Stream Water-Quality Monitoring Conducted in Support of the Iowa Nutrient Reduction Strategy

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University and the IIHR Hydroscience and Engineering Center

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Executive Summary

Monitoring of nitrogen and phosphorus in streams and rivers throughout Iowa is an essential element of the Iowa Nutrient Reduction Strategy (INRS). Sampling and analysis of surface water is necessary to develop periodic estimates of the amounts of nitrogen and phosphorus transported from Iowa. Surface and groundwater monitoring provides the scientific evidence needed to document the effectiveness of nutrient reduction practices and the impact they have on water quality. Lastly, monitoring data informs decisions about where and how best to implement nutrient reduction practices, by both point sources and nonpoint sources, to provide the greatest benefit at the least cost.

The impetus for this report comes from the Water Resources Coordination Council (WRCC) which states in its 2014-15 Annual Report “Efforts are underway to improve understanding of the multiple nutrient monitoring efforts that may be available and can be compared to the nutrient WQ monitoring framework to identify opportunities and potential data gaps to better coordinate and prioritize future nutrient monitoring efforts.” This report is the culmination of those efforts.

The report’s primary focus is to document known stream monitoring efforts in Iowa that can help answer questions such as, “How much nitrogen and how much phosphorus are being exported from Iowa?” “What reductions in nitrogen and phosphorus occur following implementation of nutrient reduction practices by non-point sources?” and “What reductions in nitrogen and phosphorus occur following installation of nutrient reduction technologies by point sources?” This is believed to be the first time a comprehensive listing of surface water monitoring in Iowa, specifically for nutrients, has been undertaken.

The report begins by discussing the numerous challenges inherent in collecting and using water quality data to demonstrate progress towards meeting the goals of the INRS. These challenges include:

1. the impact that legacy nutrients and lag time have on documenting water quality changes;
2. the importance of having comprehensive data on nutrient reduction practices implementation;
3. the effect of variable precipitation and steam flow and the impact that climate change could have on determining water quality trends; and,
4. the value of long-term monitoring to measure progress and the importance of properly situated and maintained monitoring locations.

The main section of the report lists and briefly describes the multiple stream nutrient monitoring efforts following the outline provided by the Iowa Nutrient Monitoring Framework. It begins with a discussion of monitoring occurring in large watersheds (i.e. HUC8); principally the Iowa fixed-station monitoring network and remote sensors deployed by the IIHR Hydroscience and Engineering Center at the University of Iowa and the U.S. Geological Survey with support from the Iowa Department of Natural Resources. It then moves to descriptions of the various monitoring projects that have been done or are currently underway in smaller watersheds (i.e. HUC12 or smaller) by various governmental, non-governmental and research organizations with funding provided through the Iowa Water Quality Initiative, the National Water Quality Initiative and multiple other sources.

The final sections of the report provide an analysis of areas where data is not yet available or where more information is needed and provides recommendations for possible next steps to improve upon existing water quality data collection efforts. These suggested next steps include:

1. the need to periodically update this report with new information as monitoring programs change, new programs begin and current programs end;
2. the urgency to develop a reliable method for providing a periodic statewide load estimate for phosphorus;
3. the formation of a work group to develop a long-range plan with recommendations and priorities for what monitoring should be conducted at what locations and at what frequencies;
4. that data from paired watershed studies be analyzed as it becomes available and adjustments be made to monitoring programs where necessary based on lessons learned;
5. that estimates made during development of the INRS regarding point source contributions of nutrients be revised based on actual data as it becomes available; and,
6. that information be developed and updated on the types and amounts of nutrient reduction practices as they are adopted in order to correlate measured water quality changes with in-field and edge-of-field practices and to document nutrient reductions before they can be measured by stream water quality monitoring.

Purpose of This Report

The Iowa Nutrient Reduction Strategy (INRS) provides a practical, scientific approach to reduce the amounts of nitrogen and phosphorus (nutrients) entering rivers and streams which ultimately flow to the Gulf of Mexico. In addition to contributing to localized water quality problems, these nutrients also contribute to an area in the Gulf of Mexico known as the hypoxic zone where dissolved oxygen levels become too low at times to support fish, shellfish and other aquatic life. The INRS establishes a goal of reducing the amounts of nitrogen and phosphorus leaving Iowa by 45% each and outlines a process for achieving this goal through increased efforts by both point sources and non-point sources to control nutrient losses due to human activities.

One of the key elements of the INRS is to develop new and maintain existing programs to measure water quality and the changes that occur over time as nutrient reduction practices are implemented by both point sources and non-point sources. While the INRS does not specify precisely how this should be done, it does contain the following statements that can serve as guiding principles:

- "The IDNR will track progress for implementing the point source nutrient reduction strategy using results from comprehensive annual ambient stream monitoring and analysis utilizing existing permanent monitoring locations and focused study areas";

- “Regarding nonpoint sources, develop new and expanded frameworks to track progress, beyond the traditional ambient water quality monitoring networks”;
- “Ambient water monitoring and effluent monitoring are key components of the assessment framework”;
- “Enhance the state’s water monitoring to support watershed implementation strategies and to be useful in verifying performance”;
- “The Iowa Department of Natural Resources will convene a technical work group beginning in 2013 to define the process for providing a regular nutrient load estimate (i.e., nutrient budget) based on the ambient water quality data network. This will include specifying the most appropriate mathematical model, the acceptability of the data, and a process for making future adjustments based on the latest information and advancements in science and technology”;[1]

The 2014-2015 Annual Report by the Water Resources Coordinating Council (WRCC) states “Efforts are underway to improve understanding of the multiple nutrient monitoring efforts that may be available and can be compared to the nutrient WQ monitoring framework to identify opportunities and potential data gaps to better coordinate and prioritize future nutrient monitoring efforts.”[2]

The primary purpose of this document is to describe and report on current known stream nutrient monitoring efforts in Iowa in the context of the Nutrient Water Quality Monitoring Framework presented in Figure 1 below. This report will also discuss the numerous challenges inherent in collecting and using water quality data to demonstrate progress towards meeting the goals of the INRS and suggest ways to improve and coordinate the collection and evaluation of water quality data for these purposes. The focus of this report is consistent with the WRCC commitment “to continue to coordinate and evaluate opportunities for monitoring locations and focused study areas in order to track progress”.

The Nutrient Water Quality Monitoring Framework was developed to illustrate the length of time needed to show a measureable change in water quality increases as the size of the watershed increases. Generally less time is needed to measure a change in the quality of runoff from an individual field of ten to a few hundred acres in size following implementation of nutrient reduction practices, whereas more time is needed to show a change in water quality at the terminus of a larger watershed that consists of tens of thousands of acres or more.

There are a variety of reasons why this is the case which are discussed in a later section of this document pertaining to challenges to monitoring surface water quality but, in general, as the watershed size increases there is an increase in the number of factors that affect water quality. Natural systems become more complex as size increases.

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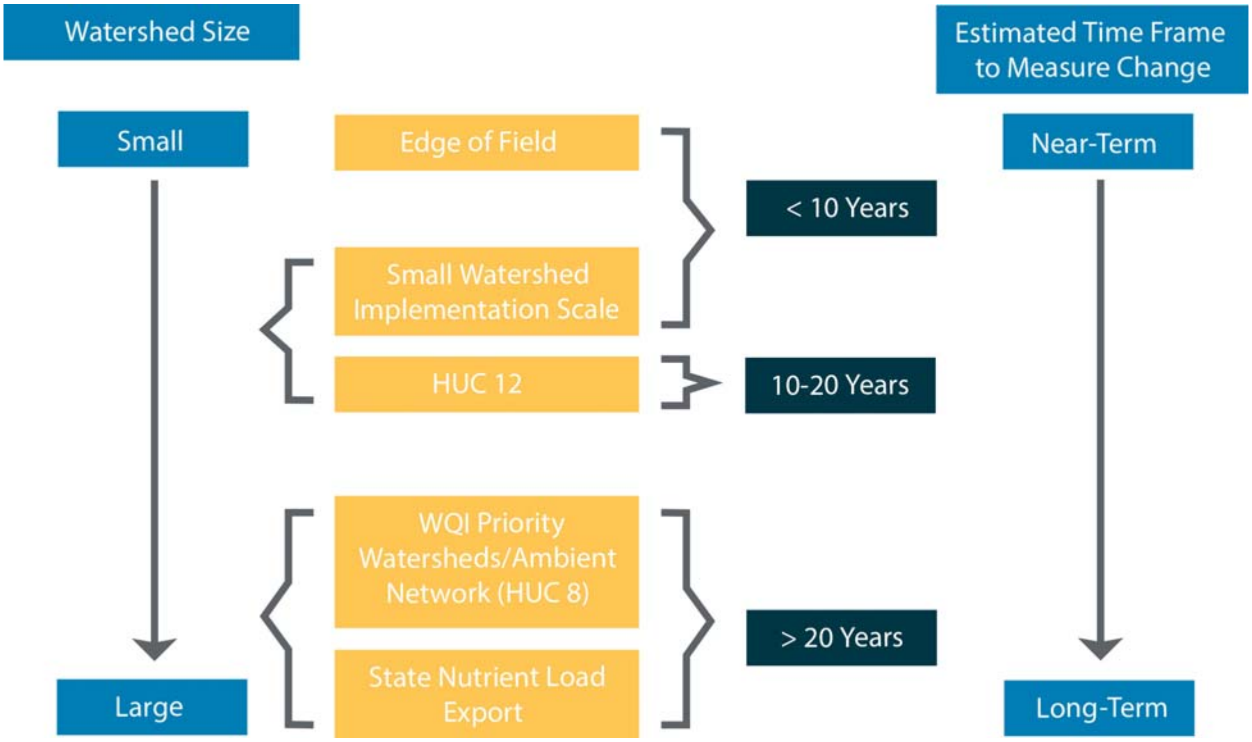
[1] Iowa Nutrient Reduction Strategy- A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico, Section 1.4.6, p. 24.

[2] Iowa Nutrient Reduction Strategy Annual Progress Report 2014-2015, p. 24

Figure 1 - Nutrient Water-Quality Monitoring Framework



What Questions are Important to Measuring Progress of the INRS?

Monitoring programs are typically designed to provide data to answer a specific question or set of questions. Referring to the Nutrient Water Quality Framework, less data collected over a shorter time period at a single location are needed to answer questions such as “How much is nitrogen reduced by a bioreactor?” or “How much phosphorus is removed by a city wastewater treatment plant?” or “By how much is phosphorus reduced when a given amount of cover crops are planted and maintained in a watershed of 1,000 acres?” Significantly more data collected over a much longer period of time and often at multiple locations are necessary to answer the question “How much nitrogen is discharged from the Iowa/Cedar River basin annually over a 20 year period?” Therefore, monitoring programs, to reliably assess changes in water quality, should be designed to answer specific questions and should consider a number of factors including, but not limited to, the size of a watershed to be monitored, the number of locations that need to be sampled, how soon results are needed, level of practice adoption/management, and the costs and other resources available to collect and analyze samples and interpret results.

The primary questions that need to be answered in order to measure nutrient reductions to document progress towards meeting the goals of the INRS include the following although these are by no means the only questions that will be asked and answered:

1. What water quality monitoring resources are available and what additional monitoring is needed to measure the impact of the INRS on reducing nutrient loads in Iowa waters?
2. What are the challenges associated with measuring changes in stream water quality?
3. How much nitrogen and how much phosphorus are being exported from Iowa?
4. What reductions in nitrogen and phosphorus occur following implementation of nutrient reduction practices by non-point sources?
5. What reductions in nitrogen and phosphorus occur following installation of nutrient reduction technologies by point sources?

What Challenges are Associated with Water Quality Monitoring?

Monitoring of natural ecosystems presents a number of technical, scientific and policy challenges which are described in this section. Each of these challenges must be overcome or minimized for a monitoring program to be successful and provide the information necessary to address the question(s) the study was designed to answer. This section discusses the challenges associated with measuring changes in the amounts of nutrients in Iowa's rivers and streams. Gaps in coverage or extent of current monitoring efforts designed to address these challenges are discussed in a later section of this report titled "Data Gaps."

Section 2 of the INRS contains a comprehensive literature review of nonpoint source practices (management practices) to reduce nitrogen and phosphorus transport at the field scale but nutrient reductions are more challenging to document at the watershed scale. A report prepared by the Northeast-Midwest Institute in collaboration with the U.S. Geological Survey (Bentanzo, et al. 2015) lists and discusses the following challenges:

> "The effectiveness of management practices can vary substantially within and among watersheds, and the cumulative effects of combinations of practices can produce results that are different than the sum of their individual reductions (Sharpley et al., 2009; Francesconi et al., 2014). Factors that can complicate watershed-scale assessments of management practice effectiveness include:
>
> - It takes time for management practices to be implemented at the watershed scale with a density that results in water quality change;
> - Land-use and land-management practices are constantly changing;
> - Legacy phosphorus already in soil and sediment can continue to be released after conservation practices have been implemented (Jarvie et al. 2013a and 2013b; Sharpley et al., 2013);
> - Precipitation and streamflow vary from year to year, which can affect the length of time required to measure water-quality change;

- There is a lack of long-term monitoring;
- It is challenging to maintain an adequate and appropriate long-term monitoring program to document results;
- Data on management practice implementation and maintenance, and other land-use changes are not available or are difficult to obtain"

In addition, current research is documenting the impact that stream bed and bank erosion can have on nutrient loading to streams.

Each of the potential challenges listed above are discussed in greater detail in the following sections.

Legacy Nutrients

The term "legacy nutrients" is used to describe nitrogen and phosphorus present in soil and groundwater resulting from both natural and anthropogenic sources. These legacy nutrients can be a significant source of the total nutrient load delivered to a stream when they are released to surface water as stream beds and banks erode and as groundwater naturally moves and is intercepted by streams and rivers.

For example, Zaimes et al. (2008b) observed that more than 220 pounds per year of phosphorus was eroded per approximately one-half mile of stream bank length in several regions of Iowa. Schilling et al. (2009) estimated that between 141 pounds and 375 pounds of nitrogen and 128 pounds of phosphorus per 0.62 miles of stream could be delivered per year to Walnut Creek in central Iowa from eroding stream banks. Results from this same study suggest that soil in the riparian zone of Walnut Creek contain nutrient concentrations at levels high enough to negatively impact shallow groundwater.

The ability of a monitoring program to correlate water quality changes with implementation of nutrient reduction practices can be greatly affected if sources of legacy nutrients resulting from stream bed and bank erosion and shallow groundwater in the vicinity of streams and rivers are not accounted for in project design.

Lag Time

The assessment of the impact of nutrient reduction practices on water quality can be complicated by the difference in time between the implementation of practices and a measureable change in water quality. If this "lag time" is not accounted for in the design and implementation of a monitoring program it can lead to incorrect conclusions about the effectiveness of practices at improving water quality (Baker et al., 2007; Jarvie et al. 2013a and 2013b; Sharpley et al., 2013). A review by Meals, et al., 2010, states:

> "Nonpoint source (NPS) watershed projects often fail to meet expectations for water quality improvement because of lag time, the time elapsed between adoption of management changes and the detection of measurable improvement in water quality in the target water body. Even when management changes are well designed and fully implemented, water quality monitoring efforts may not show definitive results if the monitoring period, program design, and sampling frequency are not sufficient to address the lag between treatment and response. The main

> components of lag time include the time required for an installed practice to produce an effect, the time required for the effect to be delivered to the water resource, the time required for the water body to respond to the effect, and the effectiveness of the monitoring program to measure the response."

The authors offer several possible approaches to overcome some of the challenges that lag time poses:

- Recognizing that lag time should be a component of any monitoring program and adjusting expectations accordingly;
- Characterizing the watershed particularly with respect to characteristics such as groundwater travel time;
- Considering lag time issues in selecting, siting and monitoring of best management practices;
- Focusing monitoring efforts on small watersheds close to the source where pollutants are delivered;
- Carefully selecting indicators of water quality change, and designing monitoring programs to effectively detect and measure change.

Limitations of Conservation Practice Data

Documentation of land-use and land-management practices and access to this documentation is needed to explain differences in water quality between and among streams. There have been few studies that have been able to document the effect of nutrient reduction practice implementation on water quality especially at the watershed scale. Reasons for this include a lack of widespread documentation of privately implemented practices within a watershed, variability of weather events, lack of real-time data regarding the use of practices, and short periods of record of water-quality monitoring. The difficulty in obtaining real-time, reliable information regarding land management practices and changes in land use leads to generalizations about non-point source nutrient contributions that may actually undermine efforts to identify practices that improve water quality.

Climate Change and Extreme Weather Events

The ability to document the impact of non-point source nutrient reduction practices on water quality may also be challenged by a changing climate. For example, recent data indicate that large phosphorus loads are exported to Lake Erie during major storms. Climate-change models suggest storms will become more frequent and more intense (Koslow et al., 2013; International Joint Commission 2014; Michalak et al. 2013a; Melillo et al., 2014), and increased loads of total phosphorus (TP) and suspended sediment will be transported to the western basin of Lake Erie (U.S. Environmental Protection Agency, 2013). Currently, the vast majority of TP and dissolved reactive phosphorus (DRP) loads occur during major storm events (Reutter et al., 2011). Studies have shown that 80 percent of annual phosphorus loadings can be produced by just one or two storms (Richards and Holloway, 1987; Betanzo, et. al. 2015).

Kyveryga and Anderson (2016) evaluated the risk of nitrogen deficiency in corn and climate data for Iowa. They found that the change in rainfall over the past 25 years has increased the probability of nitrogen deficiency in corn plants in northwest Iowa. The authors defined extreme rainfall events as those that fell outside the 95th percentile distribution of historic spring and summer rainfall. Six out of 88 years (1893-1980) or (6.8%) were classified as extreme while 13 years or 37.1% were considered extreme for the 29 years from 1981 to 2010. An increase in the amount of rain overall, and especially an increase in the number of extreme rainfall events, may lead to greater losses of both nitrogen and phosphorus to surface water.

Section 1 of the INRS states:

> “The current understanding is that in tile-drained landscapes, N losses are greater due mostly to subsurface drainage and dominated by nitrates. The largest losses can occur with sustained flows that usually occur in the spring and at a time with little evapotranspiration and nutrient uptake. In “rolling” or hilly landscapes with good drainage, phosphorus losses can be greater. Surface runoff and sediment are the predominant carriers. The largest losses can occur with “flashy” rainfall runoff events, such as in spring when there is less vegetative cover.”

If the number and intensity of storms increases due to changing climate it may be more difficult to demonstrate that nutrient reductions have occurred using stream monitoring alone. Although monitoring during and after storms is necessary to accurately estimate nutrient loadings to streams and rivers, and to quantify performance of agricultural management practices, obtaining such data can be difficult and expensive.

Location of Monitoring Sites

The selection of appropriate monitoring sites is also critical for answering the principle questions relevant to the INRS. To detect the effectiveness of nutrient reduction practices, monitoring sites must be located in watersheds where such practices can, and will continue to be, extensively implemented. Further, tributary water-quality and streamflow data at these sites must be available if trends in concentration and load are to be measured over time. Finally, data on management practice implementation and other changes in land use and nutrient sources throughout a watershed must be available to correlate water-quality change with alterations to the land. Without this information, the relationship between nutrient reduction practices and water quality cannot be evaluated, even if such practices are delivering reductions in nutrient loads.

Data collected at watershed monitoring sites[3] measures the cumulative effect on water quality of the implementation of nutrient reduction practices and total water balance within the particular watershed. Monitoring at small watershed headwater sites allows reductions that have been measured at the edge-of-field scale to be verified, and allows measurement of the cumulative effects of multiple different practices across a range of varying soil, drainage, slope, and cropping patterns that occur in the watershed. As watershed size increases, it becomes progressively more difficult to achieve the degree of practice implementation needed to produce a consistently measureable change in water quality. If water quality changes resulting from implementation of nutrient reduction practices cannot be detected

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[3] For purposes of this document, small watersheds refers to watersheds at a HUC 12 scale which typically range in size from 10,000 – 40,000 acres or 15 to 62 mi^2. Large watersheds refers to river basins at a HUC 8 scale which in Iowa range from 249,600 to 1,238,400 acres or 390 to 1,935 mi^2. There are 56 HUC 8 watersheds in Iowa and approximately 1600 HUC 12 watersheds. The Mississippi and Missouri Rivers (HUC 2) are not addressed by this document.

in small watersheds, there is little chance that the impacts of such practices will be measureable in larger watersheds.

On the other hand, results from monitoring in small watersheds cannot be extrapolated directly to large watersheds. A number of factors influence the fate and transport of nutrients as they move downstream. When monitoring is conducted at the outlet of a major river or stream, cumulative inputs from numerous smaller streams, point sources, and nonpoint sources in areas of the watershed with and without widespread nutrient reduction practices in place plus in-stream chemical transformations and varying rates of nutrient transport and delivery makes it more difficult detect changes in water quality but monitoring these cumulative inputs is no less important.

Importance of Long-Term Data Collection

Monitoring sites that are sampled consistently over long time periods is critical for evaluating long-term trends in water quality. Long records are necessary to be able to distinguish water-quality changes caused by short-term weather patterns from those resulting from implementation of nutrient reduction practices. Monitoring programs in small watersheds (e.g. <HUC 12) with 5, 10, or more years of data are uncommon but the information provided by longer-term monitoring programs cannot be obtained using short-term studies. The development of water monitoring programs needs to take into account that natural systems often respond slowly to change. Measuring changes in water quality, especially in larger watersheds, will require long-term monitoring programs.

Maintaining long-term monitoring programs is challenging because it requires a sustained, long-term funding commitment. Costs for personnel, transportation and equipment to collect samples, perform laboratory analysis and for data storage and analysis are all factors in the cost of water quality monitoring. In addition, policy makers are constantly challenged with having to decide how to prioritize and distribute finite dollars among many competing needs including long-term monitoring programs.

Variable Precipitation and Stream Flow

Variation in the amounts and timing of precipitation and resulting stream flows may present the biggest challenge to documenting trends in water quality and the impact of nutrient reduction practices. Section 1 of the INRS states “Precipitation that results in excess water (thus surface runoff and/or subsurface drainage) can and does come at any time. When that happens some nutrients are certain to be lost.” Year to year variation in precipitation is likely the biggest factor in the variability of nutrient concentrations and loads and the main reason why measuring statistically significant trends in nutrients is difficult.

Schilling, et al. (2013) state that “Variations in precipitation affect stream flow and the transport of nitrate in streams”. Concentrations are known to fluctuate with discharge (Schilling and Lutz, 2004) and the relation between nitrogen export and discharge is well established (Basu et al., 2010; Raymond et al., 2012). Recent modeling suggests that both precipitation and discharge are important variables in evaluating daily nitrate concentrations in agricultural watersheds (Feng et al., 2013).

Even if other challenges can be overcome with improved monitoring and data analysis, it isn’t possible to control when and how much rainfall is received and this variability and unpredictability makes measuring trends in water quality very difficult. Funding is appropriated to be spent within a few years and lawmakers and the public expect change rapidly, this puts pressure to distribute funds within a short period of time and not obligate funding that won't be spent for another 5 or more years.

What Nutrient Monitoring and Assessment Efforts are Currently Underway in Iowa?

This report focuses primarily on current efforts to monitor stream water quality. The results of these efforts can potentially be used to measure nutrient loads in designated priority watersheds, to determine changes in nutrient loads in smaller watersheds resulting from implementation of management practices and to determine changes in the amounts of nitrogen and phosphorus leaving Iowa. Monitoring of nutrients in Iowa is performed by a number of different entities for different purposes and at different watershed scales. Table 1 provides a summary of known nutrient monitoring conducted in Iowa and provides basic information on each including the frequency and duration of sampling, parameters tested, watershed name and size and the general purpose(s) for each monitoring effort. Each of these efforts is described in greater detail in this section.

While the primary purpose of this report is to identify what water quality monitoring data and information are currently available that may be useful in answering the questions most relevant to determining the success of the INRS, at the same time it is important to acknowledge the importance of other nutrient monitoring that takes place. For example, research is taking place on new and existing in-field and edge-of-field nutrient reduction practices and documenting their effectiveness. Wastewater treatment facilities are required to monitor nutrients in raw waste and final effluent. Samples are collected and analyzed for nutrients to document water quality conditions prior to the development of a Total Maximum Daily Load (TMDL) and to provide a baseline against which to measure water quality improvement. A utility that provides drinking water measures nitrate in both source water and finished water to assure safe drinking water for its customers. Data collected for these and other purposes may also be useful in measuring progress under the INRS and the information gathered can help inform future efforts.

Table 1

Water Quality Monitoring for Nutrients

Project	Responsible Entity	Purpose	Project Status	Watershed Name	Watershed Size	Parameters Measured	Sampling Frequency
Fixed-station Stream	IDNR	Biennial WQ assessments (305b) WQS development NPDES permitting	Active	Various	≥ HUC 8	NH_4, NO_2-N+NO_3-N, TKN, Diss PO_4-P, total PO_4-P, TSS, TDS, VSS, Flow, Other	Monthy
Lake	IDNR	Biennial WQ assessments (305b) WQS development	Active	Various	NA	NH_4, NO_2-N+NO_3-N, TKN, Diss PO_4-P, total PO_4-P, TSS, TDS, VSS, Flow, Other	3x Recreation Season
Biological	IDNR	Biennial WQ assessments (305b) WQS development	Active	Various	?	Chlor a, NO_2-N+NO_3-N, TKN, Diss PO_4-P, total PO_4-P, TSS, TDS, Flow, Other	1x to Monthly
Groundwater	IDNR		Active	Various	NA	NH_4, NO_2-N+NO_3-N, TKN, Diss PO_4-P, total PO_4-P, TDS, Pesticides, Degradates, Other	Annually[1]
IWQIS	IIHR/USGS	INRS implementation progress WQI project support Nutrient budget estimating	Active	Various Targeted watersheds		NO_3-N	Continuous

Paired Watersheds							
Sny McGill/Bloody Run	IDNR	Management Practices Effectiveness	Inactive	Sny McGill	<HUC 12	?	
Wall Lake Inlet/Black Hawk Lake	IDNR/NRCS	Management Practices Effectiveness	Active	Black Hawk Lake	?	?	
NWQI Projects		Management Practices Effectiveness					
Badger Creek	?		?	?	?	None	?
Lower SF Chariton River	?		?	Chariton	?	None	?
Lost Branch-Chariton River	?		?	Chariton	?	None	?
IAWQI Projects		Management Practices Effectiveness					
Miller Creek	Black Hawk SWCD		Active	Middle Cedar	HUC 12	Nutrient species (other parameters variable)	?
Van Zante Creek	Marion SWCD		Active	South Skunk	HUC 12	Nutrient species (other parameters variable)	?
West Fork Crooked Creek	Washington SWCD		Active	Skunk	HUC 12	Nutrient species (other parameters variable)	?
Boone River	Wright SWCD		Active	Boone	HUC 12	Nutrient species (other parameters variable)	?
Central Turkey River	Winneshiek SWCD		Active	Turkey	HUC 12	Nutrient species (other parameters variable)	?
Benton/Tama	Benton SWCD		Active	Middle Cedar	HUC 12	Nutrient species (other parameters variable)	?
Rock Creek	IA Soybean Assn		Active	Upper Cedar	HUC 12	Nutrient species (other parameters variable)	?

N. Raccoon Headwaters	Buena Vista SWCD		Active	North Raccoon	HUC 12	Nutrient species (other parameters variable)	?
Elk Run	ACWA		Active	North Raccoon	HUC 12	Nutrient species (other parameters variable)	?
Bluegrass & Crabapple Creeks	Audubon SWCD		Active	East Nishnabotna	HUC 12	Nutrient species (other parameters variable)	?
Squaw Creek	Prairie Rivers RC&D		Active	South Skunk	HUC 12	Nutrient species (other parameters variable)	?
Polk County WMA	Polk SWCD		Active	North Raccoon	HUC 12	Nutrient species (other parameters variable)	?
Lower Skunk River	Henry SWCD		Active	Skunk	HUC 12	Nutrient species (other parameters variable)	?
Des Moines Water Works		Source water assessment	Active	Raccoon	HUC 8	NO_3-N	5x/week
Conservation Learning Lab		Small watershed assessment CREP wetlands Iowa Wetland Landscape Systems Initiative	Active	?	< HUC 12	N, P, Flow	
Golf Course Project	IDNR/ISU	Nutrient losses from golf courses	Active	Various	<HUC12	NO_3-N, P	Quarterly
Rock Creek Watershed	?	?	?		?	?	?
English River Watershed	?	?	?		?	?	?
Lyons Creek Monitoring	IDNR	?	Inactive		?	NO_3-N	1/2 weeks
Walnut/Squaw Creek	IDNR	?	Inactive	Des Moines	?	NO_3-N	

Nutrient Monitoring by Point Sources

There are 149 municipal and industrial point sources subject to the INRS listed in Section 3.1 of the Strategy. Each of these is required by its National Pollutant Discharge Elimination System permit to measure the concentrations and amounts of total nitrogen and total phosphorus in the raw waste and final effluent from its facility and to evaluate and implement nutrient reduction practices found to be both feasible and reasonable. Samples are required to be collected weekly for a 2 year period to establish baseline conditions. After implementation of nutrient reduction practices these facilities will be required to monitor to determine the amount of reduction achieved by individual facilities and this data can be totaled to measure reductions achieved by major point sources on a statewide basis. Because reductions achieved by individual point source dischargers can be directly measured, this method is free of most of the challenges associated with trying to document nutrient reductions by non-point sources.

The results of monitoring by point sources are submitted to the Iowa Department of Natural Resources (IDNR) monthly and are stored in the NPDS database from which reports can be easily produced. This monitoring data is not considered “ambient stream monitoring” but is necessary information needed to answer the question “What reductions in nitrogen and phosphorus occur following installation of nutrient reduction technologies by point sources?” and is critical to accounting for measured changes in water quality. This information is also valuable when assessing stream monitoring data for a watershed in which a point-source is located, especially during low stream flow periods when non-point contributions are minimal.

Stream Nutrient Monitoring

This section of the report describes known stream nutrient monitoring projects in Iowa. Following the Nutrient Water Quality Monitoring Framework it progresses from describing monitoring that takes place in larger watersheds (i.e. generally HUC 8 or larger) to small watersheds (i.e. < HUC 12).

Large Watersheds

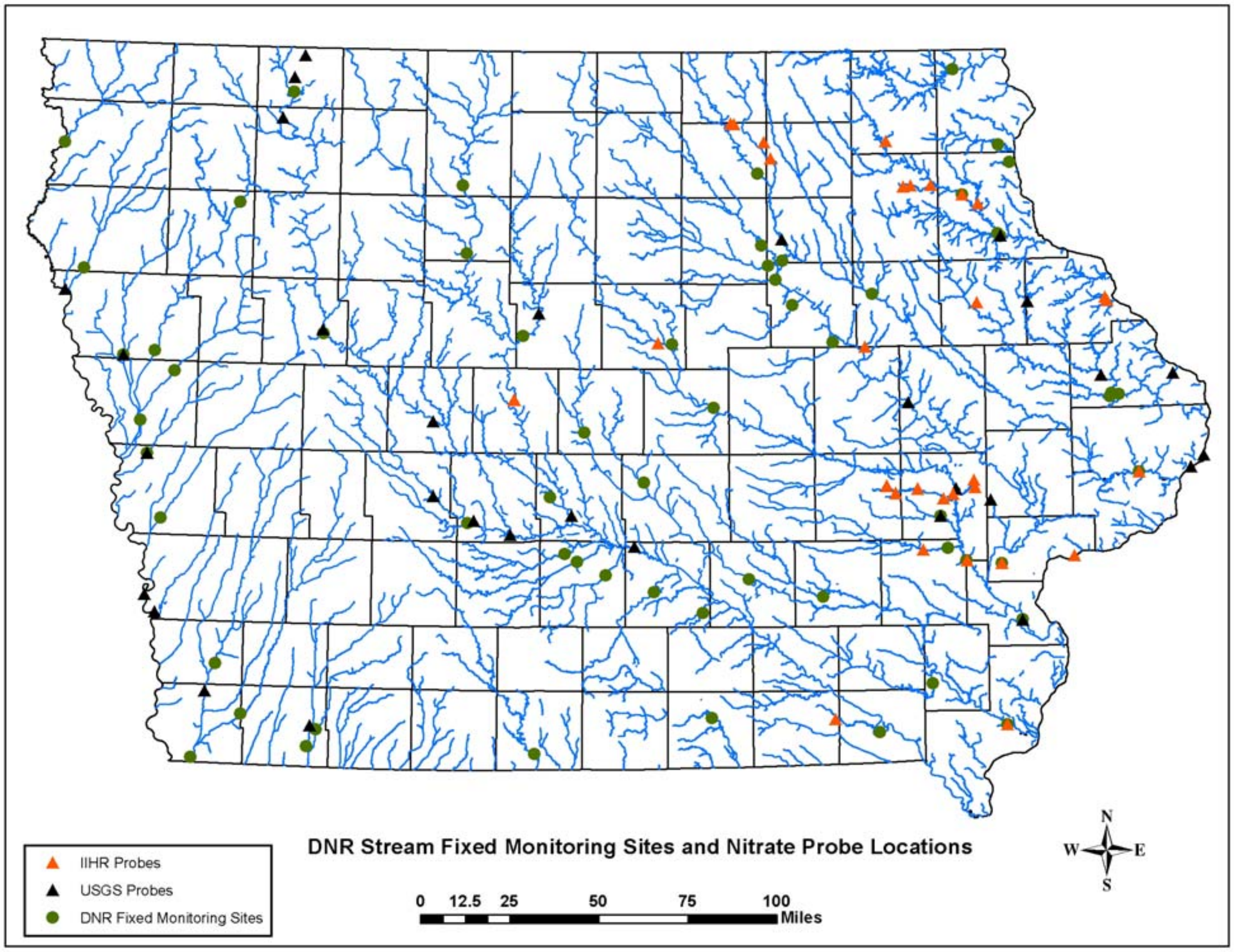
Fixed-Station Network

The primary source of data for determining changes in statewide nutrient load export and the contributions that designated priority watersheds make to the statewide nutrient load is the fixed-station stream monitoring network.

Monitoring at fixed-station stream water quality monitoring sites in Iowa began in the late 1970s. The number of monitoring locations, the frequency of monitoring, and the parameters monitored have varied over time for a variety of reasons including changing objectives and available funding. Sixteen locations have been monitored on a monthly basis since 1986 thus offering a 30-year continuous record of water quality monitoring at these locations. Until 2000, the majority of the approximately 95 active and discontinued locations represented by the fixed-station network were monitored on a quarterly basis. Since 2000, all fixed stations have been monitored monthly for water quality parameters including both nitrogen and phosphorus.

In 2015 the fixed-station monitoring network included 60 sites that were monitored monthly and served primarily to provide data to evaluate water quality status and trends in Iowa's interior rivers and streams. Figure 2 shows the locations of these sites, and Appendix A lists each site with information on location (county, river basin, etc.) and identifies those sites used in the 2014 nitrate load calculation. Monitoring objectives have evolved throughout the history of the stream monitoring program. Initially, the focus was to provide data to characterize water quality in large rivers and reservoirs. However, these monitoring locations were biased toward measuring water quality impacts from large point source discharges and runoff from urban areas. The network was modified in 1986 to provide a broader geographic representation of streams that drain medium and large-size watersheds across the state thus eliminating those earlier biases. Drainage areas at these current locations range from 88 km2 (34 mi2) to 36,358 km2 (14,038 mi2) and the median size is 2,124 km2 (820 mi2).

Figure 2 - Locations of Water Monitoring Sites (2015)



Data from these sites is used to prepare the biennial report of Iowa's water quality for the U.S. Environmental Protection Agency and the public. The data also support water programs within the Iowa Department of Natural Resources, such as water quality standards and wastewater permitting, and has been used more recently to evaluate long-term trends in levels of nutrients and other water quality parameters.

Samples from these monitoring sites are collected and analyzed by the State Hygienic Laboratory following a USEPA-approved Quality Assurance Project Plan and USEPA approved test methods. This data is available to the public from the Iowa STORET/WQX water quality database (https://programs.iowadnr.gov/iastoret/).

IIHR Hydroscience and Engineering

The IIHR – Hydoscience and Engineering (IIHR) center at the University of Iowa conducts research in a variety of areas including hydraulics, hydrology, and water quantity and quality. IIHR operates a continuous water quality monitoring network that has steadily increased in size since 2012. Remote sensors installed throughout Iowa provide near real-time data, which are relayed back to the center every 15 minutes. The sensors measure nitrate, dissolved oxygen, water temperature, specific conductance, turbidity and pH.

Sensors were deployed at 30 locations throughout the state in 2015 and the network will expand to 45 sites in 2016 (Figure 2 and Appendix B). The number and location of IIHR monitoring sites can vary from week to week depending upon research needs, equipment maintenance, and other factors. Sites are selected based on a number of factors including:

- Sensing equipment funded specifically for a research proposal or project in a selected watershed.
- Major interior river sites based on their strategic importance for nutrient load estimations.
- Significance of the stream for recreation, municipal water supply, or other designated uses.
- Suitability of the site for sensor equipment, i.e. security, water depth, etc.
- Requests from outside stakeholders.

The sensors that are positioned to provide data to assist in determining statewide nutrient load estimates are located in close proximity to a USGS gaging station to provide the stream flow information needed to calculate loads. Other sensors are located to provide information to monitor nutrient reduction progress in targeted watersheds.

The IIHR has developed the Iowa Water-Quality Information System (IWQIS) to disseminate water quality data from remote sensors as well as climate data such as rainfall amounts and frequency, daily snow melt data and air temperature. IWQIS displays near real-time data on nitrate and other water quality variables in a user-friendly, Google Maps interface. It provides researchers, agencies, and land-owners with a valuable tool they can use to directly monitor the impact of land-use strategies/changes on downstream water-quality, enables watershed stakeholders to understand the fate and transport of nutrients in Iowa’s waterways; and helps in measuring the impact of the INRS on water quality. Users can see the total amount of nitrate being carried along a waterway at a certain time, and can compare those levels to previous years. All archived IIHR water quality data is also made available to interested persons upon request. IWQIS can be accessed at https//iwqis.iowawis.org.

Nutrient Load Estimates

The INRS called on the IDNR to convene a technical work group beginning in 2013 to define the process for providing a regular nutrient load estimate (i.e., nutrient budget) based on the fixed-station stream water quality monitoring network. This was to include specifying the most appropriate estimation method, the acceptability of existing data with which to evaluate methods, and a process for making future adjustments based on the latest information and advancements in science and technology.

An interdisciplinary team of Iowa scientists and engineers from state, federal, university and commodity groups was assembled to evaluate and recommend a nitrate load estimation procedure for the State of Iowa. Representatives from IDNR, ISU, IDALS, ISA, USGS, and UI first met on December 3, 2013. The work group first developed a methodology to compare the six most commonly used nitrogen load estimation models and also assembled a single standardized data set to use in comparing model results. Individual work group members were assigned to calculate a load estimate using the standardized data set and one of the load estimation methods. The full work group then compared the results obtained using each method.

The work group recommended using the linear interpolation method because it provides the simplest and most straightforward approach to estimate loads. Linear interpolation fills data gaps between measured concentrations by a straight line. Because of its simplicity different users can expect to produce approximately the same load estimate from a given set of data. Linear interpolation was also found by others to provide the overall best results for load estimation in agricultural and mixed-use watersheds. However, linear interpolation requires consistent sample collection to be effective. Missing sampling periods that lengthen the interval between measurements will result in greater potential error in load estimation.

After accepting the work group recommendation, the linear interpolation method was used to develop statewide nitrate load estimates for calendar years 2013 and 2014. Data from 63 fixed-station monitoring sites were used for the 2013 estimate and 50 sites for the 2014 estimate. Linear interpolation was used to fill in daily concentrations between measured monthly sample results. Interpolated daily concentrations were then multiplied by corresponding daily stream flows to obtain daily nitrate loads. In addition to recommending that the linear interpolation method be used for estimating nitrate loads, the work group recommended that the sampling frequency for nitrate increase from the current once per month to a minimum of biweekly at each of the fixed-station locations to enhance the ability to quantify changing water quality due to implementation of nutrient reduction practices.

A similar effort to that undertaken for estimating nitrate loads is underway to develop a method to quantify phosphorus loads. However, quantifying phosphorus loads has challenges distinct from those associated with quantifying nitrogen loads. The work group has compiled multiple phosphorus data sets to be used to evaluate different load estimation methods. The data sets indicate that the monthly frequency of monitoring at fixed-station sites is not sufficient to estimate phosphorus loads because the amount of phosphorus in rivers and streams changes very rapidly with changes in stream flow. It is unlikely that phosphorus load estimates can be obtained without event-based sampling or continuous monitoring. Unlike nitrate however, there are no in-stream phosphorus sensors available that can help overcome this challenge. The work group is exploring the possibility of using a surrogate parameter, possibly turbidity, which can be measured with currently available and deployed sensors. Evaluation of potential surrogates is expected to be completed in 2016.

Finally, it may be possible to eliminate altogether the need for load estimation models for both nitrate and phosphorus by using in-stream sensors (Feng et al., 2013; Davis et al., 2014). Although sensors require periodic maintenance and calibration they provide actual measurements of pollutant concentrations on a nearly continuous basis. When coupled with stream flow measurements made at or near the location of each sensor, loads can be measured rather than estimated.

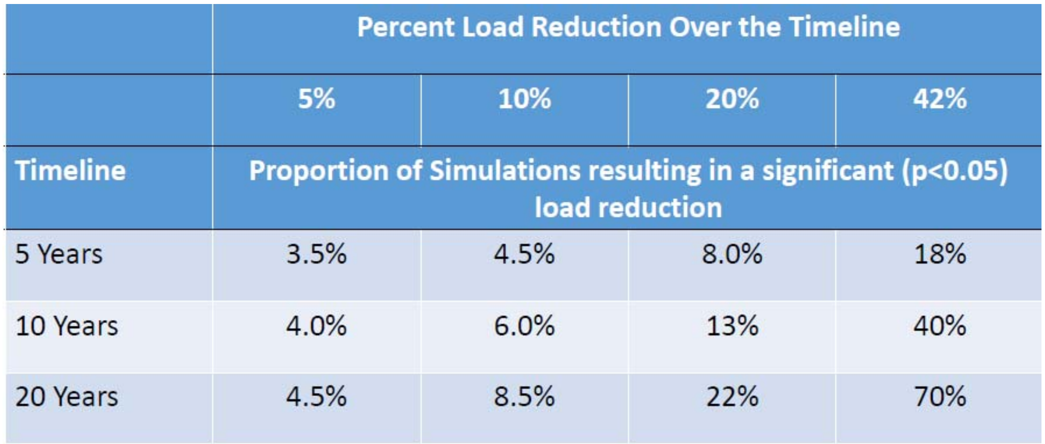
Importance of Statistical Significance in Measuring Change

Statistical tools are normally used to design water quality monitoring programs to ensure the appropriate amount of data is collected over a given time period to be able to detect change. Statistics are also used to evaluate data in order to determine if a perceived trend in a set of monitoring data is significant or is simply the result of variability inherent in all natural systems. Two examples serve to illustrate the importance of statistical significance in the design of monitoring programs and the analysis of data.

Nitrate samples have generally been collected five times each week by the Des Moines Water Works for a long period of time and analyzed for nitrate. Samples are collected at the water intake located just upstream of the confluence of the Raccoon and Des Moines Rivers. Data from 1986 through 2014 were evaluated to answer the question, “What is the chance of measuring a reduction in nitrogen load in the Raccoon River after 5, 10 or 20 years if nutrient inputs in the watershed are reduced by 5, 10, 20 or 42%?” (Castellano, et. al. 2015). The results of this evaluation are shown in Table 2. If nitrate loads in the Raccoon River were reduced by 20%, there would be only a 22% chance that a **significant** reduction ($p < 0.05$) would be measureable after 20 years. In other words, even if reductions in nitrate were achieved through implementation of nutrient reduction practices, it may not be possible to show that the reductions result in a statistically significant change in water quality. The reason for this is discussed in an earlier section of this report that describes the challenges associated with variable precipitation and stream flow. Precipitation in Iowa is highly variable which results in variable stream flows and corresponding variable nutrient loads both within a given year and from year and from year to year. This could mean is that even if significant progress is made in reducing nutrients discharged to surface water in a watershed from both point sources and nonpoint sources, the effects of those reductions may not be measurable as lower nutrient loads at the large watershed scale for a long period of time following their implementation.

Table 2

Probability of Measuring a Reduction in Nitrate in the Raccoon River over Time



	Percent Load Reduction Over the Timeline			
	5%	10%	20%	42%
Timeline	Proportion of Simulations resulting in a significant ($p<0.05$) load reduction			
5 Years	3.5%	4.5%	8.0%	18%
10 Years	4.0%	6.0%	13%	40%
20 Years	4.5%	8.5%	22%	70%

In another study, Li, et al, 2013 evaluated nitrate concentration trends in Iowa Rivers during a 14 year period from 1998 – 2012 using monitoring data from 60 fixed-station monitoring sites. Water samples were collected and analyzed monthly beginning in October 1998 (21 sites) or October 1999 (32 sites). Monitoring at an additional six sites did not begin until 2000 or later. Forty-six of the sixty sites had sufficient data to evaluate trends in nitrate concentration data using the time series method. The watersheds associated with these 46 sites ranged from 34 mi^2 to 7,780 mi^2 or from HUC 12 to HUC 8 in size. The study determined that 37 of the 46 sites (80%) did not show statistically significant trends (increases or decreases) over the monitoring period ($p > 0.1$). Six monitoring sites in western Iowa had statistically significant increasing trends ($p < 0.05$). Three additional sites in western and southern Iowa showed nominally significant increasing trends ($p < 0.1$). Aggregated across the entire state, the overall trend during this time period was a statistically significant increase in the concentration of nitrate in surface water ($p < 0.05$).

Despite the challenges involved, maintaining a fixed station water quality monitoring network is critical to answering the question "How much nitrogen and how much phosphorus are being exported from Iowa?" Data collection should continue at these sites to measure changes in nutrient concentrations and loadings over time as nutrient reduction practices continue to be implemented throughout these watersheds. Monitoring these large watersheds provides critical information to estimate the total nutrient loads both from priority watersheds and from the state as a whole. This information is also needed to measure long-term water-quality changes that may result from agriculture, urban development, or climate change; and to support additional research.

Small Watersheds

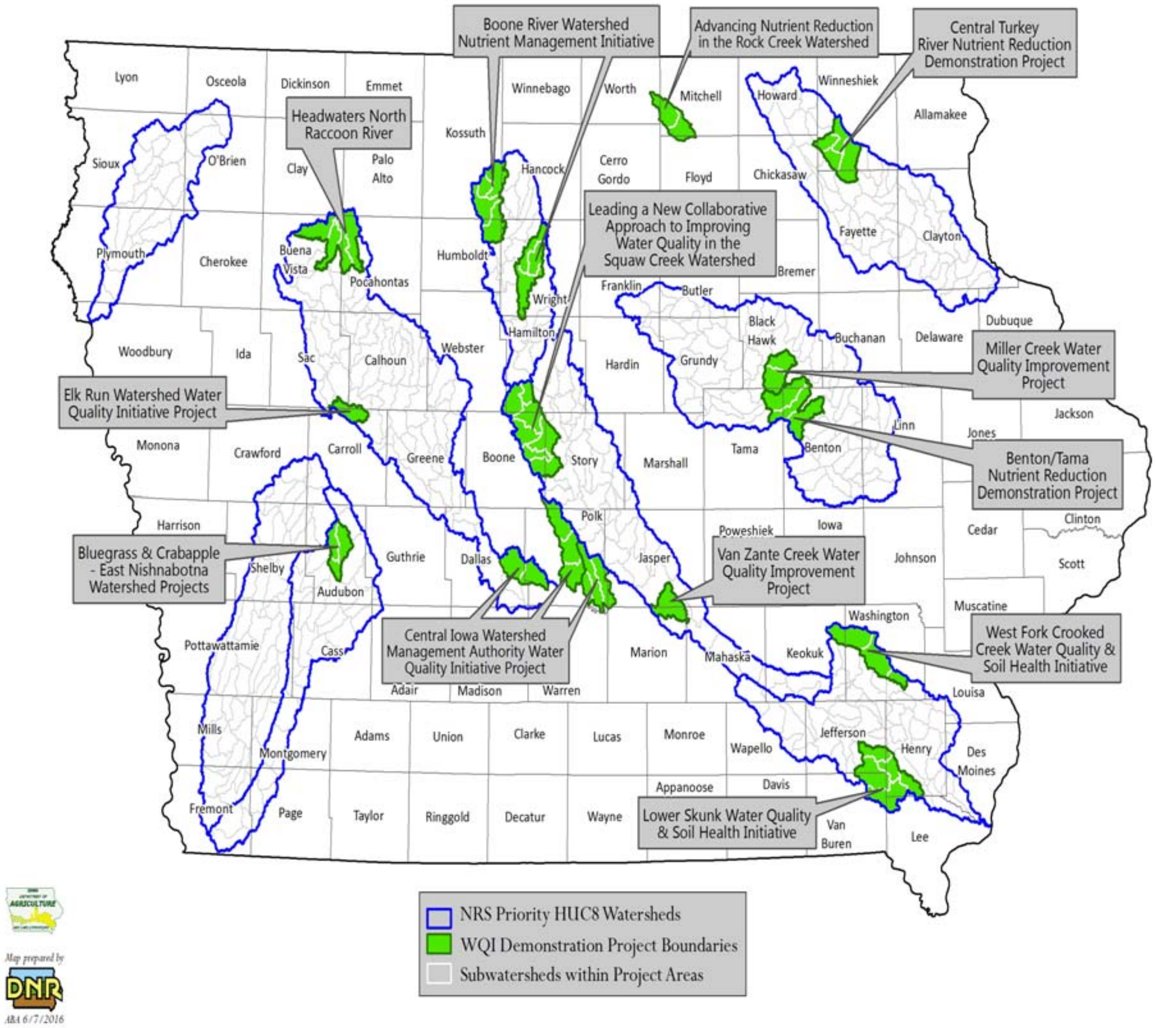
Iowa Water Quality Initiative

The Iowa Water Quality Initiative (WQI) was established during the 2013 legislative session to help implement the INRS. The WQI seeks to harness the collective ability of both private and public resources and organizations to rally around the INRS and deliver a clear and consistent message to the agricultural community to reduce nutrient loss and improve water quality. A number of demonstration projects have been established to promote increased awareness and adoption of available conservation practices and technologies. Projects serve as local and regional hubs for demonstrating nutrient reduction practices and providing practical information to farmers, peer networks, and local communities.

A total of 45 demonstration projects are currently located across the state. This includes 16 targeted watershed projects, 7 projects focused on expanding the use and innovative delivery of water quality practices and 22 urban water quality demonstration projects. Eighteen of these projects focus on small scale targeted watershed areas for agricultural based conservation practice implementation in alignment with the INRS. More than 150 organizations are participating in these projects with the goal of building capacity and developing successful new strategies for meeting the goals of the Iowa NRS.

Watersheds represented by these demonstration projects vary in size but generally consist of between one to four HUC 12s or between 20,000 acres to over 100,000 acres. All projects are led by local groups and partners and are funded for a minimum of three years with the possibility that one or more projects will continue longer subject to available funding. These projects were initiated as demonstration and engagement projects with the eventual goal of scaling conservation implementation progress and efforts both within and beyond the current project watershed areas. Consequently, water quality monitoring conducted by the majority of these projects focuses primarily on informing watershed stakeholders of nutrient loading and targeting resources for effective conservation implementation and planning decisions. A subset of the watershed and practice-based projects currently conducting water quality monitoring is shown in Figure 3.The frequency of sample collection and analysis for nutrients and other parameters varies but is generally weekly or bi-weekly throughout the monitoring season and includes monitoring of tile lines as well as steam water quality. Information about each of these demonstration projects can be found at http://www.cleanwateriowa.org/practice-demonstration-projects.aspx.

Figure 3 - WQI Demonstration Projects



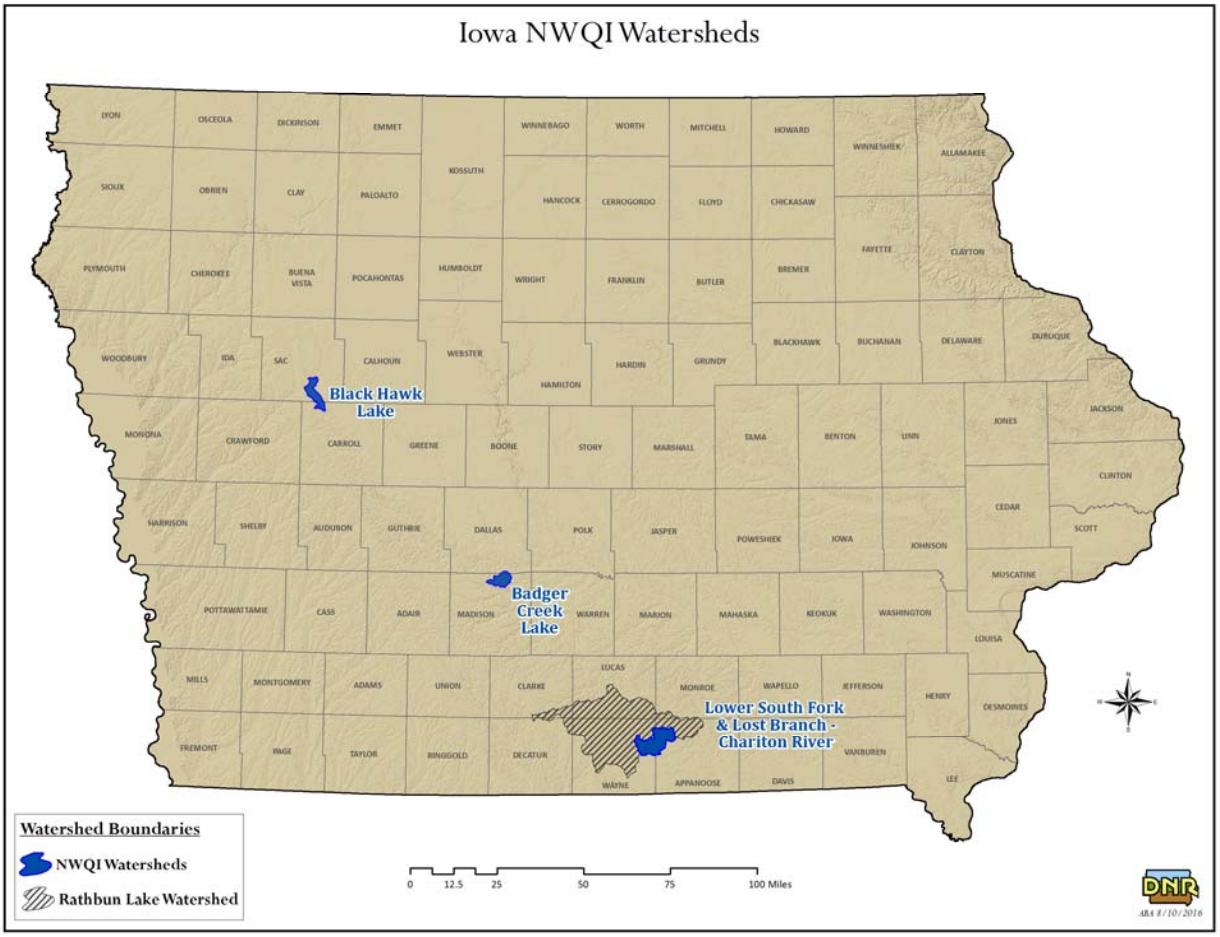
National Water Quality Initiative

In 2012, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) launched the National Water Quality Initiative (NWQI), in collaboration with the Environmental Protection Agency (EPA) and state water quality agencies, to reduce nonpoint sources of nutrients, sediment, and pathogens related to agriculture in small, high-priority watersheds in each state. These priority watersheds have been selected by NRCS State Conservationists in consultation with state water quality agencies and NRCS State Technical Committees where targeted on-farm conservation investments will deliver the greatest water quality benefits. NWQI provides a means to accelerate voluntary, private lands conservation investments to improve water quality with dedicated financial assistance through NRCS's Environmental Quality Incentives Program (EQIP) and Clean Water Act Section 319 or other funds to focus state water quality monitoring and assessment efforts where they are most needed to measure change. A key part of the NWQI targeting effort includes the implementation of conservation systems that avoid, trap, and control run-off in these high-priority watersheds.

Water quality monitoring plays a critical role in the NWQI. State water quality agencies are assessing progress through in-stream water quality monitoring in at least one watershed per state using Clean Water Act Section 319 or other funds. The objective of NWQI stream monitoring is to assess whether water quality and/or biological conditions related to nutrients, sediments, or livestock-related pathogens has changed in the watershed, and if so whether this can be associated with implementation of agricultural conservation practices. Through EQIP, edge-of-field monitoring projects are taking place in a select number of NWQI watersheds in order to assess the impact of conservation practices at the field scale, calibrate USDA water quality models, and inform adaptive management.

In Iowa there are currently four NWQI watershed projects; Wall Lake Inlet/Black Hawk Lake, Badger Creek, Lower South Fork Chariton River and Lost Branch – Chariton River (See Figure 4). Only one of these, the Wall Lake Inlet/Black Hawk Lake project measures surface water quality and there is too little data available so far to begin to identify changes, if any, in nutrient concentrations or amounts.

Figure 4 - NWQI Watershed Projects



Paired Watersheds

Paired watershed projects involve the selection of two watersheds of similar size and land use characteristics. In one watershed conservation practices are extensively implemented while the other receives few new conservation practices. Stream water quality is monitored in both watersheds to assess the effect on water quality of the installed practices. There are four examples in Iowa, described below, of the use of the paired watershed approach to evaluate water quality effects associated with nutrient reduction conservation practices.

Sny Magill Watershed

From 1991 until 1999, extensive best management practices (BMPs) were implemented throughout the Sny Magill watershed in northeast Iowa with the purpose of improving stream water and habitat quality. Many different BMPs were installed in this 35.6 mi^2 watershed, including tiled terraces, catchment basins, nutrient and pest management plans, and streambank protection structures. All of the structures and plans were implemented with the objective of decreasing sediment, nutrients, and fecal contamination in Sny Magill Creek. The adjacent Bloody Run watershed was selected to serve as a control and to statistically verify water quality changes in Sny Magill Creek. Promotion of conservation practices in the Bloody Run watershed accelerated beginning in 2002 after the conclusion of the study period and resulted in expanded adoption of structural and other conservation practices similar to what had previously taken place in the Sny Magill watershed.

Beginning in October 1991 and continuing for ten years, a consortium of state and federal agencies collected and analyzed samples in an effort to document the effectiveness of the installed BMPs through monitoring of water quality, stream habitat, fish, and benthic macroinvertebrates. The study was performed as part of the National Monitoring Program developed under Section 319 of the Clean Water Act. Monitoring in both watersheds was done on an even-interval (daily, weekly, and monthly) basis on three paired main channel and three tributary stations. Monitoring was continuous throughout the 10-year study period.

This “paired-watershed” approach was used to monitor water quality in the Sny Magill watershed because, as several authors have noted, the paired watershed approach is the most appropriate monitoring design to use when evaluating the impact of a BMP or system of BMPs on stream water quality at the watershed level (Spooner et al., 1985).

To avoid or minimize some of the problems experienced in this study that led to unexpected results the study’s authors recommended considering the following when designing and conducting future paired watershed studies:

> (1) An adequate period of time is needed to collect baseline data before BMPs are put in place. This time period should be, at a minimum, 3-4 years in length to firmly establish pre-treatment relationships between the two watersheds.
>
> (2) A forward thinking, flexible, monitoring strategy is required at the outset of the project. Resources can be more efficiently used and conserved if the end goal and statistical methods of the project are kept in mind throughout the study period.
>
> (3) The lag time between initial BMP installation and measured changes in stream water quality might take many years, perhaps even decades. This is especially true of watersheds that are highly groundwater dependent, or that have significant pre-existing sediment deposits in the stream system.
>
> (4) A reduction in the size of the study area would have made it easier to target the implementation of BMPs. Targeting one or two parameters would have better focused the monitoring design with an increased likelihood of quantifying water quality changes.
>
> (5) A monitoring design that used more paired monitoring sites instead of single unpaired stations would have been better able to significantly prove increases or decreases in water quality.
>
> (6) It is important for future projects to address all sources of a pollutant including those contributed by stream bed sediments, stream banks and groundwater.

(7) Even a daily sampling frequency might not be adequate to quantify pollutant concentration and load when concentrations and/or stream flow vary drastically over a short period of time.

Walnut/Squaw Creek Watershed

From 1995 through 2005 monitoring was conducted in the Walnut Creek and Squaw Creek watersheds in central Iowa using the paired watershed approach to evaluate the response of stream nitrate concentrations to major changes in land use (Schilling, et. al, 2006). During this five year period the area planted to row crops in the Walnut Creek watershed decreased by more than 25% with the conversion of crop land to native prairie on the Neal Smith National Wildlife Refuge. During the same period, the area of row crops increased by 9.2% in the Squaw Creek watershed as land previously enrolled in the Conservation Reserve Program (CRP) was put back into row crop production.

Nitrate concentrations decreased significantly throughout the Walnut Creek watershed while nitrate concentrations increased significantly in the Squaw Creek watershed. Nitrate reductions are thought by the study's authors to be the result of several factors, including reduced water and nitrate flux through the soil under perennial cover compared to row crop systems, reduced fertilizer N inputs on refuge-owned lands, and reduced overland flow nitrogen contributions during runoff events. The reverse was believed to be true of land that either remained in row crops or was brought back into row crop production.

The study's authors believe the results from the Walnut Creek monitoring project attest to the necessity of conducting long-term monitoring to evaluate the effects of land use change and conservation practices on water quality. They state that lag times for observing water quality improvements are rarely less than several years long, and lag times of decades are the norm rather than the exception. In the Walnut Creek watershed, the first statistically significant changes in nitrate concentrations were observed approximate three years after land use changes began. Long-term monitoring is needed to factor out the effects of climate and account for possible improvements in water quality that may take many years to manifest themselves in a stream.

Lyons Creek Watershed

The concentrations of nitrate in three tiled Iowa watersheds were evaluated to assess their suitability for use of the paired watershed approach to determine the effectiveness of nutrient reduction practices and to detect water quality changes. The objectives of this study were to: (i) evaluate the concentrations of nitrate discharged from three drainage tile systems in north-central Iowa during a 4-yr period; (ii) assess the degree of similarity in physical characteristics, concentration patterns, and correlation among the three paired sites; and (iii) perform an MDC (minimum detectible change) analysis on different configurations of the paired sites.

The Lyons Creek watershed is located in north-central Iowa and encompasses and area of approximately 16 mi^2. Three distinct subwatershed districts within the Lyons Creek basin were investigated. The three subwatersheds drain approximately 1500 acres, 618 acres and 2700 acres. Land use within these subwatersheds consists of row cropped fields (>90%) with much of the land underlain with drainage tiles installed and managed by individual landowners. These "private" tile networks drain to larger diameter, drainage district managed, feeder lines each with its own outlet.

Grab samples were collected from each of the three outlets every 2 weeks on the same day of the week at approximately the same time of day from 2009 through 2012 and were analyzed for nitrate nitrogen.

The MDC analysis was conducted to assess the likelihood that BMP implementation in two of the three drainage districts (one control and two treatment areas) would result in discernible nitrate concentration changes. The results showed that the number of samples needed to detect a minimum of a 10% change in nitrate concentration varied from 25 to 474, or 1 to 18.2 years of bi-weekly sampling, could be needed depending on how watersheds were paired. Using only data from March to July, when the movement of nitrate is greatest, detecting a 10% change for four of the pairs may only require 28 samples collected biweekly during a 1 - to 2-yr period.

The study concluded that paired watershed studies can be effective for discerning water quality changes that result from implemented BMPs but that the first step in these studies must be to evaluate basin comparability during a pre-BMP calibration period. The selection of control and treatment pairs can have a significant effect on the number of samples required and the ability to detect change. The MDC can also be used to help in the selection of appropriate nutrient reduction practices. In order to demonstrate that BMPs will result in a measureable change in water quality, practices must be implemented that are capable of achieving reductions greater than the calculated MDC.

Black Hawk Lake

Black Hawk Lake watershed was selected for intensive paired subwatershed and stream monitoring as part of the NWQI program because of an active and successful watershed project, with many BMPs being implemented on private and public lands. The goal of NWQI monitoring in the Black Hawk Lake watershed is to determine if water quality improvement strategies have been effective at reducing sediment and nutrient loads by quantifying long-term water quality trends before, during, and after active BMP implementation efforts.

The Black Hawk Lake Watershed is comprised of 15 subwatersheds. Monitoring sites are established in three of these subwatersheds and during 2015 samples were collected and analyzed at two of these sites for ammonia nitrogen, nitrate+nitrite nitrogen, total nitrogen, dissolved reactive phosphorus and total phosphorus following a Quality Assurance Project Plan (QA/WM/40-01). Conservation practices including terraces, CRP, wetlands, and a higher degree of non-structural practices (i.e., no-till and cover crops) are used extensively in one of the three subwatersheds while few practices are used in the other watersheds. This allows for a direct comparison of the effectiveness of the installed practices.

Samples were collected approximately weekly from June through October 2015 and this sampling is scheduled to continue for five years to evaluate trends in water quality before, during and after BMP installation. Flow-weighted composite samples will be collected during both rainfall-runoff events and dry weather periods. The 2015 data have been summarized and spreadsheets containing the raw data and summary statistics are housed at the IDNR. Too little time has passed since the start of this project to draw any conclusions about changes in water quality.

Conservation Reserve Enhancement Program

The Iowa Conservation Reserve Enhancement Program (CREP) is a joint effort of the Iowa Department of Agriculture and Land Stewardship (IDALS) and the USDA Farm Service Agency in cooperation with local Soil and Water Conservation Districts that provides incentives to landowners to voluntarily restore wetlands targeted for water quality improvement in the heavily tile-drained regions of Iowa.

The goal of the program is to reduce nitrogen loads and movement of other agricultural chemicals from croplands to streams and rivers. A representative subset of wetlands is monitored and mass balance analyses performed to document nitrate reduction. In addition to documenting wetland performance, this allows for the continued refinement of modeling and analytical tools used in site selection, design, and management of future CREP wetlands. In 2015 a total of 20 CREP wetlands were monitored.

The monitored wetlands are instrumented with automated samplers and flow meters to measure inflows and outflows. Water levels are monitored continuously at outflow structures in order to calculate changes in pool volume and discharge and wetland water temperatures are recorded continuously for modeling nitrate loss rates. An annual report has been prepared each year since 2007 that document the results of that year's monitoring and evaluates performance measures such as patterns in nitrate concentrations and loads and patterns in nitrate loss. Additional information including copies of each annual report can be accessed at http://www.iowacrep.org/

Conservation Learning Lab

The Conservation Learning Lab is a three-year pilot project between the Iowa Department of Agriculture and Land Stewardship (IDALS) and the Natural Resources Conservation Service (NRCS) designed to answer the questions "Can the high levels of implementation necessary to meet the goals of the INRS be obtained on a small watershed scale?", and "Can water quality improvements be documented accordingly?"

The INRS Science Assessment estimated the potential reductions in nitrogen and phosphorus loads that could be achieved by a wide range of in-field and edge-of-field conservation practices. These estimates were based on a careful review/assessment of the published research on the effectiveness of various practices and their potential applicability. However, most of the studies used in developing the Nutrient Reduction Strategy were conducted at the plot scale. While these studies were essential, the report highlighted the critical need for studies that scale up the area of practice implementation in order to better assess water quality impacts across landscapes and with multiple practices.

Nutrient loads and load reductions at the plot scale can differ substantially from loads actually delivered to surface waters. For example, phosphorus in subsurface tile flow at the plot scale can be substantially lower than at the scale of even a few hundred acres. Nutrient loads at larger watershed scales (HUC 12 and above) can also differ substantially from loads actually delivered to surface waters due to the effects of in-stream processes (for example, the effects of bed and bank erosion and phosphorus exchange with stream sediments). Most prior work on practice performance and nutrient loads in Iowa has been done at either the plot scale or larger watershed scale (HUC 12 and greater). However, the most appropriate scale for assessing agricultural nonpoint source loads to surface water is the scale at which the load is actually delivered. This is the scale on which the proposed Central Iowa Conservation Learning Lab is focused.

The demonstration is a three-year pilot project that will couple conservation practice implementation on the watershed scale with leveraging of ongoing projects that are evaluating the water quality performance of wetlands (Conservation Reserve Enhancement Program wetlands) and the hydrologic and water quality impacts of drainage systems (Iowa Wetland Landscape Systems Initiative). If this Conservation Learning Lab pilot is successful, the project can be expanded to demonstrate and evaluate sites over a broader geographic range and can be used for collection of detailed land use and management information.

The focus will be on extensive implementation of nutrient reduction practices in two small watersheds; one in Story County (~1400 acres) and another in Floyd County (~650 acres). The nutrient reduction practice most likely to be implemented is planting of cover crops. In addition to widespread practice implementation, the project will evaluate corresponding N and P loads delivered to surface waters and relate these loads to land use, nutrient management and soil test phosphorus. Long-term, this demonstration should improve the predictability of practice performance, improve the understanding of practice uncertainty, increase farmer implementation of practices through outreach and education, and validate load reduction tools developed to evaluate progress toward nonpoint source load reduction.

The Conservation Learning Lab project demonstration areas will also be instrumented for close-interval, automated sampling and flow measurement and will be monitored as part of companion projects. Nutrient concentrations in discharge from small agricultural watersheds can display tremendous variability, and peak concentrations can occur during either very low or very high flow periods. However, nutrient loading is strongly correlated with flow. This is particularly true in small watersheds where water flow is low during much of the year but increases dramatically and rapidly following rain events. It is during high water flow periods in such systems that accurate estimates of nutrient concentrations are most critical for estimating loads. It is not possible to accurately estimate nutrient loads from weekly or less frequent grab samples. Close-interval sampling is necessary to capture flow-dependent loading events, and data from this sampling will be coupled with a flow-proportionate sample analysis strategy to address the need for close-interval data during high flow periods and simultaneously control the total number of sample analyses. Nutrient concentrations and flow data will be used to calculate mass nutrient loads from the contributing watershed area for evaluation against land use and management information and GIS-based load estimates.

To better evaluate the effects of land use and management on nutrient export, project staff will work with cooperating landowners/farmers to collect information on nutrient management, crop yield, and soil test phosphorus. Detailed nutrient management and soil test phosphorus information will be collected. This information will be used to evaluate the measured loads from each of these systems and potentially the role of soil test phosphorus on P loads delivered to surface waters. This work will also be useful in validating GIS-based load estimation tools (as envisioned in the Iowa Nutrient Reduction Strategy’s Nonpoint Source Nutrient Reduction Science Assessment).

Data Gaps

The most significant data gap associated with large watersheds is the lack of event-based monitoring particularly for phosphorus. Most phosphorus enters streams and rivers during and immediately following precipitation events. However, sampling at fixed-station monitoring sites occurs at a set frequency (e.g. monthly) and without regard to stream flow conditions. The calculation of phosphorus loads based on this data likely underestimates the amount of phosphorus in Iowa's rivers and streams perhaps by a wide margin. To remedy this problem priority needs to be given to identifying and implementing an alternative method of estimating phosphorus loads through the use of a surrogate that can be measured more frequently, preferably continuously with in-stream sensors, similar to the existing in-stream nitrate sensors that have been deployed.

Limited data on nitrogen and phosphorus loads in small watersheds is currently available although this will change in specific locations as certain watershed-based projects where loads are calculated advance. Monitoring flow in small watersheds is challenging due to the wide swings in flow regimes, including, but not limited to more low or no flow periods vs. a larger watershed. This lack of loading data also makes it difficult to establish appropriate baselines to compare changes in water quality. However, these projects could encounter similar issues as other projects described in this document unless the following are considered in the project design. First, projects should take long term perspective of activities including monitoring. Secondly, projects should focus on installing and tracking the appropriate practices that can positively impact nutrient reductions as indicated by the Strategy and other research based initiatives. Projects must account for this data gap by focusing monitoring at an appropriate scale and timeframe.

Information on the extent of nutrient reduction practices implementation within watersheds is lacking. This information is needed for several reasons. First, information on changes on the landscape including the types and extent of nutrient reduction practices implementation is necessary in order to associate measured changes in water quality with changes on the landscape. Secondly, in cases where extensive nutrient reduction practices are implemented but there is no statistically significant change in water quality this information can be used together with information on the effectiveness of various practices from the science assessment section of the INRS to document nutrient reductions. This indirect approach may be the only means of documenting progress in the short-term until sufficient water quality data is available.

Next Steps

This document is only the first step in documenting existing, known stream water quality monitoring that supports the INRS. To build upon the information presented and improve monitoring efforts the following next steps are recommended:

- The primary purpose of this document is to describe and report on current, known stream nutrient monitoring efforts in Iowa that support implementation of the INRS. It mainly describes monitoring being conducted by governmental agencies but acknowledges that monitoring is also performed by non-governmental entities as well. Organizations and individuals involved with stream nutrient monitoring should be encouraged to provide information on those efforts and this report should be revised and updated on a periodic basis as new information becomes available.

- A reliable method to prepare periodic statewide phosphorus load estimates is critical to tracking the impact of the INRS on surface water quality. A priority should be placed on completing an evaluation of means for determining phosphorus loads including the use of a surrogate parameter and an evaluation of real-time sensing methods with a goal of completing this assessment in 2016.

- Monitoring of surface water in small watersheds (<HUC12) and paired watershed studies offers the most promise for demonstrating progress at nutrient reduction especially in the near term. A number of these studies are currently underway or planned. Data from these studies should be analyzed as they become available and necessary adjustments made to monitoring programs to address challenges encountered and to better characterize stream water quality. Lessons learned during the course of these studies should be readily available for the design of future studies.

- A technical work group should be formed and tasked with developing practical, implementable recommendations and priorities for what monitoring should be conducted at what locations and at what frequencies to help answer the questions identified at the beginning of this document as being critical to measuring progress under the INRS. In particular this work group should focus attention on how best to address data gaps and overcome challenges with the development of reliable statewide nutrient export estimates and with determining nutrient reductions following implementation of non-point source nutrient reduction practices.

- The contribution of point sources to the statewide nutrient load in the INRS was based on estimates of the concentration of nitrogen and phosphorus in untreated sewage and an assumption that treatment plants do not remove nutrients except when specifically designed to do so. Estimates were necessary because monitoring data were not available at the time. As nutrient feasibility studies are now being completed and submitted, actual data on raw waste and final effluent concentrations and removal percentages should be used to revise the previous estimates and assumptions and obtain a more accurate picture of point source contributions.

- Information on the types and amounts of nutrient reduction practices that are implemented is critical to evaluating progress under the INRS. This information is needed in order to correlate measured water quality changes with in-field and edge-of-field practices adoption and to estimate nutrient reductions before they can be measured by stream water quality monitoring.

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Appendix A

Fixed Station Monitoring Locations

Storet ID	Station Name	County	HUC8	HUC8 NAME	2014 NO3 Load Calc Site	Load Calc Gage Number	WQ Flow Gauging Station	Comment
10070001	Beaver Creek near Cedar Falls	Black Hawk	07080205	Middle Cedar	X	05463000	Beaver Creek at New Hartford (5463000)	
10770001	Beaver Creek near Grimes	Polk	07100004	Middle Des Moines	X	05481950	Beaver Creek near Grimes (5481950)	
10070004	Black Hawk Creek at Waterloo	Black Hawk	07080205	Middle Cedar	X	05463500	Black Hawk Creek at Hudson (5463500)	
10220003	Bloody Run Creek Site #1 (BR01)	Clayton	07060001	Coon-Yellow	X	05389400	Bloody Run near Marquette (5389400)	
10400001	Boone River near Stratford	Hamilton	07100005	Boone	X	05481000	Boone River near Webster City (5481000)	
10430001	Boyer River near Missouri Valley	Harrison	10230007	Boyer	X	06609500	Boyer River at Logan (6609500)	
10630002	Cedar Creek near Bussey	Marion	07100009	Lower Des Moines	X	05489000	Cedar Creek near Bussey (5489000)	
10440001	Cedar Creek near Oakland Mills	Henry	07080107	Skunk	X	05473400	Cedar Creek near Oakland Mills (5473400)	
10570001	Cedar River Downstream of Cedar Rapids (DS1)	Linn	07080206	Lower Cedar	X	05464500	Cedar River at Cedar Rapids (5464500)	
10340001	Cedar River near Charles City (DS1)	Floyd	07080201	Upper Cedar	X	05457700	Cedar River at Charles City (5457700)	
10700001	Cedar River near Conesville	Muscatine	07080206	Lower Cedar	X	05465000	Cedar River near Conesville (5465000)	
10090001	Cedar River near Janesville	Bremer	07080201	Upper Cedar	X	05458500	Cedar River at Janesville (5458500)	
10040002	Chariton River at 461st St.	Appanoose	10280201	Upper Chariton		06903900	Chariton River near Rathbun, IA	
10890001	Des Moines River near Keosauqua	Van Buren	07100009	Lower Des Moines		5490500	Des Moines River at Keosauqua, IA	
10550001	East Fork of The Des Moines River near St. Joseph	Kossuth	07100003	East Fork Des Moines		05478265	East Fork Des Moines River near Algona, IA	Discharge record started 10/2011
10360001	East Nishnabotna River near Shenandoah (US1)	Fremont	10240003	East Nishnabotna	X	06809500	East Nishnabotna at Red Oak (6809500)	
10730002	East Nodaway River near Clarinda	Page	10240010	Nodaway			No gage	
10920001	English River at Riverside	Washington	07080209	Lower Iowa	X	05455500	English River at Kalona (5455500)	
10750001	Floyd River near Sioux City	Plymouth	10230002	Floyd	X	06600500	Floyd River at James (6600500)	
10500001	Indian Creek near Colfax	Jasper	07080105	South Skunk	X	05471200	Indian Creek near Mingo (5471200)	
10640002	Iowa River Downstream of Marshalltown (DS1)	Marshall	07080208	Middle Iowa		05451500	Iowa River at Marshalltown (5451500)	
10420001	Iowa River near Gifford	Hardin	07080207	Upper Iowa			Iowa River near Steamboat Rock (Corps STBI4)	
10580002	Iowa River near Lone Tree	Louisa	07080209	Lower Iowa		05455700	Iowa River at Lone Tree (5455700)	

10580003	Iowa River near Wapello	Louisa	07080209	Lower Iowa		5465500	Iowa River at Wapello, IA	
10180001	Little Sioux River near Larrabee	Cherokee	10230003	Little Sioux	X	06605850	Little Sioux River at Linn Grove (6605850)	
10300001	Little Sioux River near Milford	Dickinson	10230003	Little Sioux			No gage	
10970001	Little Sioux River near Smithland	Woodbury	10230003	Little Sioux	X	06606600	Little Sioux River at Correctionville (6606600)	
10670003	Little Sioux River near Turin	Monona	10230003	Little Sioux		6607500	Little Sioux River near Turin, IA	
10670002	Maple River near Mapleton	Monona	10230005	Maple	X	06607200	Maple River at Mapleton (6607200)	
10490005	Maquoketa River at Spragueville	Jackson	07060006	Maquoketa		5418500	Maquoketa River near Maquoketa, IA	Downstream from N. Fk. Maquoketa R.
10490004	Maquoketa River west of Maquoketa	Jackson	07060006	Maquoketa			No gage	
10910001	Middle River near Indianola	Warren	07100008	Lake Red Rock	X	05486490	Middle River near Indianola (5486490)	
10360003	Nishnabotna River near Hamburg	Fremont	10240004	Nishnabotna		6810000	Nishnabotna River above Hamburg, IA	
10490001	North Fork Maquoketa River near Hurstville	Jackson	07060006	Maquoketa	X	05418400	North Fork Maquoketa River near Fulton (5418400)	
10810001	North Raccoon River near Sac City (DS1)	Sac	07100006	North Raccoon	X	05482300	North Raccoon River near Sac City (5482300)	
10910002	North River near Norwalk	Warren	07100008	Lake Red Rock	X	05486000	North River near Norwalk (5486000)	
10540001	North Skunk River	Keokuk	07080106	North Skunk	X	05472500	North Skunk River near Sigourney (5472500)	
10520001	Old Mans Creek nr Iowa City	Johnson	07080209	Lower Iowa	X	05455100	Old Man’s Creek near Iowa City (5455100)	
10840001	Rock River near Hawarden	Sioux	10170204	Rock	X	06483500	Rock River near Rock Valley (6483500)	
10120001	Shell Rock River at Shell Rock	Butler	07080202	Shell Rock	X	05462000	Shell Rock River at Shell Rock (5462000)	
10560002	Skunk River near Augusta	Lee	07080107	Skunk		5474000	Skunk River at Augusta, IA	
10430002	Soldier River near Pisgah	Harrison	10230001	Blackbird-Soldier	X	06608500	Soldier River at Pisgah (6608500)	
10250001	South Raccoon River near Redfield	Dallas	07100007	South Raccoon	X	05484000	South Raccoon River at Redfield (5484000)	
10910003	South River near Ackworth	Warren	07100008	Lake Red Rock	X	05487470	South River near Ackworth (5487470)	
10850002	South Skunk River near Cambridge (DS1)	Story	07080105	South Skunk	X	05471000	South Skunk River below Squaw Creek near Ames (5471000)	
10620001	South Skunk River near Oskaloosa	Mahaska	07080105	South Skunk	X	05471500	South Skunk River near Oskaloosa (5471500)	
10270001	Thompson Fork - Grand River at Davis City	Decatur	10280102	Thompson	X	06898000	Thompson River at Davis City (06898000)	
10220001	Turkey River near Garber	Clayton	07060004	Turkey	X	05412500	Turkey River at Garber (5412500)	
10030001	Upper Iowa River near Dorchester	Allamakee	07060002	Upper Iowa	X	05388250	Upper Iowa River near Dorchester (5388250)	
10220002	Volga River near Elkport	Clayton	07060004	Turkey	X	05412400	Volga River at Littleport (5412400)	
10820001	Wapsipinicon River at De Witt	Scott	07080103	Lower Wapsipinicon	X	05422000	Wapsipinicon River near De Witt (5422000)	
10100001	Wapsipinicon River near Independence (US1)	Buchanan	07080102	Upper Wapsipinicon	X	05421000	Wapsipinicon River at Independence (5421000)	

10070003	West Fork Cedar River at Finchford	Black hawk	07080204	West Fork Cedar	X	05458900	West Fork Cedar River at Finchford (5458900)	
10460001	West Fork Des Moines River near Humboldt	Humboldt	07100002	Upper Des Moines	X	05476750	Des Moines River at Humboldt (5476750)	
10970002	West Fork Ditch at Hornick	Woodbury	10230004	Monona-Harrison Ditch	X	06602020	West Fork Ditch at Hornick (6602020)	
10650001	West Nishnabotna River near Malvern	Mills	10240002	West Nishnabotna		06807410	West Nishnabotna at Hancock (6807410)	Gage is too far away to do loads
10730001	West Nodaway River near Shambaugh	Page	10240009	West Nowaway	X	06817000	Nodaway River at Clarinda (6817000)	
10630003	Whitebreast Creek near Dallas	Marion	07100008	Lake Red Rock		05487980	Whitebreast Creek near Dallas (5487980)	

Appendix B

IIHR Remote Sensor Locations

IIHR sites fall into one of three basic categories: (1) strategic site for N load estimations related to the Iowa Nutrient Reduction Strategy (INRS); (2) monitoring for INRS Water Quality Initiative (WQI) projects; (3) IIHR Research Projects; (4) HUD1 projects. In the table below, USGS sites are designated as category 4. Many of the USGS will be similar in purpose to the IIHR load estimation sites.

Code	Name	Years Monitored	Type	Code	Name	Years Monitored	Type
WQS0001	Iowa River at Iowa City	2012-2015	1	WQS0031	Big Spring Fish Hatchery Spring	2015	3
WQS0002	Clear Creek Coralville	2012-2015	3	WQS0032	Middle Raccoon River Panora		1
WQS0003	Clear Creek Oxford	2012-2015	3	WQS0033	Des Moines River Keosauqua		1
WQS0005	English River Kalona	2012-2015	1,2,3	WQS0034	Cedar River Batavia		2
WQS0006	Iowa River Lone Tree	2012-2015	1	WQS0035	Miller Creek LaPorte City		2
WQS0007	Cedar River Conesville	2012-2015	1	WQS0036	Thompson River Davis City		1
WQS0008	Slough Creek CREP Wetland Outlet	2013-2015	3	WQS0037	East Nishnabotna River Brayton		2
WQS0009	Otter Creek at Elgin	2013-2015	3,4	WQS0038	Squaw Creek Ames		2
WQS0010	Skunk River Augusta	2013-2015	1	WQS039	Boone River Goldfield		2
WQS0011	Clear Creek Homestead	2014-2015	3	WQS0040	Boyer River Logan		1
WQS0012	Slough Creek CREP Wetland Inlet	2014-2015	3	WQS0041	Little Sioux River Turin		1
WQS0013	Beaver Creek Bassett	2014-2015	3,4	WQS0042	Maple River Mapleton		1
WQS0014	Beaver Creek Colwell	2014-2015	3,4	WQS0043	Floyd River James		1
WQS0015	Otter Creek Hornet Road	2014-2015	3,4	WQS0044	Des Moines River Stratford*		1,3
WQS0016	Otter Creek West Union	2014-2015	3,4	WQS0045	East Nishnabotna River Riverton		1
WQS0017	Brockcamp Creek Ft. Atkinson	2014-2015	2	USGS	North Raccoon River Sac City		4
WQS0018	Roberts Creek Elkader	2014-2015	2	USGS	North Raccoon River Jefferson		4
WQS0019	S. Chequest Creek Douds	2014-2015	2,4	USGS	South Raccoon River Redfield		4
WQS0020	Mississippi River Pool 16 Fairport	2014-2015	1,3	USGS	Raccoon River Van Meter		4
WQS0021	Rapid Creek Iowa City	2014-2015	3	USGS	Des Moines River Des Moines 2nd Ave.		4
WQS0022	Rapid Creek tributary Iowa City	2014-2015	3	USGS	Boone River Webster City		4
WQS0023	Wapsipinicon River DeWitt	2015	1	USGS	Nodaway River Clarinda		4
WQS0024	S. Fork Iowa River New Providence	2015	1,3,4	USGS	Maquoketa River Green Island		4
WQS0025	S. Fork Catfish Creek Dubuque	2015	3,4	USGS	Turkey River Garber		4
WQS0026	Middle Fork Catfish Creek Dubuque	2015	3,4	USGS	Iowa River Wapello		4
WQS0027	Lime Creek Brandon	2015	3	USGS	Cedar River Palo		4
WQS0028	Des Moines River Boone	2015	1,3	USGS	Mississippi River Camanche		4
WQS0029	Alluvial Well, Boone	2015	3	USGS	West Nishnabotna River Randolph		4
WQS0030	Manchester Fish Hatchery Spring	2015	3				