Cover Page

Project Title: Hydrologic monitoring to support NRCS practice evaluation and development in the Great Lakes and Mississippi River Watersheds

Grantee Entity Name: Water Resources Monitoring Group, LLC

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Project Summary

To evaluate the effectiveness of tax-payer investments, the NRCS supports the use of surface-water gauging stations to determine the quantity and quality of water leaving farmlands. Edge-of-field monitoring activities are cost-shared through NRCS Conservation Activity 201 Edge-of-Field Water Quality Monitoring, Data Collection and Evaluation and Conservation Activity 202, Edge-of-Field Water Quality Monitoring, System Installation. Unfortunately, edge-of-field monitoring requires a substantial investment as it requires significant labor and current monitoring equipment is costly to purchase, install, and maintain.

The main goals of this project were to increase the implementation and quality of edge-of-field water monitoring through the installation and field testing of low-cost prototype edge-of-field surface-water runoff and tile drainage monitoring systems, development of training materials related to administration of monitoring programs, evaluation of how low-cost monitoring could be used to support other conservation activities, and to evaluate the effectiveness of treatment trains as edge-of-field water quality treatment practices.

As a result of the project, we demonstrated that ***low-cost surface-water monitoring platform was able to produce estimates of edge-of-field discharge and water quality that were comparable to conventional systems under non-frozen conditions- reducing monitoring costs by up to 50%***. Results of farmer surveys indicate that data produced by the low-cost monitoring systems are highly valued for evaluating conservation practice implementation. Treatment trains were effective at reducing nutrient loads at the edge-of-field. Moreover, through this CIG project we developed tools needed to increase the adoption of edge-of-field water monitoring.

Project Background:

There are several drivers influencing the cost of current monitoring programs. Major items include initial hardware costs, flume and/or weir installation cost, lack of coordination, and limited data sharing between monitoring programs. Table 1, below, compares cost estimates for multiple references.

Table 1. Edge-of Field monitoring costs.

Program	Equipment Costs	Installation Costs	Operation and Maintenance
Discovery Farms, WI	$30,000	Not available	$45,000/yr.
Discovery Farms, MN	$19,000	Not available	$30,000/yr.
NRCS	$20,000	$50,000	$20,000/yr.

In this project we attempted to address these challenges by adapting the Internet of Things (IoT) ecosystem for use in EoF monitoring. The primary benefits of the IoT system include scalability, lower hardware costs, lower power consumption, real-time data transmission, and lower cost data servers which are linked to a graphic user interface for user access.

Moreover, our intent was not only to reduce the cost of hardware associated with edge-of-field monitoring; but also move toward offering a fully integrated monitoring system. An integrated monitoring program includes turn-key hardware and software solutions that are easy to install and operate, provide standard protocols for installation, operation, and maintenance of equipment; and provide training and education on monitoring methods and procedures to ensure transparent and consistent results across monitoring projects.

Project Goal and Objectives

The goal of the project was to address the challenges in using surface water monitoring stations to evaluate impacts of practice implementation to address water quality problems.

Specific project objectives were:

Objective 1	Field-test low-cost edge-of-field water monitoring gauge for use with NRCS Conservation Activity 201 and 202.
Objective 2	Develop an interim NRCS conservation activity for extensive edge-of-field monitoring.
Objective 3	Prepare technical guide and offer training for organizations and individuals planning to conduct monitoring utilizing NRCS Conservation Activity 201 and 202.
Objective 4	Evaluate potential to reduce agricultural pollutants through use of treatment trains.
Objective 5	Evaluate the impact of extensive monitoring on implementation of NRCS Code 590 and Code 118.

Project Methods

Objective 1. Field-test low-cost edge-of-field water monitoring gauge for use with NRCS Conservation Activity 201 and 202.

Low-cost prototype monitoring gauge testing was conducted at multiple sites in Pierce, Polk and Grant counties in Wisconsin and in Ohio's Western Lake Eerie Basin. The installations in Wisconsin were focused on qualitative assessments of functionality and usability while the Ohio installations were used to quantitatively evaluate the low-cost monitoring systems. The quantitative assessment conducted in Ohio was based on data comparisons with "conventional" monitoring sites that were co-located with the prototype gauges.

The conventional sites were installed and operated by the United States Agricultural Research Service and managed by Dr. Kevin King. Conventional installations included 5 surface-water gauging stations and 5 tile drainage gauging stations located on commercial farms within the Blanchard River Demonstration Farms Network. Analysis of comparative data was conducted by USDA ARS personnel.

Objective 2. Develop an interim NRCS conservation activity for extensive edge-of-field monitoring.

Current edge-of-field monitoring standards (CA201 and CA202) are not designed to support low-cost water quality monitoring. As written the activities are very prescriptive in required hardware specifications used for monitoring and require collection of samples for specific analyses (e.g. total phosphorus, total nitrogen). Additional flexibility is required to conduct low-cost monitoring utilizing the currently available Internet of Things technologies.

Therefore, an interim standard of low-cost EoF monitoring was developed by reviewing current conservation activities 201 and 202, interviewing EoF monitoring experts, and careful consideration of the goals and objectives of the low-cost monitoring systems. The draft conservation activity "Hydrologic Data Management System to Support Adaptive Farm Management" was designed to provide technical service providers flexibility to gather various types of water-related data with varying levels of accuracy based upon the stipulated monitoring objective. The activity focuses on producing data of a known quality and completeness which is adaptable to multiple uses rather than utilizing a rigid set of methodologies designed to produce a specific set of water quality parameters.

Objective 3. Prepare technical guide and offer training for organizations and individuals planning to conduct monitoring utilizing NRCS Conservation Activity 201 and 202.

After working closely with individual farmers during prototype testing, presentations at local farmer led field days and consultation with national experts a draft technical guide was prepared to assist landowners and producers in understanding the monitoring aspects and requirements of Activities 201 and 202.

Objective 4. Evaluate potential to reduce agricultural pollutants through use of treatment trains.

A series of wetlands were designed and established in Lenawee County in southeast Michigan on the Bakerland Farm. The series of wetlands (aka "Treatment Train") were designed to reduce pollutant load to the stream through surface-flow and vertical flow treatment wetland cells. Drainage control structures instrumented with the prototype low-cost monitoring equipment were installed at entrance and exit of cell 1 (surface-flow wetland) and at the exit of cell 2 (vertical flow wetland). Flow was estimated using v-notch weirs which were installed in the drainage control structures and flow-weighted samples were collected for determination of water quality parameters.

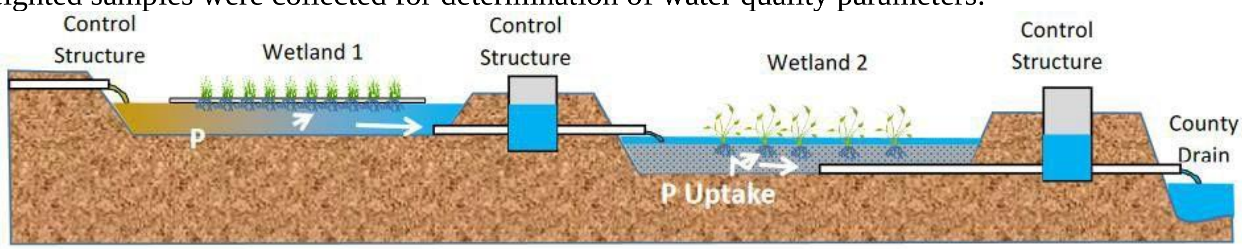


Figure 1: Schematic of the wetland treatment train evaluated as part of this project.

Objective 5. Evaluate the impact of extensive monitoring on implementation of NRCS Code 590 and Code 118.

Since 2016, Michigan State University's Institute of Water Research has been conducting edge-of-field water monitoring with farmers located in the western Lake Erie Basin near Adrian, Michigan. The pilot study collected edge-of-field water samples and flow data from participating farmers tile drainage outlets. Samples were analyzed and farmers were provided with estimates of water drainage volume and nutrient loading from specific fields within their farms. In-depth interviews with participants (n=9) were conducted to determine farmer attitudes and perspectives on water monitoring as a tool to support conservation.

In addition to the pilot study, a broader survey of 56 farmers from within the River Raisin Watershed was conducted to identify attitudes toward edge-of-field water monitoring and BMP (e.g. Nutrient Management) implementation.

Project Results

Objective 1. Field-test low-cost edge-of-field water monitoring gauge for use with NRCS Conservation Activity 201 and 202.

Our field testing affirmed that our low-cost ultrasonic and pressure sensors produced accurate flume and tile stage measurements (depth of water) compared to our time-lapse imagery and the USDA-ARS logged data at the same sites. Figure 2, below, is a plot of observed stage data versus logged stage (sensor) data for the Stateler site 1 flume. Figure 3 is a plot of the low-cost pressure sensor stage data versus the conventional gauging station stage data for the George Farm tile gauging station. A slope and coefficient of determination (R^2) near 1 for both plots indicate an excellent agreement between values.

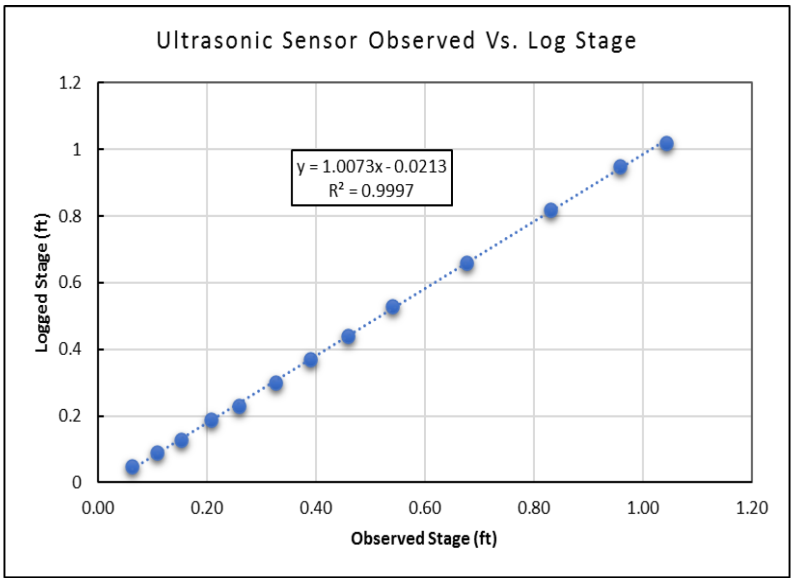


Fig 2: The figure above illustrates the ultrasonic sensor flume stages for Statler flume plotted against observed stage readings captured from time-lapse photographs. Sensor readings are typically within 0.02' of the observed value.

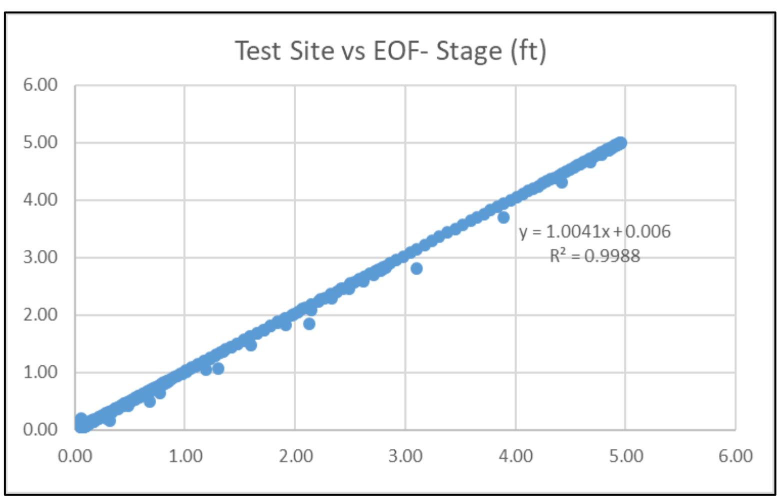


Fig 3: Plot of low-cost pressure sensor data versus conventional gauging station stage sensor data.

Results of monitoring indicated that there was consistent agreement between the conventional and prototype surface-water runoff monitoring gauges for estimates of discharge volume and estimated concentration of dissolved reactive phosphorus. In addition, estimated discharge and DRP concentrations between prototype and conventional tile drainage gauging stations exhibited good agreement when tile outlets were not submerged. However, when submergence occurred at the tile outlet, the prototype gauge discharge estimates did not agree with estimates produced by the conventional gauges equipped with area depth velocity sensors.

The table below lists estimates for cubic feet of discharge for multiple events monitored by prototype and conventional surface-water runoff gauging stations on several sites within the study. Results of linear regression analysis displayed in Figure 4 indicate that estimates of discharge obtained via the prototype gauge correlate well with discharge estimated using the conventional surface-water runoff gauge-slope equals 0.986 and coefficient of determination (R^2) equals 0.9975. Regression analysis indicates that the regression model is very significant ($P < 0.001$).

Table 2: Discharge estimates from conventional and prototype surface-water runoff gauging stations across multiple farms.

		Gauging Station	
Site	Event Date	Prototype	Conventional
		(cf)	(cf)
AR1	5/27/2019	129	30
AR1	5/13/2019	1,459	1,475
AR1	7/21/2019	2,396	2,482
AR1	5/28/2019	3,690	2,773
BE3	6/1/2019	7,195	7,595
CT1	6/20/2019	5,627	7,899
BE3	6/20/2019	7,673	13,754
AR1	6/20/2019	21,104	21,895
CT1	6/15/2019	35,021	40,984
ND1	6/20/2019	187,502	183,231

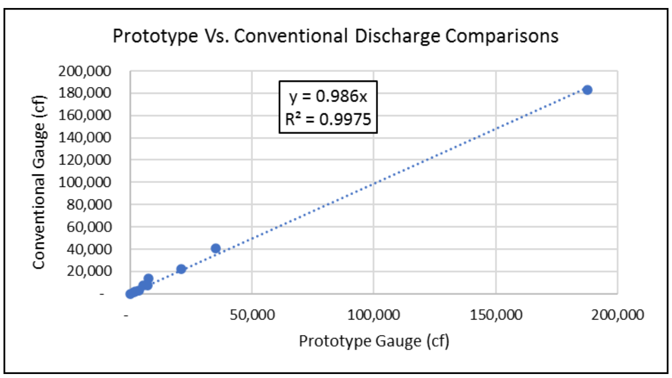


Fig 4: Plot and linear regression of discharge estimates for prototype and conventional surface-water gauging stations.

Prototype tile drainage monitoring sites performed well if tile outlets were not submerged. Figure 5, below, is a plot of prototype and conventional gauge discharge estimates recorded when not submerged. Discharge estimates from the prototype gauge correlate well with the conventional gauge.

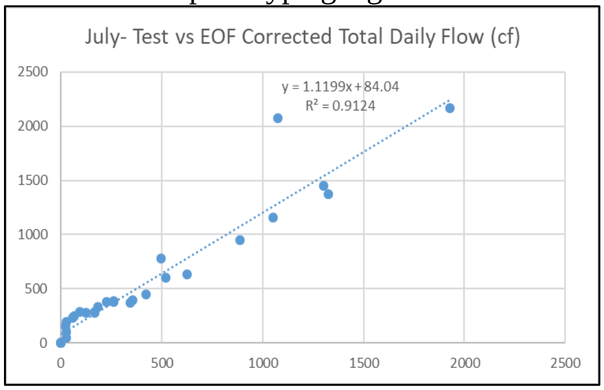


Fig: 5. Discharge comparisons for the prototype and conventional gauges are in good agreement when tile outlet was not impacted by submergence.

The tile drainage system at the George Farm, in contrast, was often submerged and as a result the discharge estimates between the prototype and conventional gauges were in poor agreement. (Figure 6) The plot and linear regression of the discharge data illustrates the poor correlation (slope equals 0.3455 and coefficient of determination equals 0.2185).

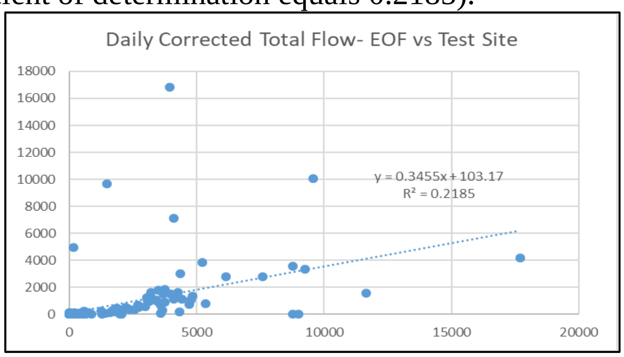


Fig: 6. Discharge comparisons for the prototype and conventional gauges have poor agreement when tile outlets were subjected to submergence.

EoF samples collected by the prototype and conventional gauging stations were collected and analyzed by USDA ARS research personnel. Table 3lists the estimated DRP concentrations for samples collected by the two gauging station types. Sample analyses are also plotted in Figure 7 along with the linear regression line, equation, and coefficient of determination. Results of the regression analysis indicate excellent agreement between estimates of DRP concentration derived from samples collected from the two samplers (slope = 0.92 and R^2 = 0.94).

Table 3. Dissolved reactive phosphorus concentration in samples collected by the two sampling systems.

		Gauging Station	
Event Date	Site	Prototype	USDA
		(ug/l)	(ug/l)
5/28/2019	AR1	0.09	0.36
6/20/2019	AR1	0.16	0.17
7/21/2019	AR1	0.47	0.51
8/22/2019	AR1	0.27	0.29
6/15/2019	CT1	1.27	1.12
6/20/2019	CT1	1.01	1.13
5/20/2019	BE3	0.11	0.12
6/1/2019	BE3	0.13	0.11
6/20/2019	BE3	0.07	0.1
6/20/2019	ND1	0.06	0.06
*6/2/2019	CT1	120.82	84.16

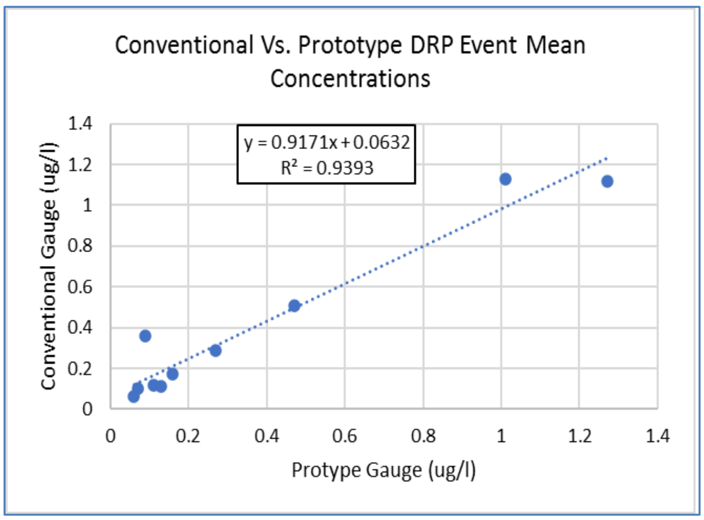


Fig 7. Plot and regression analysis of DRP concentration in samples collected by the two sampling systems.

Our prototype field testing affirmed that our two-stage monitoring system was frequently utilized and able to effectively correct estimates of discharge when flume submergence occurred. This capability was beneficial because it gives a better estimate of discharge and, reduces flow-weight composite sample bias introduced by the submergence. it also decreases the amount of time spend on data correction. An example of real-time stage correction is depicted in the figure below. The data was collected from a prototype surface-water gauging station on June 10, 2019. The data indicates that the flume was submerged during the second rise in the hydrograph.

Submergence was due to ponding downstream from the flume. If the uncorrected stage data is used to estimate discharge, the total runoff for this event was approximately 51,400 cubic feet. However, after the flume stage is corrected for submergence, the estimated discharge is reduced to 21,100 cubic feet- a significant reduction in flow.

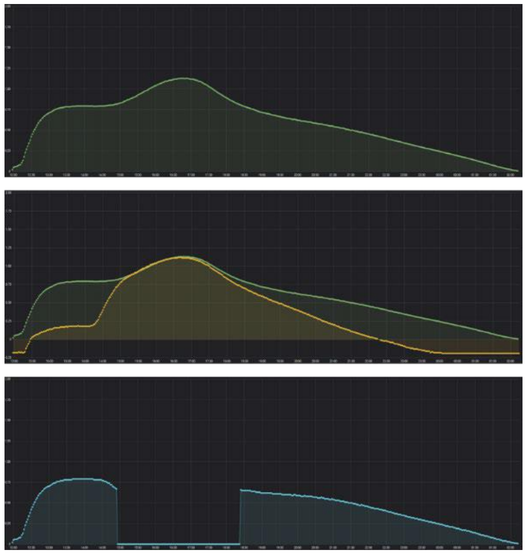


Fig 8: The top panel illustrates flume stage (green line), the center panel is a plot of flume and tailwater stage (yellow line), and the bottom panel is a plot of the corrected stage (blue line) values.

Based on field results, we made several modifications to our system. Firstly, we developed two alternative methods for gauging tile sites to overcome submergence. The first alternative design utilizes a commercially available drainage control structure (DCS) with a V-notch weir to gauge discharge. We designed a sampler electronics enclosure that hinge-mounts to the top of the DCS and stage and tailwater sensors which mount directly on the V-notch weir. With this design, farmers can easily access the DCS and adjust controlled drainage depths without the need to reset sensor parameters. This alternative decreases the potential for submergence because the V- notch weir can be set at a higher elevation compared to the tile outlet. We have also developed an alternative design which incorporates a low-cost ADV sensor for locations that lack a DCS.

Figure 9. Modified equipment enclosure mounted to the drainage control structure

Figure 10. Hinged enclosure allows easy access to drainage control structure.

The second significant system modification was to the equipment enclosure. Results of infield testing showed that electronics mounted under the top panel were difficult to access if troubleshooting was required. Moreover, the location of the sample container required technicians to disconnect the sample line when collecting samples; and often the sample line would not get reconnected after sample retrieval- resulting in missed events. The modified equipment enclosure is elevated and has full width front and back doors to improve access. One door provides easy access to the electronics and the other door opens for access to the sampler. This modified system also automatically positions the sample line after the sampler is retrieved and replaced.

Figure 11. Modified equipment enclosure installed with wingwall and flume.

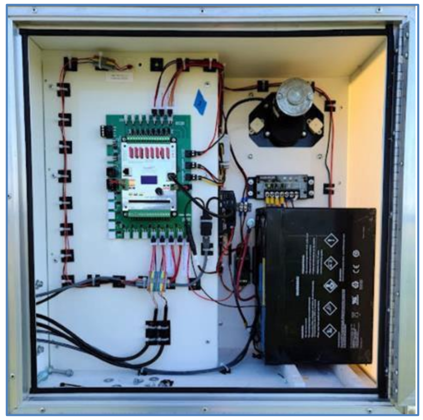


Figure 12. Rear door of provides excellent access to electrical-mechanical systems provides excellent access to electrical-mechanical systems.

Figure 13. Front door of enclosure provides access to sample pump and sample container.

Thirdly, a new interface board was also developed. It connects the data logger to peripheral devices. The interface board greatly improves field robustness, functionality, and operational ease. WRMG is further developing this technology to include upgraded hardware that will provide additional refinements.

Objective 2. Develop an interim NRCS conservation activity for extensive edge-of-field monitoring.

A draft NRCS Code for Hydrologic Data is provided with this report as Appendix 1 at the end of this report.

The draft code provides a framework for moving edge-of-field water monitoring and data collection forward in a way which is compatible with the wide array of low-cost sensors, samplers, and data collection options which are currently available and bound to become more prevalent in future monitoring programs.

The draft code allows flexibility in instrumenting water monitoring gauging stations with various sensors, loggers, and samplers while maintaining a clear and consistent focus on setting targets for data quality, completeness of data, methods for data review, and recommendations to follow in order to create interoperable water monitoring data sets.

Objective 3. Prepare technical guide and offer training for organizations and individuals planning to conduct monitoring utilizing NRCS Conservation Activity 201 and 202.

The Edge of Field Monitoring Guide is provided as Appendix (2) accompanying this report.

Edge-of-field monitoring is much more than collecting water samples. It is also about building relationships built on trust and respect with both NRCS personnel and the participating producer. As a technical service provider, you must keep in mind that you are conducting work on privately owned land and thus need to communicate effectively with the producer as to respect their property, understand the constraints however small they may be such as not rutting up turn rows with vehicles or closing gates behind you. You must understand that you are providing a service to the producer but under the constraints of EQIP contracts and that your services will be aimed at what the farmer wants to monitor in terms of field and conservation practices.

The draft guide provides an overview of edge-of-field water monitoring activities and provides valuable insight on specific items to consider in order to run a successful CA 201/ 202 monitoring program. Development of the guide is based on field experience of practitioners with experience in water monitoring, on-farm research, and NRCS conservation activity requirements.

Objective 4. Evaluate potential to reduce agricultural pollutants through use of treatment trains.

Results of measurements of discharge and nutrient concentrations from the drain tile (TT1) as it moves through the first wetland and empties into wetland two (TT2) indicated substantial nutrient reductions. For example, in 2020 annual loading reductions were 54, 41.5, and 63 percent for dissolved reactive phosphorus, nitrate, and total phosphorus, respectively. Additional data describing treatment train performance is provided in the Appendix 3 at the end of this report.

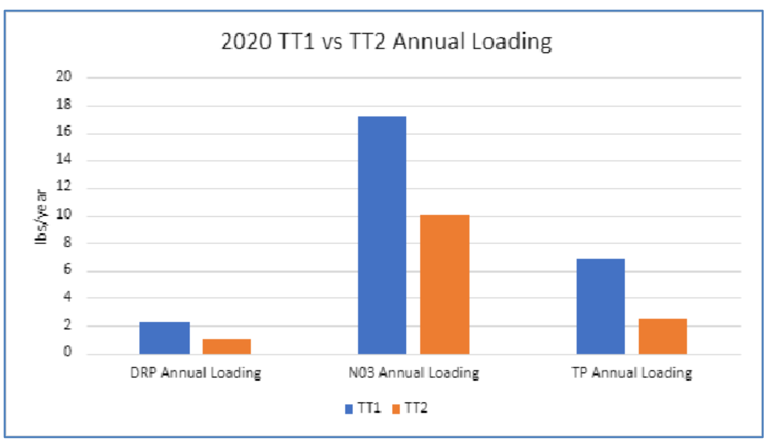


Figure 14. 2020 TT1 vs TT2 annual loading for DRP, nitrate, and TP from January 9 - December 29, 2020.

Objective 5. Evaluate the impact of extensive monitoring on implementation of NRCS Code 590 and Code 118.

Surveys farmers from within the River Raisin Watershed was conducted to identify attitudes toward edge-of- field water monitoring and BMP (e.g. Nutrient Management) implementation. The survey findings indicate that there is sizeable support from this farming community for a tile-monitoring program, as well as potential to increase participation in conservation through replication of this model on a larger scale. Of the farmers included in the survey, 73% said they were rather extremely interested or very interested in participating in an anonymous tile drain monitoring program, and 94.6% said they would be willing to adopt a conservation practice if high levels of nutrients were found to be leaving their fields. The following excerpts from the survey questions illustrate key findings from the survey related to the usefulness of on-farm water monitoring for support of nutrient management and conservation activities.

How useful do you think this information would be to you for making future farm management decisions related to reducing subsurface nutrient loss?										
Not useful	1	2	3	4	5	6	7	**8.4**	9	10	Very Useful

How necessary do you think this information is for helping farmers to achieve on-farm environmental goals, such as reducing subsurface nutrient loss?											
Not useful	1	2	3	4	5	6	7	**8**	9.1	10	Very Useful

How willing would you be to have this data collected on your farm?											
Not Willing	1	2	3	4	5	6	7	**8.9**	9	10	Very Willing

If data indicated water quality results that concerned you, how motivated would you be to implement additional best management practices?											
Not Motivated	1	2	3	4	5	6	7	**8.8**	9	10	Very Motivated

How supportive are you of research pursuing the development of low-cost equipment that could provide field-specific water quality data to you?											
Not Supportive	1	2	3	4	5	6	7	**8.9**	9	10	Very Supportive

Project Challenges:

There were numerous challenges faced by this project. Some have been recounted above, such as the weather challenges which resulted in numerous changes in design, fabrication and installation of equipment and software across all test sites and locations. The positive result is both intensive and extensive systems are much more robust and resilient, and suitable for installation for numerous applications.

The project was conducted in part during the COVID pandemic. This impacted the ability to access the sites; meet with cooperators and address equipment maintenance and operation issues in a timely fashion. Despite these challenges cooperators stayed with the program and as a result the systems that evolved are much more flexible in their applications.

Project Impact:

Impacts are discussed in the accompanying attached documents. Simply stated the largest project impact is the use of lower cost, lower resolution approaches to Edge of Field monitoring provides the opportunity for greater farmer use to evaluated practices adopted under NRCS Conservation Activities 201 and 202. Farmers can access data in a timelier fashion and are able to better use the data to guide individual management decisions.

Project Outputs:

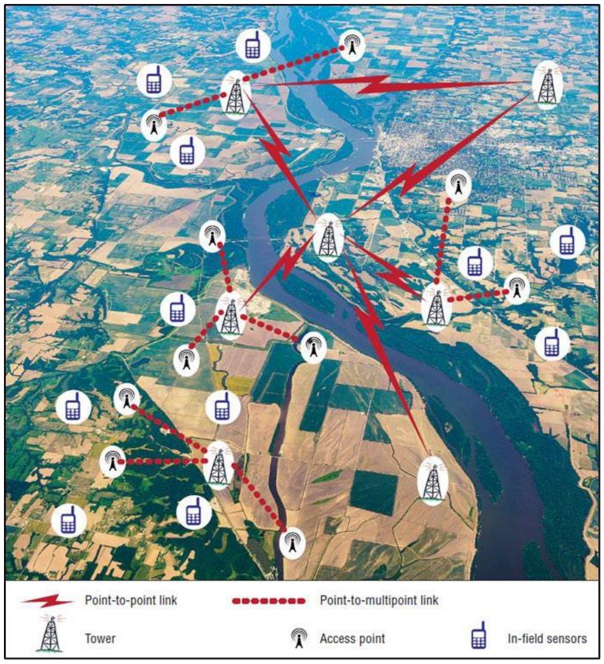
As a part of this project, we were requested to make presentations at national meetings to report on progress and results. Presentations, posters, and demonstrations were presented in person at Norman, Oklahoma in 2018, Pittsburgh, Pennsylvania in 2019 and virtually in 2020. These posters are provided as Appendix 4accompanying this report.

Potential next steps: Dennis here is where we can list/discuss your view on the next steps of evaluating broader implementation within watersheds etc.

Potential next steps are discussed as part of the accompanying documents. Next steps include expanding use of EOF in critical areas of practice adoption in watersheds to give a picture of watershed impacts of changing management practices. The systems need improvement to provide real time data to farmer cooperators in their management decision process.

Low-cost monitoring approaches based on the IoT ecosystem of sensors, software, telemetry systems, and real-time data visualization provide a tremendous opportunity for improved farm management and water quality outcomes. This new technology can be used to enhance current monitoring activities by facilitating a greater number of monitoring locations at multiple environmental scales collecting varying types of environmental data.

Future research is needed to determine feasibility of coupling intensive monitoring (e.g. CA 201/202) and distributed low-cost, IoT-based monitoring technologies with real-time computer modeling (e.g. APEX) efforts. Through these combined approaches it may be possible to accurately predict water loss, erosion rates, and nutrient loading to surface-water resources across entire watersheds on a field-by-field basis.



Point-to-point link
Point-to-multipoint link
Tower
Access point
In-field sensors

Appendix 1. Draft Interim Standard

United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

HYDROLOGIC DATA MANAGEMENT SYSTEM TO SUPPORT ADAPTIVE FARM MANAGEMENT

Draft Code XXX

DEFINITION

The process of integrating, grading, correcting, storing, and distributing in-field hydrologic data to support adaptive farm management.

PURPOSE

This practice is used to support and improve one or more of the following management objectives:

- improve water use efficiency,
- reduce edge-of-field surface-water runoff,
- reduce nitrogen and phosphorus loss from cropland acres, or
- reduce soil erosion.

CONDITION WHERE PRACTICE APPLIES

This practice is applicable to all farmland acres.

CRITERIA

General Criteria Applicable to All Purposes

Operate and maintain hydrologic data management system which integrates sensor data, evaluates data, grades data quality, corrects or deletes erroneous data, stores data, and provides stakeholders secure access to data in real-time or near real-time. This system will rely on completion of the following activities:

- Create data quality goals based on monitoring objectives.
- Create a hierarchical data quality standard which includes data quality dimensions, data quality elements, and indicators based on data quality goals (Table 1).
- Data quality dimensions include availability, usability, reliability, relevance, and presentation quality.
- Define data quality elements for all the data quality dimensions.
- Develop data quality indicators for the data quality elements. Indicators should be quantitative and, to the extent possible, support an automated review process.
- Develop data cleansing and correction methodologies for data streams. Cleansing methods should identify spikes, gaps, and out of range values and describe acceptable data correction methods.

- Develop data quality scoring for each of the previously defined indicators. Data quality scores and definitions should be stored and transferred with data requests for transparent reporting of data quality.

Table 1. Example of data dimensions, elements, and indicators.

Dimensions	Elements	Indicators
Availability	Accessibility	Is there on-line access to download data Can data easily be accessed/utilized to support CART, APEX, STEWARDS Data is protected from unauthorized access
	Timeliness	Data available to farmers in real time Corrected data available within reasonable timeframe Data update interval
Usability	Credibility	Data generated by trained technicians Data has been audited Data values are within acceptable ranges
Reliability	Accuracy	Data are within accuracy goals Information is not ambiguous
	Consistency	Data presented is consistent with other data sources
		Data types remain consistent with time Data is verifiable
	Integrity	Data format is clear and meets criteria Data has structural integrity (complete) Data has content integrity (no unauthorized changes)
	Completeness	Does data deficiency in one component impact overall usability of data with multiple components
Relevance	Fitness	Is the data relevant to the theme
Presentation Quality	Readability	Data is clear and understandable? It is easy to judge that data provided meet needs? Metadata is clear and easy to understand?

(Cai and Zhu 2015)

Additional Criteria to Support Data Management

Provisions will need to be made to include links and references to supporting data such as field notes, photographs, videos, chain of custody sheets, etc.

Monitoring systems should allow stakeholders access to real time, or near real-time data through graphic user interfaces accessible through the world wide web.

Historic data must be available through a graphic user interface that allows users to select data of interest for specific days and time periods as needed.

CONSIDERATIONS

Consider the following when planning installation of in-field sensors, data loggers, and telemetry systems:

- data quality goals should be determined based on monitoring objectives,
- in-field sensor installations should be designed to allow for some internal quality control of

data,

- data system should support NRCS Conservation Assessment Ranking Tool (CART) efforts,
- data management system should support integration with existing USDA data repositories (e.g., STEWARDS).
- data management system should be designed to support common hydrologic modeling programs (e.g., APEX). Any other models? SWAT?
- data that is intended for use in adaptive management should be presented in terms and units familiar with the stakeholders (e.g., pounds per acre).
- data intended for use in adaptive management should be accompanied with related information which provides context. This information could be qualitative (e.g., good, average, poor) or quantitative (e.g., 25th percentile).

PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the following:

- detailed methods and plans for data cleansing and corrections,
- criteria for assigning data quality grade to each indicator,
- plans for review of quality assurance and quality control activities with in-field technicians and lab technicians to ensure activities are implemented as specified,
- Data managers must prepare audit procedures and schedule for review of automated and manual data review procedures

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for system operators which includes the following:

- Records of audits conducted to evaluate automated and manual review of data management activities,
- A list of all sensors installed that details the vendor's name, vendor contact information, part number, and sensor specifications,
- Lab test results for sensor accuracy and precision,
- Instructions on pre-install conditioning requirements for in-field sensors such as soil moisture sensors,
- Sensor installation instructions,
- In-field calibration procedures for installed sensors,
- Schedule for Remote and infield sensor checks and sensor validations,
- Data logger configuration settings for in-field sensors,
- Installation and removal schedule for all in-field hardware,
- Operation and maintenance log books to record scheduled maintenance activities,

RELATED STANDARDS

Irrigation System, Microirrigation (Ac.) (441)

Irrigation System, Surface and Subsurface (Ac.) (443)

Irrigation and Drainage Tailwater Recovery (No.) (447)

Irrigation Water Management (Ac.) (449)
Edge-of-Field Water Quality Monitoring Data Collection and Evaluation (201)
Edge-of-Field Water Quality Monitoring System Installation (202)
Hydrologic Monitoring System Installation DRAFT CODE

REFERENCES

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Appendix 2. Draft Edge of Field Monitoring Guide w/o Accompanying forms

WRMG - *Water Resource Monitoring Group*

An Edge-of-Field Monitoring of Water Quality Guide for Technical Service Providers: Challenges, Obstacles and Insights for Conservation Activities 201 and 202

Draft

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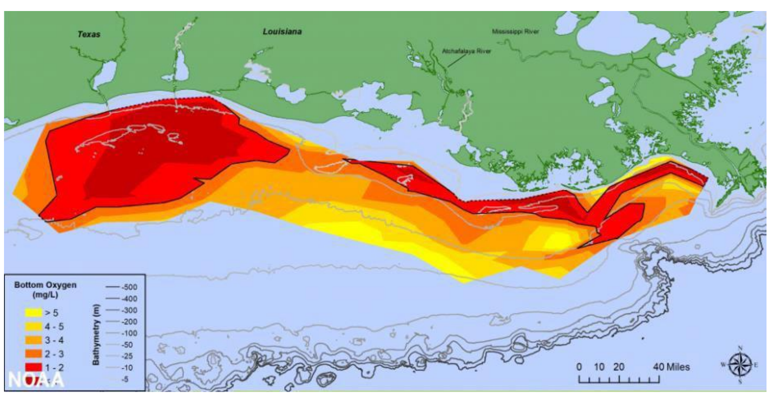
An Edge-of-Field Monitoring of Water Quality Guide for Technical Service Providers: Challenges, Obstacles and Insights for Conservation Activities 201 and 202

Mike Daniels, Dennis Busch and Jim Anderson

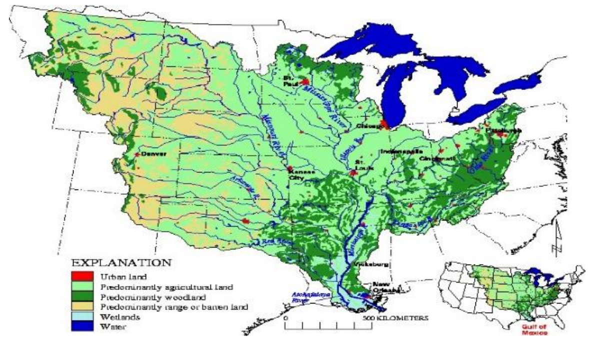
Introduction

Nutrient enrichment continues to be a major impairment to the designated uses of fresh and coastal waters of the United States (Schindler et al. 2008; Milachak et al. 2013; Kleinman et al. 2015). Prominent water quality issues, such as harmful algae blooms in Lake Erie (NOAA 2017a) and a large hypoxic zone in the northern Gulf of Mexico (NOAA 2017b), have prompted unparalleled activity in developing action plans to correct these issues (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2008; Great Lakes Interagency Task Force 2017).These plans have included modeling efforts and basin-scale studies to geographically identify the source, as well as estimate the relative nutrient loading, as a foundation for setting reduction goals and developing corrective actions (Alexander et al. 2008; White et al. 2014;Tomer 2018).

Nutrient runoff from cropland is receiving greater attention as a major source of nutrients from nonpoint sources (Dubrovsky et al., 2010; U.S. Environmental Protection Agency, 2010). This is especially true in the Mississippi River Basin (MRB), as recent model estimates suggest that up to 85% of the phosphorus (P) and nitrogen (N) entering the Gulf of Mexico originates from agriculture (Alexander et al., 2008).



A major effort to reduce nutrient delivery to the Gulf is the launching of U.S. Department of Agriculture – Natural Resources Conservation Service (NRCS) Mississippi River Basin Healthy Watersheds Initiative (MRBI), a voluntary landscape initiative.



This initiative provides funding as financial assistance to producers to install conservation practices (CPs) that have the potential to reduce nutrients from cropland (U.S. Department of Agriculture – Natural Resources Conservation Service, 2018).

The MRBI piloted an innovative conservation activity (NRCS CA-201 and CA-202) to assist landowners by providing financial assistance for edge-of-field monitoring (EOFM) of cropland to help farmers: (1) to quantify nutrient and sediment losses from individual management units such as fields; and (2) to demonstrate CP efficacy for a given set of conditions (Daniels et al., 2018).

Edge-of-field monitoring (EOFM) of runoff from individual agricultural fields is critical to improving our understanding of the fate and transport of nutrients applied as animal manures and fertilizer to agricultural lands along the complex watershed continuum (Reba et al. 2013; Harmel et al. 2016; Sharpley et al. 2016b). Within the last decade, EOFM has moved from mostly research applications to routine adoption for education and performance assessment of environmental indicators on private, working farms. EOFM helps producers more clearly see how their management systems affect in-stream water quality and watershed functions (Sharpley et al., 2017). Additionally, EOFM helps producers more clearly see how their management systems affect in-stream water quality and watershed functions (Sharpley et al., 2017).

Kalcic et al.(2018) points out that differences in geographical scale in defining a waterqualityissue,and thescale atwhichthe solution should be applied or defined, can create disconnects in determining progress toward a stated goal. Agricultural producers often focus on the field or farm scale where they make management decisions. In contrast, agency personnel focus on larger watersheds and/or multiple watershed scales, and often policy makers focus on political rather than hydrological boundaries (Table 1).

Table1. Roleof edge-of-field (EOF) monitoringandmodelingtools inaddressing nitrogen (N) andphosphorus (P) loading to downstream waters.

STEP	ACTIONS / TOOLS
Determine sources scale	• Gather site-specific measured data at the field, farm, and watershed • Use model to determine sources in absence of measured data (best professional judgement and stakeholder input can be valuable as well).
Determine sources	• Gather site-specific measured data at the field, farm, and watershed
Estimate source contribution	Use measured EOF runoff data to estimate field-scale N and P losses. In the absence of site-specific data for agricultural (cultivated and pasture/range), forest, and drainage contributions, see the MANAGE data- base (Harmel et al. 2008, 2016). • Use end-of-pipe data for point sources. • Use measured in-stream data and models to estimate fate and transport.
Determine type(s) and location(s)	• Use measured EOF and small watershed data and models to optimize practice type and location on fields, conservation practices (CPs) farms, and small watersheds with the largest loading and/or where the practice(s) will be more effective.
Evaluate effectiveness	Use measured EOF and downstream data and multiyear time frame to assess effectiveness if adequate funding is available. • Use model if a more rapid estimate is required or in the absence of funding for monitoring. If necessary, conduct research. Use field or laboratory studies to improve models and better understand processes.
Use additional CPs	Determine whether additional CPs are needed based on monitoring data, improved scientific understanding, and refined model predictions

King et al. (2018) utilized a network of 40 EOFM sites to evaluate the “4Rs” of fertilizer management (“right source, rate, time, and place”) that are being promoted by the fertilizer industry to address nutrient loss from agricultural fields (Nutrient Stewardship 2017). The results highlight the importance of understanding field hydrology on surface and subsurface P transport. King et al. (2018) also point out that the effectiveness of the nutrient management practices will likely vary across fields with different characteristics. This understanding will lead to more effective reduction strategies by allowing remedial measures to be implemented in a more spatially explicit manner to meet local hydrologic and crop production conditions.

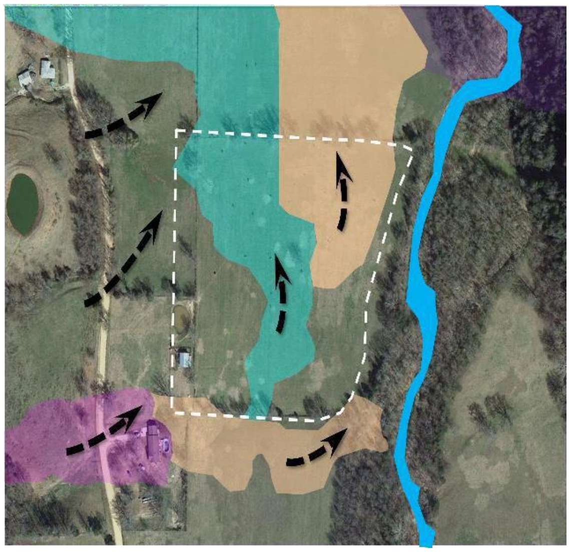
While interest and application of on-farm routine EOFM as a mechanism for performance indicators of nutrient management, soil health and resilience to climate change, there are associated challenges and obstacles and needed improvement in the overall process regarding providing EOFM as a technical service provider. This guide has been developed to outline the overall process of not just implementing monitoring but how to address non- technical issues of providing technical assistance to farmers who utilize conservation activities 201 and 202.

Implementing Conservation Activity 201 and 202 as a Technical Service Provider

Conservation Activity 201 (Appendix 1) addresses the USDA-NRCS standard operating procedures associated with collecting and managing EOFM monitoring of data in a manner to be “defensible scientific foundation capable of providing data at the level required for evaluating the effectiveness of a practice or a practice system”. The guidance for implementing 201 provides specifics for how to collect data, required water quality parameters to be monitored, how to manage data in terms of handling, storage, statistical analysis, and reporting requirements. Often many think that EOFM monitoring is strictly about nutrient concentrations in runoff water, but CA 201 also requires documentation and reporting of hydrological parameters associated with hydrographs such as peak discharge and total discharge.

Two key elements associated CA 201 that are required before data collection can initiate is the approval of the Water Quality Monitoring Plan and the Quality Assurance Project Plan (QAPP). Elements of the Water Quality Monitoring Plan include:

- name and contact information of landowner
- names and contact information of technical service provider
- description of monitoring stations with station ID assigned by NRCS
- roles and responsibilities of all parties
- purpose of monitoring, i.e., what practices will be monitored
- detailed site description of monitoring stations to include:
  - identify the station name
  - the Farm Service Agency (FSA) Farm, Tract and Field numbers
  - the drainage area of the station
  - the land use and if this is the control or treatment site
    - the location map should include a point indicating the GPS coordinates of the station location as well as a polygon outlining the drainage area for the station.



- Soils Description to include the soil properties for the drainage area of the monitoring stations to include, soil map Unit, acres, % of drainage area and hydrologic soil group

- Monitoring System Description including the equipment to be used on the site (pictures are helpful for this in terms the participant will understand

- Sampling to include information to help the participant understand how frequently someone will visit the site and what they will be doing when they are there

- Participant Requirements

- Reporting Requirements

- Monitoring Timeline.

Formal water quality monitoring associated with federal programs is almost always accompanied with a Quality Assurance Project Plan (QAPP). Among other items, a QAPP will fully describe the process of sample preservation, handling, and processing. The QAPP documents the results of a project's technical planning process, providing in one place a clear, concise, and complete plan for the environmental data operation and its quality objectives and identifying key project personnel. Sections required in the QAPP include:

Project Overview and Objectives
- Project Organization and Management
- Monitoring Approach
- Sample Procedures

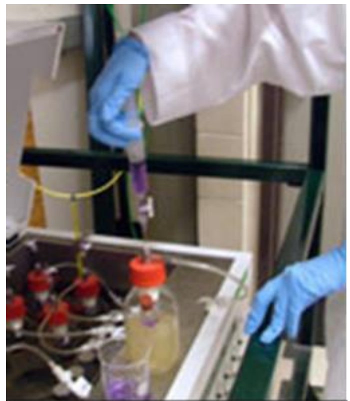


Photo Courtesy of EPA

Testing and Measurement Protocols

- Quality Assurance /Quality ControlA/QC)
- Data Handling Procedures
- Assessment and Oversight.

Conservation Activity 202 (Appendix 2) addresses the requirements of installing monitoring equipment and a schedule of estimated costs different installation scenarios.

Basic Principles of EOFM Monitoring

Financial assistance is available to EQIP-eligible farmers from NRCS to conduct routine EOFM to quantify nutrient and sediment loss, determine effectiveness of conservation practices and to provide performance indicators of the interaction of agricultural management practices and field hydrology.

However, most producers are not able to conduct their own EOFM and rely on technical service providers (TSP's) to implement CA's 201 and 202. TSP's can include environmental, hydrological, and agricultural consulting firms, individual crop consultants, private contractors', university researchers and extension specialists as well as certified nutrient management planners. EOFM will become increasingly important to gain knowledge about the relationship between agricultural management and water quality and to promote voluntary approaches to nonpoint source pollution which is difficult to regulate.

Defining Purpose and Shared Goals

EOFM monitoring is much more than collecting water samples. It is also about building relationships built on trust and respect with both NRCS personnel and the participating producer. As a technical service provider, you must keep in mind that you are conducting work on privately owned

land and thus need to communicate effectively with the producer as to respect their property, understand the constraints however small they may be such as not rutting up turn rows with vehicles or closing gates behind you. You must understand that you are providing a service to the producer, but under the constraints of EQIP contracts and that your services will be aimed at what the farmer wants to monitor in terms of field and conservation practices.

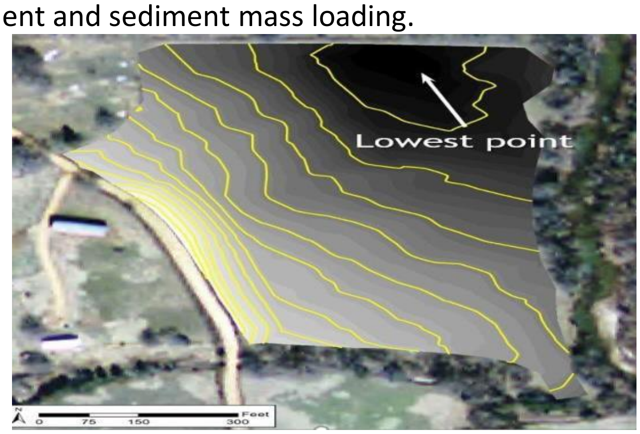
It is highly recommended that you as a service provider schedule a meeting with the NRCS official and the producer to:

- Determine the purpose of monitoring such as what practices will be installed
- Understand the EQIP Contract and its constraints such as when payments are made
- Ensure that common informal field names correspond to the field name in the EQIP contract such as develop map of the fields included in the contract
- Determine an operating procedure to address the producer concerns about accessing their property
- Describe the monitoring stations that will be placed on property and how often and when you may be accessing them.

All this information and all the elements of the Water Quality Monitoring Plan should be discussed and agreed upon. The Water Quality Monitoring Plan must be submitted to NRCS for approval, but it is highly recommended that this document also be reviewed and approved by the agricultural producer a mechanism towards more effective communication. Many TSP's may feel this is unnecessary and time- consuming, but it absolutely is essential to avoid issues and misunderstandings that can delay fulfilling the EQIP contract or even have the contract ruled as null and void.

Finding appropriate Location for EOFM

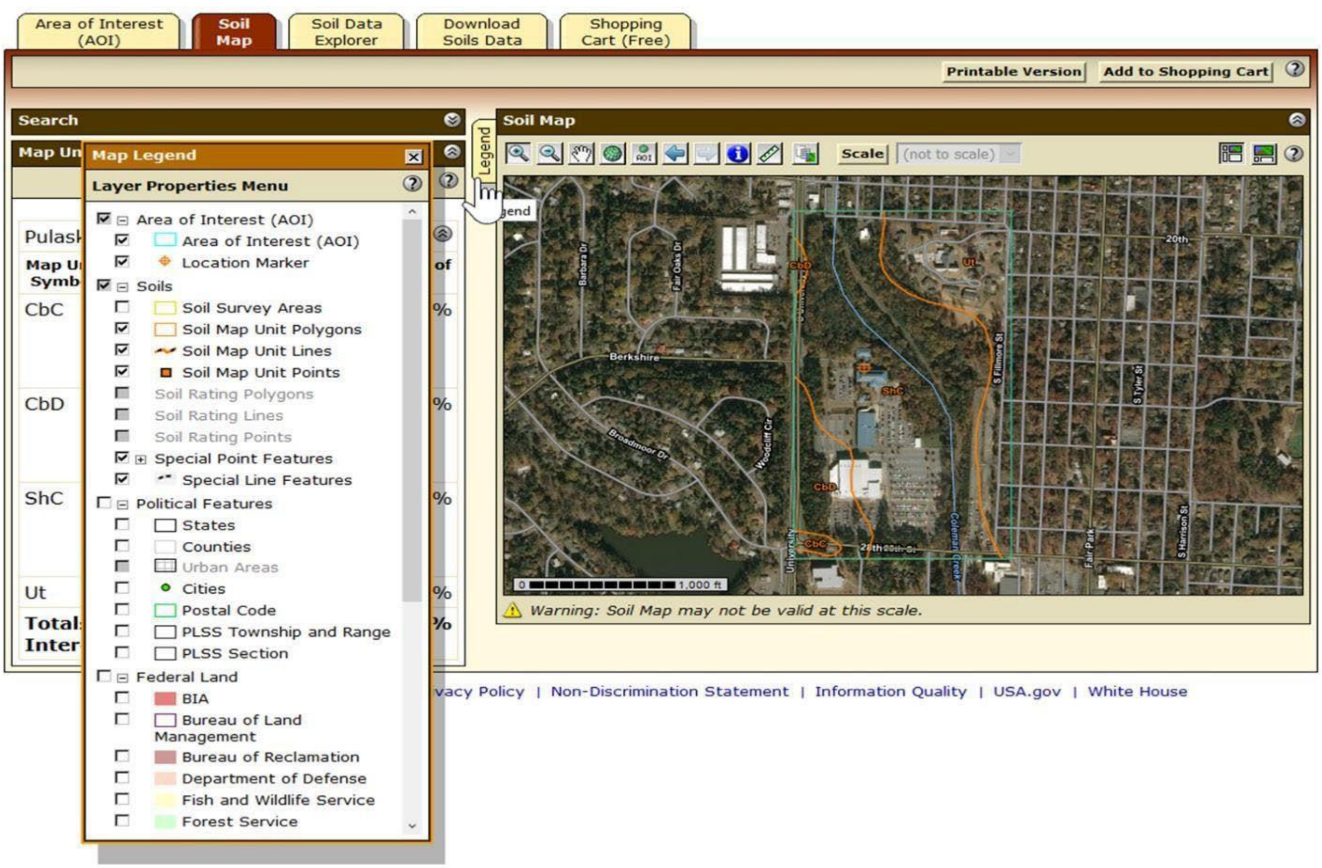
Before installing a EOFM monitoring station on farm, locating the proper placement of a station is critical to future performance. EOFM stations cannot be placed just anywhere without consideration of the local hydrology. Two essential requirements for EOFM include: 1) hydrological isolation of the field be considered so that the runoff water collected originates only from that field and that there is not run on from other fields, roads and hydrological features such as intermittent streams or drainage ditches and 2) that runoff water exits at one central location with adequate evacuation beyond the station from the field so that all runoff water volume is measured to be able to determine nutrient and sediment mass loading.



One of the most critical and often most overlooked consideration of determining a EOFM station is ensuring that there is adequate evacuation of water that has flowed through the flume so that a hydraulic jump, a sudden change in drop of water elevation, is present. Pooling or ponding of water after exiting the flow structure may eliminate the hydraulic jump and create submergence that can affect the accuracy of runoff volume measurements by lowering discharge velocity or even causing back flow through the flume in the wrong direction. Submergence is more common where EOFM is being conducted on topography with small slopes that create smaller hydraulic jump exiting the flow structure.

A producer can provide valuable input to ensure that these two criteria are met as they have observed the results of the hydrological conditions over time. But producer observations need to be verified with reconnaissance data by the provider in the following ways:

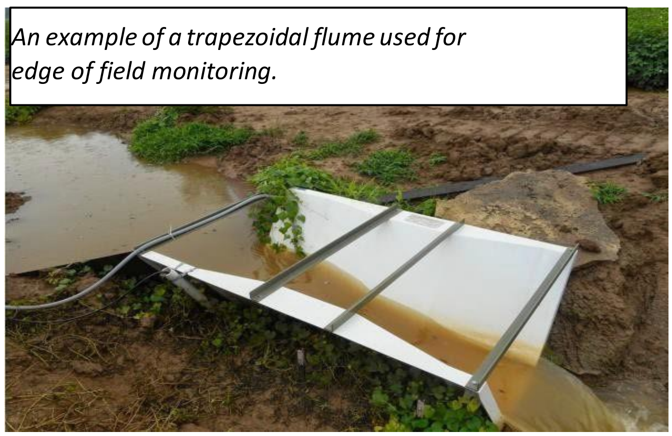
- Spend some time on location during storm events to observe any obvious breaches in criteria
- Study topographical maps or appropriate-scaled digital elevation models or utilize LIDARdata if available
- Conduct field level elevation survey if need to refine topology estimates especially inlow slope landscape positions (0-1 % slope) that can be associated with row crops
- Use Web Soil Survey to download soils information



Many times, if criteria are not fully met, alteration of the local topology and hydrology can be made with earthen berms or small earthen dams. However, hydrological alteration in this manner can be expensive especially if it requires heavy equipment to facilitate. Before counting on these alterations, get it approved by the producer and consider what it may mean in terms of backing water onto adjacent fields or limiting the drainage rate from the field.

Defining Drainage Area and Estimating Runoff Volume

An important component of edge-of-field monitoring is to measure runoff or discharge volume through a geometrically defined outlet or flow structure such as an unpressurized drainage pipe, weir, or flume. Even a discharge ditch or intermittent flow pathway can be used but defining the flow geometry can be much more difficult and may require tedious incremental geometric measurements to determine variable cross sectional flow area with varying stage heights. The other difficulty with intermittent flow pathways is the lack of calibration between stage height and flow.



An example of a trapezoidal flume used for edge of field monitoring.

For the nature of intermittent runoff from agricultural fields, it is highly recommended that flow structures such as factory calibrated flumes or existing unpressurized flow drainage pipes be utilized. If existing drainage pipes are used, then parameters needed for Manning's equation for open channel flow such as slope of the pipe, pipe diameter and friction coefficient should be determined so that flow estimated by determining flow velocity and stage height can be verified and calibrated against Manning's equation.

Weirs can be used but require ponded water on the entry side such as monitoring runoff from a flooded rice field or for in stream measurements. Utilizing weirs for EOFM have very limited application for most agricultural fields except for crops such as rice that require shallow flooding.

As mentioned earlier, it's highly recommended to use a flume as a water flow structure to measure runoff volume. There are many kinds and sizes of flumes that can be utilized in EOFM, but it is critical to estimate runoff volume from a defined drainage area to properly size and select the flume that is right for that monitoring station.

Because it is critical to properly size a flume to be able to measure runoff volume in a reasonable time without ponding water before entering a flume, it is important to define the drainage area, flow routing and the estimated runoff volume before installing a station. Two computer tools are available to help TSP's with these tasks are WinTR-55 Small Watershed Hydrology tool which can be downloaded for free from USDA- NRCS: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1042901 for calculating storm runoff volume, peak rate of discharge, and storage volumes for storm water management structures. The other tool is the propriety GIS software, ARCGIS and its component ARC HYDRO data model, toolset, and workflows developed over the years to support specific GIS implementations in water resources. Instructional guides for WinTR-55 and for ARC HYDO (Merwade, 2012) can be found in Appendices 3 and 4, respectively. Often these tools are used in tandem as part of the pre-installation planning.

Components of EOFM monitoring station

EOFM monitoring as described in CA 201 is for the purpose of determining nutrients and sediment loss from a known geographical area such as field and the associated volume of runoff for a given storm or irrigation event. To determine nutrient and sediment loss (estimated from Total Suspended Solids),water samples must be collected and analyzed in the lab. Sample results are normally report in concentration units of parts per million and more specifically, mg L^{-1}. The issue with strictly measuring concentration oof runoff parameters is that its highly dependent on runoff volume which is often highly variable within an event and between events. Runoff volume is needed to determine mass loss or loading using the simple relationship:

$$\textbf{Concentration = Mass / Volume}$$

or the mass of a constituent of runoff equals its concentration * runoff volume. For example: the mass of total Nitrogen loss in runoff is defined as

$$\textbf{Mass}_{\textbf{Total N}} \textbf{ = Concentration}_{\textbf{Total N}} \textbf{ * runoff volume}$$

where mass is in units of milligrams, concentration is in units of milligrams per liter and runoff volume is in units of liters.

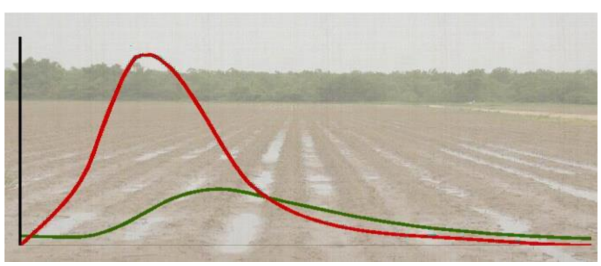
Water quality nutrient parameters measured in streams are often reported in concentration only because its expensive and difficult to gauge flow volume at a given cross-sectional location perpendicular to flow direction. But again, stream flow can fluctuate dramatically with hydrological response to storm events and cross-sectional area of flow can vary greatly along different point in the stream.

By measuring runoff flow or discharge with EOFM, one can estimate mass loading from a given area which is important to relating losses back to nutrient applications from manure or fertilizer allowing one to gain insight more readily on the performance of a given practice. However, concentration data can be sued for simple comparison to water quality data in a receiving body such as a stream or lake where only concentration data is available. However, keep in mind that concentration may be derived from drastically different volumes water such as large lake as compared to the relatively small runoff volume measured at a EOFM location.

Therefore, the two major components of EOFM are a flow structure such as a flume to estimate discharge from a given location and a sampling mechanism to collect water samples during a runoff from a storm event.

Due to the nature of stormwater-generated runoff, sampling is best performed with an automated sampler that can be programmed to collect subsamples when runoff initiates until it ceases, or the maximum composite sample volume is collected. The runoff or discharge volume through a flow structure such as a flume plotted over time is known as a hydrograph.

The part of the hydrograph where runoff is increasing is known as the rising limb and the part of the hydrograph where runoff begins decreasing is known as the falling limb. The portion of the hydrograph where the rising limb and falling limb intersects is known as the peak. Because the concentration of nutrients cand greatly fluctuate at different parts of the hydrograph, the sampler needs to be programmed to collect subsamples for all parts of the hydrograph that are composited into one water sample for analysis. Essentially, you are determining the average concentration for the whole runoff event by physically averaging rather than collecting multiple, individual samples and mathematically determining the mean.



Composite sampling is important because it reduces the cost associated with water analysis as it greatly reduces the number of samples. However, it is important to program your sampler properly to get a good distribution of subsamples relative to the shape of the hydrograph. Since the hydrograph is a plot of discharge volume versus time, you can either program the sampler to collect samples at equal time intervals or at equal discharge intervals. Because runoff is storm-driven and intermittent, collecting samples at equal discharge intervals is the most probable way of collecting a uniform set of subsamples. This is known as flow pacing. There is not mathematical way of determining the optimum flow pacing as every runoff event and hydrograph may be different. Determining the flow pacing is an iterative trial and error process until he you find a pacing that provides uniform subsampling with respect to the hydrograph. Time pacing is best used when the discharge is constant and uniform such as a discharge stream from a water treatment plant.

Commercial options of programable, automated samplers are limited. However, research is being conducted to develop comparable but cheaper sampling systems. Teledyne Isco's 6712 portable automated sampler is the most popular. Regardless of the manufacturer, an automated sampler consists of a programmable computer or data logger that integrates runoff discharge sensors that are needed to determine the instantaneous discharge volume, a sampling tube connected to a pumping system and a composite collection device. And a rain gauge.

Several different discharge sensors are available. For the Isco 6712, stage height, or height of water above a fixed elevation can be determine with the 720 pressure transducer and flow module. These work best in conjunction with flumes where discharge volume has been pre-calibrated to stage height at a given point in the flume determined pre- installation. For other flow structures that have not been pre-calibrated or have a non-uniform cross-sectional area of flow, the 750 area-velocity meter is available as a plug in and play to the ISCO 6712. The area velocity center measures the discharge velocity at a given point using doppler radar technology as well as stage height to determine the discharge flow rate by:

The accuracy of the velocity measurements is highly dependent on the return signal to the radar and the signal strength can greatly fluctuate depending on conditions. Keeping the nose of the sensor clear of dust and other particles that interfere with the obtaining the return signal is important.

The ISCO sampler is fully waterproof, but housing is highly recommended to project the electrical connections to the power source, connections to sensors and to telemetry modems.

Another peripheral to the sampler the rain gauge

The sampler can be programmed to collect and store flow volume data

- Data Analysis and storage
    - Water Quality
    - Hydrographs
    - Load determination

Obstacles and Challenges for TSP's in EQIP Funded EFOM Pre-planning Time and Effort

Perhaps a big misconception in implementing CA 201 is the amount of planning, site visits, meetings, data collection and field reconnaissance that may be required before CA 202 can initiate. Finding the right field and situation for EOFM is an important consideration before any monitoring station should be established, however, there is no reason to search incessantly to find the perfect place to monitor as such as place doesn't exist. Every single monitoring location may be inherently different with its own set of challenges in establishing a proper monitoring station. The TSP needs to be aware and inform the cooperating producer that it can take considerable time in planning and several site visits before a station can be established and for monitoring to commence.

This preplanning needs to be conducted in conjunction with the landowner as the TSP may need the insight from the landowner who may be able to provide valuable insight on flow patterns and field exit locations from years on continuous visible observations. However, it this insight may be streamline the process, if there is doubt, then it's still a good idea to take their comments and insight under advisement but continue to evaluate until visual observations can be corroborated with other data.

Understanding ordering time requirements of specialized monitoring equipment and flow structures

For TSP's that are new to edge of field monitoring, it may be shocking how long it can take to receive a flume after ordering it. Often, companies that make flumes and other flow structures may not keep flumes in stock but manufacture them on demand, which often requires a drafting of construction blueprints with dimensions and measurements that will have to be confirmed by the buyer. It may take weeks or months to get an order filled and shipped.

Understanding EQIP Funding Mechanisms for CA 201 and 202 – How does the TSP get paid?

Once a site is determined as a feasible location and agreed upon by the TSP, landowner and NRCS Official, then CA 202, installing the monitoring station can initiate. CA 201 and 202 are

implemented and funded via a landowner successfully applying for and obtaining a EQIP contract for a given tract of land (Defined by FSA). Often these EQIP contracts (Appendix 5) will contain several line items for the tract of land for each individual conservation practice and for CA 201 and 202. EQIP contracts for CA 201 and CA 202 are for five years of monitoring. Often, the landowner seeks financial assistance to implement conservation practices that will be monitored with EOFM. The NRCS cannot legally share a EQIP contract with a TSP without the expressed written permission of the contracted landowner. To accurately invoice for EOFM monitoring services, the TSP will need to request that the landowner allow NRCS to share the contract or ask the landowner to share the EQIP contract number and the individual contract line item for CA 201 and 202.

Financial assistance payments for practices and activities under the auspices of an EQIP contract are not issued until the practice is implemented to the satisfaction of the residing NRCS official. This is also true for CA 201 and 202 which implies that TSPs will have to purchase the monitoring equipment and supplies upfront and install. Once installed, the residing NRCS official will document the installation and provide official NRCS station identification and record equipment serial numbers on an NRCS form.

Once the form is signed, then the TSP can invoice the landowner who can request payment from NRCS for the particular EQIP contract and individual line-item number for CA 202.

The NRCS provides two mechanisms for landowners to pay TSP's. The first is simply that NRCS pays the landowner directly, who in turn, pays the TSP who has submitted an invoice to the landowner. It is important that the landowner receive and retain this invoice along with the copy of the cashed check for tax purposes. Financial assistance via EQIP is considered as income for the landowner and is taxable. However, expenses incurred in installing or implementing practices such as paying TSP or private contractor are tax deductible. In this manner, the landowner will not have to pay taxes for implementing CA 201 and 202.

The second mechanism often used by NRCS at the request of a landowner who will employ a TSP is for NRCS to make a direct payment on behalf of the landowner to the TSP, which is authorized via a signed Assignment of Payment Form (Appendix 6). This form also protects the landowner from paying taxes on the financial assistance.

Obviously, the one drawback for the TSP in being paid for services rendered via an EQIP contract is that the TSP is not paid until CA 202 installation is completed and certified by NRCS and the payment option is decided. Payment is not immediate after installation as NRCS has regulations that must be followed in dispersing payments, and it can take time for NRCS to get all their internal approvals in order.

Once CA 202 is completed and certified, then monitoring can initiate. Payments for CA 201 made to the landowner on an annual basis and will not be made until the landowner provides NRCS with an annual monitoring report. Since the TSP is conducting CA 201, the TSP usually prepares the monitoring report for the landowner, who in turn, submits to NRCS for payment. The annual CA 201 report triggers the EQIP payment using one of the two mechanisms described above.

Payments for CA 202 is one lump sum payment once NRCS has certified the installation while an annual lump sum payment for CA 201 is made after monitoring report has been submitted and approved. Keep in mind that there will be other expenses that need to be budgeted from these lump sum payments such as travel to site, maintenance, replacement parts for and repair of samplers and water sample analysis. Other costs include housing for sampler, 12-volt marine batteries to use with solar power, monthly telecommunication bill for telemetry and water control device such as a flume.

It is highly recommended that the TSP develop a five-year projected budget for CA 201 and 202 with enough detail including estimated travel costs and sample analysis to ensure that the EQIP contract covers costs. The total contract value for CA 201 and 202 can be provided by the presiding NRCS official.

Need for Planning Meetings Between NRCS, Landowner and TSP to Review EQIP Contracts

While NRCS programs such as EQIP and CSP that provide financial assistance are strictly voluntary, EQIP contracts are legally binding, and as with any type of legally binding contract, they do contain requirements for fulfilment of contract from both parties and financial penalties for breach of contract by the landowner.

The EQIP contract is a legally binding contract between USDA-NRCS and the participating landowner. As a TSP, you are being contracted by the landowner to help them fulfil their contractual obligations. Therefore, to avoid misunderstandings between the TSP and landowner and NRCS that might result in breach of contract, it is highly recommended that the TSP request a meeting with the participating landowner and the presiding NRCS officer to review expectations and requirements associated with CA 201 and 202 funded by an EQIP contract.

As mentioned above, the TSP will need to prompt the Landowner to provide the TSP access to view and obtain a copy of the EQIP contract via expressed written consent to NRCS. The TSP needs to carefully review the contract before the initial meeting so that everyone involved is on the same page. This meeting or series of meetings are extremely important and will help the TSP and landowner ensure that EQIP contract is fulfilled for the duration of contract. Some topics that need to be covered:

Ensure that all parties have the same, shared, or cross-referenced field name as field names can vary between the farmer, the FSA field designation found in the official tract description provided by FSA. Create a map that clearly identifies the field name and the corresponding EOFM monitoring station or cross reference. Be sure to check acreage against FSA records and actual measured acreage to avoid discrepancies.

- Ensure that all parties understand the exact language in the contract that could be specific to crop rotations, implemented conservation practices or other items.

- Define who owns the data on how that data can be used or revealed to the public.

- Clearly define how weather and other uncontrollable situations that would cause monitoring to be discontinued temporarily should be addressed. For example, EOFM stations have been damaged by flooding, tornadoes, hailstorms, and wildlife that can cause delays in monitoring sometimes up to six months.

- Clearly define how uncontrollable factors may include necessary actions by the landowner to repair turn rows, drainage pipes, irrigation wells or weather that prohibits the landowner from planting or harvesting or anything that would compromise the integrity of the practice being monitored.

- Re-iterate that EQIP contracts are for 5 years of monitoring and inferences concluded after a short term of monitoring, for example: one growing season, that might prompt change or adaptive management may create a breach of contract unless prior approval granted by NRCS. For example, producers may want to switch crops as commodity prices fluctuate yet the new desired crop may not be specified in the EQIP contract, or the producer suffered yield loss as result of the implemented conservation practice and no longer wants to continue practice.

- Ask the landowner to define “ground rules” for accessing their property such as driving on turnrows and in fields, pre notification or schedule of farm visits, placement of monitoring station with respect to turnrow and farm equipment clearance, vegetation maintenance around sampling station such as chemical or mechanical, opening and closing gates, fencing of monitoring equipment to avoid contact with livestock, etc. Use common courtesy as you are on someone else's property and respect their rules.

Understanding Constraints Placed on Producers

While working with landowners as a TSP can be a rewarding experience, your relationship and experience in working with farmers can be enhanced by keeping in mind that famers face many constraints especially on their time and finances. Farmers are usually more than willing to accommodate you as a TSP and even lend a helping hand with their expertise and farm equipment, but they are extremely busy and there are real costs associated with the use of farm equipment. If you think you will need their assistance, plan, and ask well in advance of when the assistance is needed especially in planting and harvest season. Be prepared to offer reimbursement in fuel costs if they use their farm equipment or in labor costs if they let an employee assist with you. Often, they will not accept it, but it is pleasing to them to know that the TSP offered.

Sometimes producers may make decisions for a variety of reason that may create conflict with what you as a TSP has set as monitoring goals or data collection goals, but if it doesn't violate the EQIP contract, this is their right as the landowner. While you may lose some information that you were hoping to gather, you must keep in mind that you have been hired to accomplish their goals, not yours.

Most of all, treat and interact with the landowner as you would want them to if you reversed roles. Following this simple advice is the key to farmer – TSP relationships.

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Appendix 3: Wetland Summary

ADDRESSING SUBSURFACE NUTRIENT RUNOFF THROUGH THE USE OF FLOATING WETLANDS

This research project focuses on using floating wetland plants and filter beds to reduce nutrient input from tile drainage before entering a tributary to Lake Erie and to increase farmer's awareness and potential adoption of subsurface nutrient treatment systems. Another part of the research is to determine how small these wetlands to reduce the amount of land needed and still have them be effective over time. Our site is located in the River Raisin Watershed in southeast Michigan on the Bakerlads farm field in Clayton, MI. The tile drain runoff enters the south branch of the River Raisin. The treatment area overall is a little over 16 acres in a field that grows alfalfa.

Two wetlands were dug, lined with a synthetic black liner and filled with water from the drainage tile (Figure 1). Three monitoring buildings containing a water level sensor, a weir, and two staff gages with a video camera allow us to determine stage height and subsequent discharge. A pump draws water samples into a sampler for every 1000 cfs that flows through the system, which we then collect for our nutrient analysis. Each building is equipped with a solar panel to help power the station.

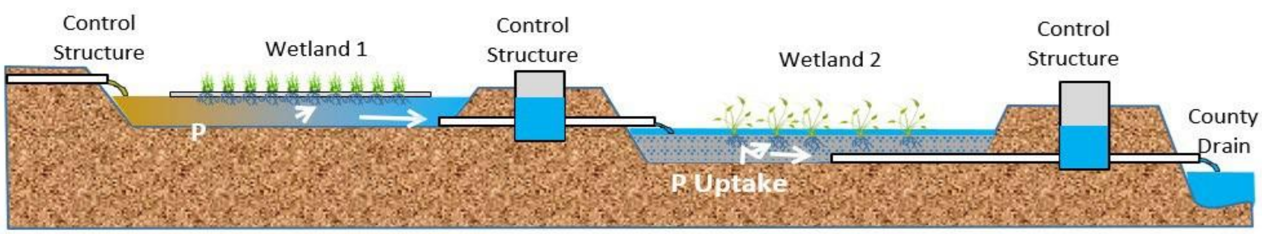


Figure 1. Diagram of floating wetland

In wetland 1, we are testing various plants species to determine which are best at removing phosphorus and increasing their biomass. The plants tested in year 1 were *Scirpus atrovirens* – green Bulrush; *Carex vulpinoidea* - Fox Sedge; *Ranunculus hispidus* – Hispid or Swamp Buttercup; and *Juncus effusus* - Common/Soft Rush. In year two we removed the Ranunculus due to poor growth and added *Acoris calamus* – Sweetflag. Overall, there are now 10 mats in the wetlands with up to 80 plants per mat.

We let the plants grow on floating mats and periodically harvest 4-6 of each species for analysis of weight and % nutrients (total P and N) in the plant. Control plants are used to determine an initial biomass and nutrient content. Figure 2 shows biomass for 2021 for both roots and shoots after subtraction of the initial estimated weight. The initial average dry weight was derived from control plants that were similar in size to those planted.

We also looked at total P concentrations in both the roots and the shoots of the plants at the end of the season on a g/g basis and on average total biomass of the plant (Figure 3a and 3b). P concentration on a g/g basis was similar in all plants with roots having slightly more P than shoots. On a biomass basis, the Scirpus species was 8 to 22 times the phosphorus concentration in the other plants' roots and shoots, respectively.

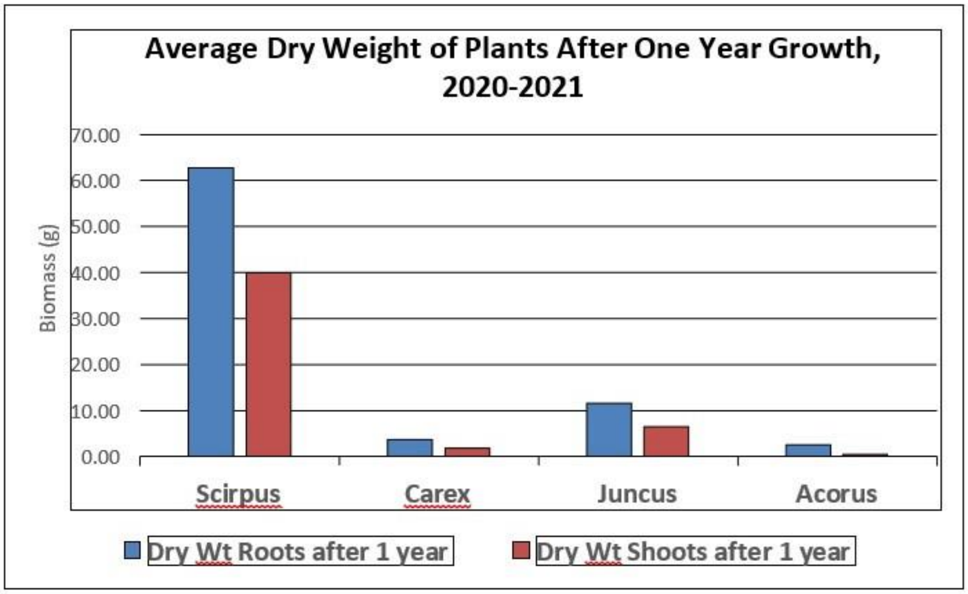
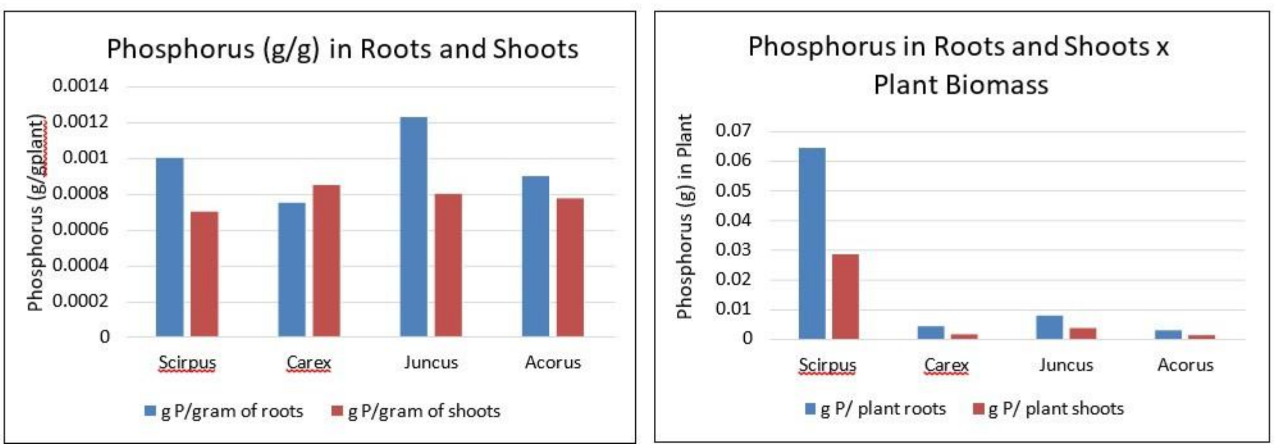


Figure 2. Biomass of four hydroponically grown plants after one season



Figures 3a and 3b. Phosphorus Concentration in four plants growing hydroponically.

In addition, we have been monitoring flow and nutrient concentrations from the drain tile (TT1) as it moves through the first wetland and empties into wetland two (TT2). In 2020 we saw annual loading reductions of 54, 41.5, and 63 percent for dissolved reactive phosphorus, nitrate, and total phosphorus, respectively (*figure 4.*)

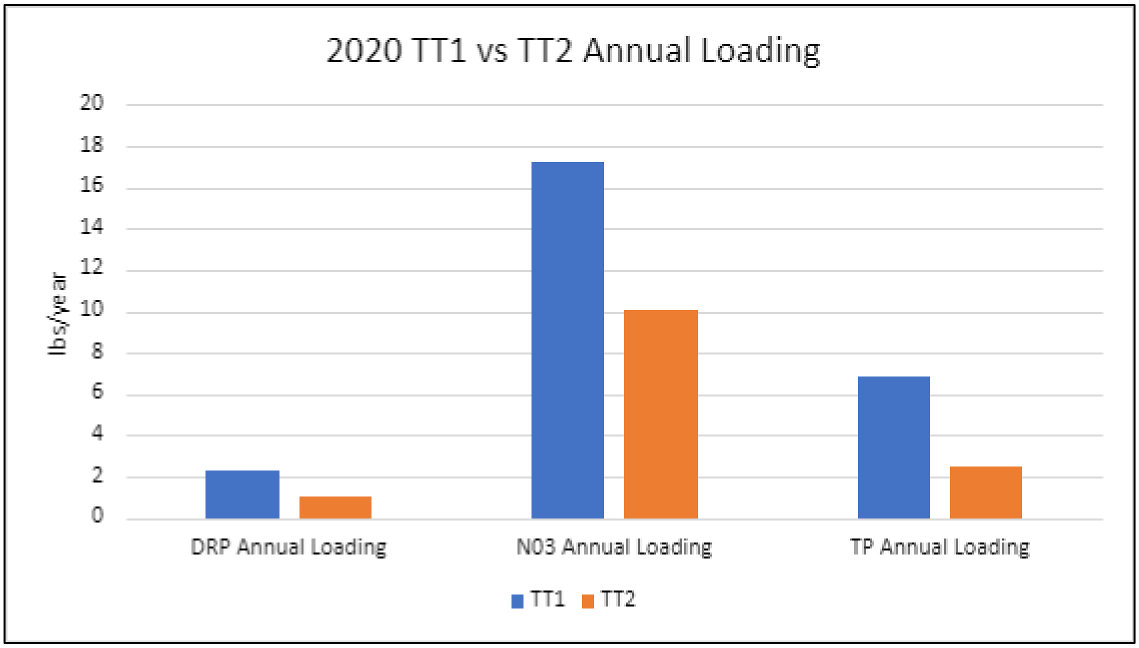


Figure 4. 2020 TT1 vs TT2 annual loading for DRP, nitrate, and TP from January 9 - December 29, 2020.

We were unable to monitor from TT3 in the year 2020 due to the pipe between ponds two and three becoming clogged. Monitoring of flow and nutrients from TT3 became accessible in August of 2021.

We have also been using this data to look specifically at reductions that occur during large rain events. Rain events are identified using the program Grafana where we can view changes in discharge as water volume through the drainage system increases (*Figure 5*).

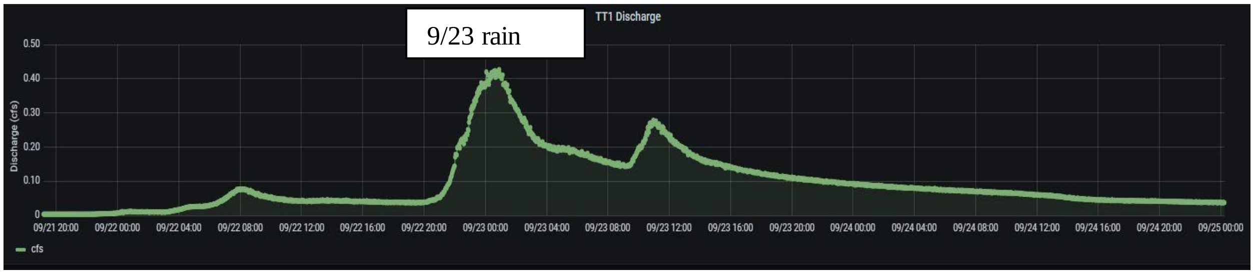


Figure 5. Image of TT1 discharge values during a rain event that occurred on 9/23/21 using Grafana.

Since water samples are only collected once a week, we cannot look at how nutrient loading fluctuated on that specific day. Instead, we look at how nutrient loading fluctuated during that week – with the first day starting when the last set of samples were collected. It was observed that during the week of this rain event, DRP, nitrate, and TP loading was reduced by 60, 98, and 58 percent, respectively, between TT1 to TT3 (*Figure 6*).

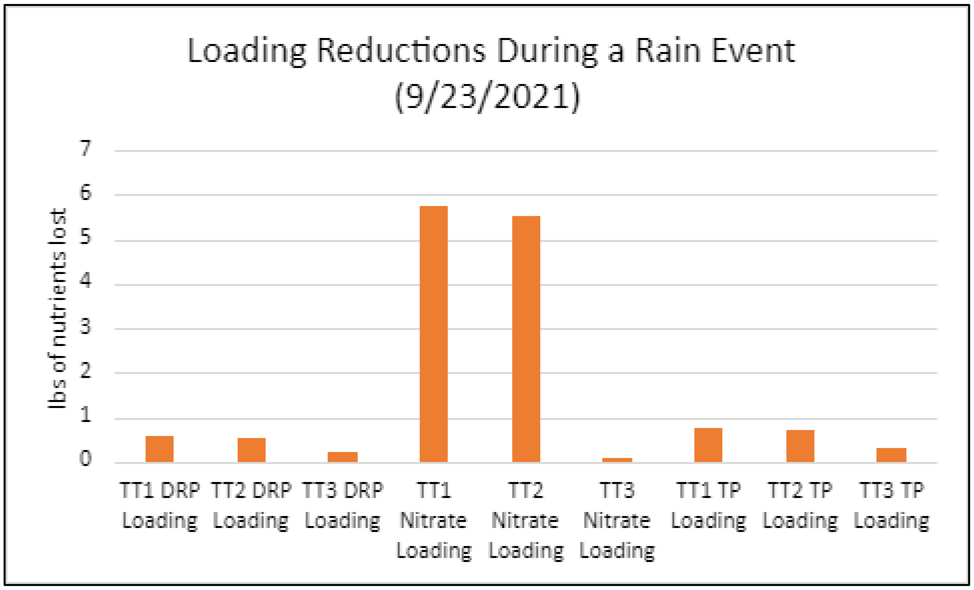


Figure 6. DRP, nitrate and TP loading reductions between cells TT1, TT2, and TT3 during a rain event.

This data can also be used to identify periods of high nutrient loss throughout the year, and the reductions associated with those as water moves through the floating wetland system (*Figure 7*).

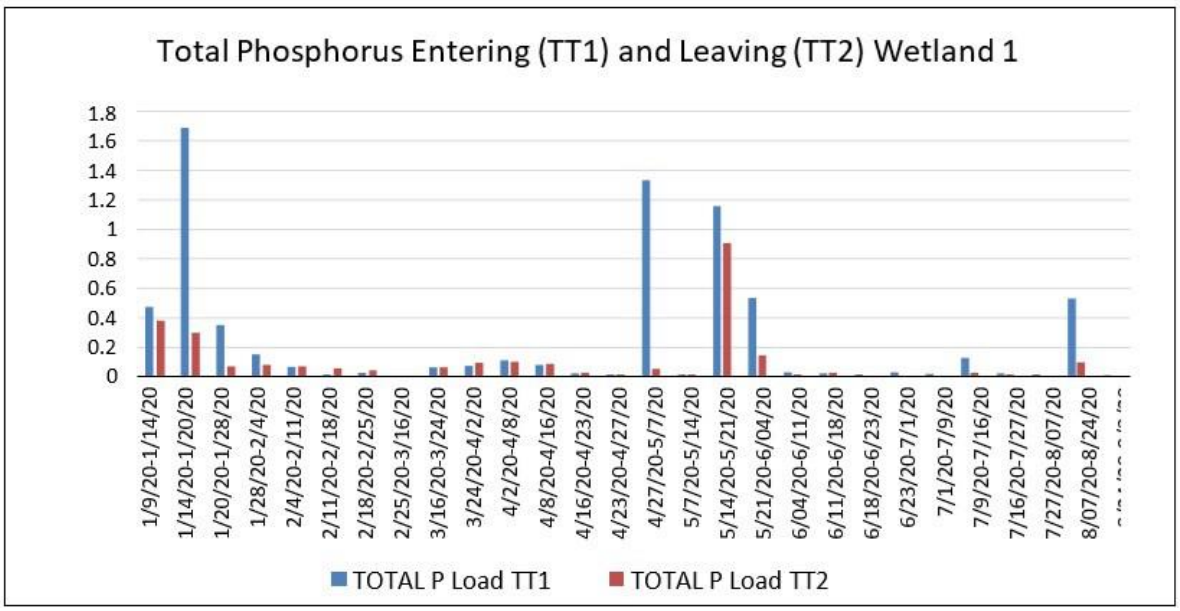
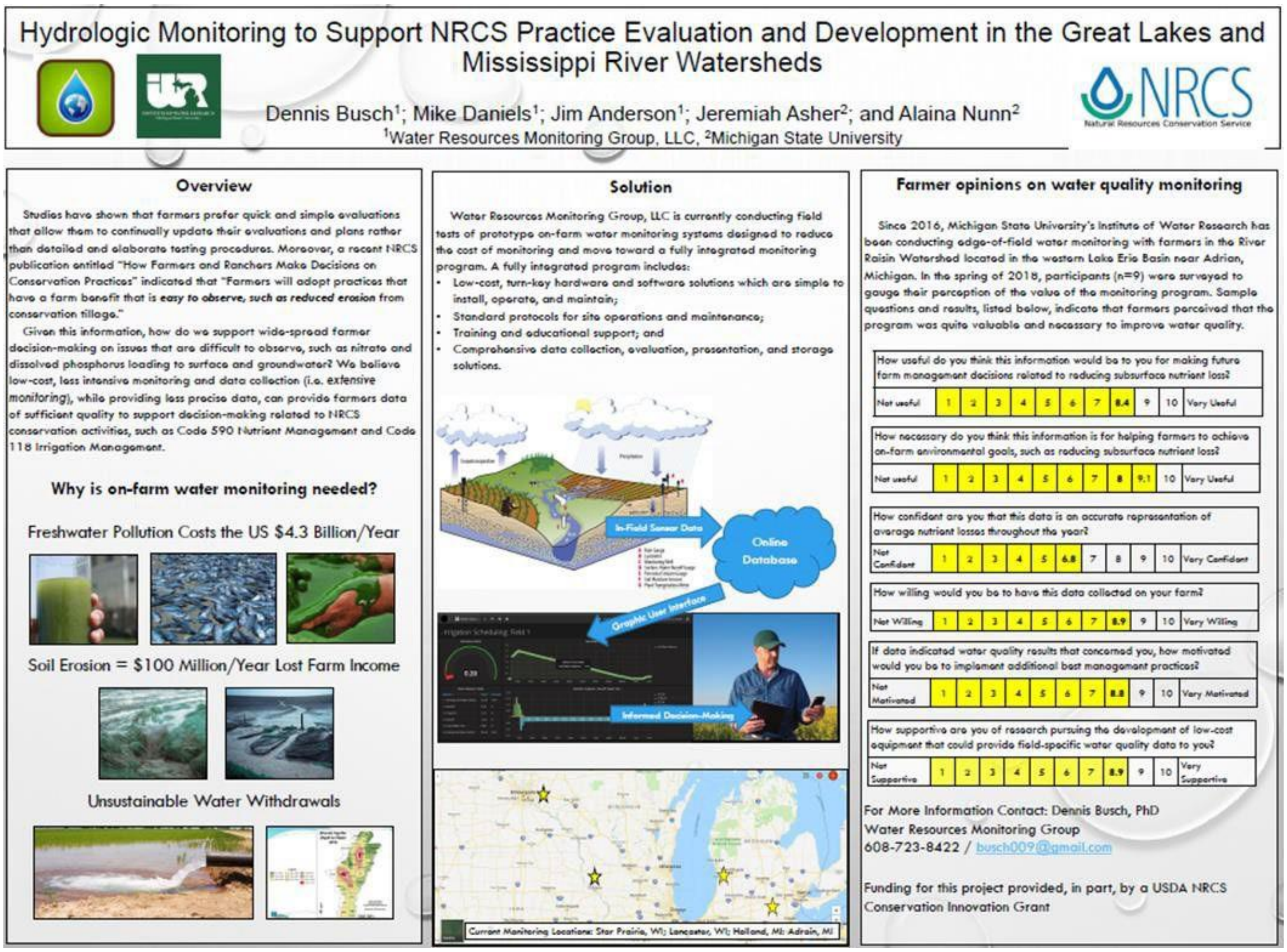


Figure 7. Total phosphorus entering (TT1) and leaving (TT2) wetland 1.

To slow down nutrient saturation for the wetland, at the end of the season, we harvested the tops of the plants. After they are dried and weighed, we plan to recycle the nutrients by spreading them on the farm fields.

As we move forward, we hope to get a better understanding of how effective these plants may be at removing P and N from the wetland, and eventually offer another practice for farmers to consider for reducing nutrient runoff from tile drains that enter receiving streams.

Appendix 4. Posters from Presentations in 2019 and 2020



Hydrologic Monitoring to Support NRCS Practice Evaluation and Development in the Great Lakes and Mississippi River Watersheds

Dennis Busch[1]; Mike Daniels[1]; Jim Anderson[1]; Jeremiah Asher[2]; and Alaina Nunn[2]
[1]Water Resources Monitoring Group, LLC, [2]Michigan State University

Overview

Studies have shown that farmers prefer quick and simple evaluations that allow them to continually update their evaluations and plans rather than detailed and elaborate testing procedures. Moreover, a recent NRCS publication entitled "How Farmers and Ranchers Make Decisions on Conservation Practices" indicated that "Farmers will adopt practices that have a farm benefit that is ***easy to observe, such as reduced erosion*** from conservation tillage."

Given this information, how do we support wide-spread farmer decision-making on issues that are difficult to observe, such as nitrate and dissolved phosphorus loading to surface and groundwater? We believe low-cost, less intensive monitoring and data collection (i.e. *extensive monitoring*), while providing less precise data, can provide farmers data of sufficient quality to support decision-making related to NRCS conservation activities, such as Code 590 Nutrient Management and Code 118 Irrigation Management.

Why is on-farm water monitoring needed?

Freshwater Pollution Costs the US $4.3 Billion/Year

Soil Erosion = $100 Million/Year Lost Farm Income

Unsustainable Water Withdrawals

Solution

Water Resources Monitoring Group, LLC is currently conducting field tests of prototype on-farm water monitoring systems designed to reduce the cost of monitoring and move toward a fully integrated monitoring program. A fully integrated program includes:

- Low-cost, turn-key hardware and software solutions which are simple to install, operate, and maintain;
- Standard protocols for site operations and maintenance;
- Training and educational support; and
- Comprehensive data collection, evaluation, presentation, and storage solutions.

In-Field Sensor Data
Online Database
Graphic User Interface
Informed Decision-Making

Current Monitoring Locations: Star Prairie, WI; Lancaster, WI; Holland, MI; Adrain, MI

Farmer opinions on water quality monitoring

Since 2016, Michigan State University's Institute of Water Research has been conducting edge-of-field water monitoring with farmers in the River Raisin Watershed located in the western Lake Erie Basin near Adrian, Michigan. In the spring of 2018, participants (n=9) were surveyed to gauge their perception of the value of the monitoring program. Sample questions and results, listed below, indicate that farmers perceived that the program was quite valuable and necessary to improve water quality.

How useful do you think this information would be to you for making future farm management decisions related to reducing subsurface nutrient loss?

Not useful	1	2	3	4	5	6	7	8.4	9	10	Very Useful

How necessary do you think this information is for helping farmers to achieve on-farm environmental goals, such as reducing subsurface nutrient loss?

Not useful	1	2	3	4	5	6	7	8	9.1	10	Very Useful

How confident are you that this data is an accurate representation of average nutrient losses throughout the year?

Not Confident	1	2	3	4	5	6.8	7	8	9	10	Very Confident

How willing would you be to have this data collected on your farm?

Not Willing	1	2	3	4	5	6	7	8.9	9	10	Very Willing

If data indicated water quality results that concerned you, how motivated would you be to implement additional best management practices?

Not Motivated	1	2	3	4	5	6	7	8.8	9	10	Very Motivated

How supportive are you of research pursuing the development of low-cost equipment that could provide field-specific water quality data to you?

Not Supportive	1	2	3	4	5	6	7	8.9	9	10	Very Supportive

For More Information Contact: Dennis Busch, PhD
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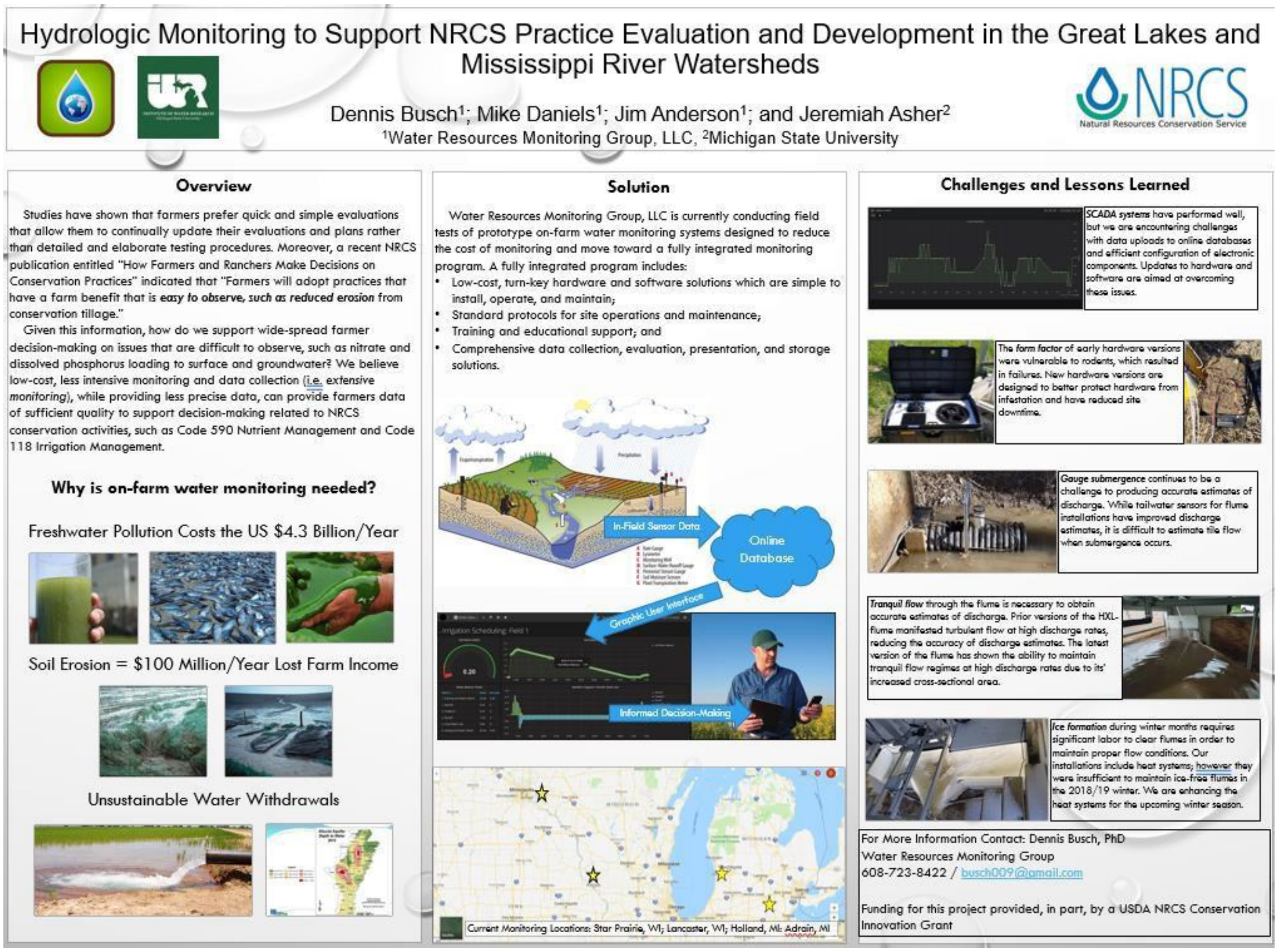
Funding for this project provided, in part, by a USDA NRCS Conservation Innovation Grant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Current Monitoring Locations: Star Prairie, WI; Lancaster, WI; Holland, MI; Adrain, MI
Challenges and Lessons Learned
SCADA systems have performed well, but we are encountering challenges with data uploads to online databases and efficient configuration of electronic components. Updates to hardware and software are aimed at overcoming these issues.
The form factor of early hardware versions were vulnerable to rodents, which resulted in failures. New hardware versions are designed to better protect hardware from infestation and have reduced site downtime.
Gauge submergence continues to be a challenge to producing accurate estimates of discharge. While tailwater sensors for flume installations have improved discharge estimates, it is difficult to estimate tile flow when submergence occurs.
Tranquil flow through the flume is necessary to obtain accurate estimates of discharge. Prior versions of the HXL-flume manifested turbulent flow at high discharge rates, reducing the accuracy of discharge estimates. The latest version of the flume has shown the ability to maintain tranquil flow regimes at high discharge rates due to its' increased cross-sectional area.
Ice formation during winter months requires significant labor to clear flumes in order to maintain proper flow conditions. Our installations include heat systems; however they were insufficient to maintain ice-free flumes in the 2018/19 winter. We are enhancing the heat systems for the upcoming winter season.
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