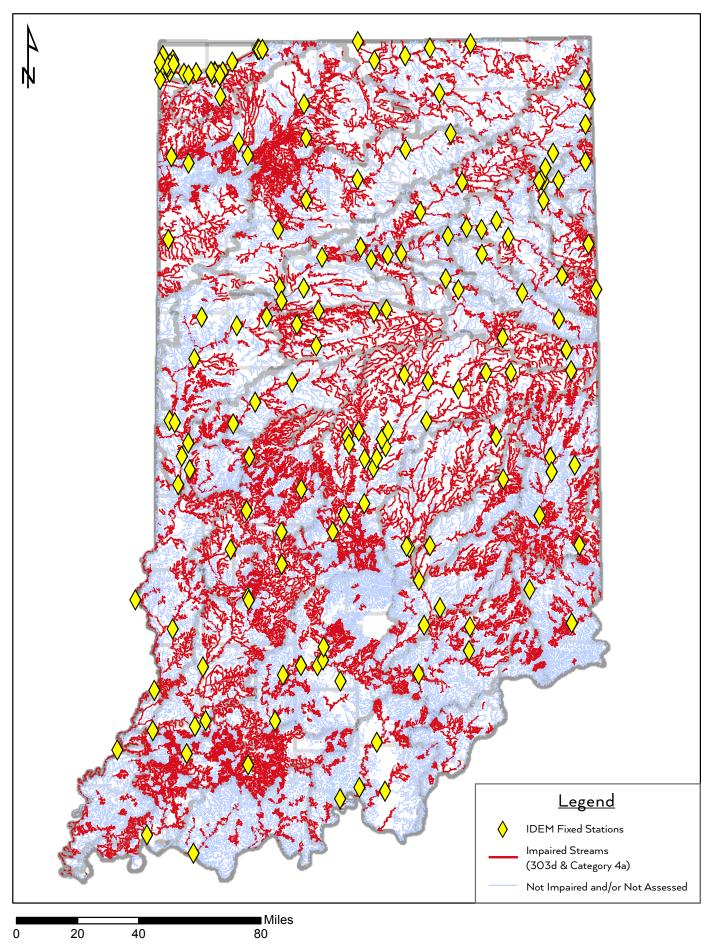


Fig. 5: IDEM Fixed Station water quality locations and impaired streams designation (48% impaired) Source: IDEM 2024 Integrated Report

#### **Network Considerations and Connections**

#### **Spatial Considerations**

It is important to remember that the data provided by varoius network instruments are site-specific and cannot be applied or extrapolated across a large area without analysis and validation. For example, a stream gage is simply measuring flow and water level at one location, and a groundwater well is only able to provide information about water level in one particular aquifer at a particular depth. The exception to this is if a nested well or well cluster is installed at the same location (i.e. multiple wells at different depths). See Figure 3 as an example of both. Well clusters and nested wells are ideal for gathering information about aquifer characteristics, including water aquifer productivity, while reducing the number of property agreements and instruments to record and transmit data.

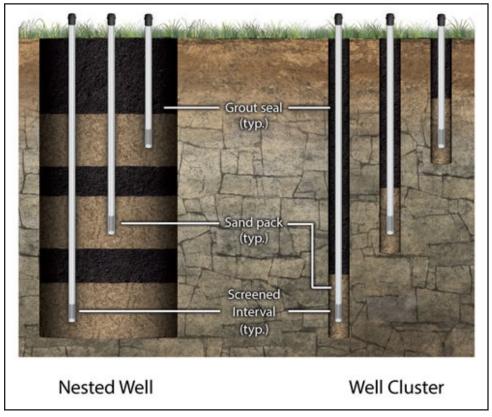


Fig. 6: Nested Well/Well Cluster | By HydrogeologyEng - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=58308775

#### Time Considerations

As noted earlier, some groundwater and surface-water data are collected continuously (the data can be read in real time as an on-going record) while other data are collected periodically (the data is collected through in-person site visits and is, therefore, a snapshot in time). Instrumentation, scientific objective, and human and financial resources all play a role in this element of data collection.

#### Ownership Considerations

Finally, there are several local-scale monitoring networks managed by health departments, utilities, universities, and volunteer groups as well as private networks of climate, soil moisture, and weather data. However, these data sets are not usually publicly available, nor do they provide statewide coverage. These networks were not considered in this report because of their sporadic nature and data-availability challenges. It should be noted that with additional coordination efforts and investment in collaborative data sharing mechanisms, these networks could supplement the existing state and federal network, and additional knowledge about Indiana's water resources could be gained.

#### Water Quantity Network Considerations

Most of the above-mentioned networks primarily measure water quantity by way of ground and surface water levels and surface water flows. It is important to note, however, that, particularly in regard to groundwater, water level measurements alone do not provide an understanding of how much water is in any given aquifer (i.e. they do not measure true water quantity) or how quickly an aquifer may recover when withdrawals are made by various water users (i.e. water capacity or aquifer productivity). Water level measurements merely track static conditions.

This is why having long-term historical records is critical to understanding the context and significance of a given water level measurement. Long-term data sets provide important insights into water cycle trends, impacts associated with use, and the sustainability of water supplies over time.

#### Water Quality Network Considerations

Water quantity and water quality are intrinsically connected. One of the simplest anecdotes that helps illustrate this relationship is, "the solution to pollution is dilution". This concept has long played an important role in the history of safely issuing multiple industrial and wastewater discharge permits on the same waterway – how much pollution a given water body can tolerate based on its volume and flow. This is a practical reminder that understanding water quantity is key to protecting and understanding water quality.

Another way to reflect on the connection between water quantity and quality is to imagine flood waters washing across thousands of acres of varied land uses during a flood event compared to what runs off or washes in during normal weather conditions. Consider the additional pollution and eroded sediment that enters rivers and streams during large flood events – quantity impacts quality. This is one reason that the USGS and its cooperating agencies have elevated some stream gages to water-quality Super Gages (described

Having long-term historical records is critical to understanding what a given water level means. Long-term data sets provide important insights into water cycle changes, impacts associated with use, and the sustainability of water supplies over time.

above and shown in Fig. 1). Because Super Gages measure both quantity and quality of surface waters, they provide important information about how pollutants move through rivers and streams and how different land use types respond when stressed. Super Gages allow researchers to measure the effectiveness of watershed best management practices and find ways to protect water quality and reduce flood impacts. Of the 256 stream gages in Indiana, only 16 are instrumented as Super Gages.

The types of physical and chemical water quality data provided by Super Gages vary for each site, which means the types of data are not consistent across geography, or in some cases, across time. In general, Super Gages collect continuous data on the following factors: water temperature, specific conductance, pH, dissolved oxygen, and/or turbidity and other criteria such as nutrients and sediment.<sup>1</sup>

While this report and its analysis focused primarily on water quantity monitoring networks and related data gaps, some consideration was given to other water quality monitoring efforts in the state because of the connections noted above. This was done so that any proposed additions or enhancements to the water quantity monitoring network would complement, when possible, water quality networks and assessments. That said, it was beyond the scope of this report to conduct a

<sup>1</sup> From the United States Geological Survey, www.usgs.gov/centers/oki-water/science/super-gage-network

current gap analysis for the monitoring networks that focus only on water quality such as the Indiana Department of Environmental Management's (IDEM) Fixed Stations Network and its Ground Water Monitoring Network (GWMN). IDEM has previously evaluated these networks in the context of their own aims. However, IDEM's Fixed Station surface-water quality locations and its related Clean Water Act Section 303(d) impaired waters data layer were considered briefly when evaluating gaps in the surface water quantity gage locations, since siting new gages close to existing fixed stations would allow for pollution load calculations. Such an alignment could enhance the State's assessment of impaired waters as well as NPDES (point source/pipe), CAFO/CFO permitting decisions and Total Maximum Daily Load (TMDL) evaluations.

See Figure 5 to understand IDEM's Fixed Station water quality monitoring network and the resulting assessment of impaired streams.

Similarly, the IDEM GWMN locations and its findings should be considered when siting any additional (proposed) groundwater wells. A lot could be learned about aquifer characteristics by aligning groundwater quality and quantity monitoring, including any potential limitations to an aquifer's water availability due to water quality concerns. Of note, IDEM's GWMN has also

Water quality and water quantity are intrinsically connected and impact each other in significant ways – the management of one requires the thoughtful management of the other.

experienced notable disinvestment over time. While once more robust, it currently focuses mainly on arsenic in residential drinking water wells. Thus, Indiana does not have an ongoing, strategically designed network in place to monitor widespread groundwater quality. Rather, the 'network' is composed of private residential wells that IDEM has been given permission to sample in the past. Part of the agreement with the participating residents is that their address and well location would not be shared with the public, therefore a map of these locations is not included in this report.

An analysis of and subsequent investment in the IDEM water-quality networks would help strategically address water quality concerns that currently limit water use(s) and/or impact public health. As mentioned above, water quality and water quantity are intrinsically connected and impact each other in significant ways – the management of one requires the thoughtful management of the other.

#### Climate Network (Mesonet Stations) Considerations

Like water quantity and quality, water quantity and climate are intrinsically connected. The water cycle is driven by rainfall and influenced by wind, evaporation, soil saturation, and many other climate-related elements. For these reasons, to truly understand and manage water quality and quantity, localized climate influences must also be understood.

To truly understand and manage water quantity and quality, localized climate influences must also be understood.

Indiana has a varied and fragmented set of climate-monitoring networks. These networks collaborate as the Indiana Mesonet. More information about the mesonet system can be found above (pages 5-6). A map of the existing mesonet network is shown in Figure 3.

Despite its importance to water planning and water budgets, the mesonet network is currently very limited in its extent statewide. See the Results and Recommendations sections regarding this important monitoring need.

#### STEP 3 - EVALUATE EXISTING NETWORKS AGAINST KEY DATA

The current monitoring networks were evaluated against a range of data to determine gaps and potential points of converging interests between agencies and user groups. These data include:

- The existing groundwater well and surface water gage network (Figures 1 and 2)
- Indiana's mapped unconsolidated aquifer systems (Figure 2)
- Significant Water Withdrawal Facilities (IDNR database, years 2002, 2012, 2013, and 2022)
- Drinking water protection areas including Source Water Susceptibility Areas (for surface water) and Wellhead Protection Areas (for groundwater)
- Population change, recent and projected (from US Census data and STATS Indiana) and the presence of poverty and minority communities (from the Center for Disease Control Environmental Justice Index)
- The new regional water study regions proposed by the Indiana Finance Authority (Figure 7 below)

Several questions drove the data analysis, with the ultimate goal of identifying water monitoring gaps and the type of instrumentation necessary at those locations. The evaluation of the network was performed using a GIS-based spatial analysis at both county and watershed scales. The work was completed under the guidance of agency professionals with decades of experience studying the hydrology and geology of Indiana. Data were converted to GIS layers, and these data layers were stacked, clipped, color-coded, and analyzed for gaps

and overlaps. Several questions drove the data analysis, with the ultimate goal of identifying water monitoring gaps and the type of instrumentation necessary at those locations. This analysis was an iterative process that incorporated input from more than a dozen professionals during several workshop-style meetings.

Data were also considered in the context of a recent effort to organize the state's water assessments into water study regions (see Figure 7 below). Because ongoing regional water availability studies conducted by the Indiana Finance Authority (IFA) rely heavily on monitoring network data, the gap analysis also included the consideration of these regional watershed-based study-area boundaries.

#### STEP 4 - IDENTIFY CRITICAL DATA GAPS

Nine (9) guiding questions governed eight multi-hour, multi-agency and consultant discussion sessions. Such discussions and evaluations identified dozens of proposed additions to the networks as well as important administrative solutions.

#### Nine Guiding Questions

- Are there stream gages on all major tributaries within moderately-sized watersheds? See Figure 1
  above to review the gaps in the existing monitoring network relative to Indiana's rivers and major
  tributary streams.
- 2. Are the aquifers in each county understood, including their geographic extent and productivity (available pumping rates and volume)? See Figure 2 above to review the gaps in the existing monitoring network relative to Indiana's known aquifer systems.
- 3. Are there lake and reservoir gages on all priority lakes and reservoirs, including those with flood risks, historical use conflicts, or other environmental sensitivities? See Figure 8 to review the gaps in the existing monitoring network relative to Indiana's lakes and reservoirs.
- 4. Where are there increases in groundwater or surface water use from Significant Water Withdrawal Facilities (SWWF)? Analysis included areas with a high density of facilities, increases in the number of new registered users over the last 20 years, and increases in use from individual

registered facilities over the last 20 years. Figures 9a and 9b compare the scale and distribution of these largest users in 2002 and 2022. For the sake of map readability, these figures do not show all SWWFs, but rather only the largest (>100 MG/Yr). Table 1 below provides data about the Significant Water Users in 2022 by water study region, user type (surface or groundwater), and volume. In 2022, there were 6066 SWWFs across the state using between 500 gallons per year and 100 billion gallons per year or more. All SWWFs facilities, including those using less than 100MG/Yr (not shown in Fig. 9a and 9b) were considered when performing the monitoring network gap analysis. This is important to recognize because many facilities below this threshold include consumptive water use such as irrigation.

- 5. Where are the important groundwater recharge areas? See Figure 10 below.
- 6. Where are the greatest areas of recent and projected population growth, and what type of land use changes have occurred in these areas (2001 2021)? See Figure 11 below and Appendix A (Land Use Changes by Type in Highest Growth Counties).
- 7. Where does the existing network intersect with drinking water protection areas? Note: the location of these areas is confidential information and was not mapped as part of this public report. It was, however, considered in the analysis.
- 8. How does the existing network help inform or protect vulnerable populations? See Figures 12 and Figure 13 below as examples of such data.
- 9. Where does the existing network intersect with meteorological, climate, and/or water cycle data collection sites? Could the Purdue University mesonet stations have a wider strategic relationship with the Indiana Water Balance Network sites, and could both be aligned with the larger groundwater monitoring well network to provide a complete picture of the water cycle, including elements such as soil moisture, runoff, and groundwater recharge. See Figure 14 below to understand various climate networks and which counties are currently without any mesonet or water balance data stations.

	<b>GROUNDWATER WELLS</b> Total 2022 Volume Withdrawn (gal)	SURFACE WATER INTAKES Total 2022 Volume Withdrawn (gal)
Central	47,245,553,000	101,138,768,000
Kankakee	27,161,781,000	23,922,593,000
Lake Michigan	1,137,295,000	22,537,159,000
North Central	39,952,612,000	233,151,251,000
Northeast	33,854,666,000	32,175,556,000
Ohio River	11,213,549,000	231,980,967,000
Southeast Central	3,493,764,000	3,493,764,000
Southeast	14,869,274,000	18,663,051,000
Southwest	21,143,589,000	237,942,883,000
Wabash Headwaters	14,260,262,000	8,603,171,000
TOTAL	214,332,345,000	913,609,163,000

Table 1a: Significant Water Withdrawal Facilities by IFA Water Planning Region and Volume

	GROUNDWATER WELLS  Number of Facilities	SURFACE WATER INTAKES  Number of Facilities	
Central	675	136	
Kankakee	1,451	282	
Lake Michigan	69	36	
North Central	1,196	118	
Northeast	1,336	163	
Ohio River	313	56	
Southeast Central	51	51	
Southeast	236	90	
Southwest	388	101	
Wabash Headwaters	462	79	
TOTAL	6,177	1,112	

Table 1b: Significant Water Withdrawal Facilities by IFA Water Planning Region and Number

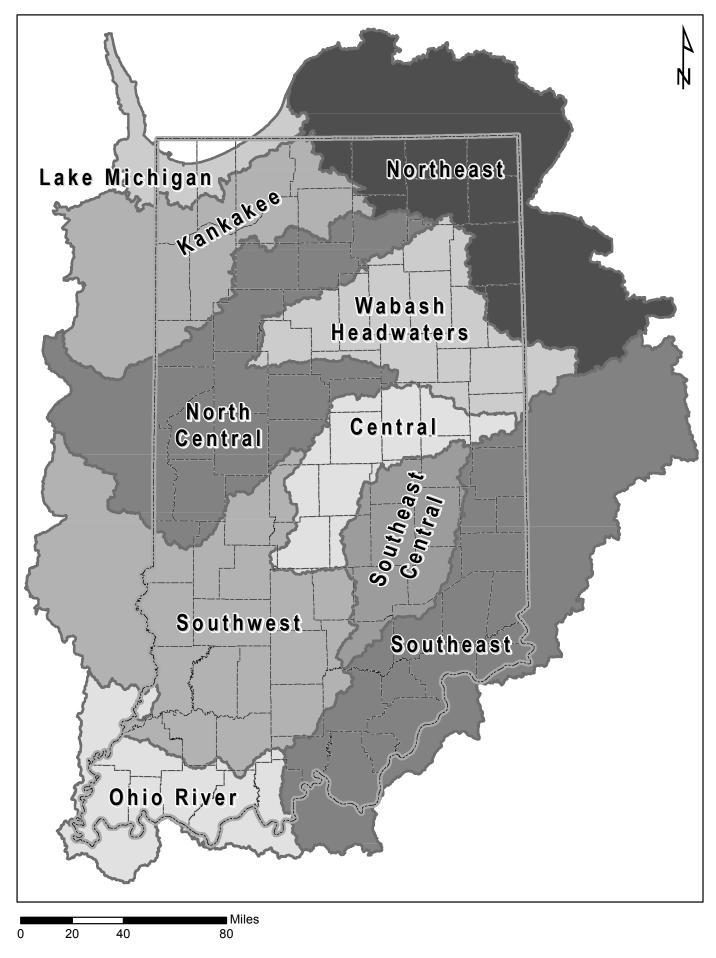


Fig. 7: Indiana Finance Authority regional water study basin boundaries

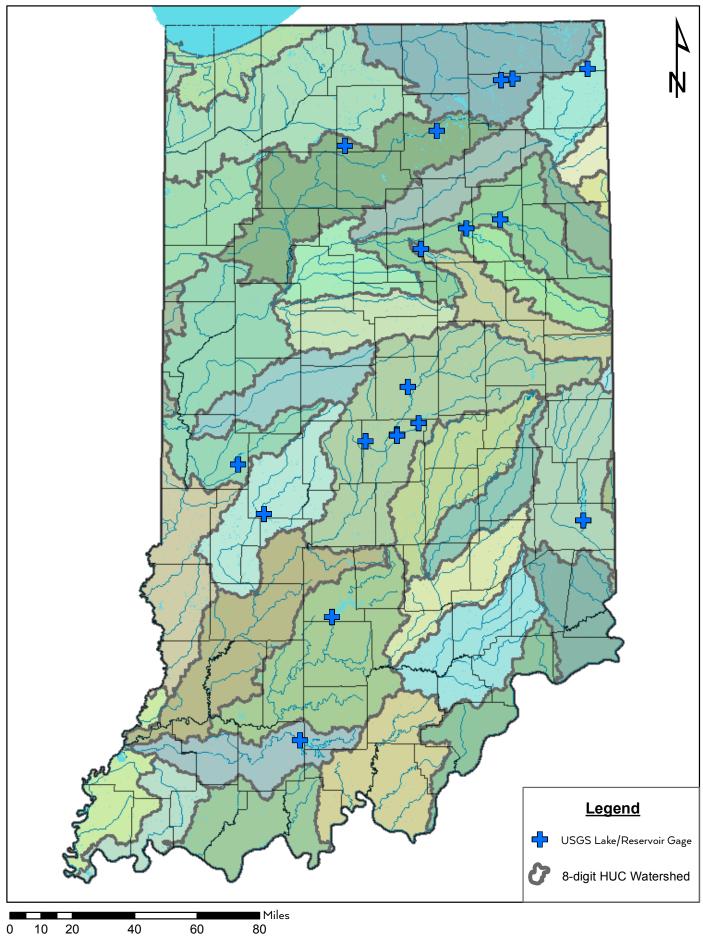


Fig. 8: Indiana watersheds described by 8-digit hydrologic unit codes (HUC 8, National Hydrography Dataset) and lake/reservoir gage locations

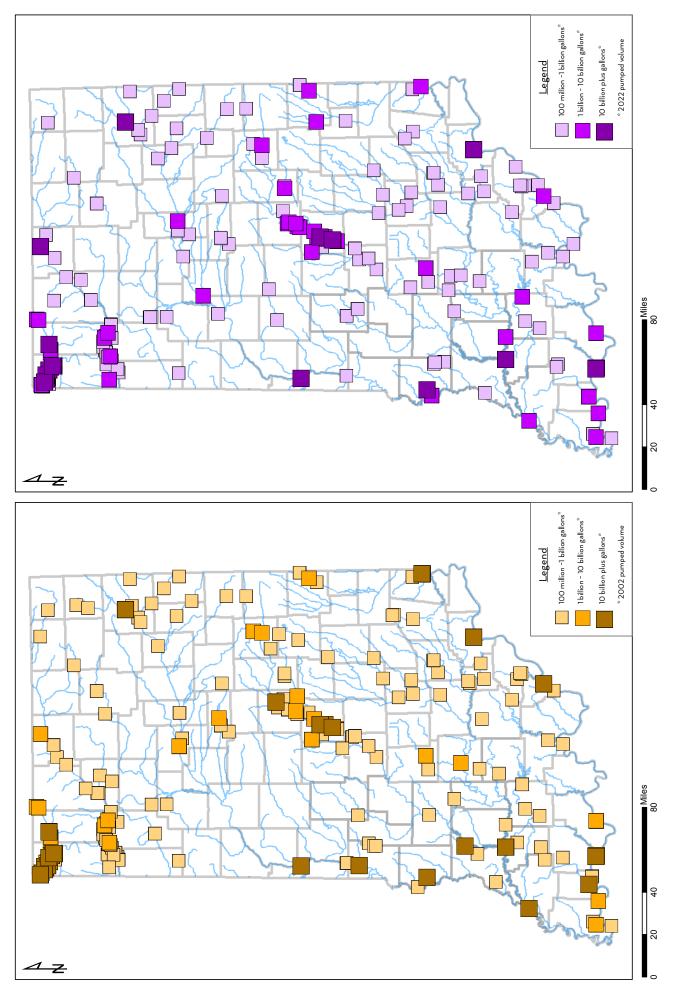


Figure 9a: Significant Water Withdrawal Facilities Surface Water Intakes, 2002 and 2022, Largest Users (> 100 MG/Yr)

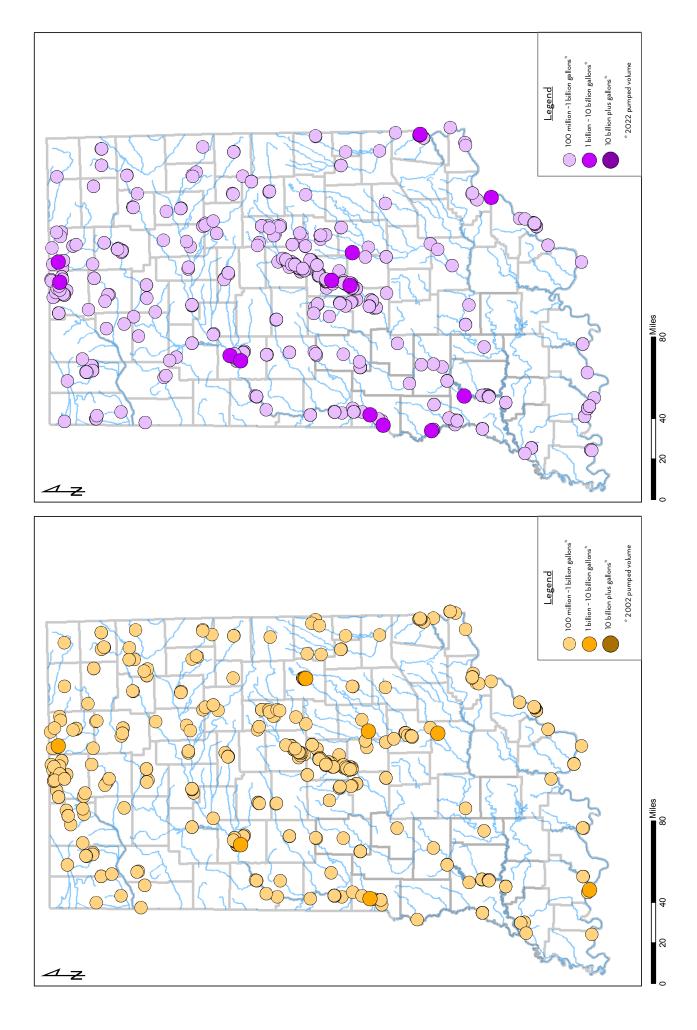


Figure 9b: Significant Water Withdrawal Facilities Groundwater Wells, 2002 and 2022, Largest Users (> 100 MG/Yr)

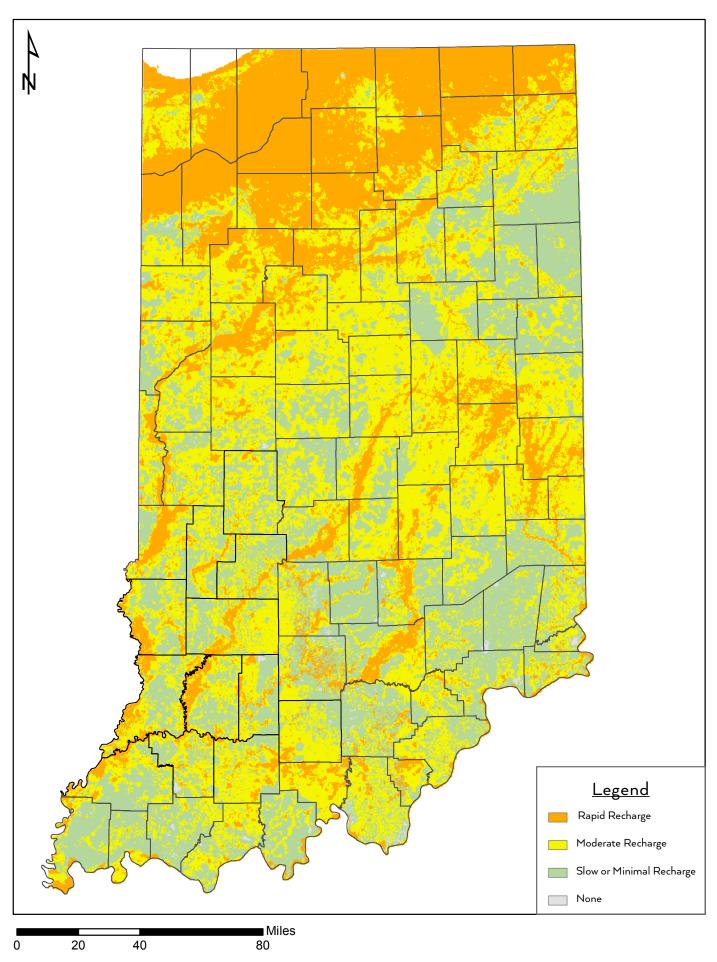


Fig. 10: Indiana soil recharge rates Source: Indiana Geological Survey

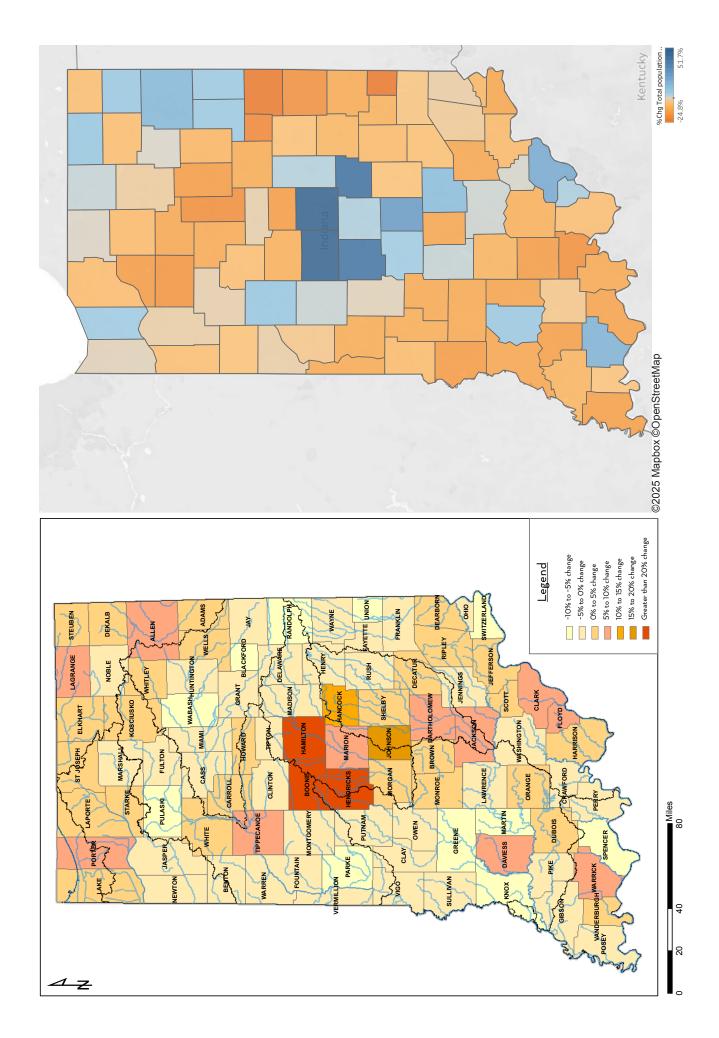
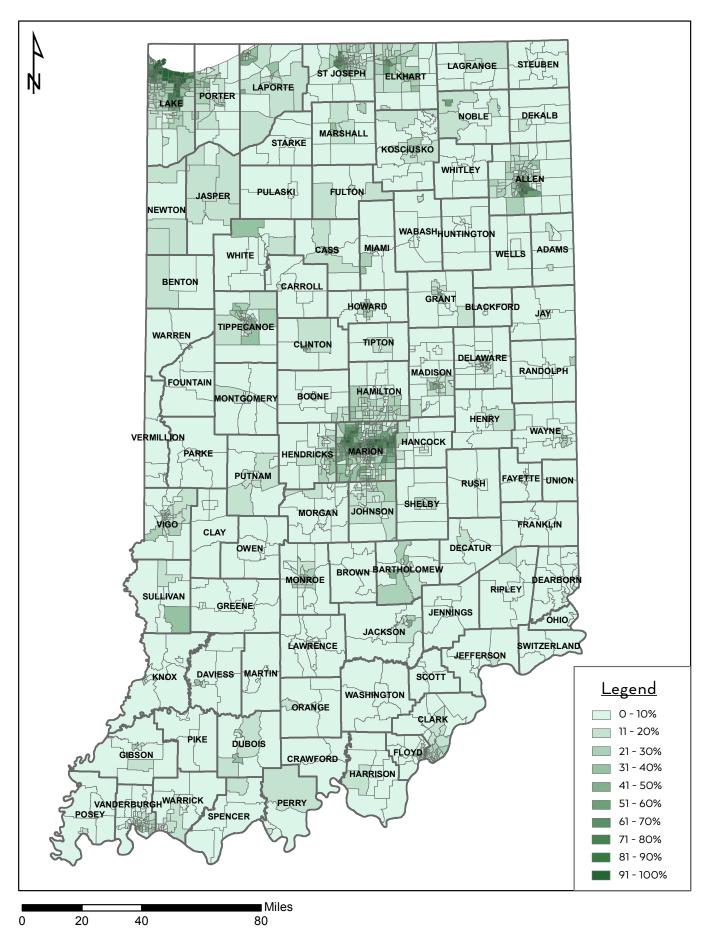


Fig. 11: Percent population change, 2010 – 2020 and 2020 – 2050 Source: US Census Bureau, 2020 Census Demographic Data Map Viewer, State of Indiana, "Population Projections." STATS Indiana



Fig, 12: Percent minority population per census tract, 2018 – 2022 Source: Center for Disease Control, Place and Health - Geospatial Research, Analysis, and Services Program (GRASP)

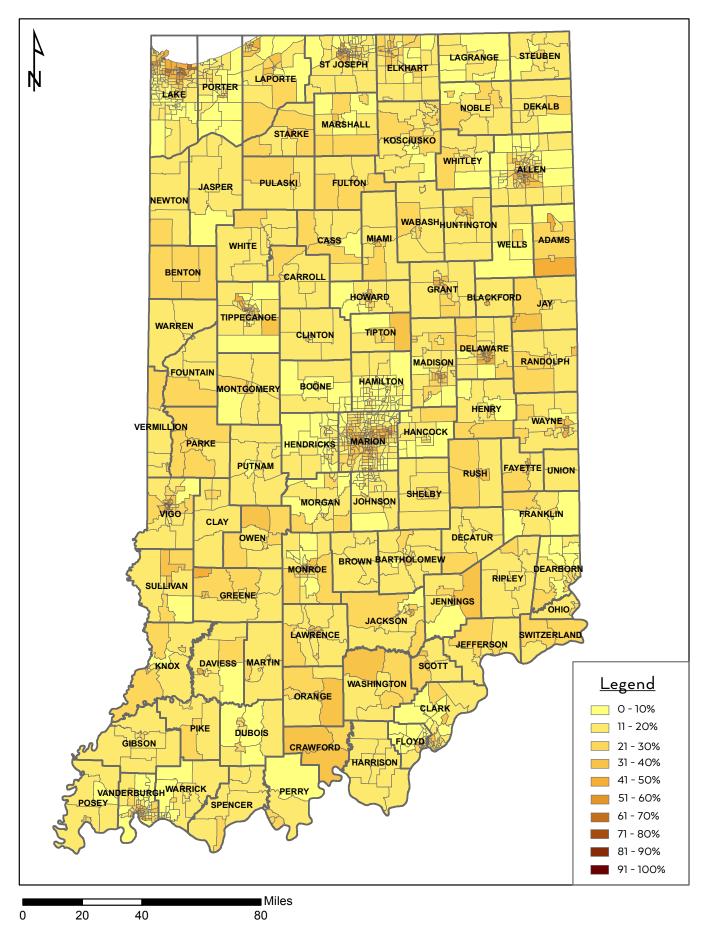


Fig. 13: Percent poverty population estimate 2018 – 2022 Source: Center for Disease Control, Place and Health - Geospatial Research, Analysis, and Services Program (GRASP)

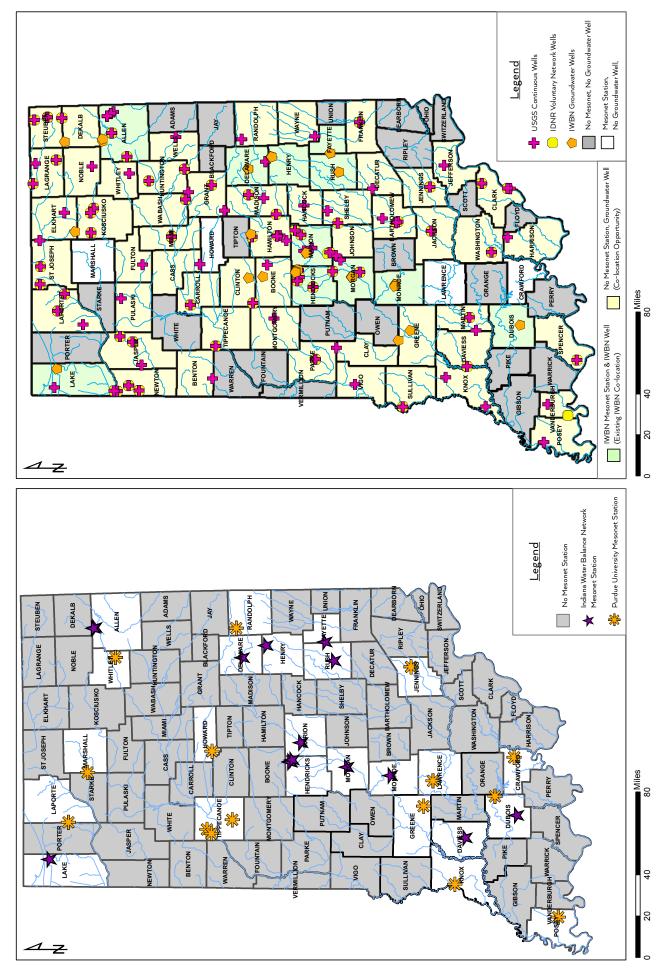


Fig. 14: Existing mesonet network and groundwater wells

### 4. Results

#### **Gap Analysis Findings**

The gap analysis described above resulted in the identification of 211 new proposed groundwater and surface-water monitoring locations and 68 mesonet stations. Table 2 below indicates how many additional monitoring locations are recommended per Water Study Region. Approximate proposed instrument locations have been plotted on a map and as a GIS layer. A digital appendix with this data layer is available upon request.

As stated earlier, it is important to note that this analysis is qualitative in nature, meaning that the specific location and associated instrumentation of any proposed new well or gage will need to be refined through field visits and close review of local conditions and property ownership. The actual siting of new monitoring wells, gages, or climate stations should rest in the hands of the water management professionals and associated agencies responsible for each of the relevant networks. These scientists

The goal of this report was to understand the regional needs and opportunities associated with the monitoring network in order to guide future investment in the network and expand its value in the overall management of Indiana's water resources.

should revisit the GIS layer of proposed locations and further evaluate each location as it relates to various strategic sampling aims laid out earlier in this report such as: source water protection areas, significant water withdrawals, social and environmental vulnerability, local geology and hydrology, long-term site viability, and, of course, property ownership.

The goal of this report was to understand the regional needs and opportunities associated with the monitoring network in order to guide future investment in the network and expand its value in the overall management of Indiana's water resources.

With that regional focus in mind, along with the State's recent efforts to quantify water demand and availability through regional studies, the results of this monitoring network gap analysis have been organized by regions. The ten Water Study Regions shown in Figure 7 above are consistent with other recent IFA regional water assessments, watershed based, and together cover the state of Indiana.

Table 2: Proposed			

Region	Proposed Groundwater Wells	Proposed Surface Water Gages	Proposed Lake/Reservoir Gages
Central	25	1	0
Kankakee	10	0	2
Lake Michigan	1	0	0
North Central	39	1	0
Northeast	17	1	6
Ohio River	4	0	0
Southeast Central	22	2	0
Southeast	14	3	0
Southwest	19	7	0
Wabash Headwaters	33	3	1
Total	184	18	9

#### **Necessary Network Investments**

Table 2 shows the suggested expansion of the monitoring network by number of proposed groundwater wells (189) and proposed surface water stream and lake/reservoir gages (18 and 9, respectively). Of the 189 proposed groundwater wells, roughly 50% are candidates for nested or clustered instrumentation based on a preliminary analysis. The proposed expansion of the mesonet network is not tracked in this table. However, the minimum guidance for climatological monitoring is to have one complete mesonet station per county. Currently, only 28 counties host a mesonet station, leaving 64 that should be added to the network. See Figure 14.

#### Costs

The cost of acquiring, installing, operating, and maintaining the monitoring equipment associated with various networks depends on a range of factors. As such, the numbers provided below are gross cost estimates based on previous work by state and federal agencies. Site conditions, funding sources, market forces and other factors can all impact the total cost of new instruments and their annual maintenance.

#### **Groundwater Monitoring Wells**

Estimated equipment cost: \$13,500 – \$16,000 per well Annual operations and maintenance cost: approximately \$6,000

The cost varies depending on several variables in addition to those factors mentioned above, including:

- Whether the data is measured manually periodically, continuously recorded, or includes real-time data transmission, each of which requires varying levels of effort for measurement depending on instrumentation, location, and ownership
- The type of real-time data transmission equipment (cellular vs. satellite transmission)
- Whether the well will be a nested or clustered pair (one shallow and one deep) or a single well

The cost of drilling a new well is not included due to the variability of cost due to location and depth. It should be considered in a detailed budget analysis.

#### **Surface Water Stream Gage**

Estimated cost: \$30,000 – \$40,000 per gage (includes installation and first year of operation and maintenance)

Annual operation and maintenance cost: approximately \$6,000 – \$15,000

In addition to the factors mentioned above, the cost for new stream gages varies depending on the parameters that are measured, namely discharge (flow volume) versus stage (river water elevation) only.

#### Super Gage Upgrade (at pre-existing surface water stream gage)

Estimated cost per sensor for installation: \$30,000 - \$65,000

Annual operation and maintenance cost: approximately \$16,000 - \$53,000

In addition to the factors mentioned above, the cost varies based on the specific parameters being monitored which could include water temperature, specific conductance, pH, dissolved oxygen, total nitrogen (or nitrate concentration), total phosphorus (or orthophosphate), turbidity, chlorophyll and/or suspended sediment.

#### **Mesonet System**

A general approach to estimating the cost of a mesonet station is to recommend approximately \$35,000 for the station itself and \$6,000/yr/station to continue to operate it and deliver the data.

A number of additional instruments could be added for developing full water-balance estimates at these stations, but they also increase the cost of the stations. Such instruments would measure or characterize:

- Deep drainage
- Water table monitoring
- Stormwater runoff monitoring
- Solar energy or net radiation
- Snow/ice precipitation
- Multi-depth soil moisture and soil temperature
- Potential evapotranspiration

A full accounting along these lines could increase costs to \$100,000 – \$150,000 exclusive of annual operations and maintenance.

#### **Prioritization**

It is beyond the scope of this report to determine which proposed additional instruments and locations are most critical to the development of a wider understanding of the state's water resources, as it depends upon the primary questions being asked and the known concerns or pressures on a given water resource at a given time. (See Section 1 on Unknown Conditions and Questions That Cannot Be Answered).

There are, however, certain key concepts that could guide the prioritization process.

- 1. Consider what insight is to be gained from garnering a new measurement. New instrumentation should be able to inform and address specific aspects of the water cycle. For example, is there a need to understand a specific pumping or recharge signal, the capacity of a given aquifer based on its recharge, or certain groundwater interactions with an adjacent river? Alternatively, is there a need to protect a drinking water supply or important recreation or ecological assets from threats?
- 2. Consider source water (drinking water) vulnerabilities. The adage, "an ounce of prevention is worth a pound of cure" is well placed in this instance. Groundwater contamination and persistent surface water pollution cause ballooning costs in treatment, remediation, and health care.
- 3. Consider where urgent public safety threats exist. The Indiana Silver Jackets are completing a study concurrent with this report which should guide investment in early warning instrumentation for flash flooding. Other threats should be similarly studied in order to determine the most efficient expansion of the monitoring system.
- 4. Consider the impact of growth. This might apply to specific economic initiatives, recreation and tourism efforts, population changes, agricultural operations (e.g. irrigation or Confined Feeding Operations), industrial needs, and more.

#### **Data Discoveries & Limitations**

#### Co-locations and Alignment

There are a number of elements of the existing network and proposed network enhancements (see Recommendations Section) that could be leveraged or provide a dual benefit if consideration and resources were given to the intentional alignment of various monitoring instrumentation. For example, new mesonet climate stations could be located on state-owned land where groundwater wells are already located or proposed to be located, and such co-located sites could then be instrumented to allow for a full water balance to be calculated at these locations.

Implementing these aligned investments would reveal crucial insights about aquifer recharge and the impacts of climate on local water cycles. Ultimately, these sorts of data could inform projections to guide the sustainable use of local and regional water supplies.

Other strategic alignments could result in the protection of drinking water and recreational water quality. For example, intentionally locating any new wells or gages near wellhead protection areas or source water susceptibility areas, and equipping such wells or gages with water quality monitoring instrumentation, could serve a sentinel function (a kind of "pollution guard dog"). Drinking water protection area data are confidential and restricted from public access so are not mapped in this

Implementing these aligned investments would reveal crucial insights about aquifer recharge and the impacts of climate on local water cycles. Ultimately, these sorts of data could inform projections to guide the sustainable use of local and regional water supplies.

report. However, an initial review of these areas was performed to understand the opportunities that exist for this type of coordinated network expansion.

Similarly, siting proposed new gages near existing IDEM surface water quality Fixed Stations would allow for improved understanding of pollution loads and sources, thus allowing agencies and conservation partners to strategically work on pollution reduction strategies, including best management practices and related incentive programs in these areas. See Figure 15 below as an example.

As future investments are made in the various networks, agency staff could further refine this idea of co-alignment and ensure that any proposed additions to the monitoring networks serve multiple aims.

#### Critical Databases and Data Collection

Almost all of what is known about large-scale water use is because of the existence of IDNR's Significant Water Withdrawal Facilities database. The importance of this database cannot be overstated. Indeed, the IFA's regional water demand and availability studies being conducted across the state would be severely hampered in their analysis and value without data from this database. However, it relies on users voluntarily reporting their use, and very few state resources are dedicated to its maintenance and the analysis of its data. Some USGS centers in other areas of the country have been instrumenting and collecting water use data from irrigation and private domestic systems to increase reliable data collection.

Also critical to understanding and holistically managing water resources is drinking water utility data kept by IDEM's Drinking Water Viewer. This database has a public and private side and contains helpful electronic data. However, Monthly Reports of Operations, known as 'MROs', are still paper forms completed by utilities and mailed/emailed to IDEM. These reports contain important information about water pumping/use, but manually compiling this data for efforts such as regional water availability studies is laborious. Conversion of the MRO-submission protocol from paper/scanned records to online digital submission (such as available for registered SWWF in the IDNR water use program) would result in a database rather than the document repository that exists now. Improvements to the collection and availability of this data set could benefit a variety of water resources evaluations and planning efforts.

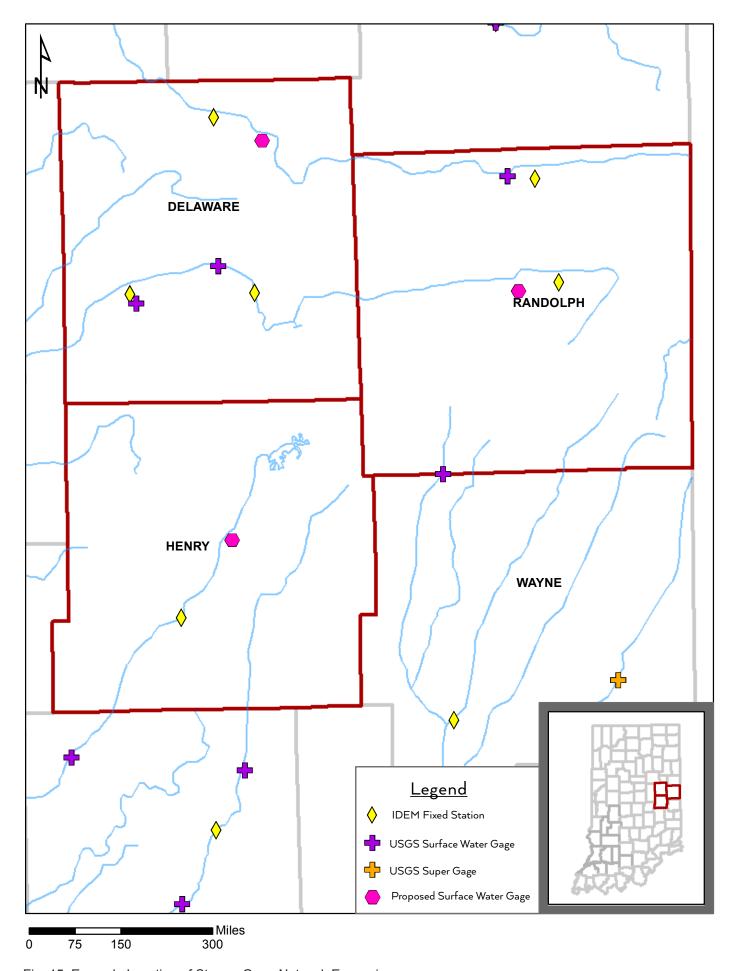


Fig. 15: Example Location of Stream Gage Network Expansion

#### **Urgency, Value, & Vulnerabilities**

Because Indiana's water monitoring network is unevenly distributed and not always optimally located, the data it provides is somewhat limited in its usefulness to those tasked with managing water resources and the decision makers who set the policies that impact this management. The disjointed nature of the system as a whole also creates some vulnerabilities and missed opportunities.

#### Consistency and Reliability

There are many factors that can impact the reliability of the data gathered from different sources. Taken together, they indicate various weak points in the monitoring network that should be addressed in order to ensure the network's integrity.

- Some monitoring wells are part of the Volunteer Groundwater Monitoring Program and, therefore, can be unreliable as a durable source of data that can be analyzed over the long term. Many state-managed instruments are located on private land and managed via volunteer agreements. This might be a more affordable way of expanding the network, but it carries risks and can undermine the value of the system as a whole. Such agreements can expire or be revoked for various reasons, threatening the integrity of the system. It is essential that the state carefully measures its dependence on these aspects of its monitoring system, replacing them with more reliable alternatives where possible, in order to reduce potential failure points.
- Some gages are monitored and/or supported by utilities or municipalities. Likewise, there has been interest in turning monitoring responsibilities for some instruments over to local utilities. This presents two risks that merit serious consideration: 1) the state can lose access to the data these instruments provide,

Historical records cannot be created if monitoring is never undertaken, and strategy cannot be created in an information vacuum.

- and 2) the state loses control of the QA/QC process for the gages.
- Many gages are non-continuous, which means that they provide data only at the moment they are
  read. If important changes or events occur to the source being observed between data readings,
  this information will not be recorded or understood. That said, periodic data readings can play an
  important role in cost-effective data collection.

#### Historical Records Need Starting Points

- There is limited knowledge about water resources in many areas of the state due to the geographical gaps in the network. Historical records cannot be created if monitoring is never undertaken, and strategy cannot be created in an information vacuum.
- Historical disinvestments have increased data gaps in time and spatial distribution, and, therefore, knowledge gaps related to norms, trends, impacts on resources, etc. These gaps are only remedied by investing now and remaining committed to such investments over the long term.

#### Return on Investment and Risk Mitigation

- The state does not possess a clear enough understanding of groundwater resources to
  adequately inform guarantees of water availability to industries that may rely on such resources.
  Without an investment that bolsters an understanding of water resources, economic development
  initiatives will face unnecessary obstacles and uncertainties. These uncertainties could present a
  risk to such initiatives as well as to future plans and growth opportunities.
- The narrow scope and expanse of the IDNR's Ground Water Monitoring Network (GMWN) limits
  the state's understanding of groundwater quality and, therefore, limits its understanding of true
  water availability and public health risks.

• The Indiana Drought Monitor would benefit from additional sources of critical weather and water information to improve its drought status determinations. The Drought Monitor is a national program that tracks drought status across the country by incorporating information about precipitation, stream flow, groundwater levels, and soil moisture, in addition to using multiple remotely-sensed spatial data, many of which utilize information from hydrologic monitoring sites. Each state contributes their drought status weekly to the National Monitor.

In the absence of a truly strategic monitoring network, solutions to water rights conflicts, water-dependent economic development opportunities, drought and flood protection, and protection of public drinking water supplies are all in a reactive rather than proactive position, risking safety, competitiveness, and long-term stability.

In Indiana, the state climatologist organizes these weekly meetings, soliciting feedback from multiple agencies and neighboring states to determine the drought status. The Drought Monitor is an important tool for 1) agencies to implement the Indiana Water Shortage Plan and 2) sectors of the Indiana economy to make management decisions for water use. It would be more effective with improved data.

Many of the risks and vulnerabilities noted above could be mitigated with investments in the monitoring network. In the absence of a truly strategic monitoring network, solutions to water-rights conflicts, water-dependent economic development opportunities, drought and flood protection, and protection of public drinking water supplies are all in a reactive rather than proactive position, risking safety, competitiveness, and long-term stability.

### Recommendations

One conclusion that continues to arise from these conversations is that large gaps in the understanding of the state's water resources pose a challenge to the state's collective ability to make informed decisions about its use.

This affects the work of planners, regulators, officials, and scientists alike, and in the state which "ranks first in the United States in the percentage of its economy that depends on water", it matters immensely.<sup>1</sup>

This report's recommendations address four overarching categories intended to help close these gaps. These categories are investment, funding alignment, data sharing and collaboration, and data analysis and staffing.

<sup>1</sup> Indiana Chamber of Commerce, 2014, Water and Economic Development in Indiana: Modernizing the State's Approach to A Critical Resource, p. 11

#### INVESTMENT

As noted earlier, many of Indiana's neighboring states and other states across the country are investing in their understanding of their water resources to advance economic development aims and to protect public health and safety. For example, Ohio initiated its H2Ohio program in 2019 with a \$172 million investment aimed at providing safe and clean water for the state. That initial investment included more than \$1 million for its water monitoring data network, enhancing the state's competitiveness in the region.

It is important that Indiana stays economically competitive, protects its citizens, and strategically manages one of its greatest assets, water. The water monitoring network is key to achieving all of these aims.

## RECOMMENDATION #1: INVEST IN NETWORK EXPANSION AND MAINTENANCE

#### **Invest in Network Expansion and Maintenance**

To enhance Indiana's water resource understanding, state and local leaders must be informed and engaged regarding the limitations of the current network and the benefits of an improved system. A strategic expansion should be initiated with the following guidelines:

- Install a stream gage on every major tributary (HUC 10- or 12-digit watershed)
- Ensure important aquifer systems have at least one continuous monitoring well and/or well cluster uninfluenced by significant water users
- Equip every county with a mesonet (climate) station and pair these stations with the full water balance network
- Enhance drinking water source areas with adequate water quality monitoring

#### Sustaining the Existing Network

Because long-term data sets are invaluable, funding must be secured in perpetuity for:

- Operation and maintenance
- Data archiving, processing, distribution, and availability
- Quality assurance and quality control (QAQC) measures

#### **FUNDING ALIGNMENT**

#### Federal Program Alignment

The United States Department of Agriculture – Natural Resources Conservation Service (USDA–NRCS) is involved in a variety of monitoring projects that utilize interagency agreements with the USGS to monitor the water quality improvements linked to specific agricultural conservation practices and overall watershed health. Examples include a new in-stream Super Gage on School Branch (Eagle Creek Watershed – Hendricks Co., IN) and two new in-stream gages on Black Creek (Maumee Watershed – Allen Co., IN). These types of network investments help provide an understanding of nutrient cycling and sediment transport off of agricultural fields enrolled in a variety of conservation practices and are, therefore, funded with USDA Farm Bill funding. If the proposed network improvements/additions noted herein were designed to monitor the impacts of conservation practices (including in-stream water quality impacts) and/or were strategically located in source water protection areas, these additional monitoring efforts could utilize Farm Bill funding.

#### State Program Alignment

IDEM has a variety of programs that could provide support to the state's monitoring network; however, the breadth of those resources varies, and alignment to specific program goals would be essential. These programs include: the Clean Water Act Section 319 nonpoint source pollution reduction program (watershed focused), PFAS assessments (source water protection focused), and a limited amount of planning money that could be used to fund gages in support of other program aims.

IFA has funding available for PFAS assessments and other source water protection aims. Such funding, if coordinated with other agencies, could be targeted toward strategic water quality-focused network investments. Other IFA funding resources may be available pending the alignment of proposed monitoring enhancements with programmatic aims such as utility planning and regional water availability studies.

#### **RECOMMENDATION #2: PRIORITIZE & ALIGN FUNDING**

- Review and prioritize the proposed network enhancements locations (see digital appendix
- Identify all potential funding sources that may align with agency objectives
- Develop an implementation timeline for high-priority locations based on funding opportunities

#### DATA SHARING AND OTHER COLLABORATION

#### Inter-Agency Coordination

The proposed monitoring network enhancements and additions identified above and herein will require agency cooperation and the extension of inter-agency MOUs. Likewise, for the state to reap the full benefits of investing in the network, improvements need to be made to data sharing and accessibility processes and the regular assessment of the network as a whole.

The Indiana Silver Jackets is an inter-agency organization that convenes regularly to discuss flood risk and prevention. Additionally, the agencies that participate in the Indiana Conservation Partnership convene to develop watershed-based evaluations and cooperative BMP implementation projects. And, finally, the Indiana Water Monitoring Council's Groundwater Focus Committee meets monthly

to discuss issues concerning groundwater. While these collaborations are producing important outputs, additional value and impact could be realized if the various efforts were knit together by strong leadership, a strategic water monitoring strategy built on collaboration, and the development of mechanisms designed to share findings with the public, industry leaders, and public officials.

#### **RECOMMENDATION #3: ESTABLISH CLEAR LEADERSHIP**

- Designate a lead agency and personnel to oversee the optimization of the monitoring network
- Ensure leadership is responsible for implementing network enhancements, aligning monitoring strategies with pressing water management needs, and facilitating data sharing across agencies and public officials

#### Universities

Significant past and ongoing academic research involves water quality and quantity monitoring. As part of this water monitoring network assessment, a list of academic researchers and staff engaged in water research statewide was compiled (see Appendix C). Some academic researchers develop water resource models from various data sets and could be engaged to develop important models using the data collected from the current monitoring networks. Additional monitoring locations could further inform such models, improving accuracy of the models and, therefore, their utility to wider professional audiences.

#### **RECOMMENDATION #4: ENGAGE ACADEMIC INSTITUTIONS**

Convene annual meetings with academic professionals to:

- Gather input on network improvements
- Align water monitoring efforts with current research
- Review and update ongoing research involving instrumentation, measurement, and modeling
- Guide future research initiatives to support statewide water management strategies

#### **Utilities and Professional Organizations**

A variety of professionals routinely engage with Indiana's water resources on behalf of private landowners, developers, and industry leaders. These include consulting geologists and hydrologists, well drillers, utilities, aggregate/mining companies, and others. Investing in mechanisms to receive, store, and share data from these professionals about relevant water resource or environmental conditions (e.g., well logs, abandoned wells locations/opportunities, utility pump test results, etc.) could advance shared understanding, uncover new or lower cost monitoring network opportunities, and create routine lines of communication between the private sector and public water resource managers.

#### **RECOMMENDATION #5: FACILITATE DATA SHARING**

- Improve key databases and establish publicly accessible repositories for water monitoring data
- Explore incentives to encourage data sharing among agencies, utilities, and other water professionals
- Develop systems to collect water use data from irrigation and private domestic sources for comparison with Surface Water Withdrawal Facility (SWWF) reported usage
- Establish an online, publicly-accessible water data hub

#### **DATA ANALYSIS & STAFFING**

Investments in the monitoring network also need investments in agency staffing. For example, to keep 10-20 wells monitored and maintained for a year requires the effort of at least one full-time person.

The importance of the various networks and databases was documented throughout this report, but it bears repeating that, in the absence of staff who are able to provide quality assurance and quality control as well as data analysis and database management, data are of limited value. Having staff dedicated to improving data access, interpretation, and analysis would assist the public and public officials in better understanding and properly stewarding the state's water resources.

Likewise, some of the 'unanswerable questions or conditions' noted at the beginning of the report will require the use of models to answer, and models require good data as input. Models can spatially extend the information from point locations (like the wells and gages in the State's various networks), thus adding to the value of those locations and therefore improving the understanding of Indiana's water resources. The addition of dedicated staff could coordinate the development of important water resource models with academic researchers.

Finally, while acknowledging that some data must remain confidential for security purposes, a publicfacing data dashboard of water information would allow for more thoughtful development of state water resources and related quality of life and economic initiatives. Additional staffing resources are critical to this advancement as well.

## RECOMMENDATION #6: EXPAND STAFFING FOR WATER RESOURCE MANAGEMENT

Increase staff dedicated to:

- Water resource assessment and interpretation
- Model development and coordination with academic researchers
- Community engagement and cooperation with public officials on water sustainability

### 6. Conclusion

Questions about water trends, future availability, economic development, recreation and quality of life, and overall sustainability are only going to increase as population and industry pressures rise. Indiana needs a water monitoring network and a strong coalition of public and private sector water professionals that can answer critical water questions efficiently and confidently. The recommendations in this report are an important first step toward a sustainable, strategically-sound water future for Indiana.

This report has identified the scale and general locations of regional water monitoring needs. As resources are assembled to implement its recommendations, the exact placement of various instrumentation should focus on the following criteria:

While Indiana is rich in water assets, understanding and monitoring those assets are key to realizing their full value.

- Protecting drinking water supplies
- Understanding groundwater aquifer systems
- Understanding surface and groundwater connections
- Understanding aquifer capacities, pumping impacts, recharge rates, and associated land use impacts to those rates
- Climate impact on local water cycles
- Assisting in the development of scientific models

The current monitoring system simply observes water levels go up and down with few linkages to cause and effect. This is not enough to ensure a sustainable future and why priority consideration should be given to the development of water resource models that test the important hydrologic and hydrogeologic processes in each region.

While Indiana is rich in water assets, understanding and monitoring those assets are key to realizing their full value.

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# Appendix A

Fig. 2 Legend Definitions

	<b>KEY-UNCONSOL</b>	.IDAT	<u>ED AQUIFERS</u>
	e - 10-50 gpm domestic, three apacity well report yields 225-750 gpm		Kankakee - 15-50 gpm domestic, 90-1600 gpm high-capacity
	ll, Lacustrine, & Backwater Deposits rally less than 5 gpm, dry holes common		Kendallville - 10-50 gpm domestic, 70-1400 gpm high-capacity
aquife	Valley - southern Indiana limited		Lacustrine Plain - 5-50 gpm domestic, 70-500 gpm high-capacity
genera	rock; in central & northern regions, lly 10-20 gpm domestic, typically pm high-capacity		Maxinkuckee Moraine - 4-60 gpm domestic, 70-2200 gpm high-capacity
	et - 5-20 gpm domestic, 100-1100 igh capacity		Nappanee - 5-50 gpm domestic, 75-1200 gpm high-capacity
capaci	ville - 10-60 gpm domestic, high- ty potential but no reported high- ty wells in the aquifer system		Natural Lakes & Moraines - typically 25 gpm domestic, 70-2000 gpm high-capacity
typical	lex - generally 10-50 gpm domestic, ly 400 gpm for large diameter apacity wells		Natural Lakes & Moraines Subsystem - commonly O-60 gpm domestic, 1 high-capacity well reports yield of 1500 gpm
Unglac	ted Till & Residuum/Till Veneer/ :iated Southern Hills & Lowlands rally less than 5 gpm, dry holes common		New Haven - 5-20 gpm domestic, 5 high-capacity wells report yields of 100-300 gpm
Eel Riv	ver-Cedar Creek - 10-60 gpm domestic, capacity wells report yields of 450 gpm		Outwash - generally 50 gpm domestic, commonly 1000 gpm for large diameter high-capacity wells
Eolian	Sands - 10-50 gpm domestic, 00 gpm high-capacity		Outwash Subsystem - generally 20 gpm domestic, commonly 300 gpm large diameter high-capacity
Hesse	n Cassel - 10-30 gpm domestic, 8 high- ty wells report yields from 75-100 gpm		St. Joseph Aquifer System & Tributary Valleys Sole Source Aquifer (including South Bend Area) - high-capacity potential throughout with reported high-capacity yields ranging from 75 - 2800 gpm
•	Aquifer - typically 10-60 gpm tic, high-capacity range 90-2000 gpm	_	St. Joseph Aquifer System & Tributary Valleys
domes	Outwash - typically 10-20 gpm tic, up to 60 gpm locally, up to 1200 gpm apacity		Sole Source Aquifer-Elkhart Area - 0 - 800 gpm, high-capacity wells shallow ~30-60' below ground surface with underlying thick clay units
Howe	Outwash Subsystem - generally 5-20 omestic, 100 gpm high-capacity		Teays Valley & Tributary - 10-50 gpm domestic, 2 high-capacity wells report yields of 1650 & 2100 gpm
	is Basin - 4-20 gpm domestic, 2 wells a buried valley report yields of		Till - generally 10-25 gpm domestic, typically 200 for large diameter high-capacity wells
	25 gpm		Till Subsystem - generally less than 10 gpm domestic only, extremely limited high-capacity potential
domes	is Buried Valley Subsystem - 10-40 gpm stic, 4 high-capacity wells report of 400-795 gpm		Topeka - 10-45 gpm domestic,250-1200 gpm high-capacity
	is Moraine - 4-10 gpm domestic, 2 high- ty wells report yields of 162 & 221 gpm		Valparaiso Moraine - 5-60 gpm domestic, 70-1200 gpm high-capacity

### Appendix B

Land Use Changes by Type in Highest Growth Counties, 2001 – 2021

### **Land Use Changes by Type in Highest Growth Counties**

		Open Space		Deve	loped - Open Spa	ace
County	<b>2001 Area</b> (acres)	2021 Area (acres)	% Change	<b>2001 Area</b> (acres)	2021 Area (acres)	% Change
Allen	3466.74254	4523.57876	30.48%	24891.70079	28333.54219	13.83%
Bartholomew	2552.890954	3242.24886	27.00%	14719.72416	13973.59485	-5.07%
Boone	476.2123804	705.519994	48.15%	11443.55447	1319.605409	-88.47%
Clark	1798.163895	2323.81105	29.23%	20085.16265	15919.40871	-20.74%
Daviess	4524.830891	5597.24663	23.70%	11220.38192	8578.194059	-23.55%
Floyd	509.6736394	613.258596	20.32%	11908.73746	9177.688165	-22.93%
Hamilton	3782.996593	4327.566	14.40%	25167.81283	26278.30845	4.41%
Hendricks	768.4749488	951.087736	23.76%	19649.21433	16604.06481	-15.50%
Jackson	2721.601156	3334.50567	22.52%	15905.51495	13476.10528	-15.27%
Johnson	1498.013482	1923.90238	28.43%	14780.47145	15606.29442	5.59%
Lagrange	4789.553707	4855.40986	1.37%	9156.60571	8167.906642	-10.80%
Marion	5657.395427	6307.11892	11.48%	43595.63057	46702.61213	7.13%
Tippecanoe	2317.72591	2718.48734	17.29%	17672.44064	1622.20013	-90.82%
Warrick	6252.411509	754.233222	-87.94%	13894.40952	11834.37705	-14.83%

	Devel	oped - Low Ir	ntensity	Develop	ed - Medium Int	ensity
Country	2001 Area	2021 Area	º/ Change	2001 Area	2021 Area	% Change
County	(acres)	(acres)	% Change	(acres)	(acres)	% Change
Allen	56265.59789	38353.3742	-31.84%	23652.69719	31442.60776	32.93%
Bartholomew	14051.69516	8732.63168	-37.85%	4476.666932	4993.42426	11.54%
Boone	15191.8776	9483.00306	-37.58%	3166.876412	6041.664995	90.78%
Clark	12170.35723	11719.0318	-3.71%	5869.141866	7765.597448	32.31%
Daviess	10547.95412	5718.70311	-45.78%	2294.937528	4610.822181	100.91%
Floyd	6466.495143	5515.88141	-14.70%	3039.324626	3485.327102	14.67%
Hamilton	33174.77999	30744.3874	-7.33%	11429.10693	24265.1998	112.31%
Hendricks	20691.90432	18715.4969	-9.55%	6004.590611	12890.6774	114.68%
Jackson	10345.23836	5701.49003	-44.89%	2844.30896	335.2012388	-88.22%
Johnson	19459.59559	16039.8913	-17.57%	6440.20349	10182.83444	58.11%
Lagrange	11033.22873	7739.33626	-29.85%	2233.637776	4246.327005	90.11%
Marion	74919.27993	74508.4924	-0.55%	58805.44262	57089.67337	-2.92%
Tippecanoe	18772.87983	15398.8034	-17.97%	9324.647652	11643.67988	24.87%
Warrick	12906.04268	7900.81803	-38.78%	3849.527158	3849.283912	-0.01%

	Devel	oped - High Ir	ntensity		Barren Land	
County	<b>2001 Area</b> (acres)	2021 Area (acres)	% Change	<b>2001 Area</b> (acres)	<b>2021 Area</b> (acres)	% Change
Allen	7103.846583	12076.9333	70.01%	1137.390615	1027.139708	-9.69%
Bartholomew	1062.755591	1817.99658	71.06%	352.8629169	231.4136105	-34.42%
Boone	592.1683673	2128.65214	259.47%	52.89885805	59.00762684	11.55%
Clark	2297.095189	4345.51876	89.17%	1673.088099	1642.723519	-1.81%
Daviess	320.9322717	1122.64078	249.81%	391.7613417	591.9208151	51.09%
Floyd	748.9021023	1328.94697	77.45%	31.77824139	58.20213319	83.15%
Hamilton	1798.72409	6088.31279	238.48%	944.1712837	263.1583604	-72.13%
Hendricks	1309.992255	5025.41755	283.62%	110.0572887	46.29530095	-57.94%
Jackson	825.3522085	1307.3725	58.40%	58.70535941	320.4250171	445.82%
Johnson	1107.956483	2899.01918	161.65%	90.64332297	193.2266617	113.17%
Lagrange	435.4460412	1349.97557	210.02%	42.9204612	142.4933113	231.99%
Marion	19684.39427	26537.7911	34.82%	858.3661961	923.6839359	7.61%
Tippecanoe	3039.307398	4529.01376	49.01%	226.8979126	193.5360856	-14.70%
Warrick	666.1387336	1348.84799	102.49%	1566.715645	601.0667034	-61.64%

	Forests - De	ciduous, Ever	green, Mixed	Shrub/Scrub	& Grassland/He	erbaceous
County	<b>2001 Area</b> (acres)	2021 Area (acres)	% Change	<b>2001 Area</b> (acres)	2021 Area (acres)	% Change
Allen	34080.87826	33573.531	-1.49%	1007.214694	2227.260394	121.13%
Bartholomew	68785.5558	73233.9085	6.47%	1517.963049	1687.113914	11.14%
Boone	14125.12733	14482.1512	2.53%	32.45770146	1074.822902	3211.46%
Clark	99360.41344	106801.951	7.49%	116.4839474	2381.540991	1944.52%
Daviess	38219.77013	44526.3897	16.50%	87.65549181	1599.054928	1724.25%
Floyd	43430.46314	47196.3752	8.67%	138.6192051	794.5399917	473.18%
Hamilton	15809.91111	15050.3944	-4.80%	126.6947418	1825.539638	1340.90%
Hendricks	28041.29279	27893.5233	-0.53%	60.49400464	1285.93947	2025.73%
Jackson	107809.1721	114065.645	5.80%	190.8841391	1839.971484	863.92%
Johnson	29432.11587	32415.5163	10.14%	27.38520084	696.4870074	2443.30%
Lagrange	6334.547646	7323.54691	15.61%	732.5087877	920.92346	25.72%
Marion	17542.43605	16829.3587	-4.06%	14.80620443	412.5198239	2686.13%
Tippecanoe	35086.41053	38621.1207	10.07%	497.6073841	2298.341987	361.88%
Warrick	76054.25638	84901.2118	11.63%	1012.817492	6943.384877	585.55%

	Pasture/	Hay & Cultiva	ated Crops	Wetlands - Wo	ody & Emergent	Herbaceous
County	2001 Area	2021 Area	% Change	2001 Area	2021 Area	% Change
•	(acres)	(acres)		(acres)	(acres)	ŭ
Allen	261153.2242	259946.172	-0.46%	9648.98183	10877.73009	12.73%
Bartholomew	151156.2101	151091.987	-0.04%	4186.194596	2966.271107	-29.14%
Boone	224011.1252	221783.907	-0.99%	1876.639928	1805.130326	-3.81%
Clark	96141.53055	86311.5012	-10.22%	1458.849522	1698.077227	16.40%
Daviess	204530.3517	201898.084	-1.29%	7322.508968	4995.231156	-31.78%
Floyd	28675.43514	26592.2505	-7.26%	730.6041164	880.7562999	20.55%
Hamilton	161791.7924	145420.109	-10.12%	3485.936814	3084.869361	-11.51%
Hendricks	184618.7397	177479.526	-3.87%	416.1014879	581.3856634	39.72%
Jackson	168707.3636	169115.763	0.24%	193847.5678	16074.67308	-91.71%
Johnson	131997.1555	12514.8938	-90.52%	911.1390546	749.8488643	-17.70%
Lagrange	169624.844	167899.372	-1.02%	43179.42618	44845.22787	3.86%
Marion	35360.75565	27057.469	-23.48%	1283.594652	13156.82253	925.00%
Tippecanoe	229275.282	224544.287	-2.06%	5853.482866	5639.569744	-3.65%
Warrick	120063.7172	113409.225	-5.54%	14069.56887	11819.7628	-15.99%

## Appendix C

List of Academic Researchers

		Indiana Acaden	ademic Researchers Focused on Water	Water
Last Name	First Name	Campus	Department or Center	Area of Interest/Specialization
Almeida	Rafael	IU Bloomington	O'Neill School of Public and Environmental Affairs	ecology, hydrology, biogeochemistry
Ardekani	Arezoo	Purdue West Lafayette	Mechanical Engineering	behavior of microorganisms in fluids
Attari	Shahzeen	IU Bloomington	O'Neill School of Public and Environmental Affairs	environmental psychology, resource conservation, social dilemmas
Autio	Bob	Purdue West Lafayette	Indiana Mesonet	
Bannon, Ph.D.	Cynthia	IU Bloomington	Classical Studies	water rights in Roman law, Roman water communities
Barr	Bob	IU Indianapolis	Earth Sciences	stream system health, flood hazard mitigation, erosion control, water quality
Barreto	Reynaldo	Purdue Northwest	Biology & Chemistry	groundwater contamination by VOC's incl gasoline
Beeker	Charles D.	IU Bloomington	School of Public Health	underwater archaeology, marine protected areas, protection of underwater resources
Benson	David	Marian University	Biology	environmental science
Berke	Melissa	Notre Dame		
Bertocci, Ph.D.	Loren	Marian University	Biology	
Bird	Broxton	IU Indianapolis	Earth Sciences	water resources and climate variability
Blatchley	Ernest	Purdue West Lafayette	Civil Engineering	water treatement and reuse
Bosch, Ph.D.	Nathan S.	Grace College	Lilly Center for Lakes and Streams	
Bowling	Laura	Purdue West Lafayette	Agronomy	watershed hydrology, GIS, soil and water conservation
Branam	Tracy	IU Bloomington	Indiana Geological and Water Survey	aquifer and groundwater characterization, abandoned mines
Burlingame	Matt	Grace College	Lilly Center for Lakes and Streams	
Chaubey	Indrajeet	Purdue West Lafayette	Earth, Atmosphere, and Planetary Sciences	stream gauging, flow and transport
Chauret	Christian	IU Kokomo	Sciences	water microbiology, waterborne diseases, water treatment
Chen	Dong	Purdue Fort Wayne	Civil Engineering	water and wastewater treatment, aqueous chemistry
Cherkauer	Keith	Purdue West Lafayette	Agricultural & Biological Engineering	midwest water resources, impacts of claimate variability
Clark, M.S.E.S.	Melissa A.L.	IU Bloomington	O'Neill School of Public and Environmental Affairs	lakes and watersheds, limnology, aquatic habitats
Craft, Ph.D.	Christopher	IU Bloomington	O'Neill School of Public and Environmental Affairs	wetlands, water quality, wetland restoration
Davis	Ginger	IU Bloomington	Indiana Geological and Water Survey	
de Almeida Miranda	Danielle	Notre Dame		
DeBuhr	Larry	Hanover College	Rivers Institute	unknown
DeMott	William	Purdue Fort Wayne	Biology	aquatic ecology, algae-zooplankton interactions
Druschel	Greg	IU Indianapolis	Earth Sciences	microbial populations and behavior in sediment-water interactions
Edmonds, Ph.D.	Douglas	IU Bloomington	Geological Sciences	sedimentology, formation of levees and deltas
Eflin	James	Ball State	Natural Resources & Environmental Mgmt	
Engel	Bernard	Purdue West Lafayette	Agricultural & Biological Engineering	water quality, drainage, irrigation, erosion control
Fein	Jeremy	Notre Dame	Civil & Environmental Engineering and Earth	fate and mobility of heavy metals and radiologic contaminants in
			Sciences	glouinwatel
Ficklin, Ph.D.	Darren	IU Bloomington	Geography	watershed nydrology, water quality modeling, drought modeling and assessment, climate change impacts
Filippelli, Ph.D.	Gabriel	IU Indianapolis	Earth Sciences	water quality impacts of heavy metals in sediment
Florea	Lee J.	IU Bloomington	Indiana Geological and Water Survey	carbonate aquifers, water sampling and monitoring

Last Name	First Name	Campus	Department or Center	Area of Interest/Specialization
Frankenberger	Jane	Purdue West Lafayette		watershed management, nonpoint source modeling, surface water runoff
Frisbee	Marty	Purdue West Larayette		
Gillespie	Robert	Purdue Fort Wayne	Biology	agricultural chemicals, water quality, aquatic species
Goforth	Reuben	Purdue West Lafayette		
Govindaraju	Rao	Purdue West Lafayette	Civil Engineering	watershed hydrology, modeling surface and subsurface water movement
Guebert, Ph.D.	Michael C.	Taylor University	Earth and Environmental Science	
Hamlet	Alan	Notre Dame	Civil & Environmental Engineering and Earth Sciences	surface water hydrology, climate change
Hamlin	Christopher	Notre Dame	History	environmental history, incuding wastewater and river pollution
Han	Bangshuai	Ball State		
Harbor	Jon	Purdue West Lafayette	Earth, Atmosphere, and Planetary Sciences	modeling land use and climate change impacts on water resources
Hasenmueller	Nancy	IU Bloomington	Indiana Geological and Water Survey	groundwater characterization, karst and sinkhole sites in Indiana
Науеѕ	Shannon	Earlham College		
Hellenthal	Ronald	Notre Dame	Biological Sciences	biological indicators of water quality, assessment and quality control of environmental information
Hook	Tomas	Purdue West Lafayette		
Hoskins	Tyler	Purdue West Lafayette		
Hwang, Ph.D.	Tae Hee	IU Bloomington	Geography	remote sensing, ecohydrology
Jacinthe	Pierre-Andre	IU Indianapolis	Earth Sciences	nitrogen dynamics and water quality, biogeochemistry of restored wetlands; conservation tillage and soil processes
Jacobus	Luke	IU Columbus		
Jafvert	Chad	Purdue West Lafayette	Civil Engineering	contaminant fate in groundwater
Jensen	Richard	Notre Dame	Economics	environmental economics, bioeconomics of invasive species, invasive species in the Great Lakes
Johnson, Ph.D.	Claudia C.	IU Bloomington	Geological Sciences	geobiology, Caribbean geology, reefs
Jones	Bill	IU Bloomington	O'Neill School of Public and Environmental Affairs (emeritus)	lake and watershed management, esp water quality
Kane	Stephanie C.	IU Bloomington	School of Global and International Studies	political ecology of water, climate change
Kelly	Jason	IU Indianapolis	History	environmental change, rivers and human behavior
Kern	Mike	IU South Bend	Sociology and Center for a Sustainable Future	sustainability
Kingsbury	Bruce	Purdue Fort Wayne	Biology and Environmental Resources Center	imperiled species, landscape management
Kladivko	Eileen	Purdue West Lafayette	Agronomy	contaminant transport, drainage, tile drain systems
Kleinschmidt	Stephen	Purdue Fort Wayne	Public Policy	local governments and environmental decision making
Krutilla	Kerry	IU Bloomington	O'Neill School of Public and Environmental Affairs	environmental policy analysis and evaluation
Lamberti	Gary	Notre Dame	Biological Sciences	wetland ecology, river and stream ecosystems
Latimer	Jennifer	Indiana State		

Last Name	First Name	Campus	Department or Center	Area of Interest/Specialization
Lave	Rebecca	IU Bloomington	Geography	fluvial geomorphology, stream restoration, political ecology
Lee	John	Purdue West Lafayette	Agricultural Economics	water resource economics, soil and water conservation, risk assessment
Lee	Linda	Purdue West Lafayette	Agronomy, Environmental & Ecological Engineering	
Letsinger	Sally	IU Bloomington	Geography	watershed modeling, contaminant fate and transport, riparian buffer zones
i)	Lin	IU Indianapolis	Earth Sciences	impact of environmental change on land and aquatic ecosystems, GIS and remote sensing
:=	Zhiying	IU Bloomington	O'Neill School of Public and Environmental Affairs	hydrology, water resources, conservation
Lodge	David	Notre Dame	Biological Sciences	freshwater ecology, invasive species in the Great Lakes
Luo	Tengfei	Notre Dame	Mechanical Engineering	thermal transfer, water desalination
Maretsky	Vicky	IU Bloomington	O'Neill School of Public and Environmental Affairs	landscape conservation, climate change, endangered species management
Marietta	Garrett	IU Bloomington	Indiana Geological and Water Survey	
Merwade	Venkatesh	Purdue West Lafayette	Civil Engineering	water resource modeling, GIS, stream dynamics, flood and drought
Maurice	Patricia	Notre Dame	Civil & Environmental Engineering and Earth Sciences	mineral-water interface geochamistry, hydrology and biogeochemistry of freshwater wetlands
Michalski	Greg	Purdue West Lafayette		
Mohtar	Rabi	Purdue West Lafayette	Agricultural & Biological Engineering	multi-scale hydrologic modeling
Moreno, Ph.D.	Max J.	IU Indianapolis	Environmental Health Sciences	waterborne illness, water quality and human health
Mudica	Kathryn	Indiana State		
Na	Chongzheng	Notre Dame	Civil & Environmental Engineering and Earth Sciences	water treatment, nanotechnology
Need	Andrea	IU Bloomington	O'Neill School of Public and Environmental Affairs	environmental law, environmental impacts of shipping on the Great Lakes
Nerenberg	Rob	Notre Dame	Bioengineering	water treatment, denitrification in agricultural streams
Neumann	Klaus	Ball State		
Nnanna	George	Purdue Northwest	Mechanical Engineering and Water Institute	water treatment
Noonan, Ph.D.	Douglas	IU Indianapolis	O'Neill School of Public and Environmental Affairs	environment and economic development, disaster mitigation and response
Novick, Ph.D.	Kimberly	IU Bloomington	O'Neill School of Public and Environmental Affairs	carbon and water cycling, watershed ecology
Peller, Ph.D.	Julie	Valparaiso University	Chemistry	water quality, Lake Michigan shoreline, emerging contaminants
Pfrender	Michael C.	Notre Dame		
Philipp	Craig	Hanover College	Chemistry	
Pijanowski	Bryan	Purdue West Lafayette	Forestry and Natural Resources	watershed and landscape ecology and geography
Prokopy	Linda	Purdue West Lafayette	Horticulture and Landscape Architecture	watershed conservation and land use, nonpoint source pollution
Pyron	Mark	Ball State	Biology	aquatic ecology, conservation of aquatic resources
Randall	Stephen K.	IU Indianapolis	Biology	crop responses to cold and drought conditions
Richards	Kenneth	IU Bloomington	O'Neill School of Public and Environmental Affairs environmental policy implementation	environmental policy implementation

Last Name	First Name	Campus	Department or Center	Area of Interest/Specialization
Royer	Todd V.	IU Bloomington	O'Neill School of Public and Environmental Affairs	water quality and nutrient standards, aquatic biogeochemistry
Rupp	Robin	IU Bloomington	Indiana Geological and Water Survey	digital elevation model of Indiana
Ryan	Travis	Butler		amphibians, ecology, conservation
Sabaj	McKailey	IU Bloomington	Indiana Geological and Water Survey	
Scarpino	Philip	IU Indianapolis	History	environmental history, U.S. rivers
Scribailo	Robin	Purdue Northwest	Biology & Chemistry	conservation ecology, aquatic plants
Sepulveda	Marisol	Purdue West Lafayette		
Shaw, Ph.D.	Joseph	IU Bloomington	O'Neill School of Public and Environmental Affairs	environmental toxicology, species adaptation
Shrader-Frechette	Kristin	Notre Dame	Philosophy	ethics and risk assessment
Silliman	Stephen	Notre Dame	Civil & Environmental Engineering and Earth Sciences	groundwater hydrology
Simsek	Halis	Purdue West Lafayette		
Stone	Jeffery	Indiana State		
Sweeten, Ph.D.	Jerry	Manchester University	Biology	stream ecology, nonpoint source pollution
Szarleta	Ellen	IU Northwest	O'Neill School of Public and Environmental Affairs and Ctr for Urban and Regional Excellence	public preferences re environmental issues, Lake Michigan region
Tank, Ph.D.	Jennifer	Notre Dame	Biological Sciences	land use and stream ecosystem function, streams in Midwestern agricultural areas
Thompson	Todd A.	IU Bloomington	Indiana Geological and Water Survey	geology of Indiana lakes and aquifers
Turco	Ron	Purdue West Lafayette		bacterial water contamination and bioremediation
Venturelli	Paul	Ball State		
Viswanathan	Chandramouli	Purdue Northwest	Civil Engineering	water resource systems analysis, reservoir operation, water resources planning and optimization
Wang	Lixin	IU Indianapolis	Earth Sciences	water cycles, land use and vegetation interactions, drought and drought effects on agriculture
Ward	Jessica	Ball State		
Welp	Lisa	Purdue West Lafayette		
White, Ph.D.	Jeffrey R.	IU Bloomington	O'Neill School of Public and Environmental Affairs	aquatic chemistry, limnology, environmental biogeochemistry
Widhalm	Melissa	Purdue West Lafayette	Purdue Climate Change Research Center	
Wilson	Jeffrey	IU Indianapolis	Geography	human health and environment
Wittig, Ph.D.	Victoria	Purdue Northwest		
Yoder	Landon	IU Bloomington		
Zhou	Zhi	Purdue West Lafayette		
Zhu, Ph.D.	Chen	IU Bloomington	Geological Sciences	aqueous geochemistry, hydrogeology
Zirogiannis, Ph.D.	Nikolaos	IU Bloomington	O'Neill School of Public and Environmental Affairs	water policy and economics, water utility performance