Title: P Index and Snowmelt Runoff Risk Assessment: Demonstration and Refinement

Principal Investigator: Dr. Anita M. Thompson

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Deliverables:

1) Assessment of the P Index loads by field for Six Mile Creek Watershed as dissolved P in snowmelt runoff, dissolved P in rainfall runoff, and sediment-bound P with baseline and improved management.
   *In Dane County LWRD (2016), MMSD (2016), and this report.*

2) A winter manure application risk assessment methodology for areas with frozen and snow-covered soils
   *Described in this report with average winter runoff volume modeling procedure outlined in Appendix D.*

3) Web and print-based winter manure runoff assessment educational publication
   *Described in this report, Appendix E.*

4) Fact sheet for identifying risk for winter runoff.
   *In this report, Appendix E*

5) Fact sheet on low cost field runoff monitoring.
   *In this report, Appendix F*

6) Presentation at NRCS CIG Showcase or other similar event.
   *Abstract submitted for presentation at 2017 Soil and Water Conservation Society Meeting*

7) Semi-annual reports.
   *Submitted separately*

8) Supplemental narratives to explain and support payment requests.
   *Submitted separately*

9) Final report.
   *This report.*

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# Executive Summary

The "P Index and Snowmelt Runoff Risk Assessment: Demonstration and Refinement" project was undertaken to evaluate and, if warranted, improve upon a critical component of the Wisconsin Phosphorus Index (WPI) – the methodology used to estimate runoff volume from snowmelt and rain on frozen and thawing soil. This project complemented a four-year pilot project by the Madison Metropolitan Sewage District, Dane County, citizen's groups, and other agencies, in the Six Mile Creek watershed (approximately 11,000 acres) located northwest of Lake Mendota to test the feasibility of using an adaptive management approach to reduce non-point P loading to the Yahara chain of lakes (MMSD 2016).

The project accomplished its three primary objectives: 1) demonstrate, test and refine the ability of the WPI to assess field management effects on runoff P losses from frozen soils, 2) adapt the refined frozen soil runoff risk assessment method (within the process-based WPI) to identify field conditions and management practices capable of minimizing runoff when applying animal manure to frozen soils, and 3) promote NRCS Conservation Practice Standard Code 799 Monitoring and Evaluation by demonstrating and improving the functionality of a prototype flow measurement gage system on farm fields in winter. Objectives 1 and 2 addressed the following 2012 CIG priority needs areas for nutrient management: a) demonstrate the application of and procedures for refining the utility of the WPI for reducing P loss across a range of soil, topographic, climatic, crop and management conditions, and b) demonstrate suites of conservation practices and document the conditions for their optimal use in protecting surface water quality if manure was to be applied to frozen soil.

Through successful application of an MHXL-flume, ultra-sonic stage measurement and low-cost data logging system, the over-winter runoff volume was monitored for three winters on three cropped fields within the Adaptive Management Pilot Project area. Comparison of unit-area field runoff volumes to unit-area watershed runoff volumes for local streams indicated that the current WPI winter runoff methodology, which is based on average watershed runoff, does not adequately reflect the effect of field conditions and management on runoff.

The first step to improving the winter runoff model was using regression techniques to examine the relationship between winter runoff, winter precipitation and field characteristics for the nine field-winters of runoff data from this project along with data from 12 other farms from other projects throughout Wisconsin (157 field-winters). This analysis showed that year-to-year variations in melt conditions obscured trends related to field characteristics and management. Subsequently, runoff and snow data from the project monitoring sites were used to develop an event-based, modified Curve Number method that accounts for variations in melt and field conditions to estimate average winter runoff volumes. The method was tested and refined with data from other project sites. This empirical method appears to accurately reflect the effect of soil type (Hydrologic Soil Group), prior crop, and tillage on winter runoff. Following additional testing with an expanded runoff dataset, the method will be incorporated in the WPI calculations in the SnapPlus nutrient management planning software and into a barnyard runoff water quality management tool currently under development.

To meet objective one, the proportion of total WPI scores from estimated winter runoff dissolved P (DP) loads was calculated with the current winter runoff model for 373 fields (6,480 acres) in the Six Mile Creek Watershed. For most of those fields, runoff DP losses for all seasons contributed to less than a quarter of the total WPI and winter losses were less than half of total DP losses. However, in one example of a low-erosion, low-WPI field examined in detail, winter DP was the largest component of the losses due to a winter manure application. The effect of three alternative field management practices (supported by the Adaptive Management Pilot project) to reduce runoff was examined using the current WPI model. All of the practices reduced erosion, and therefore sediment-bound P losses, yet increased estimated winter DP losses very slightly or not at all. Compared to the current WPI model, winter runoff DP losses using the new runoff model were not very different when averaged across the rotation. However, there were large differences in winter runoff in individual years, especially in years with unincorporated manure applications.

The new empirical winter runoff model provides water quality planners and agricultural producers with a tool to address agricultural runoff quality from snow-covered and frozen ground. The model can help planners determine what fields on a farm are less runoff-prone if late-fall or winter applications are necessary in a particular year. Reducing phosphorus loss from agricultural fields can reduce negative downstream impacts of phosphorus pollution to surface waters (i.e. reduce algal blooms) and allow rural and urban communities to realize economic benefits from surface waters.

Multiple state and local Wisconsin programs will benefit from the integration of the winter runoff model into the WPI in SnapPlus software. In addition to incorporating the winter runoff model in the WPI, we can use it to provide field winter runoff ratings for winter spreading plans required by the recently revised Wisconsin 590 Nutrient Management Standard. SnapPlus is currently used to create the majority of 590 nutrient management plans in Wisconsin. The WPI is also used to determine strategies for reducing runoff P in non-point projects throughout the state similar to its use in the Adaptive Management Pilot Project.

<u>Project Recommendations:</u>

- Adopt the edge-of-field winter runoff collection system technology developed for this project.
- After additional testing and refinement, implement the new winter runoff model algorithms into the WPI to increase average winter snowmelt runoff volume forecasting accuracy.
- Use the winter runoff algorithms to create tools and educational materials that help producers identify least risky fields for runoff if they need to make a late-fall or winter application of manure.

The project required a one-year no-cost extension for two reasons: 1) the field site selection process required more time than anticipated, and 2) the installation of field monitoring equipment was delayed by one winter field season due to site selection issues as well as equipment updating. A 60-day extension on the final report was granted to finish the winter runoff modeling which required adaptations from the original project plan. Project funds were spent completely and properly allocated to all subcontracts.

# Introduction

This project was undertaken to evaluate and, if warranted, improve upon a critical component of the Wisconsin Phosphorus Index (WPI) – the methodology used to estimate runoff volume from snowmelt and rain on frozen and thawing soil. In this report, the term 'winter runoff' will be used to indicate all runoff from snowmelt and rainfall on frozen and thawing soil, while 'rainfall runoff' indicates runoff under non-frozen conditions.

## Key Personnel

University of Wisconsin-Madison:

- Dr. Anita Thompson, Professor, Department of Biological Systems Engineering, was responsible for overall project management and supervision as well as conducting the baseflow separation analysis, and preparation of the final report.
- Dr. K. G. Karthikeyan, Professor, Department of Biological Systems Engineering assisted with project design and management
- Dr. John Panuska, Natural Resources Extension Specialist, Department of Biological Systems Engineering, assisted with design of the field components of this project, investigated existing winter runoff models, guided winter runoff volume model development, and prepared final report.
- Dr. Laura Ward Good, Associate Scientist, Department of Soil Science and Wisconsin P Index project leader, evaluated the proportion of the WPI for fields in the Six Mile Creek watershed attributable to winter runoff, developed a new winter runoff model to be incorporated into the WPI, determined how use of this model will affect representative of Six Mile Creek WPI values, and prepared final report.
- Zachariah P. Zopp, Assistant Researcher, Department of Biological Systems Engineering, provided field component maintenance, conducted snow water equivalence analysis, assisted with winter runoff modeling, and prepared final report.

University of Wisconsin-Platteville:

- Dr. Dennis Busch, Research Manager at the University of Wisconsin-Platteville Pioneer Farm, was responsible for installation and operation of three prototype flow gages in cropped fields over three winters and for the development and evaluation of an in-field user interface.

## Project Objectives

Objective A:

A.1 Demonstrate the ability of a process-based P Index formulation to assess management effects on runoff P losses from fields under frozen soil conditions.

A.2 Test and refine the method used in a process-based P Index to determine the effect of field management practices on frozen soil runoff volume.

Objective B:

Adapt the refined frozen soil runoff risk assessment method (within the process-based P Index) to identify field conditions and management practices capable of minimizing runoff when animal manure is applied to frozen soils.

Objective C:

C.1 Promote NRCS Conservation Practice Standard Code 799 Monitoring and Evaluation by demonstrating the prototype flow measurement gage on farm fields under winter conditions observed in Dane County, Wisconsin.

C.2 Improve the functionality of the prototype flow gage by adding a user-friendly interface that will allow landowners to easily access gage data.

To achieve these objectives, the following project tasks were completed:

- Determined the proportion of total WPI scores for 373 fields (6,480 acres) in the Six Mile Creek Watershed that was from estimated winter runoff dissolved P loads.
- Examined the sensitivity of the WPI to changes in winter management for representative fields in the Six Mile Creek watershed.
- Monitored over-winter runoff volume for three winters on three cropped fields.
- Measured snow water equivalent on the monitored fields.
- Compared field runoff volumes to local watershed runoff volumes and determined that the winter runoff methodology used in the current WPI, which assumes specified relationships between field-scale and watershed runoff, is not adequate.
- Used regression techniques to examine the relationship between winter runoff and winter precipitation and field characteristics and selected RUSLE2 variables for the nine field-winters of runoff data from this project and 181 field years of winter monitoring data from other projects located on 14 farms throughout Wisconsin. This analysis showed that year-to-year variations in melt conditions obscured trends related to field characteristics and management.
- Used the snow water equivalent data and runoff data from the three sites monitored for this project to develop an event-based method that accounts for variations in melt conditions when estimating average winter runoff volumes. This method was also adequate for predicting winter runoff from other sites.
- Developed a plan for incorporating the new winter runoff calculation method into the WPI.
- Examined the effect of using the new winter runoff method on the WPI values in representative profiles from Six Mile Creek watershed.
- Prepared winter runoff educational materials and will present at the upcoming 2017 Soil and Water Conservation Meeting in Madison, WI.

## Funding and Relationships

This project was undertaken in collaboration with the Madison Metropolitan Sewage District and the Dane County Land Conservation Division. Their pilot Adaptive Management project in the Six Mile (Dorn/Spring) Creek watershed (HUC12: 070900020602) included an inventory of field management information that we were able to use for the evaluation of winter runoff calculation effects on WPI scores on real fields in this area. With funding from the Pilot Project, the U.S. Geological Survey has been conducting in-stream monitoring at four stream sites in the area. We used the in-stream data from three of these sites to calculate watershed-wide winter runoff volumes to compare to the monitored field runoff. In addition to the Pioneer Farm, the following researchers and groups provided us with field runoff and crop management data: William Jokela, US Agricultural Research Service; University of Wisconsin-Extension Discovery Farms Program; John Norman, UW-Soil Science (emeritus); and Greg Olson, Sand County Foundation.

# Background

Problem Definition: The snowmelt period is known to be a time of significant phosphorus loading from agricultural runoff to Wisconsin streams and lakes. For example, Lathrop (2007) reports 48% of the total annual phosphorus loading in the Yahara River watershed, which contains Lake Mendota, occurred during January to March as measured from 1990-2006. Confounding this issue is that farmers currently do not have a reliable way to identify how field management can decrease the likelihood of winter runoff from areas where soil phosphorus levels are high or to identify fields with a lower snowmelt runoff likelihood if they need to winter apply manure when storage is not available. Winter manure spreading is occurring throughout Wisconsin and better management tools are needed to mitigate the adverse impacts of this practice.

Past and Current Efforts to Address the Problem: This problem has been addressed using the Wisconsin Phosphorus Index (WPI; Good et al., 2010), the Runoff Risk Advisory Forecast (RRAF) tool and more recently adaptive management. Comparison of watershed-scale and observed field-scale runoff data suggest that watershed-scale values are typically less than field-scale values, thus under predicting winter runoff P loading. Because the WPI is a field-scale management tool and the data suggest the potential to underestimate winter runoff P loads, it is desirable for the WPI to use field-scale winter runoff volume in its calculations. This project demonstrated and evaluated frozen soil runoff on cropped fields in the Six Mile Creek Watershed using the current WPI and new approach developed as a product of this project. The results of this project will be used to refine the WPI's winter runoff method and any refinements will be incorporated into the WPI.

*WPI*: We developed the WPI used in the current Wisconsin 590 standard at the University of Wisconsin (UW). It is a process-based tool that estimates average annual runoff P loads from a field and delivery to the nearest surface water. These load estimates account for P in runoff from soil, applied manures and fertilizer. Average annual loads are estimated separately by crop year and P transport pathway. Individual crop year P loads are summed for sediment-bound and dissolved P losses from soil, manure and fertilizer in snowmelt runoff and rainfall runoff. We have rigorously validated its process-based equations with relevant field runoff data from Wisconsin, and are capable of providing an accurate assessment of runoff P loss risk when good estimates of average annual runoff and erosion are available (Good et al., 2012). In the WPI, average annual erosion and rainfall runoff are currently estimated using standard NRCS methods. RUSLE2 is used for erosion, while a modification of the Runoff Curve Number formula is used for rainfall runoff. The modified runoff formula uses field and management-specific Curve Numbers generated by RUSLE2. To accomplish this computation, the WPI is integrated with the RUSLE2 soil erosion model in nutrient management planning software, SnapPlus, which is used in preparation of the large majority of the nutrient management plans in Wisconsin (WDATCP, 2016) and is developed and maintained by the UW Soil Science Department. In SnapPlus, the rotational average WPI is reported for each field along with the sediment-bound Particulate WPI and dissolved Soluble WPI components for each crop year.

*Frozen soil runoff risk assessment*: Currently, there is no widely accepted method for estimating average runoff from snowmelt and rainfall on frozen and thawing soils that is appropriate for a field-scale management planning tool like the WPI. Therefore, an empirical method was developed for the WPI using long-term average frozen soil period runoff from U.S. Geological Survey (USGS) monitored agricultural watersheds (Good et al., 2010). The method is sensitive to soil texture, slope, and field management. Using this method, prior to calculating an individual field's P Index, the initial runoff volume at the watershed scale is adjusted using a "Fall Soil Condition" factor that accounts for potential in-field melt water storage in surface depressions from tillage. The Fall Soil Condition Factors (FSCFs) were adapted from the Soil Fall Conditions Factors in the Minnesota P Index (Moncrief et al, 2006) using a formula from Molling et al. (2005). The FSCFs provide a research-based method to account for the relative effects of management (i.e. tillage system induced surface roughness) on snowmelt runoff at the field scale. However, one concern about this method is the use of watershed-scale measurements to estimate field-scale runoff. Existing field runoff data for winter are not adequate to validate the frozen soil runoff volume method (in the WPI), but these runoff data do show that the volume estimates are directionally correct (e.g., fall tilled fields have less snowmelt runoff than nearby untilled fields (Bormann et al., 2012)).

Another tool currently in use to address winter manure spreading runoff risk is the Runoff Risk Advisory Forecast tool (RRAF). The RRAF was developed to advise farmers of when weather and soil conditions are likely to lead to runoff; state and federal agency partners in Wisconsin, including NRCS, have developed the Runoff Risk Advisory Forecast maps (http://www.manureadvisorysystem.wi.gov/app/runoffrisk), a basin-level real time assessment of runoff risk. It is important for Wisconsin producers that we complement the RRAF with a field-level runoff risk assessment based on site-specific conditions to be used both for nutrient management planning and when farmers without storage have no choice but to spread under risky frozen soil conditions and need to select the lowest runoff risk fields for spreading. In addition, Wisconsin’s Nutrient Management Planning Standard 590 was recently revised, requiring livestock producers to identify fields for emergency winter spreading and to have detailed plans for reducing runoff risk when spreading any manure produced during the winter that cannot be stored (USDA-NRCS-WI, 2015).

*Assessing winter runoff P loss potential using watershed adaptive management*: Extensive efforts are underway to reduce P inputs by 50% to improve water quality in the Yahara chain of lakes, which is part of the Rock River TMDL watershed. At the start of this project, the Madison Metropolitan Sewage District, in partnership with Dane County, citizen’s groups, and other agencies, was embarking on a pilot project in the Six Mile (Dorn/Spring) Creek (HUC12: 070900020602) watershed to test the feasibility of using an adaptive management approach to reduce non-point P loading to the lakes. In adaptive management, all contributors of P (point and nonpoint) work collaboratively to offset loads by identifying and funding cost effective nutrient control practices throughout the watershed. Wisconsin is the only state in the United States that includes an adaptive management option in state administrative code language, and this pilot project will be the first of its kind in Wisconsin. The specific objective of the pilot project is to determine if sufficient opportunities exist within the Six Mile Creek watershed to achieve a 50% reduction in agricultural runoff P export using changes in field management that are both acceptable and implementable by producers. In addition, the two adjacent watersheds, Waunakee and Pheasant Branch, are designated Mississippi River Basin Healthy Watershed Initiative (MRBI) project watersheds due to their disproportionately high P contributions to the Yahara lakes.

Agricultural operations in the three project watersheds are predominantly small and medium sized dairies, with six dairies large enough to be considered concentrated animal feeding operations (CAFOs). In these three watersheds, the WPI is being used not only to identify fields where P loading can be reduced but also to evaluate suites of potential practices to achieve the desired reductions.

In this part of the Upper Mississippi River Basin, accurate estimates of management and site effects on snowmelt runoff are important to delineate high P loss areas and evaluate suitable management options. USGS monitoring of Pheasant Branch from 1990 through 2010 showed that, on an average, 36% of the annual total P loading occurred during the melt months of February and March (USGS, 2012). Importantly, the average P load during these two months was approximately equal to the average load from May through July, a period with higher sediment losses. These watersheds have erodible (i.e. sloping) silt loam soils where no-till and minimum till practices are often adopted to reduce sediment-bound P losses. However, these practices result in fields with less surface roughness and fewer depressions after crop harvest as well as a tendency for snow to accumulate in over-winter crop residue, leading to higher snowmelt runoff volumes. For some field conditions, fall tillage may result in lower annual total surface runoff P losses. Thus, quantifying the effects of management (fall tillage in particular) on snowmelt runoff allows for the selection of management scenarios that can lower total average annual P loads from specific fields.

<u>Agriculture or environmental sector benefited by this project:</u> Both the agricultural and environmental sectors benefit from the project. Agricultural producers are provided with improved tools to allow them to make management decisions that minimize phosphorus loss from agricultural systems. Excessive phosphorus in natural systems results in eutrophication. One consequence of this is excessive algal growth or an algal bloom. Algal blooms are unsightly, produce foul odors, can be toxic if ingested and can deplete dissolved oxygen from the water column after senescence resulting in fish kills and damage to other aquatic life.

<u>Natural resource issues addressed:</u> Improved tools to predict snowmelt runoff can facilitate reduced manure nutrient and bacterial losses from agricultural systems. Reduction of pollutants from these systems improves overall water quality of streams and lakes. In addition, keeping manure and other soil amendments in place on agricultural fields can increase nutrients available for crops and organic matter to improve soil health. Better management of agricultural production systems supports long term sustainability and more efficient use of natural resources.

# Review of Methods

## Demonstrating the WPI:

The Dane County Land Conservation Division (LCD) collected nutrient management information in SnapPlus databases from 25 farms located partially or completely in the Six Mile Creek Watershed. These databases include soils, soil test, crop, tillage and fertilizer and manure applications, for about 60% of the cropland acreage in the Six Mile Creek Watershed. The databases covered 6,480 acres in 373 fields. We merged these databases, removing farm identifiers, and computed the WPI within the SnapPlus software. Crop rotations in the database ranged from two to eight years and the total database included 1,925 field years. As part of its efforts for the Adaptive Management Pilot Project, Dane County LCD used this database to identify the extent of phosphorus loss reductions needed to meet project goals in this area and management alternatives to help achieve these reductions (Dane County LWRD, 2016; MMSD, 2016).

Using the merged SnapPlus database, we examined the effect of the winter runoff calculation on the total WPI and on winter dissolved P losses (soluble WPI). We calculated the ratio of rotation average WPI to rotation average soluble WPI, annual rainfall and winter runoff, and rainfall and winter soluble P losses. For each field year, we identified the proportion of the soluble WPI resulting from winter runoff. From the merged database, we selected fields that represented each quartile of total P loss as estimated by the WPI. We selected a field from the lowest quartile to be representative of low phosphorus loss fields not likely to be the focus of reduction efforts and one from the upper quartile to represent fields that may be targeted for reductions. For the high WPI field, we ran SnapPlus with alternative managements supported by the Adaptive Management Pilot Project to quantify potential reductions. Then we compared current dissolved P loss calculations for these fields with the original and alternative managements to those using the revised winter runoff volume developed for this project (described in the *Winter Runoff Model* section of this report).

## Field Monitoring:

### *Site Selection and Location*

A total of three agricultural fields (denoted as A, B, and C) within Dane County, Wisconsin were chosen for winter runoff monitoring (Fig. 1). Field A is located in the Cherokee Lake and Yahara River subwatershed (HUC 12: 070900020504) and fields B & C are located in the Six Mile Creek subwatershed (HUC 12: 070900020602). Installation of on-site flow monitoring equipment was completed in 2013 for all three fields, prior to the start of the 2014 winter season (December 1, 2013 through March 31, 2014).

Agricultural field site selection was based on a three part screening process to ensure the resultant fields provided both quality data and access for the duration of the study. Prospective cropped fields managed by local farmers were first screened for public ownership in two adjoining subwatersheds located in Dane

County. Ownership by project partners was desired to provide reliable access as well as added flexibility to alter a management practice if required. Next, prospective agricultural fields were evaluated over a range of characteristics (Table 1). Lastly, prospective fields were inspected during rainfall and snow melt events prior to monitoring site installation to ensure the boundaries of the field subwatersheds were not influenced by outside runoff beyond our control (i.e. road runoff). From the prospective fields, a total of three were chosen (denoted as A, B, C) because they: 1) were expected to have an array of conditions leading to differences in expected snowmelt runoff volume, 2) were owned by project partners and managed by local farmers, and 3) were not heavily influenced by outside runoff beyond our control.

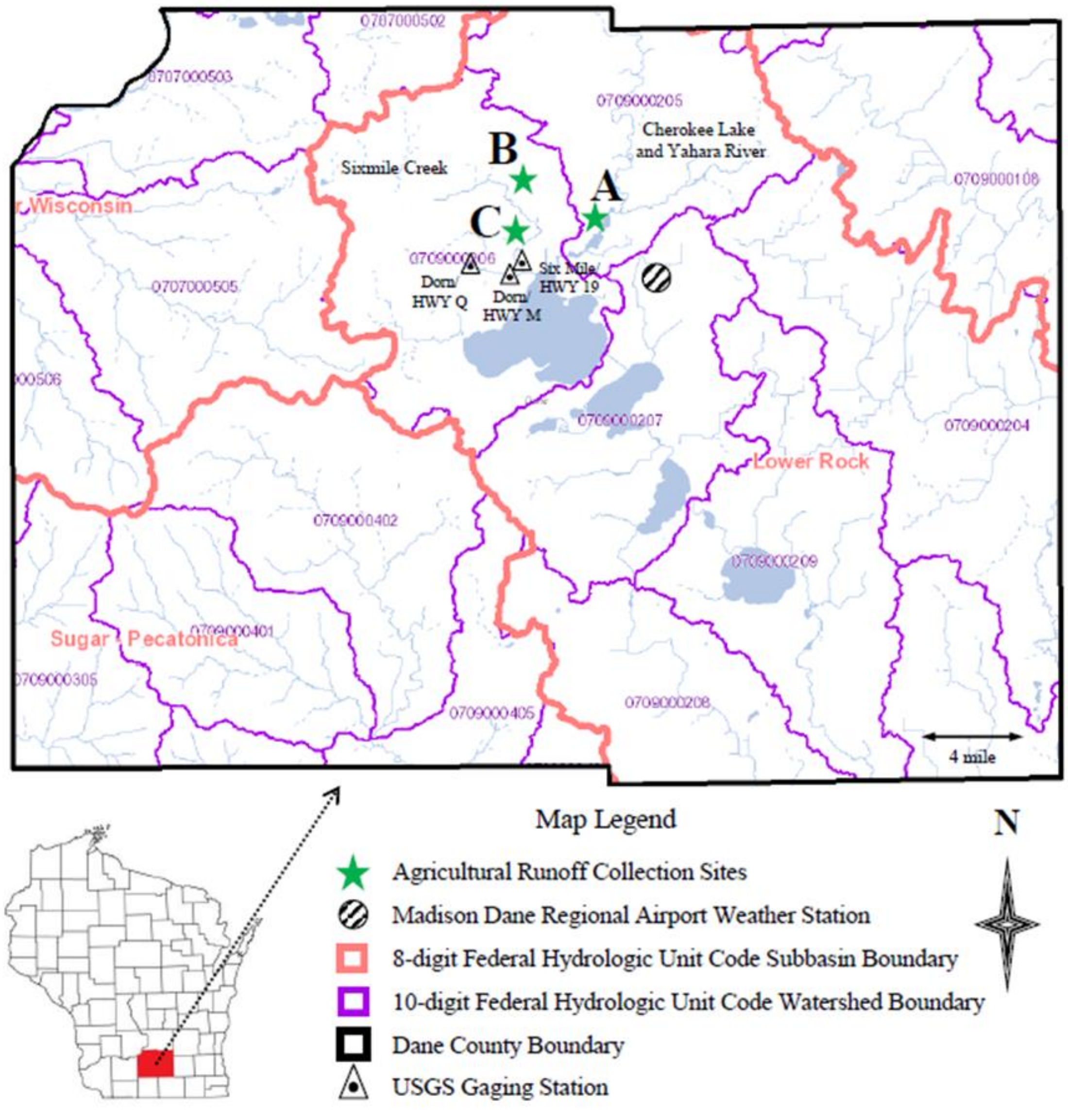


Figure 1. Locations of the three monitored agricultural fields (A, B, C) and USGS stream gaging stations (Dorn/Hwy Q, Dorn/Hwy M, and Six Mile/HWY 19) in relation to Watershed and Subbasin Boundaries.

Table 1. Physical characteristics and cropping rotations for the three agricultural fields selected for monitoring.

| Field Name | Soil Type | Area (ac) | Winter Year | Fall tillage | Prior Crop | Average Slope % | Grassed Waterway (Y/N) | Hydrologic Class | Field Aspect | Contour Planted (Y/N) |
|---|---|---|---|---|---|---|---|---|---|---|
| A | McHenry silt Loam | 19.9 | 2014 | Chisel | Corn Grain | 6 | N | B | North | N |
| | | | 2015 | None | Corn Grain | | | | | |
| | | | 2016 | None | Soy | | | | | |
| B | Ringwood silt loam | 29.37 | 2014 | Vertical Till | Soy | 9 | Y | B | West | Y |
| | | | 2015 | None | Corn Grain | | | | | |
| | | | 2016 | None | Soy | | | | | |
| C | McHenry silt Loam | 2.94 | 2014 | None | Corn Grain | 10 | N | B | South | Y |
| | | | 2015 | None | Corn Grain | | | | | |
| | | | 2016 | None | Soy | | | | | |

Site selection began in the fall of 2012. Finding suitable single-use watersheds to monitor that did not drain multiple fields proved much harder than expected. Site A has approximately a quarter of its watershed in woods, while Site B drains part of additional fields with similar crop management in the upper part of its watershed and had a berm installed prior to the winter of 2016 that impeded flow from these upper fields (Fig. 2). All of the sites selected had average slopes of 6% or greater. While our intent was to have variations in fall tillage across the sites in more than one monitoring year, project partners were understandably reluctant to encourage additional tillage on these steep slopes. We had originally selected a site with lower slope that was routinely plowed in the fall, but run-on from a residential area was observed during snowmelt in March 2013.

Additionally, three of the four USGS stream gaging stations were selected for the comparison of field and stream winter runoff volumes. The USGS stream gaging stations: 1) Dorn/Hwy Q, 2) Dorn/Hwy M, and 3) Six Mile/HWY 19 (Fig. 1) all reside within the Six Mile Creek subwatershed. Daily weather information for the duration of the study was obtained from the Madison Dane Regional Airport Weather Station. The weather data was accessed using the “cli-MATE” webpage, operated by the Midwestern Regional Climate Center (MRCC, 2016). While the location of the weather station was not in the study subwatersheds, it was located in an adjoining subwatershed and no farther than approximately six miles from any monitored agricultural field.

*Field Monitoring Equipment*

Field monitoring equipment was located in pre-fabricated buildings, located at the edge-of-field where overland runoff was directed and concentrated (Fig. 3C). In order to properly site the edge-of-field runoff collection station, natural topographic, grassed waterways or other engineered management features and field watershed boundaries were accounted for. The runoff collection station, was comprised of four main components: 1) a Modified HXL-Flume with Integrated Heat System, 2) Ultrasonic Stage Sensor, 3) Integrated User Interface, and 4) Stage Camera (Fig. 3A-C). The station was powered by deep cycle marine batteries capable of supplying 100 amp hours of power. Solar panels recharged the batteries with a supply of 18 amp hours/day during winter daylight conditions. The ambient snow pack of the agricultural fields was also monitored using a snow water equivalence method.

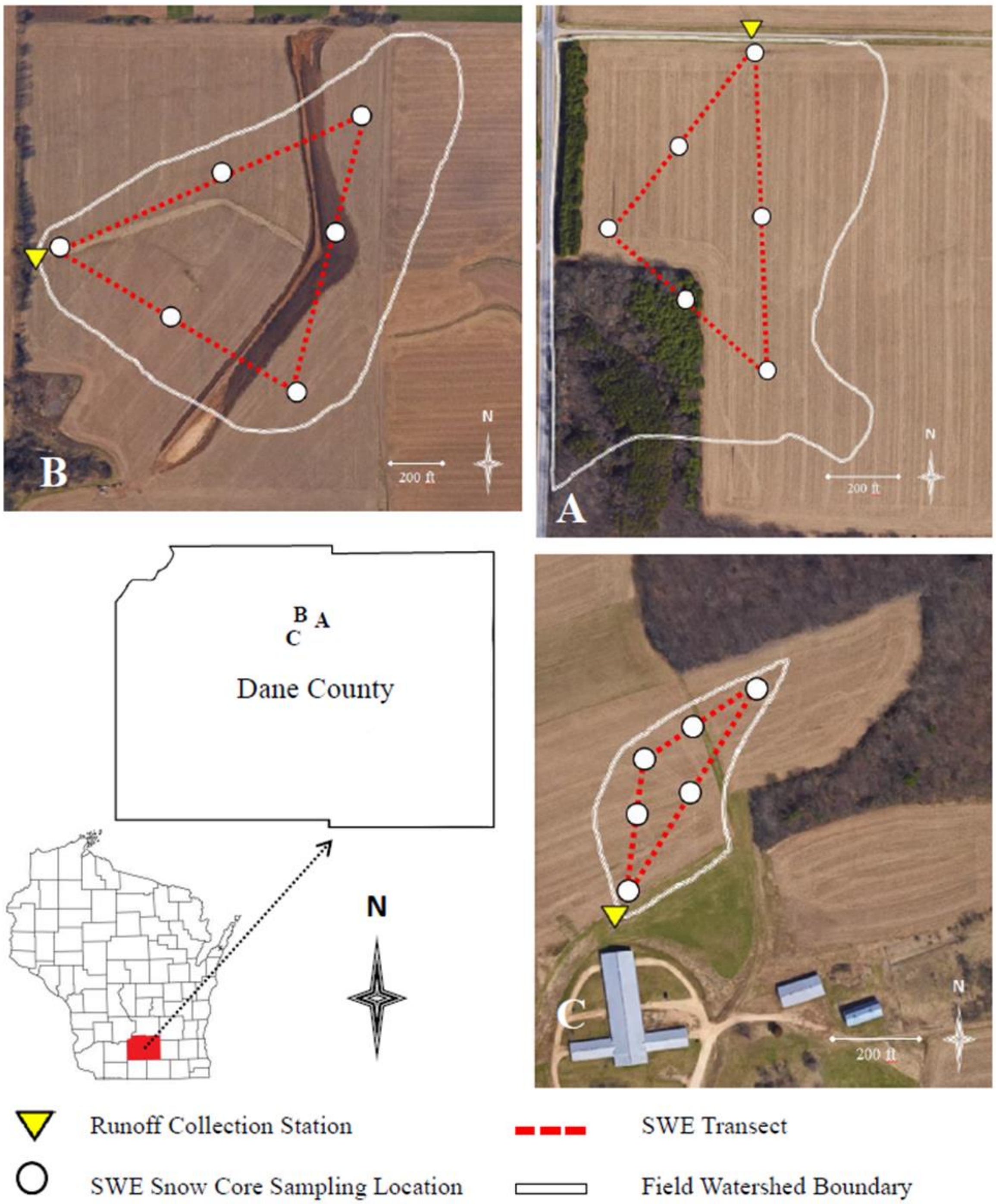


Figure. 2. Approximate locations of agricultural fields monitored for snowmelt runoff, with corresponding runoff collection station location, snow water equivalence (SWE) analysis transects and SWE snow core sampling locations.

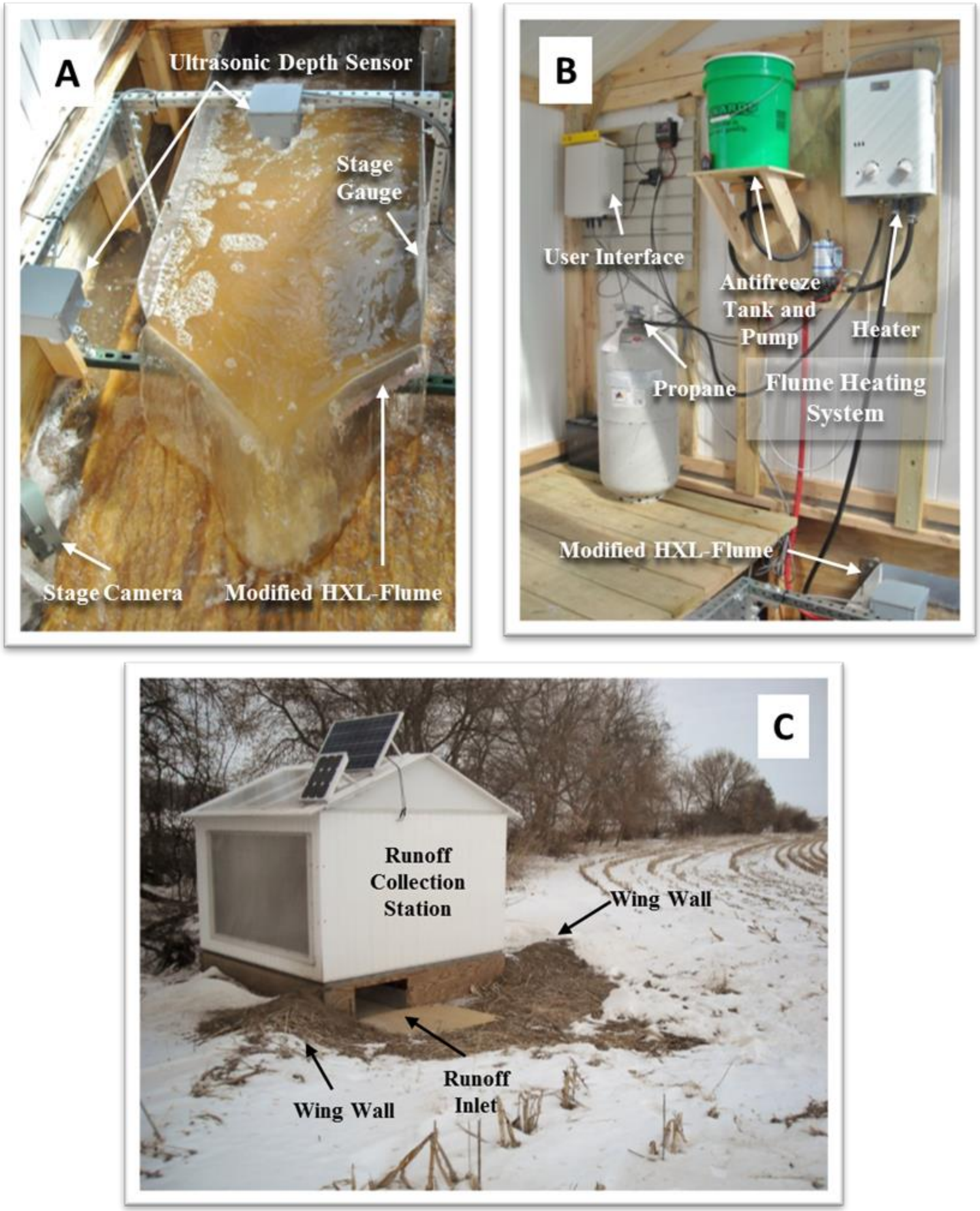


Figure 3. Pictures of field runoff monitoring stations showing: A) a modified HXL-flume under runoff conditions, B) details of the modified HXL-flume heating system as well as data logging and user interface system, C) external view of monitoring station.

1) <u>Modified HXL-Flume with Integrated Heat System</u>

The use of precalibrated devices for measuring edge-of-field runoff is common for on-farm research and monitoring programs. Specifically, the H-flume is frequently used in edge-of-field monitoring applications because they accurately estimate discharge and they have the ability to transport solids with little obstruction. Unfortunately, the H-flumes are costly to purchase and require significant in-field berming to direct flow into the flume when measuring large discharges. Moreover, the flumes require significant labor during the winter in northern climates in order to keep the device ice-free so discharge can be accurately estimated.

In response to the challenges associated with the use of H-flumes for measuring edge-of-field discharge in northern climates, the modified HXL-flume (MHXL-flume) was developed (Fig. 4). This prototype flume is designed to gauge low flow rates through a convergence while high discharge rates overtop the convergence and allow for larger discharge rate measurements at lower heads than traditional H flumes. Moreover, in an effort to reduce operational costs during winter runoff monitoring, a heat pan was integrated into the floor of the flume to allow circulation of heated fluid beneath the flume. The heat pan is turned on by an on-site technician to release ice from the metal surface and expedite ice removal and cleaning.

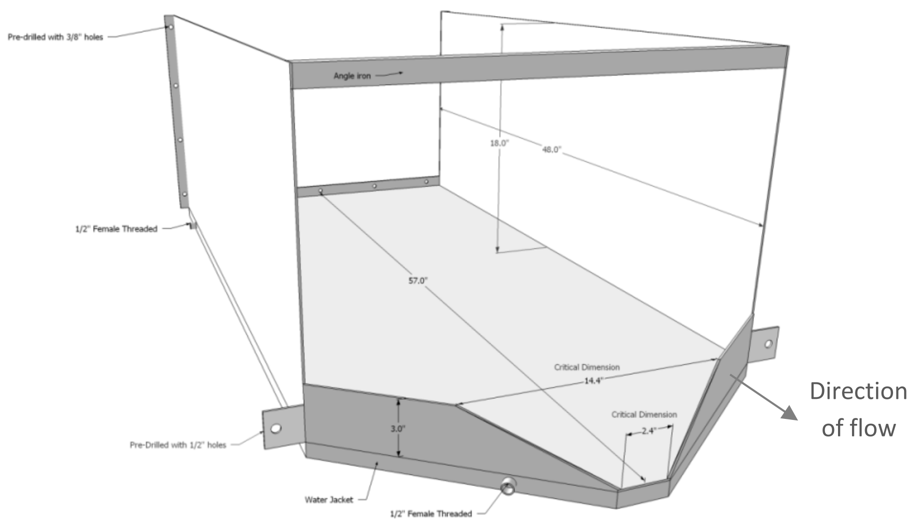


Figure 4. Schematic of the MHXL-flume.

The innovative MHXL-flume reduced both installation and labor costs. The low-profile of the MHXL-flume resulted in soil berms (Fig. 3C) that were smaller in both height and length than what would have been required for equivalent H-flume installations. The integrated heater also proved a significant time savings for removing ice of any thickness. Within ten to twenty minutes of heating, the bond between the flume and the ice would melt and the ice could easily be removed (Fig. 5). Conventional flumes require hours of manual labor to break and remove ice in small pieces. The propane RV shower heater (Fig. 3B) was prone to damage caused by mice and openings were covered with hardware cloth to keep mice out.

In an effort to reduce cost, alternative flumes were constructed using state-of-the-art CNC metal cutting and bending techniques. This manufacturing technique reduces cost of flumes by approximately 60%. Several of these flumes were evaluated at the St. Anthony Falls Laboratory (SAFL) in Minneapolis, Minnesota to determine accuracy and precision of discharge estimates (Fig. 6).

2) Ultrasonic Stage Sensor

Ultrasonic stage sensors (Fig. 3A) were used to measure water stage (depth) in the flume which is then used to estimate discharge via a rating curve generated through experimentation at SAFL. Field testing indicated that the sensors accurately estimated stage values.

Figure 5. Thick ice easily removed after running the flume heater for ten minutes.

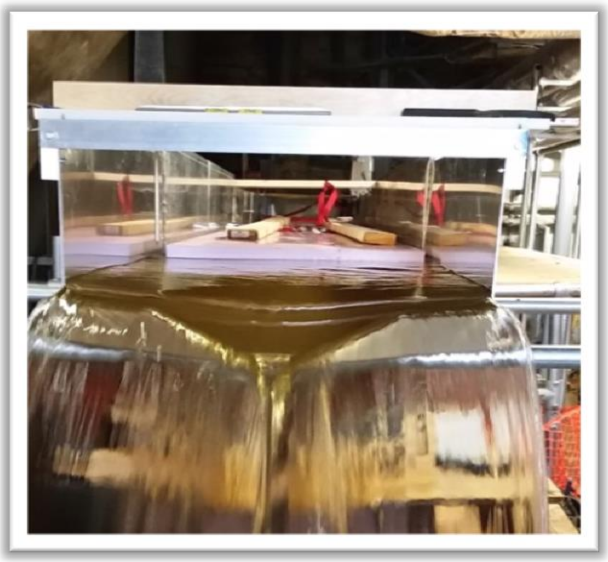

Figure 6. MHXL-flume flowing at St. Anthony Falls Laboratory.

3) Integrated User Interface

A user-interface for the low-cost prototype data logger (project deliverable) was developed to collect edge-of-field surface-water runoff data within NRCS Conservation Activities 201 and 202. A full copy of the user interface instruction can be found in Appendix B. The user-interface (Fig. 7) was integrated into the low-cost data logging system. The interface includes a 4x20 LCD screen and 4x4 matrix keyboard. The user-interface represents a significant improvement in the functionality of the data logger for the following reasons:

1) Status of the logging system can easily and quickly be determined without a peripheral device or knowledge of the system by reading data from the screen;

2) Users may view current data and important settings without the use of a complicated menu structure;

3) The interface greatly simplifies initialization of the system because it eliminates the need for an additional external device, such as a laptop, previously required to make changes to settings;

4) In conjunction with the user-interface, a pause logging capability was added, which allows users to extract the sd card and download data quickly and easily;

5) Adjustments to settings such as sample interval are very simple with the user-interface.


Figure 7. Integrated User Interface Panel.

4) Stage Camera

On-site cameras (Fig. 3A) were used to photo document field conditions in the gauging station. Cameras were configured to upload images on a preset time interval to a cloud based storage system allowing site managers to view conditions in near real-time. Several hardware and software alternatives were evaluated for the time-lapse photo application; Table 2 describes the alternatives and lists their advantages and disadvantages. Overall, the IP camera proved to be the best solution for capturing imagery, but this required significant configuration of hardware.

Table 2. Description of time lapse photography methodology

| Criteria | Hardware and Software Alternatives Evaluated | | |
|---|---|---|---|
| | Game Camera with Eyefi Card | Cell Phone with Time lapse App and Dropbox | IP Camera with Remote Upload |
| Remote Image Upload | Yes, but the Eyefi sd card would frequently lose Wi-Fi signal and stop uploading | Yes, but the time lapse app would quit if the phone receive an incoming communication (e g text) | Yes, the upload worked well |
| Cost | Moderate ($300) | Low ($100) | Moderate ($500) requires web relay to control on/off due to high power consumption |
| Power Use | Low power consumption | Low power consumption | High power consumption |
| Remote Control | No remote access and control of this system | No remote access and control of this system | Yes, all aspects of the camera operation can be controlled remotely |
| Photo Quality | Adjustable resolution Good Quality | Adjustable resolution Good Quality | Adjustable resolution Good Quality |
| Text Overlay | Yes | No | Yes |
| Time Stamp | Yes | On filename, no overlay | Yes |
| Site ID Stamp | Yes | No | Yes |
| Site ID Filename | Yes | No, photos were renamed with site ID via additional software | Yes |
| Ease of Configuration | Camera was easy to setup but the Eyefi card was difficult to configure and prone to failure | Difficult to configure because it uses several components | Moderately difficult |
| Temperature Rating | Good for Winter Use | Failed at low temperatures | Good for Winter Use |
| Water and Dust Rating | Good for Field Use | Need to be protected from elements | Good for field use |
| Robustness | The camera would end the timelapse unexpectedly and stop taking photos | Susceptible to the elements and unexpected failures | Good |

### *Snow Water Equivalence Method & Estimated Snowpack*

Snowfall and snowpack density vary throughout the winter season and are difficult to predict for specific locations. While snowfall density varies primary as a result of atmospheric weather conditions, snowpack density is also affected by processes such as densification and snow metamorphism (Brasnett, 1999; Mizukami and Perica, 2008) and thus increasingly difficult to model. A physical measurement of snowpack can be determined using a snow water equivalence (SWE) analysis. SWE is the transformation of a known quantity of snowfall or ambient snowpack depth into an equivalent depth of water. An SWE analysis was used in this study to determine the equivalent depth of water contained in the ambient snowpack of the agricultural fields monitored in this study prior and subsequent to a snowpack meting event.

An average SWE value over a large land area, such as an agricultural field, requires multiple snow core and snow depth samples. A total of six snow cores were collected at varying points along the three transects at each field site (Fig. 2) using a 91 cm length x 7.3 cm I.D. cylindrical acrylic tube with one sharpened end (Fig. 8; US Army, 2012). Snow depths were recorded at either 10m or 20m intervals along three transects, encompassing the entire land area (van der Kamp et al., 2003) to produce a minimum of 20 snow depth measurements (Fig. 2; Tiessen et al., 2010). If ice or a dense snowpack were present a similar tube with a metal saw blade attached to the inside was used to cut and extract the entirety of the ice or snowpack.


Figure 8. Snow core sampler used in SWE analysis.

**Field to Stream Comparison**

Measured in-field snowmelt runoff was compared to watershed stream snowmelt to investigate current assumptions in the WPI describing the relationship between watershed flow and edge-of-field runoff volume. Streamflow data from three USGS continuous in-stream flow monitoring sites in agricultural subwatersheds of Six Mile Creek and the adjacent Dorn Creek were used in the analysis (Table 3, Fig. 1). A baseflow separation analysis was conducted using HySEP-Fixed (USGS Groundwater Toolbox 1.1.1). Daily streamflow at each site was separated into baseflow and runoff for the entire period of record. Daily runoff volume was summed over the frozen/thawing ground period for 2014, 2015 and 2016 and compared to runoff volumes from the edge-of-field sites A, B, and C (locations shown in Fig. 1) for the same periods. Unit area runoff volumes for the three field sites are compared to the average unit area runoff volume from the continuous monitoring sites in Figure 9.

Table 3. Site information for USGS continuous in-stream flow monitoring.

| Site Number | Site Name | Watershed Area (miles$^2$) | Predominant Land Use | Streamflow Record |
|---|---|---|---|---|
| 05427880 | Six Mile Creek @ State Highway 19 | 24.8 | Agricultural | 6/23/2012 – 12/29/2015 |
| 05427927 | Dorn Creek @ County Highway Q | 9.95 | Agricultural | 6/23/2012 – 6/27/2016 |
| 05427930 | Dorn Creek @ County Highway M | 12.6 | Agricultural | 7/4/2012 – 4/28/2016 |

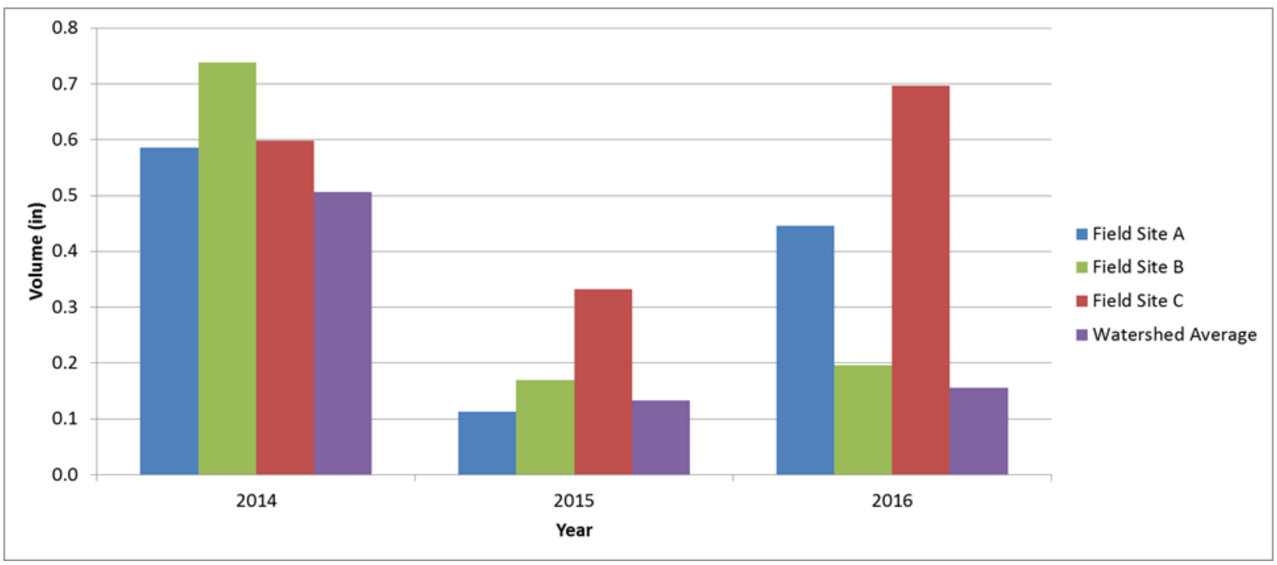


Figure 9. Edge-of-Field to Watershed Scale Comparison of Runoff Volume during Frozen/Thawing Ground Period. Watershed average for 2016 excludes site 05427880 because the flow record was incomplete.

The goal of this comparison was to test the assumptions about the relationships between field and watershed unit-area runoff inherent in the current WPI FSCF methodology for estimating average winter runoff. The ratio of edge-of-field to watershed runoff was most consistent in 2014 and most variable in 2016 (Table 4). Overall, unit-area runoff volumes from edge-of-field sites were greater than the watershed average (Table 4), as anticipated by the FSCF for these fields (Table 5). The WPI FSCF values are similar to the measured field-to-watershed-runoff ratios in 2014 and less similar in other years except for Site B. The FSFC values were not consistent with the relative order of the measured ratios across sites and years. These differences may be attributable to differences in the prior crop or other field characteristics (Table 1) not accounted for in the FSFC.

Table 4. Ratio of unit-area edge-of-field runoff volume to unit-area average watershed runoff volume.

| Year | Site A | Site B | Site C |
|---|---|---|---|
| 2014 | 1.2 | 1.5 | 1.2 |
| 2015 | 0.8 | 1.3 | 2.5 |
| 2016 | 2.9 | 1.3 | 4.5 |

Table 5. Fall Soil Condition Factor (FSCF)* for monitored fields

| Year | Site A | Site B | Site C |
|---|---|---|---|
| 2014 | 1.4** | 1.5 | 1.5 |
| 2015 | 2 | 1.5 | 1.5 |
| 2016 | 2 | 1.5 | 1.5 |

*Factor used to adjust base winter runoff volumes to account for fall tillage and slope effects on winter runoff (Good et al. 2010). Values range from 0.1 (fall moldboard plow on the contour) to 2 (established alfalfa and managements with no fall tillage where operations are not on the contour).
** Adjusted to account for 28% of the watershed being in woodlands (Factor = 2) and 72% fall chisel-plowed not on contour (Factor = 1.2).

**Winter Runoff Model**

The initial effort to model winter runoff used data collected for this as well as other research projects from different geographic locations around Wisconsin. These data were input into a statistical modeling framework designed to describe winter runoff (WR) or the ratio of winter runoff to precipitation (WR:P) as explained by a number of physical and environmental field factors. The sources of the data used in this analysis are listed in Appendix C.

Within the model WR was defined as all runoff measured from December 1 through March 31, except for a few site years when the period extended into April to accommodate a late thaw. The December 1 through March 31 time period is also the winter period used for most of Wisconsin in the WPI and generally coincides with average freezing and thawing dates. Due to the difficulty and potential errors associated with collecting frozen precipitation field data, these data were not collected for any of the field monitoring sites used in the analysis. In place of frozen precipitation field data, water equivalent precipitation field data from the closest daily temperature and precipitation weather observation station to the runoff monitoring site was input the model (MRCC, 2016). Soil map units were identified using Web Soil Survey maps, as was average slope % in the absence of site-specific data from the original studies. The field aspect (four quadrants: north, east, south, west) was determined from site maps. The RUSLE2 soil loss program (ver. 2.5.9.0, USDA-NRCS, 2016) was used to analyze the crop rotations on all monitored fields to produce the following selected values expected to be indicative of over-winter field conditions: March 31 daily Curve Number, random roughness (mm), net surface cover, Manning's n, and RUSLE2 ridge effect (USDA-ARS, 2013). Using the RUSLE2 daily roughness factor rather than a field measurement in the analysis was adopted after several unsuccessful attempts to appropriately characterize field roughness from site-specific field measurements. As the SnapPlus software runs RUSLE2 and its outputs are already used in WPI equations, any value generated by RUSLE2 can potentially be used for WPI runoff volume calculations. Additional factors used in the analysis were: prior crop, fall tillage, year, WPI FSCF, Hydrologic Soil Group, presence of contouring, and prior crop.

The modeling dataset initially included about 200 site-winters of monitoring data. After a review of the dataset, site-winters were removed if a following condition was present: 1) the measured winter runoff volume appeared to be controlled by another hydrologic process unrelated to the field characteristics used in our analysis, or 2) the runoff volume had apparent measurement error. An example of data removal occurred at the Agricultural Research Station at Marshfield, WI (ARS-M; Appendix C) where some sites would occasionally have more than twice the average runoff as compared to an adjacent site with the same management, soil and similar topography. In addition, for some site years, winter runoff was more than 1.1 times winter precipitation. Sites that included the effects of multiple managements occurring in the watershed, including edge-of-field filter strips, could not be adequately described by the field characteristics used in the analysis and were removed from the dataset. The final dataset included 157 site-winters of data and is available upon request.

Initially attempts were made to determine the site and management effects on WR:P, the variable currently used directly in WPI winter runoff model. Initial attempts included an applied regression tree, linear regressions, correlation analysis and multiple regression methods using the R statistical package (R, 2008); none of which were able to identify a robust relationship between field conditions, precipitation volume and observed WR:P. These methods were also used to find a model for WR and were again unsuccessful.

Of all of the site characteristics examined, including random roughness, Curve Number (CN) was determined to have the best relationship to WR:P and WR. This relationship may be a result of the site characteristics being used in the CN equation. Hydrologic Soil Group, soil biomass, surface cover, roughness, and soil consolidation are used in RUSLE2 daily CN computation (USDA-ARS, 2013). Increasing slope had a negative effect on WR, but this is likely due to the Hydrologic Soil Group D (high runoff potential) soils in this database having relatively shallower slopes than the less runoff prone soils.

Both WR:P and WR have significant linear relationships with daily CN and the WPI FSCF, but these relationships did not adequately explain the variation in WR:P and WR across all site years (Table 6). Calculated runoff (Q), another model factor was determined using the CN-equation (USDA-NRCS, 2004a) and assumed the summed winter precipitation was contained in a single event. Again, the relationship between this calculated runoff and measured WR though significant, was not useful for prediction across all sites (Table 6). When data were examined by year, however, there were some years where CN or calculated Q explained significantly more of the WR variation in that year, with $R^2$ as high as 0.68 for calculated Q for the 16 sites monitored in winter 2007 (Table 7). Years with similar ranges in precipitation, such as 2006 and 2007, had very different WR ranges and relationships (Table 7). The differences between years lead us to examine how to account for the differences in snowmelt dynamics through an event-based modeling framework rather than one that used aggregated winter precipitation and runoff.

Table. 6 Winter Precipitation, Winter Runoff, and $R^2$ for relationship between Winter Runoff: Precipitation ratio and Winter Runoff and selected field characteristics for 157 monitored site -winters.

| Factor | Median | Range | $R^2$ | | |
|---|---|---|---|---|---|
| | | | Fall soil condition factor from WPI | CN | Calculated Q using CN and summed Winter Precipitation |
| Winter Runoff: Precipitation | 0.15 | 0-1.1 | 0.07*** | 0.23*** | 0.02* |
| Winter Runoff (mm) | 28 | 0-182 | 0.15**** | 0.16**** | 0.05*** |

Significance * 0.10, ** 0.05, *** 0.01,****0.001

Table. 7 Winter Precipitation, Winter Runoff Volume, and $R^2$ for regressions between Winter Runoff volume and curve number (CN) or runoff (Q) calculated with summed winter precipitation, by water year.

| Year | n | Range Winter Precipitation(mm) | Range Winter Runoff (mm) | $R^2$ | |
|---|---|---|---|---|---|
| | | | | CN | Q calculated with CN and summed Winter Precipitation |
| 2004 | 17 | 116-206 | 4 - 98 | 0.51*** | 0.38*** |
| 2005 | 17 | 150-202 | 7 - 160 | 0.24** | 0.31** |
| 2006 | 17 | 134-245 | 0 - 43 | 0.10** | NS |
| 2007 | 16 | 134-193 | 7-77 | 0.48*** | 0.68**** |
| 2008 | 16 | 195-293 | 2-154 | 0.28** | NS |
| 2009 | 12 | 118-243 | 48 -127 | NS | 0.42** |
| 2010 | 17 | 92-180 | 1-99 | NS | NS |

Significance * 0.10, ** 0.05, *** 0.01,****0.001

The goal of the event-based modeling effort was to develop a relatively simple method that could adequately describe field-scale runoff during snowmelt and rain on frozen ground for the WPI. First, existing snowmelt algorithms were reviewed. Models considered in this review included more mechanistic tools such as the Water Erosion Prediction Project (WEPP; Flanagan and Nearing, 1995), the Soil and Water Assessment Tool (SWAT; Neitsch et al., 2011) and the Snowmelt Runoff Model (SRM; Martinec et al., 2008). Other less mechanistic approaches were also considered. These included the NRCS National Engineering Handbook (USDA-NRCS, 2004b) and a simple energy balance approach (Kustas and Rango, 1994). The mechanistic models provide a solid science basis for the processes, but were determined to be too data intensive and complex for planning tools like the WPI. This investigation did, however, suggest that the likely reason for the lack of success of a statistical approach was the critical importance of the energy balance as a driver in the snowmelt process.

The degree day method (USDA-NRCS, 2004a) was selected for the modeling effort as it could account for the energy balance in quantifying snowmelt events. The degree day method uses the mean daily air temperature (calculated as the mean of the 24-hr. maximum and minimum air temperatures), a base temperature (32° F or 0° C) and a degree-day coefficient to indicate when melt will occur and melt rate. Furthermore, 24-hour precipitation and snow depth records were used to estimate how much water would be trapped in the snow and how much released for runoff during a 24-hour period. The model was developed using the runoff volumes and measured snow water equivalents from the three monitored project field sites, along with temperature and precipitation water equivalent data from the Dane County Regional Airport (MRCC, 2016). Calculated runoff was determined from the CN formula using the estimated daily water release as precipitation and the March 31 CN for each site generated by RUSLE2 as described previously. All CNs were converted from antecedent moisture condition (AMC) II to AMC III in accordance with USDA (2004a). For each site-winter, we compared the sum of the calculated and measured runoff events (Fig. 10). The complete procedure for calculating winter runoff is described in Appendix D.

Several adjustments were made to obtain the best fit with the observed runoff volume, including adjusting the melt rate coefficient to 0.13, which is at the high end of the range recommended in the National Engineering Handbook (0.035-0.13 inches per degree-day Fahrenheit; USDA, 2004a). Additionally, the snow water-holding capacity was set to 0.7 in/in as discussed in Singh et al. (1997). To account for frozen soil conditions, the initial abstraction was reduced for the CN calculation to half its normal value (Haith et al. 1992, see Appendix D). In 2016, standard December-March winter period was adjusted because the soil was not frozen for early December precipitation events or had already thawed for late March ones. Using the AMC III CN and modified initial abstraction for these events dramatically over-predicted runoff.

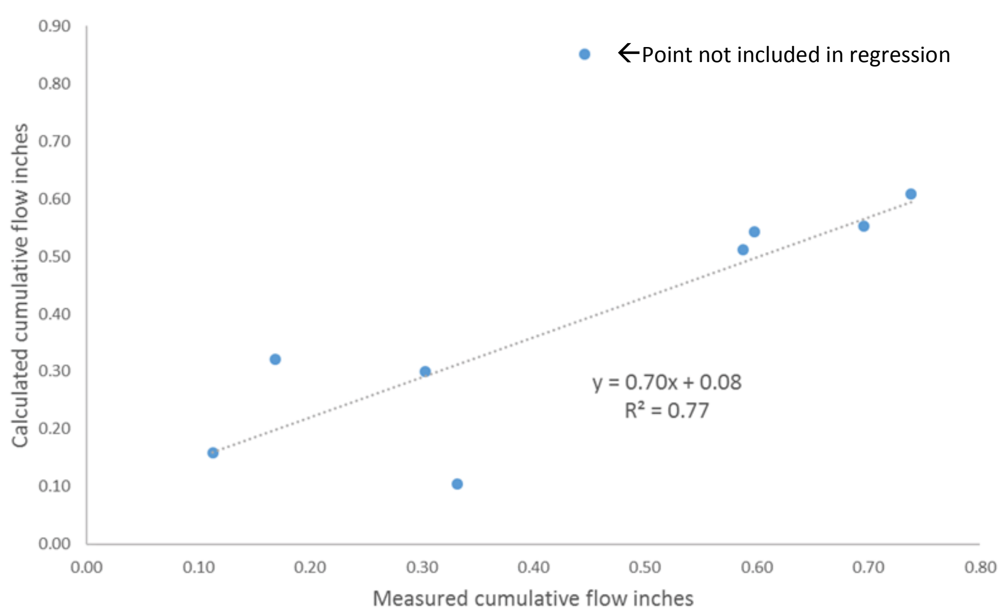


Figure 10. Relationship between measured and calculated cumulative frozen soil period runoff (WR) for three monitoring sites in Dane County, winters 2014-2016.

The slope shown in Fig. 10 was significant (p-value = 0.005) but the intercept was not. One site-year's data point (Site A in 2016; Fig.10) was not included in the regression. With the point included, the regression was significant ($p = 0.047$), but the $R^2$ was only 0.45. The calculated WR for the 2016 site year was much higher than the measured value primarily because there was one melt event in the calculation that was not observed in the measured data. All three sites had this same "non-event" in the 2016 calculations, but it influenced the summed WR for site A more than the others. What was observed at Site A may be a result of the type of errors inherent with using a simple 24-hr minimum and maximum temperature to calculate melt rate, or it may be that data from the airport did not match on-site conditions.

Modeled WR results compared to monitored values from the field sites were sufficiently encouraging to test the model on other sites that did not have measured snow-water-equivalent data. For this analysis, WR was calculated from the snow depth measurements available with the 24-hr precipitation for the nearest observation station (MRCS, 2016) using the procedure described in Appendix D. In addition to the project monitored sites, WR for ARS-M and the Pioneer Farm sites was calculated because they had a range of crops (corn, oats and alfalfa) on a number of different fields at each site. The MMSD Pilot site which was located near our project sites in Dane County and was cropped in alfalfa was also included. These sites covered a range of Hydrologic Soil Group characteristics used in CN determination: all of the Dane County sites were group B, Pioneer Farm sites were group C, and ARS-M sites were group D. When the calculations using the AMC III CN were complete, a relationship similar to that shown in Fig. 10 was apparent for most sites. The obvious exception was WR following established alfalfa (with no fall tillage). Those sites had AMC III CN between 70 and 89, but the model underestimated WR until the CNs following alfalfa were uniformly increased to 96. Using an adjusted CN of 96 there was a near 1:1 relationship between calculated and measured runoff for the alfalfa sites (Fig. 11). Using CN 96 following alfalfa and AMC III CN following all other crops, the regression for all of the sites combined was highly significant ($p < 0.0001$), however overall WR was underestimated (Fig. 12).

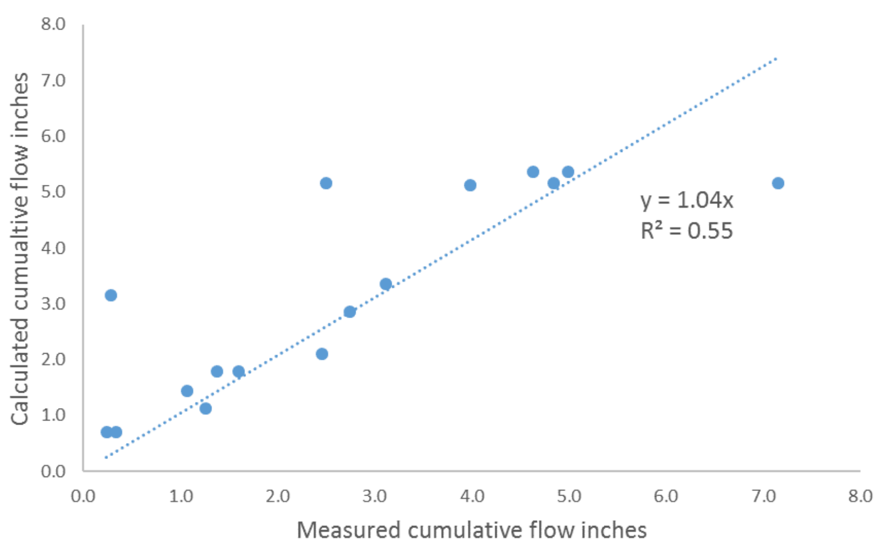


Figure 11. Measured and calculated cumulative frozen soil period runoff (WR) for Pioneer Farm, ARS-M, and MMSD Pilot monitoring sites following established alfalfa. Runoff calculation uses CN of 96.

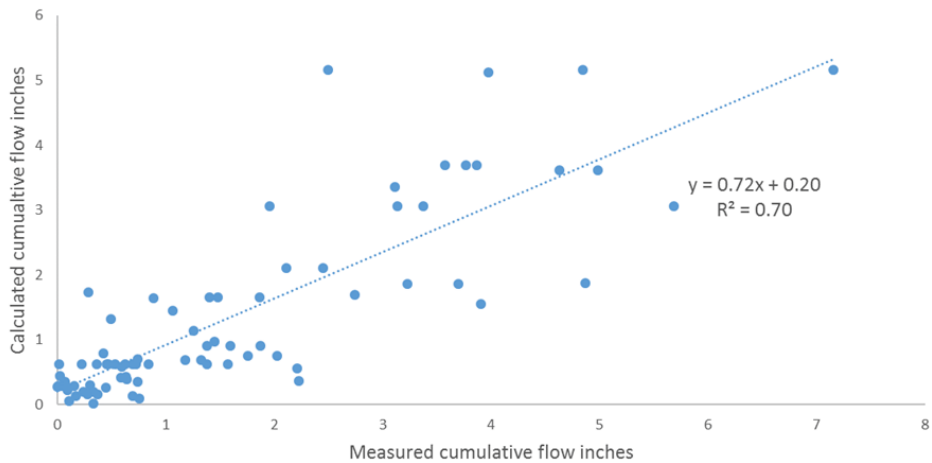


Figure 12. Measured and calculated cumulative frozen soil period runoff (WR) for all UW-Winter Runoff, Pioneer Farm, ARS-M, and MMSD Pilot monitoring sites. Runoff calculations in years following alflafa use CN of 96; all others sites use CN generated by RUSLE2 modified to AMC III.

Efforts were made to further improve the model in order to produce a measured to predicted WR relationship closer to 1:1. Examination of predicted and measured events showed that the model was generally predicting the events correctly and that it was predicting sufficient melt volume to produce the measured runoff. Adjusting the melt coefficients or snow storage rate did not improve model performance. Through iterative adjustment, it was found that increasing the modeled AMC III CN by 2 for our monitored sites (the data shown in Fig. 10) adequately predicted runoff volumes (Calculated cumulative flow = 0.997 x Measured cumulative flow, $R^2$=0.65).

Increasing all of the AMC III CNs by 2 (except for those already adjusted up to 96 for alfalfa) in the larger dataset shown in Fig. 12, resulted in calculated volumes that were still underestimated (Calculated cumulative flow = 0.89 x Measured cumulative flow, $R^2$=0.72). It is possible that the Hydrologic Soil Group C and D soils at Pioneer Farm and ARS-M require greater CN adjustment than the B soils in our project area. It is also likely that some of the underestimation stems from not accounting for snow accumulation occuring with certain management practices. One indication that this might be true is that removing the three site years with an over-winter cover crop from the dataset increases the slope to 0.92 with $R^2$ = 0.73. Increasing the number of runoff sites and years in the analysis would help answer these types of questions. For calculating WR for the Six Mile Creek WPI example fields for this report, AMC III plus 2 CNs was used as they produced a good fit with measured data on our monitoring sites which are in the same area on similar soils.

An additional observation to note about Fig. 12 is that there are some points with the same calculated WR over a wide range of measured WR. For example, the 3 points with calculated WR of 5.2 inches correspond to measured WR ranging from 2.5 to 7.2 inches. These represent watersheds at Pioneer Farm or ARS-M that have the same soil map unit and crop management and therefore the same CN for calculating runoff in that year. The fact that there can be such a wide range of measured runoff on fields with the same weather, mapped soil, and management suggests that while the factors comprising the CN do account for trends across all sites, they do not appear to adequately account for site-specific hydrology.

**Implementing the Winter Runoff Model in the WPI**

To get an average modeled winter runoff volume for specific field conditions, histograms of winter-event volume will be created for each county similar to the ones used in the WPI for rainfall runoff. These are described in Good et al. (2010) and the accompanying 2015 addendum. A representative weather observation station will be selected for each county from the Midwest Regional Climate Center database (MRCC, 2016). We will then follow the steps outlined in Appendix D using temprature, precipitation and snow depth records to calculate daily runoff volume from December through March for a 20-year period for each station. An event size histogram will be constructed to determine the average number of events per year by size class using a 0.05 inch size class increment of available water over the entire range of events. Event WR will be calculated using our modified CN equations and the available water for each size class. Each WR value will then be mutliplied by the average number of events per year in its respective size class to estimate the average annual WR from the events in that size class. The average annual WR from each size class will be summed over all size classes to get the average total WR volume.

## Project Schedule of Events

Table 8: Schedule of project activities from 2012 to 2016. Black boxes indicate when the activity was conducted.

| Activity | 2012 | 2013 | | 2014 | | 2015 | | 2016 | |
|---|---|---|---|---|---|---|---|---|---|
| | Non Winter | Winter | Non Winter | Winter | Non Winter | Winter | Non Winter | Winter | Non Winter |
| P Index inventory and watershed assessment | | | | | | | | | |
| Install prototype monitors | | | | | | | | | |
| Field monitoring frozen soil period runoff | | | | | | | | | |
| Field-test gage user-interface | | | | | | | | | |
| Stream flow monitoring | | | | | | | | | |
| Measure field roughness | | | | | | | | | |
| Measure snowpack | | | | | | | | | |
| Analysis of frozen soil period stormflow volume | | | | | | | | | |
| Flow model comparisons and testing | | | | | | | | | |
| Revision testing | | | | | | | | | |
| Finalize, distribute snowmelt runoff assessment tools, software, publicize | | | | | | | | | |

# Discussion of Quality Assurance

## Project Site

The three part screening for the selection of the agricultural fields formed the project site quality assurance plan. The three part screening process (details provided in the *Field Monitoring* section of this report) ensured that the following factors were accounted for in the selection process: 1) public ownership of the field in two adjoining subwatersheds located in Dane County, 2) physical characteristics listed in Table 1, and 3) inspection of field during rain or snow melt events to ensure field subwatersheds were not influenced by outside runoff. The fields selected using this screening process possessed the broadest array of field conditions, were accessible, and were absent substantial outside runoff.

## Sampling Design and Procedures

The runoff collection stations utilized in this study were comprised of four main components discussed in the *Review of Methods: Field Monitoring Equipment* section of this report. In order to ensure precision, accuracy and reliability of the data, the MHXL-Flume was subjected to additional laboratory and field evaluation. The Ultrasonic Stage Sensor was continuously evaluated during field operations to ensure production of accurate stage data.

### *MHXL-Flume Lab Evaluation*

Three 0.125’ MHXL-flumes were precision machined and tested at the University of Minnesota St. Anthony Falls Laboratory (SAFL) in order to develop rating curves for the MHXL-flume series. Laboratory tests included installation of the three flumes in series and subjecting flumes to multiple flow rates to determine the stage-discharge relationship. Discharge was measured using time capture techniques as well as measurements from pre-calibrated in-line flumes (1.0’ and 2.5’ H-flumes). Seven discharge rates were utilized to establish the stage-discharge relationship for the low-flow portion of the flume (<=0.125’ stage; Fig. 13), and 11 discharge rates were used to establish the stage-discharge relationship for the high-flow portion of the flume (>0.125’ to 0.5’ stages; Fig. 14). Plots of data with polynomial regression trend lines indicate a strong relationship between stage and discharge and are included below (<=0.125’ stages $R^2$ = 0.9958, >0.125’ stages $R^2$ = 0.9986).

In order to determine accuracy and precision of flume discharge estimates, 138 pairs of stage and discharge measurements were obtained from 12 prototype flumes. The stage values were used to determine estimates of discharge using a scaled version of the 0.125’ rating curve. These data were compared to measured discharge obtained using time capture techniques for low discharges and flume (1.0’ and 2.5’ H-flumes) measurements for higher flows. Fig. 15 illustrates that the low-cost MHXL-flumes produced precise estimates of discharge ($R^2$ = 0.9968) but the results were less accurate than the more expensive machined flumes and generally underestimated discharge (slope of the line = 1.0658).

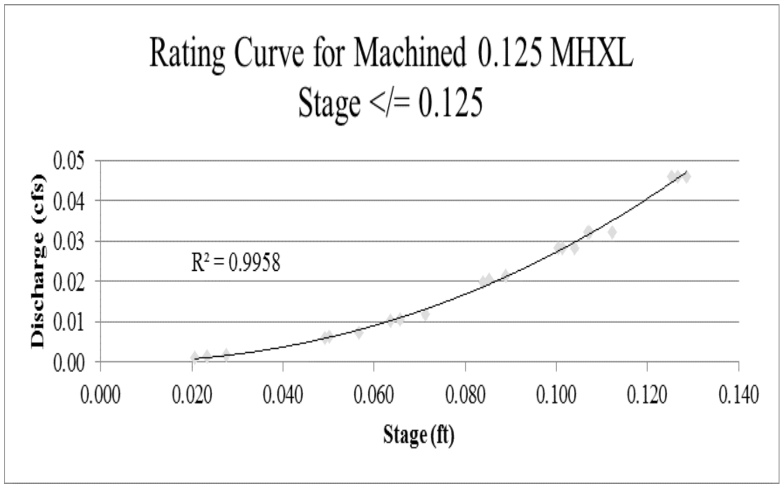


Figure 13. MHXL low-flow rating curve

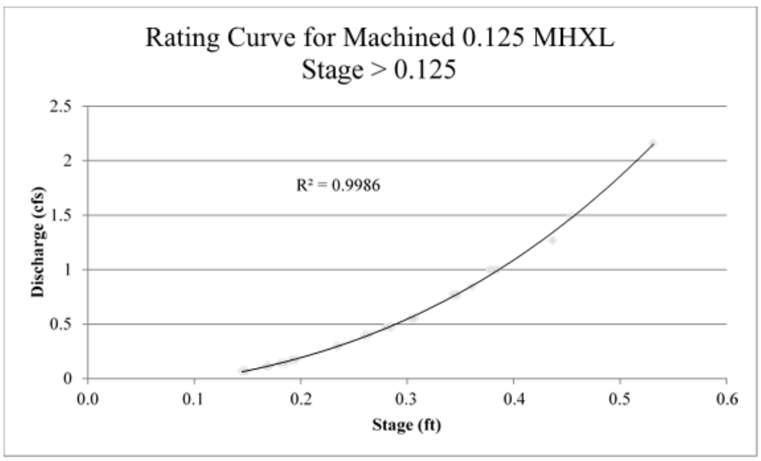


Figure 14. MHXL high-flow rating curve

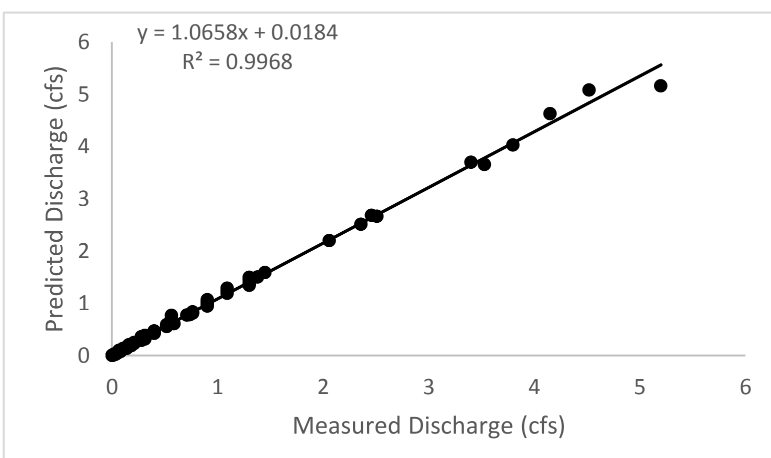


Figure 15. Linear regression of measured discharge against predicted discharge (based on scaled 0.125' MHXL rating curve

While results are encouraging, lab and field test results indicate that at high discharge rates flow within the flume becomes turbulent and difficult to gauge; this condition is exacerbated with below-grade installations. Such conditions may be resulting in underestimation of discharge rates.

*Field Evaluation of Equipment*

Field evaluation of the MHXL-flume during snowmelt monitoring demonstrated that while the flume was reliable and the design greatly facilitated ice removal prior to events, a site visit was still required by technicians in order to operate the flume heater and clear ice from the flume prior to the start of the runoff event. The efficiency of operating runoff gauging stations during snowmelt would be greatly enhanced if the operation of the heating system could be conducted remotely without the need for a site visit by a technician.

Records indicate that ice formation was a frequent occurrence during the snowmelt monitoring season. At the Site A gauging station there were 14 events. Of the 14 events, 9 had ice before and/or after the event, 4 events had a large amount of sediment accumulated or standing water in the flume, and 1 event had ice occur during the event. The event that had ice occurring during the event was a multi-day event when the flume froze overnight. At the Site C gauging station there were 12 total events. Of the 12 events, 5 had a large amount of sediment accumulated or standing water in the flume, 5 had ice before and/or after the event, and 1 of the events had ice occur during the event. For Site B there are about 6 events; 4 of these events had ice during the event, and 2 of these events had ice only occurring before or after the event. The event that had ice occurring during the event was a multi-day event when the flume froze overnight.

*Ultra-Sonic Stage Measurement*

The field evaluation of the ultra-sonic stage measurement system was comprised of a comparison between stage values recorded by the ultra-sonic system and the stage values recorded by a technician at the same time at each gauging station (Figs. 16-18). A visual analysis of the linear regressions (Figs. 16-18) indicate that the slopes of all the regression equations are nearly 1 and that the $R^2$ values are all greater than 0.97. Based on these linear regressions, the ultra-sonic stage measurement systems accurately measure stage height in a replicable manor.

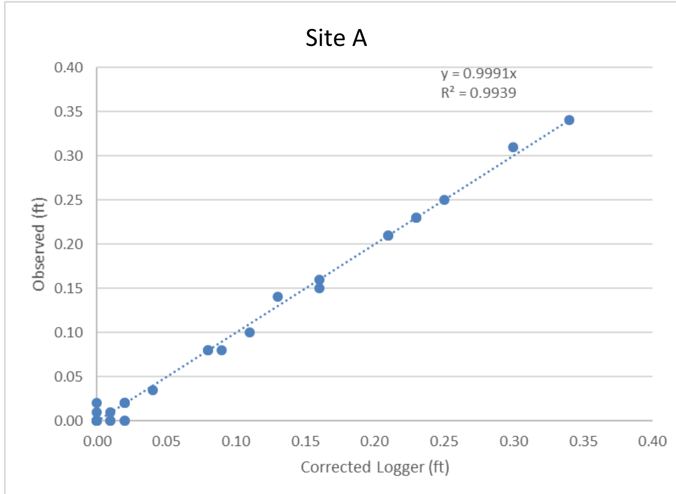


Figure 16. Ultra-sonic stage logger (x-axis) versus technician stage observation (y-axis) at Site A

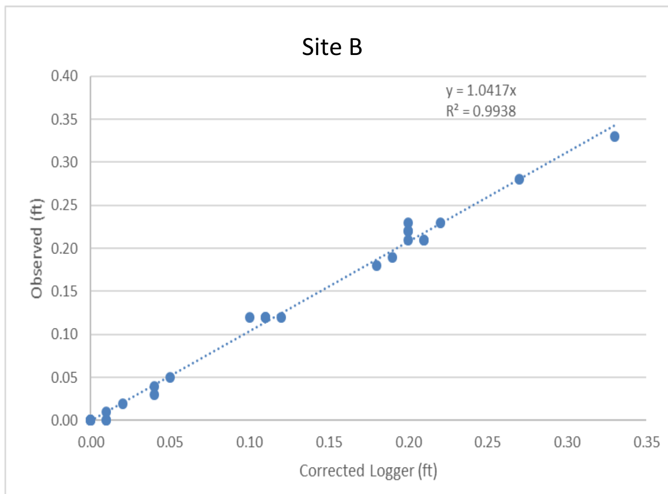


Figure 17. Ultra-sonic stage logger (x-axis) versus technician stage observation (y-axis) at Site B

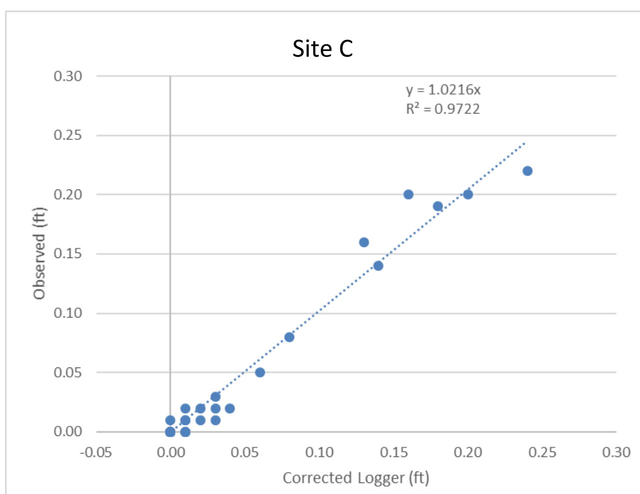


Figure 18. Ultra-sonic stage logger (x-axis) versus technician stage observation (y-axis) at Site C

*SWE Analysis*

A linear regression analysis was utilized to compare individual SWE cores to snowpack depth measurements and to ensure quality and replication of the SWE method and data. The SWE of individual cores was calculated by multiplying the snow core depth by its gravimetrically measured density. Linear regressions between the six individual SWE measurements and corresponding depths at each field site produced suitable fits ($R^2$ ranging from 0.78 to 0.99; example for site A in Fig. 19) for further analysis. The linear regression for each field and the average snowpack depth (average of the 20 snow depth measurements) for that field were used to estimate a field average SWE. Rainfall was also factored into field average SWE if all of the following were met: 1) the rainfall occurred subsequent to the completion of the snowpack melt, 2) the rainfall occurred on frozen soil, 3) the rainfall originated prior to the winter season end date of March 31st. The estimated average snowpack values were used in the WR model to more accurately reflect field conditions compared to those provided by the offset Madison Dane Regional Airport Weather Station.

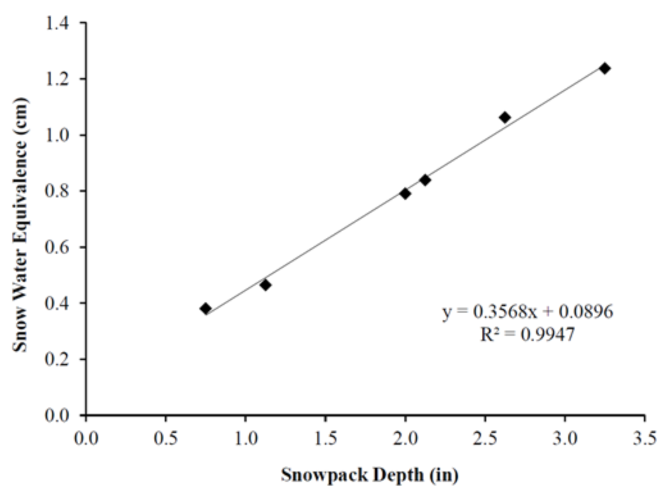


Fig. 19. Linear regression for site A on March 3, 2016 to illustrate the suitable relationship between the six individual SWE measurements and their corresponding snowpack depths.

## Data Analysis and Quality Control

### *Field Equipment Quality Assurance Protection Plan: In Brief*

Significant efforts were invested in quality assurance activities to promote collection of reliable data that accurately reflect field conditions. These activities are described in detail in Appendix G: Quality Assurance Protection Plan (QAPP). In brief, the QAPP applies to activities including daily monitoring of uploaded site photos and logger data, as well as daily checks of forecasted weather to ensure that stations were prepared for runoff events. If imagery or logger data indicated problems, such as low battery, sediment in the flume, or ice in the flume, a technician serviced the hardware prior to the next expected event. After runoff events, data were downloaded from cloud servers and stage values were plotted against observed stage values (on-site technician observations and time lapse photo observations) to ensure accurate stage values were recorded. Time lapse photos were also used to improve data corrections in the case of ice or sediment accumulation in the flume.

During site visits technicians completed a site checklist and conducted simulated events to ensure systems were functioning as expected. Events were simulated by placing a target of known dimensions under the ultrasonic stage sensor and comparing observed stage to logged stage. During simulated events technicians would also ensure that discharge was calculated correctly and data was uploading as expected.

# Findings

## Winter Runoff Findings

In the new winter runoff model, the RUSLE2 daily CN for the field is the only factor in the equations that accounts for variations in field conditions. Within the RUSLE2 software, CN is recalculated daily taking into account empirical observations of interactions between soil properties (as represented by Hydrological Soil Group), soil surface roughness, soil biomass (buried residue, roots), ground cover, and soil consolidation (USDA-ARS 2013). Soil consolidation is an index based on time since mechanical disturbance. Increasing soil biomass reduces the daily CN, reducing calculated runoff. Tillage generally decreases the daily CN for some interval afterwards. It is likely that some of the empirical daily CN equations do not properly reflect soil and field condition interactions for frozen soil. For example, fields following established alfalfa generally had lower daily CN than fields with similar soils following corn silage. However, raising the CN for the over-wintering alfalfa fields was found to improve the models fit to observed runoff data. The reason for the comparatively larger winter runoff from alfalfa is unknown at this time. Speculative reasons include snow accumulation in the alfalfa, surface sealing, and compaction (Fig. 20). Examining a larger field runoff dataset might allow empirical improvement of the CN calculations for frozen soils. Furthermore, while the RUSLE2 daily CN calculation integrates the effects of a number of properties initially thought to influence winter runoff volume, it does not account for others, notably aspect, contouring (oriented ridges), and slope. The effects of these properties on aggregated WR were unable to be identified through statistical analysis, but effects might be discernable through analysis of individual runoff events with an expanded field runoff dataset.

Figure 20. Snow covered alfalfa field

## Winter Runoff Phosphorus Loss Risk Assessment in Six Mile Creek

In Six Mile Creek's merged WPI database, documented crop rotations on the 373 fields ranged from two to eight years. Rotations included both alfalfa or alfalfa-grass hay and row crops on 185 of the fields (2,842 acres). The remainder were in rotations of continuous corn (silage and grain), corn and soybean, or corn soybean and wheat. Some tillage with either one or two passes per crop was common. Only 29 fields (632 acres) were completely no-till during the documented rotation. Almost all of the fields had fall and/or spring manure applications during one or more of the crop years in the rotation, but only 13% had winter applications.

Estimated particulate P losses were greater than soluble P losses for almost all fields in Six Mile Creek. Total WPI ranged from 0.1 to 17, with a median of 3, and the proportion of the total WPI coming from dissolved P released from soil and amendments (Soluble WPI) decreased as the WPI increased (Table 9). With the current method of calculation, WR has a much smaller volume range than rainfall runoff (RR) (Table 9). The maximum average WR is 1.8 because the base winter runoff for this area is 0.9 inches and the maximum FSCF is 2. In contrast, the distribution of Soluble WPI values from winter runoff is similar and only slightly lower than that from rainfall runoff (Table 9). This comparatively large contribution of soluble P in winter runoff relative to runoff volume is because winter Soluble WPI calculations used larger frozen soil period runoff to precipitation ratios in calculating dissolved P from manure remaining on the surface after fall or winter applications.

Table 9. Distribution of rotational average Wisconsin P Index (WPI) values and annual component calculations for Six Mile Creek fields.

| **Rotational Average WPI** | | | | | |
|---|---|---|---|---|---|
| | Min | 1st Quartile | Median | 3rd Quartile | Max |
| Total WPI | 0.1 | 2.0 | 3.0 | 4.5 | 17.0 |
| Soluble WPI (% of total WPI) | 64% | 35% | 24% | 23% | 13% |
| **Annual Components WPI Calculations** | | | | | |
| | Min | 1st Quartile | Median | 3rd Quartile | Max |
| Annual Rainfall Runoff (in) | 0.3 | 1.3 | 2.1 | 2.7 | 7.7 |
| Annual Winter Runoff (in) | 0.4 | 1.1 | 1.8 | 1.8 | 1.8 |
| Annual Rainfall soluble P losses* (WPI lb/a) | <0.1 | 0.2 | 0.3 | 0.5 | 3.7 |
| Annual Winter soluble P losses** (WPI lb/a) | <0.1 | 0.1 | 0.2 | 0.3 | 3.3 |

*Includes dissolved P losses from soil in runoff and from manure and fertilizer applications in the fall, spring, and summer

** Dissolved P losses from soil in winter runoff and from manure applied in the winter.

Comparing Soluble P losses calculated with the current and new WR methods, we found use of the revised WR model is not likely to change the overall distribution between particulate and soluble WPI components for watershed fields. However, it will change the calculated winter soluble P losses in individual years for fields with a range of WPI values.

For the representative low WPI field, the rotational average WPI was 1, with dissolved P losses constituting the majority of the losses (Fig. 21a). Despite having an excessively high soil test P (STP) of 77 ppm and steep (9%) average slope, particulate P losses were relatively low because the field was in continuous no-till. Winter runoff accounted for 78% of the original WPI calculated soluble P losses, with the largest source being a winter manure application in one year of the rotation. The revised WR model resulted in very little change in overall winter runoff losses, but there were large differences between the results of each model in each winter (Fig. 21b). These differences are a result of the differences in crop management's impact on runoff volume in the two models. With the new model, the winter with the manure application had 65% less runoff, resulting in 48% lower winter dissolved P losses. If the winter manure application on this field had been before the first year of corn following an alfalfa crop, the dissolved P losses under the new model would have been much greater due to the approximately three times greater average winter runoff following alfalfa than no-till corn on this field.

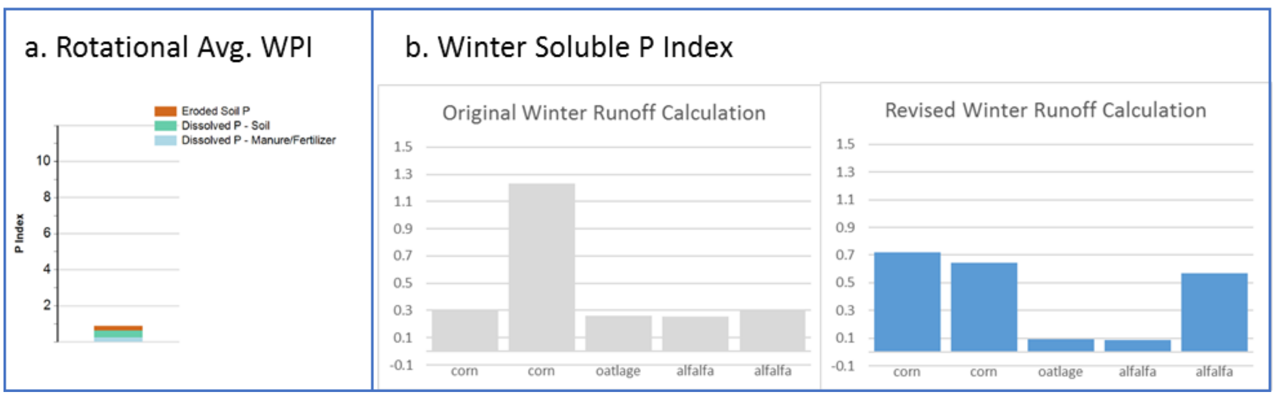


Figure 21. Representative lower runoff P loss in Six Mile Creek Watershed: a. Original rotational Wisconsin Phosphorus Index (WPI), b. Winter Soluble P Index by crop year calculated with the original and revised WR volume method. Winter Soluble P Index columns labeled with following crop.

The representative high WPI field had the same Ringwood silt loam soil with average 9% slope as the representative low WPI field, and also had a similarly high STP of 93 ppm. The greater expected average P losses for this field were due to particulate P losses as erosion was much greater than for the low WPI field with less surface cover and more tillage. The three Adaptive Management Pilot Project alternative field managements: low disturbance manure injection (LMDI), use of cover crops, and strip-till brought the field rotational average WPI value down substantially through reducing erosion (Fig. 22 I-IV a). For the original management, LMDI, and strip-till, using the new WR model did not substantially affect over-all winter losses, though there were differences in the results for each crop year (Fig. 22 I, II, IV b). The no-till scenario with a cover crop after corn silage had the lowest total WPI and the highest Winter Soluble WPI values with the new WR model (Fig. 22 III a and b). The winter soluble P loss was high due to a surface manure application in the fall prior to a high-runoff winter.

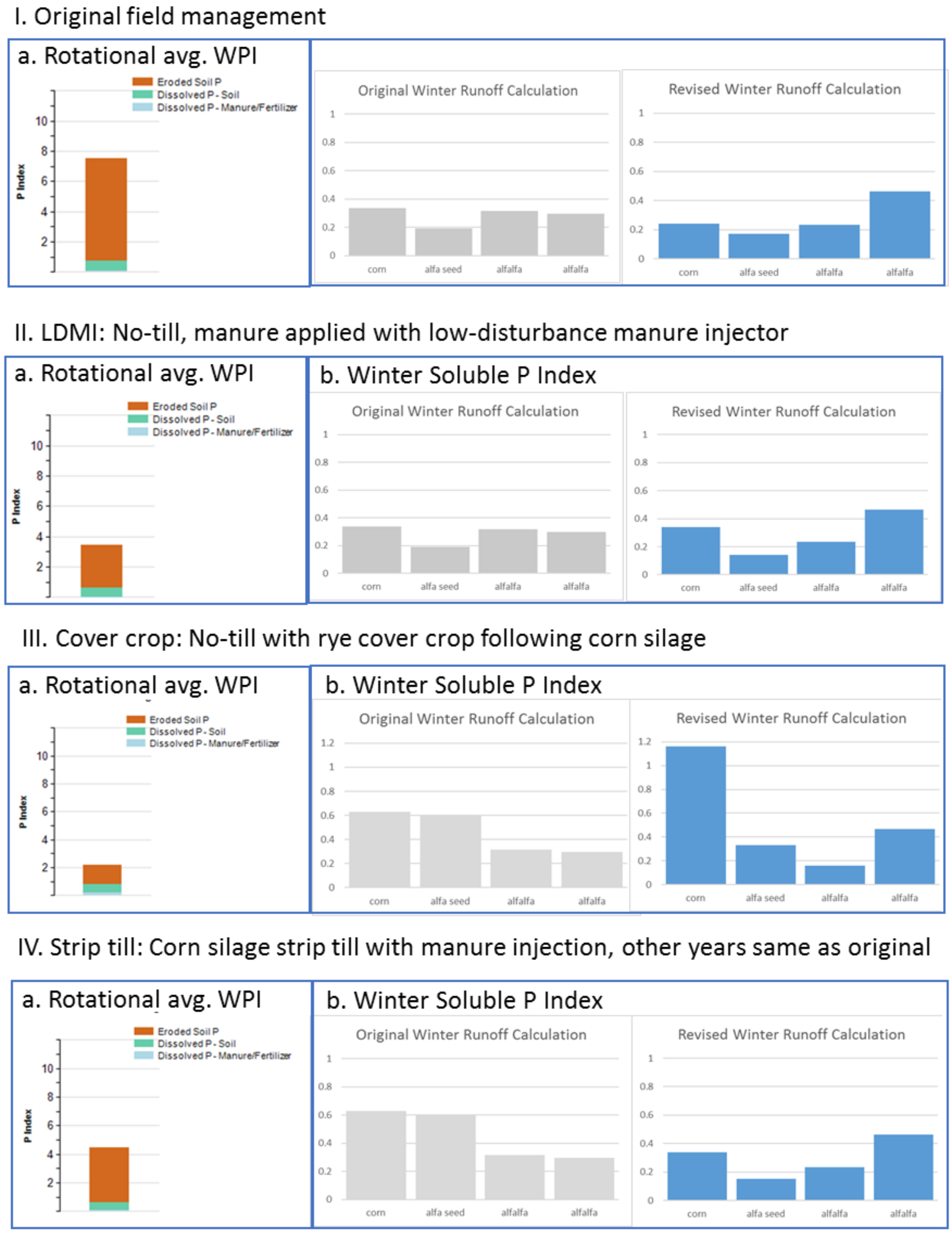


Figure 22. Representative high runoff P loss in Six Mile Creek Watershed with original and remedial management scenarios. For each scenario: a. Original rotational Wisconsin Phosphorus Index (WPI), b. Winter Soluble P Index by crop year calculated with the original and revised winter runoff volume method. Winter Soluble P Index columns labeled with following crop. Field characteristics include: Ringwood silt loam soil, 9% slope; crop rotation of Fall chisel-plowed silage and alfalfa seeding, 2 years alfalfa; with liquid manure incorporated with tillage plus spring surface application before alfalfa.

# Conclusions and Recommendations

**Winter Runoff Assessment**

The WR model developed as part of this project will give water quality planners a better tool to address agricultural runoff quality from snow covered and frozen ground. It appears to be sufficiently robust to predict snowmelt runoff volumes for planning level applications at the field scale. As shown in the Six Mile Creek examples, the use of this model may not significantly change rotational WPI values but it can indicate high runoff risk fields for unincorporated fall and winter manure applications. We will incorporate the WR algorithms into the WPI in the SnapPlus nutrient management planning software and into a barnyard runoff water quality management tool currently under development.

This empirical model can and should be refined with additional field runoff data. Before final implementation, we plan to expand the monitored winter runoff dataset to include more sites with different types of crops and soils. Testing the WR model with more data may identify how best to adjust CN to achieve a 1:1 relationship between measured and predicted WR. In addition, when processing the 20-years of precipitation and temperature data for each observation site, we will automate the process for determining when the soil is not frozen or snow covered in the December – March "winter" period. December events that occurred before the soil is frozen and March events that occurred after thaw will be categorized as fall and spring events, respectively, and included in the appropriate season's rainfall histogram. We will also identify April events that occurred prior to melt and include those in the winter histogram.

**Field Instrumentation**

The MHXL-flume and ultra-sonic stage measurement system, through laboratory and field evaluations, has been shown to be a reliable and accurate instrumentation system for measuring winter snowmelt runoff volume. The addition of the heating system to the MHXL-flume has also facilitated the efficient removal of ice prior to or after a winter snowmelt event. The efficiency of the current MHXL-fume heating could however be improved if the heating system could be remotely operated. Remote operation of the heating system paired with the wireless stage camera would allow the MHXL-flume to be cleared of ice prior to a melt event or used to prevent ice formation during an event without the need for a technician to be physically present at the station. The wireless stage camera would provide real time visual documentation of the operation of the remotely operated heating system as well as the progression of ice thawing.

The low-cost data logging system with user interface is a field tested, functional, and reliable system for recording runoff volume data. The system is also capable of flow-weighted water sampling and is adaptable to a variety of primary flow measuring devices (i.e. H-Flume, MHXL-Flume, custom flume). Designed to be user friendly, the user interface display continually rotates real time flow and program information to the user without the need for program training. The interface is also easily programmable and remotely accessible. A fact sheet is also being developed (draft shown in Appendix F) to promote the low-cost edge-of-field runoff monitoring system developed in this project.

Power supply to the data logging and stage measurement system did at times encounter low power situations requiring the exchange of batteries. Prolonged active monitoring at times lead to these low power situations as the power demand from the system exceeded the recharge rate provided by the solar panels. The newest version of the data logging system in development by Dennis Busch (project Co-PI) utilizes about 50% less power and therefore minimized the potential for future low power situations.

# Appendices

## Appendix A. References


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## Appendix B. User-Interface for Prototype Data Logger

# Development of an integrated user interface for the low-cost prototype data logging device used in surface-water runoff monitoring.

**Project:** P-Index and Snowmelt Runoff Risk Assessment: Demonstration and Refinement

**Funding:** USDA NRCS Conservation Innovation Grant (CIG)

**Author:** Dennis L. Busch, Senior Scientist UW-Platteville Agroecosystems Research Program

One of the deliverables for this CIG project was the development of a user-interface for the low-cost prototype data logger being developed to collect edge-of-field surface-water runoff data within NRCS Conservation Activities 201 and 202. This report summarizes efforts related to the development and field testing of the interface and describes methods for adjusting logger settings and in-field data acquisition.

The image below illustrates the user interface that was integrated into the low-cost data logging system. The interface includes and 4x20 LCD screen and 4x4 matrix keyboard. The user interface represents a significant improvement in the functionality of the data logger for the following reasons:


1. Status of the logging system can easily and quickly be determined without the need for any peripheral device or knowledge of the system by simply reading data from the screen;

2. It allows users to view current data and important settings without the use of a complicated menu structure;

3. The interface greatly simplifies initialization of the system because it eliminates the need for an additional external device, such as a laptop, previously required to make changes to settings;

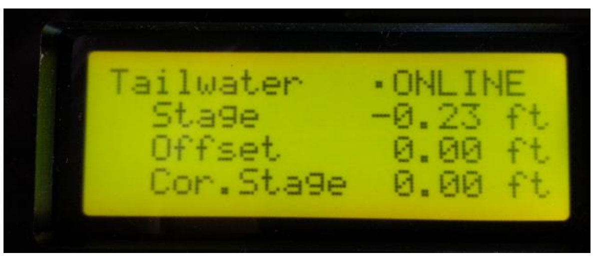
4. In conjunction with the user-interface we added a pause logging capability which allows users to extract the sd card and download data quickly and easily; and

5. Adjustments to settings such as sample interval are very simple with the user interface.

# Data Logger Home Screens

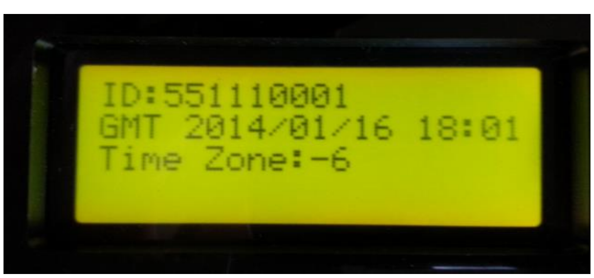
The user interface on the upgraded data logging units continuously scroll (30 seconds per screen) through four "home screens" that display current data related to stage measurements, discharge estimates, and logger settings (e.g. sample interval, site id, timestamp, and time zone). This allows technicians to view current data without accessing via a complicated menu structure. The images and text below describe in detail the information displayed on each of the home screens.


**ONLINE**- Indicates that data logger is connected to Ethernet device.
**Flume Stage**- Sensor output, depth of water in flume.
**Flume Offset**- Adjustable user entered offset. Used to set Cor. Stage = observed stage.
**Flume Cor. Stage**- Stage that has been corrected by the offset. Should be the same as Observed Stage
**Stage – Offset = Cor. Stage**




**ONLINE**- Indicates that data logger is connected to Ethernet device.
**Tailwater Stage**- Sensor output, depth of water downstream of flume.
**Tailwater Offset**- User applied offset to adjust observed stage to logged stage.
**Tailwater Cor. Stage**- Stage that has been corrected by the offset. Should be the same as Observed Stage.


**FF Stage-** Free Flow Stage, the stage value corrected for submergence of flume.
**Current Q**- Discharge rate (cfs) calculated based on stage and discharge equation.
**Total Q**- Sum of discharge over monitored period (not single event).
**Sample Int.-** Sample Interval, flow (cf) between sample collections.




I**D:** Site Identification, NRCS FIPS for state(WI=55) and county
(Sauk = 111), and site ID (e.g. 0001)
**GMT**- Timestamp in GMT or UTC time.
**Time Zone-** difference between local time and UTC/GMT.

# Data Logger Keypad


A = Up Arrow / negative sign

B = Down Arrow

C = Clear/Backspace

D = Decimal

* = Enter / Menu Access

## *How do I change the flume stage values?*

Corrected Flume Stage should equal observed stage. If they are not the same, the Corrected Flume Stage can be adjusted by a user-entered Flume Offset.

Calculation: **Flume Stage – Flume Offset = Flume Cor. Stage**

Example: If the flume stage is 0.00 and the information below is displayed on the data logger, how do adjust settings so observed stage equals Flume Corrected Stage?

Flume Stage = 0.04
Flume Offset = 0.00
Flume Corrected Stage = 0.04

Answer: Increase the Flume Offset to 0.04 feet.

**Keypad Entry**

| | |
|---|---|
| 1. Press "*" (enter) on the keypad | * |
| 2. "Flume Offset" should be selected on the next menu. | |
| 3. Press "*" (enter) | * |
| 4. Press "A" (up arrow) four times to increase flume offset to 0.04' | A |
| 5. Press "*" (enter) | * |

## *How do I change the sample interval?*

| | | | |
|---|---|---|---|
| 1. Press "*" (enter) on the keypad to enter menu. | * | | |
| 2. Press "B" (down arrow) until "Sample interval" is selected | B | | |
| 3. Press "*" (enter) | * | | |
| 4. Enter sample interval (cf) using keypad numbers. Example: 100 cubic feet. | 1 | 0 | 0 |
| 5. Press "*" (enter) | * | | |

# Menu Structure

## Press  to enter Menu

1) **Flume Offset**- Up or down arrow to change offset by increments of 1/100th of a foot.
2) **Tailwater Offset**- up or down arrow to change offset by increments of 1/100th of a foot.
3) **Sample Interval**- Use keypad to enter volume in cubic feet between collected samples
4) **Pause Logging**
5) **Credit**
6) **Exit**
7) **Initialization**
    a) **PreSamplePurge**- Runs pump backward to purge line. Enter value in milliseconds (e.g. 20 seconds should be entered as 20000)
    b) **CollectionDuration**- Length of time to run pump forward and collect sample (milliseconds)
    c) **PostSamplePurge**- Run pump backward to purge line (milliseconds).
    d) **SiteID**- NRCS FIPS codes for state and county plus site ID (e.g. 551110001)
    e) **Discharge Eq. Type**
        i) **1.0’ H-flume**
        ii) **2.0’ H-flume**
        iii) **2.5’ H-flume**
        iv) **0.25’ MHXL**
        v) **0.375’ MHXL**
        vi) **0.5’ MHXL**
        vii) **Custom Flume** (3rd order polynomial)
        viii) **Manning Equation**
    f) **Sensor offset-** distance from flume floor to back of sensor.
    g) **Network**- IP and MAC address
    h) **Adjust Date/Time**
        i) **Time Zone**
        ii) **Adjust Date (GMT)**
        iii) **Adjust Time (GMT)**
    i) **File management**- list of downloadable files.
    j) **Back**

## Appendix C. Source of Runoff Monitoring Data used for Winter Runoff Volume Analysis

| Farm or Project | WI County | Years of monitoring | Number of field watersheds | Crop types | Source for runoff volume and field management data |
|---|---|---|---|---|---|
| UW-A | Columbia | 2004-2006 | 1 | No-till corn grain | J. Norman, UW-Madison Soil Science |
| UW-B | Buffalo | 2004-2006 | 2 | No-till corn, alfalfa | J. Norman, UW-Madison Soil Science |
| UW-K | Winnebago | 2004-2006 | 1 | Fall tilled corn, soy | J. Norman, UW-Madison Soil Science |
| UW-KE | Waukesha | 2004-2006 | 1 | Alfalfa | J. Norman, UW-Madison Soil Science |
| UW-O | Ozaukee | 2004-2006 | 1 | Fall tilled corn silage, alfalfa | J. Norman, UW-Madison Soil Science |
| DF-1 | Sheboygan | 2007-2011 | 3 | Pasture, over-wintering pastures | US Geological Survey, UW Discovery Farms |
| DF-2 | Kewaunee | 2004-2008 | 3[1] | Fall tilled corn silage and alfalfa | US Geological Survey, UW Discovery Farms |
| DF-3 | Lafayette | 2004-2010 | 3 | No-till corn grain and silage, soy | US Geological Survey, UW Discovery Farms |
| ARS-M | Marathon | 2007-2014 | 4[2] | Tilled corn silage, oats, alfalfa | W. Jokela, US Agricultural Research Service |
| Pioneer Farm | Lafayette | 2003-2012 | 11 [1,2] | Tilled corn grain, silage, oats, alfalfa | US Geological Survey and D. Busch, UW-Platteville Pioneer Farm |
| WBM | FondduLac | 2013-2014 | 1 | Grass alfalfa hay | US Geological Survey and W. Branch Milwaukee River Project |
| MMSD Pilot | Dane | 2011-2013 | 1 | Alfalfa | USGS, Dane County Land Conservation Department |
| UW-Winter Runoff | Dane | 2104-2016 | 3 | No-till and tilled corn, soy | This project |

[1]All sites not monitored in all years.
[2] Analysis did not include data from all monitored site years.

## Appendix D. Procedure for Calculating Available Water and Snowmelt Event Runoff

### I. Calculating volume of water available for runoff

**Step 1.** Select appropriate weather observation site from Midwestern Regional Climate Center cli-MATE database ( http://mrcc.isws.illinois.edu). Download needed data for selected time period: Date, Daily Mean Temperature (DMT°F) Precipitation (P, water equivalent, inches), Snow fall (SF, in) Snow Depth (SD, in).

**Step 2.** Processing winter-period data.

a) Substitute 0 for all of the precipitation and snow measurements that have a T for trace
b) Remove all M (for Missing) for snow depth or other data. Exam each missing date to enter reasonable values. Where necessary, review the data for that date for nearby stations to determine substitutions.
c) Adjust winter period by removing days from the beginning and end of the selected winter period (Dec. 1 through March 31 for southern half of Wisconsin) with Mean Temperature greater than 32° F. that day and for the 9 preceding days and no standing snow. Also examine early April in the record to determine if there was an unbroken sequence of more than 10 days with Mean Temperature less than 32° F with snow depth greater than 0 that continued into April. Include April daily records that fit this description as winter records.

**Step 3.** Calculate Water available for runoff from snowmelt plus precipitation for each day by calculating the following:

**Degree days (DD)** is DMT - 32° F.

**Accumulated frozen precipitation (AFP)** is the water equivalent of the snowpack at start of day. If no snow (Snow Depth =0), accumulation is 0 (note that this zeroing out of accumulation does cause a "gap" on some melt days if the snow pack is measured at the end of the day, but need to keep the zeroing out as a check against continuing to accumulate water after the snow is gone). If Snow Depth > 0, AFP is Prior day's AFP + Prior day's P - minus Prior day's AWR (defined below). Sometimes in this method the estimated AFP water equivalent in inches becomes greater than the standing snow, but this is unrealistic frozen precipitation build up is corrected when measured SD goes to 0. Note: When measured snow water equivalent information is available, it should be used for AFP.

**Melt rate** in inches per day is the Degree day coefficient for melt (DDC) x DD. DDC = 0.13 in/degree day F. This is only calculated when both DD and SD are greater than 0.

The snow-water-capacity calculations below account for rain and melt water storage in the snow pack. When this storage is not accounted for, calculated water release comes too quickly and frequently.

**Original snow water capacity (OSWC)** is the water holding capacity in inches of the standing snow from yesterday and equals Prior day's SD + SF in inches times 0.07 inch water holding capacity per inch.

**Available snow water capacity (ASWC)** assumes that if the prior day's AWR is greater than 0, then the prior day's ASWC was over-filled by P or melt water and the only additional source of storage is new SF. If there was no water release the day before (Prior day's AWR = 0), then the storage in inches is the minimum of either (Prior day's ASWC + (Prior day's SF x 0.7) – Prior day's AWR) or today's OSWC. Keeping

ASWC at or below the OSWC maintains realistic capacity when standing snow depth is lowered through consolidation, evaporation, etc. and storage capacity is reduced.

**Available Water for Runoff (AWR)** is unadsorbed liquid water in inches.

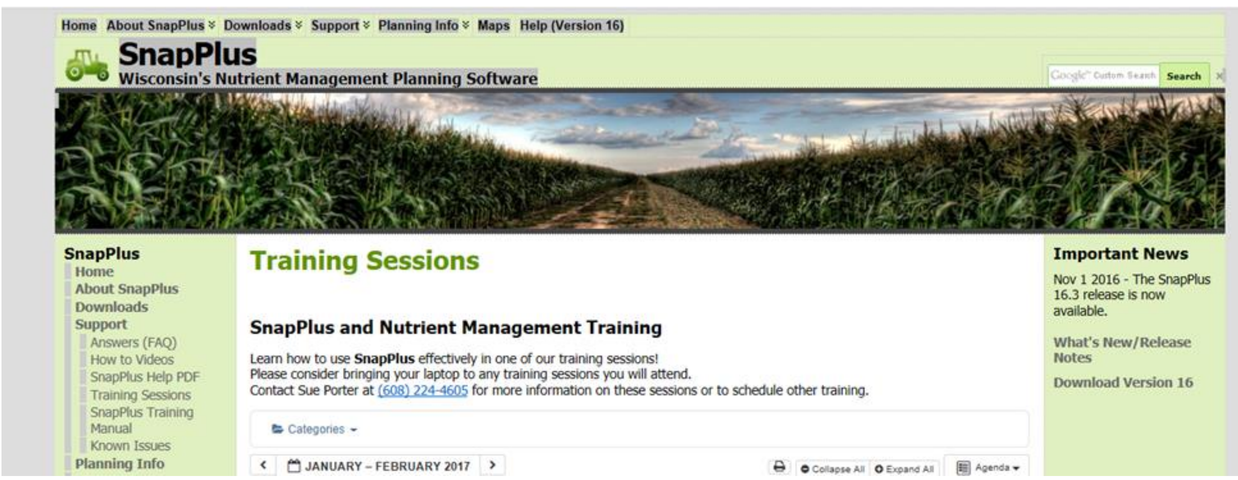
- If DMT is 32° or below, AWR is 0.
- If DMT is > 32° F (Melt rate >0), and if today's ASWC is > than P + Melt rate, then AWR is 0.
- If DMT is > 32° and SD = 0, then AWR=P.
- If DMT is > 32° and SD > 0 and ASWC < P + Melt rate and Melt rate is > AFP, then AWR = P + AFP.
- If DMT is > 32° and SD > 0 and ASWC < P + Melt rate and Melt rate is < AFP, AWR = (P + Melt rate - AWSC).

**II. Calculating Winter Event Runoff**

1) From RUSLE2 field calculation output, select the daily curve number (CN) for March 31 of the crop year.
2) Convert the RUSLE2 CN from Antecedent Moisture Condition (AMC) II to AMC III.
3) Calculate flow (Q) using a modified runoff curve number (CN) equation. To account for frozen conditions, the initial abstraction is set at 0.1S rather 0.2S, where S= ( 1000/CN)-10.
   Where AWR > 0.1S, $Q = (AWR-0.1S)^2/(AWR+0.9S)$.

## Appendix E: Winter Runoff Risk Assessment Education and Outreach

Following review by Wisconsin NRCS and state agencies, the SnapPlus development team at the UW-Madison will incorporate it into their nutrient management planning software (free download from http://snapplus.wisc.edu/. In SnapPlus, it will be used within the Wisconsin P Index calculations and to provide field winter runoff risk ratings on the Winter Spreading Plan report. Information on this winter runoff risk assessment In SnapPlus will be posted when the revised version is available for download. At that time, it will be incorporated into the training program, Help materials, and How-to-videos posted under Support on snapplus.wisc.edu. Winter runoff risk assessment will also be included in SnapPlus and nutrient management training materials for farmers. On the next page is an example winter runoff fact sheet.




Winter runoff risk assessment will also become part of the Runoff Risk Advisory Forecast (RRAF) website (http://www.manureadvisorysystem.wi.gov/app/runoffrisk) on the "Need to spread on a high risk day?" page. The RRAF website is currently being completely revamped to accommodate a new 4-km$^2$ gridded forecast model from the National Weather Service. Information similar to the example fact sheet will be included on the new site to help farmers identify factors that make winter runoff risk vary at the field scale.

# SnapPlus

Wisconsin's Nutrient Management Software

Resource Management

## Snowmelt Runoff Potential

### What you should know to avoid spreading manure on runoff-prone fields

Year-round runoff monitoring of Wisconsin cropland shows that some fields have more runoff in snowmelt and rain on frozen soil in a year than they have with rainfall. When considering where and how to make late fall and winter applications of nutrients, the runoff-generation potential of a field should be considered in addition to its proximity to surface water and drainage pathways. Year to year weather variability makes it hard to see patterns in how field conditions affect winter and spring melt on individual fields and farms. Examination of over-winter runoff monitoring data for multiple years and sites across Wisconsin makes some patterns clear.

### On farm:

Soils designated to be relatively more runoff prone in the Web Soil Survey (Hydrologic Groups C and D soils) are likely to be more runoff-prone under frozen conditions too.

*The influence of soils and field condition can cause relatively flat areas to generate more runoff than steeper areas with less run-off prone conditions.*

**FOR ANY GIVEN FIELD:**

**More runoff ==> More nutrients lost in runoff**

*UW-Platteville Pioneer Farm*

**Fall tillage can lead to somewhat less snowmelt runoff .**

*Chisel-plowed field with a portion of the snowmelt runoff retained in furrows.*

**Winters following established alfalfa are more runoff-prone than those following row-crops, provided there is no fall tillage.**

UW Extension University of Wisconsin-Extension

College of Agricultural & Life Sciences University of Wisconsin-Madison

For more information, contact John Panuska, jcpanuska@wisc.edu or Laura Good, lwgood@wisc.edu

## Appendix F. Low-Cost Edge-of-Field Runoff Monitoring (DRAFT FORM)

Prepared by: Dennis Busch, Univ. of WI-Platteville, (In draft form and not ready for distribution)

Conservation practices are implemented within agricultural fields and knowledge of conservation impacts on water quality are incomplete without monitoring at the individual field scale. The Mississippi River Basin Initiative (MRBI) recognized the importance of monitoring water quality at multiple scales including the field scale by devising a tiered approach to assess conservation effectiveness. Moreover, the Natural Resources Conservation Service provides farmers funding to support edge-of-field runoff monitoring through Conservation Activities 201 and 202. From a research standpoint however, edge-of-field runoff monitoring has been largely orphaned in favor of plot-scale and watershed scale monitoring. Watershed loads of sediment and nutrients do not provide accurate estimates of upland contributions from fields that have preventive practices implemented. On the other hand, plot-scale research quantifies movement of sediment and nutrients, but it is not always clear how the results are representative of actual field losses, especially where conservation practices such as grassed waterways are in use.

To determine the export of sediment and/or nutrients at the field scale, accurate measurements of both discharge and concentration must be obtained at the edge of the field. The use of automated equipment is commonly recommended as an appropriate method for pollutant load estimation (Harmel, King, and Slade, 2003; Harmel et al., 2006; Harmel and Haggard, 2006). For example, a runoff monitoring station may include ultrasonic sensors to measure water depth in H-flumes, dataloggers to store the information and trigger the refrigerated automated sampler to collect samples of runoff. This methodology produces accurate estimates of pollutant loads (e.g. Total Phosphorus load +/- 10%) (Harmel et al., 2006); however, the cost of equipment, maintenance, and operation of these sites is substantial: equipment costs approximately $21,000 and annual operating costs are in excess of $25,000 (Busch, Birr, and Tomer, 2010). The high capital and labor costs prevent conventional systems from being widely deployed, and may deter effective multi-scale efforts in MRBI watershed projects.

In an effort to reduce the cost of edge-of-field surface-water monitoring, scientist have developed innovative low-cost automated and passive sampling approaches. These innovative systems attempt to reduce monitoring costs by reducing the cost of hardware as well as operational and maintenance costs. The following describes several low-cost monitoring technologies developed to reduce edge-of-field runoff monitoring costs. Technologies described include both automated and passive monitoring approaches.

**Low-Cost Passive Monitoring Systems**

Passive samplers can be significantly lower cost than automated systems, and are typically easier to install and operate than automated systems. Passive samplers require no external power, are installed directly in the flow path, and rely on the flow of water to collect a sample. However, depending on the landscape and season, operating costs can be high due to heavy reliance on field technician labor needed to maintain equipment. Some examples of passive monitoring systems include the following.

1. Multi-Slot Divisor Samplers. Geib (1933) designed a multi-slot divisor that would collect a representative sample of runoff water. This sampler splits the discharge by directing flow through several adjacent vertical slots. While discharge from one slot is diverted to a sampler while the rest is wasted. The multi-slot sampler design was modified by Pinson et al. (2004) to create a crown with triangular divisors that sits on a standard 5-gallon pail. In laboratory setting, this device has proven reliable and accurate (Pinson et al., 2004). However, year-round experience with this device in the field at Pioneer Farm has shown it to offer many challenges (Parker and Busch, 2011).
2. Rotating Slot Divisor Sampler (aka Coshocton wheel). An alternative design to the multi-slot divisor where flow is partitioned by multiple vertical slots is the rotating slot divisor where a single horizontal slot rotates on a disk which is place beneath the flume exit, and with each disk rotation a portion of the total flow is diverted to a sample container (Carter and Parsons, 1967). While the multi-slot divisor samplers have proven effective in some settings, they require large head drops to operate and are not capable of monitoring large catchments without large sample containers. For example, the maximum flow rate for the crown divisor is only 1.05 cfs (Pinson et al., 2004); and the Coshocton wheel collects 1% of total discharge (Carter and Parsons, 1967). If a Coshocton sampler were used to monitor the 3.4 acre basin 11 at Pioneer Farm, a large runoff event would result in a sample of approximately 130 $ft^3$.
3. Tipping Bucket Sampler. Tipping bucket devices have also been used to estimate runoff volume and sample collection. The low-cost ($180) tipping bucket device with a pipe sampler developed and tested by Khan and Ong (1997) estimated the flow rate within 2% and soil loss within 10% of actual values; however, the maximum catchment size for this sampler is 50 $m^2$.
4. Single-Stage Siphon Sampler. As the name implies, the single stage siphon sampler collects one sample at a predetermined stage through a siphon action that is created due to the configuration of the sample and vent tubes. While this is also an inexpensive sampling device, it does not collect a flow-proportional sample; therefore, total flow cannot be determined.

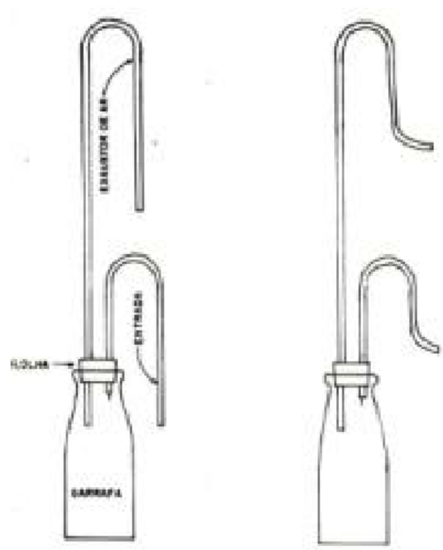


Figure 1. Single-stage siphon samplers.

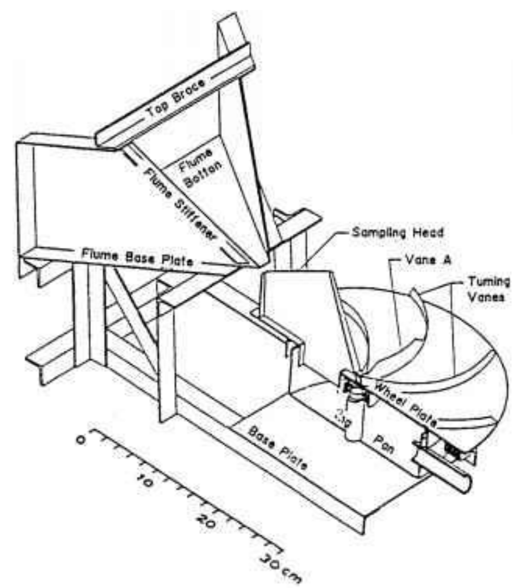



Figure 2. Coshocton wheel installed beneath an H-flume. The wheel in the illustrations is cut-away to show structure beneath the disk.

**Low-Cost Automated Monitoring Systems**

Currently, the most common method of pollutant load estimation is through the use of automated devices. However, automated monitoring equipment is expensive to purchase and maintain and requires on-site power. Recently scientists have developed a prototype prototype edge-of-field runoff monitoring gauge designed to minimize financial and technical barriers to edge-of-field monitoring in northern climates. The prototype system includes low-cost hardware components (i.e. custom electronic data logger, OEM stage sensors, low-cost peristaltic pump, low-profile flume) and innovative system designs (i.e. flume heaters, equipment enclosures, integrated systems) intended to reduce equipment and installation costs as well as reduce the cost of operating and maintaining gauging stations (Dennis Busch, unpublished data).


Figure 3. Low-cost prototype datalogger.

Figure 4. Modified HXL-flume.

Figure 5. Ice is easily removed from flumes with integrated hydronic heat systems.

Recently several field projects have been conducted to evaluate the prototype system at several locations in multiple states within the Mississippi River Watershed. The results of prototype field tests have shown the prototype system to be a feasible alternative to conventional automated systems, and highlighted components of the prototype system that could be improved. Low-cost ultrasonic stage sensors produced accurate estimates of flume stage when compared to time-lapse photos of in flume staff gauges (R2 = 0.97). The modified flume is designed to gauge larger discharge events at lower heads, therefore lowering the height of berms and wing walls and installation costs. In laboratory tests, the flume performed well overall; however, turbulent flow resulted in less accurate stage readings at high discharge rates. Integrated flume heaters and gauge enclosures, while increasing equipment costs, significantly decreased the time and effort required to prepare stations for monitoring winter snowmelt events, and improved working conditions for technicians maintaining the gauging stations. The low-cost sampler produced similar estimates of suspended sediment (R2 = 0.95) and NO3-N (R2 = 0.89) when compared to a conventional automated sampler. Several iterations of the data logging hardware have been developed and field tested in an effort to address deficiencies and increase capabilities and reliability.

Parker, P.J. and D. Busch. 2010. “Comparison of two standpipe samplers,” *18th National Nonpoint Source Monitoring Workshop*, Milwaukee, WI, November 16-18, 2010.

Pinson, W.T., D.C. Yoder, J.R. Buchanan, W.C. Wright, and J.B. Wilkerson. 2004. “Design and evaluation of an improved flow divider for sampling runoff plots,” *Applied Engineering in Agriculture*, 20(4), pp. 433-438.

APHA. 2005. Standard Methods for the Examination of Water and Wastewater 20th ed.. Washington, D.C.: American Public Health Association.

Harmel, R.D., R.J. Cooper, R.M. Slade, R.L. Haney, J.G. Arnold. 2006. Cumulative Uncertainty in Measured Streamflow and Water Quality Data for Small Watersheds. *Transactions of the American Society of Agricultural and Biological Engineers*, 49(3): 689-701.

## Appendix G. Quality Assurance Project Plan (QAPP)

# NRCS QUALITY ASSURANCE PROJECT PLAN

## USDA/NRCS Conservation Innovation Grant:

## P Index and Snowmelt Runoff Risk Assessment: Demonstration and Refinement.

Prepared for:

USDA NRCS

Prepared by:

*Dennis L. Busch, PhD*
*Busch009@gmail.com*



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# Table of Contents

# Quality Assurance Project Plan (QAPP)

This document provides an outline and description of minimum information required in each section for the QAPP when a project does not use EPA funds. When a project uses EPA funds, an EPA QAPP will be required. The participant will be responsible for the content in the QAPP and approval by EPA.

## SECTION 1.0: PROJECT OVERVIEW AND OBJECTIVES

### 1.1 General Overview

The objective of this project is to evaluate prototype edge-of-field surface-water monitoring equipment. The equipment is designed to measure discharge using stage sensing and calibrated flow structures. The prototype equipment will be installed at three locations near Madison WI to collect winter runoff and snowmelt discharge estimates. This data will be used by project partners to improve the runoff estimates generated by the WI P index.

**Project Overview**

### 1.2 Project Obectives

- Determine how well prototype equipment functions during snowmelt conditions by comparing logged measurements to observations and time lapse photo data.
- Evaluate the dependability of prototype hardware.
- Evaluate usability of prototype hardware equipment.

## SECTION 2.0: PROJECT ORGANIZATION AND MANAGEMENT

### 2.1 Organization Contacts

The contact information for project participants is located below.

### 2.2 Program Participants and Responsibilities

The table below describes the responsibilities of program participants. After installation of hardware, UW-Platteville will provide remote assistance for gauge operation and maintenance, and provide leadership for data analysis activities. Local partners will provide leadership for day-to-day operation and maintenance of the gauging stations and equipment. Local partners include:

1. Anita Thompson, Univ. of WI.
2. Laura Ward-Good, Univ. of WI.
3. John Panuska, Univ. of WI.
4. Zach Zopp, Univ. of WI,

Table 1. Program Participants and Responsibilities

| Organization | Responsibilities |
|---|---|
| UW-Platteville<br>Dennis Busch | Prepare QAPP for Project<br>Equipment Installation<br>Prototype Operation and Maintenance Training<br>Remote Monitoring of Data and Imagery<br>Calculate Discharge and Loads for Prototype hardware |
| Local Partner | Assist With Site Installation<br>Operate and Maintain Stations 4 Stations<br>Troubleshoot Hardware<br>Collect Data as Needed<br>Conduct Simulated Events |

## SECTION 3.0: MONITORING APPROACH

### 3.1 Monitoring Design

The project is designed to evaluate low-cost prototype surface-water monitoring hardware. Evaluation will be based on paired data collection and analysis: prototype hardware and time lapse photometric data. Evaluations will focus on discharge estimates as well as system functionality as reported by field technicians.

### 3.2 Sampling Locations

The sampling locations included in this study are located near Madison and Waunakee WI..

### 3.3 Monitoring Duration and Frequency and Pollutant of Concern

Runoff discharge will be estimated for all events within the (x-month/start date-end date) study period. Samples will be collected for quality analysis at the discretion of the local partner. The gauging stations within this project are located in multiple watersheds. The table below lists the site name, study period, HUC-12 watershed, and pollutant of concern for each specific location.

Table 2. Gauging station monitoring duration and frequency.

| Site Name | Site Number | Start Date | End Date | Frequency |
|---|---|---|---|---|
| Bong Road | 550250001 | January 2014 | May 2016 | Snowmelt Q Only |
| Saddlebrook | 550250002 | January 2014 | May 2016 | Snowmelt Q Only |
| Schumacher | 550250003 | January 2014 | May 2016 | Snowmelt Q Only |

### 3.4 Sample Parameters

N.A. No samples collected.

### 3.5 Hardware/Software

See Table XX "Site Data" for specifics on each site's hardware and software.

SECTION 4.0 SITE OPERATIONS AND MAINTENANCE

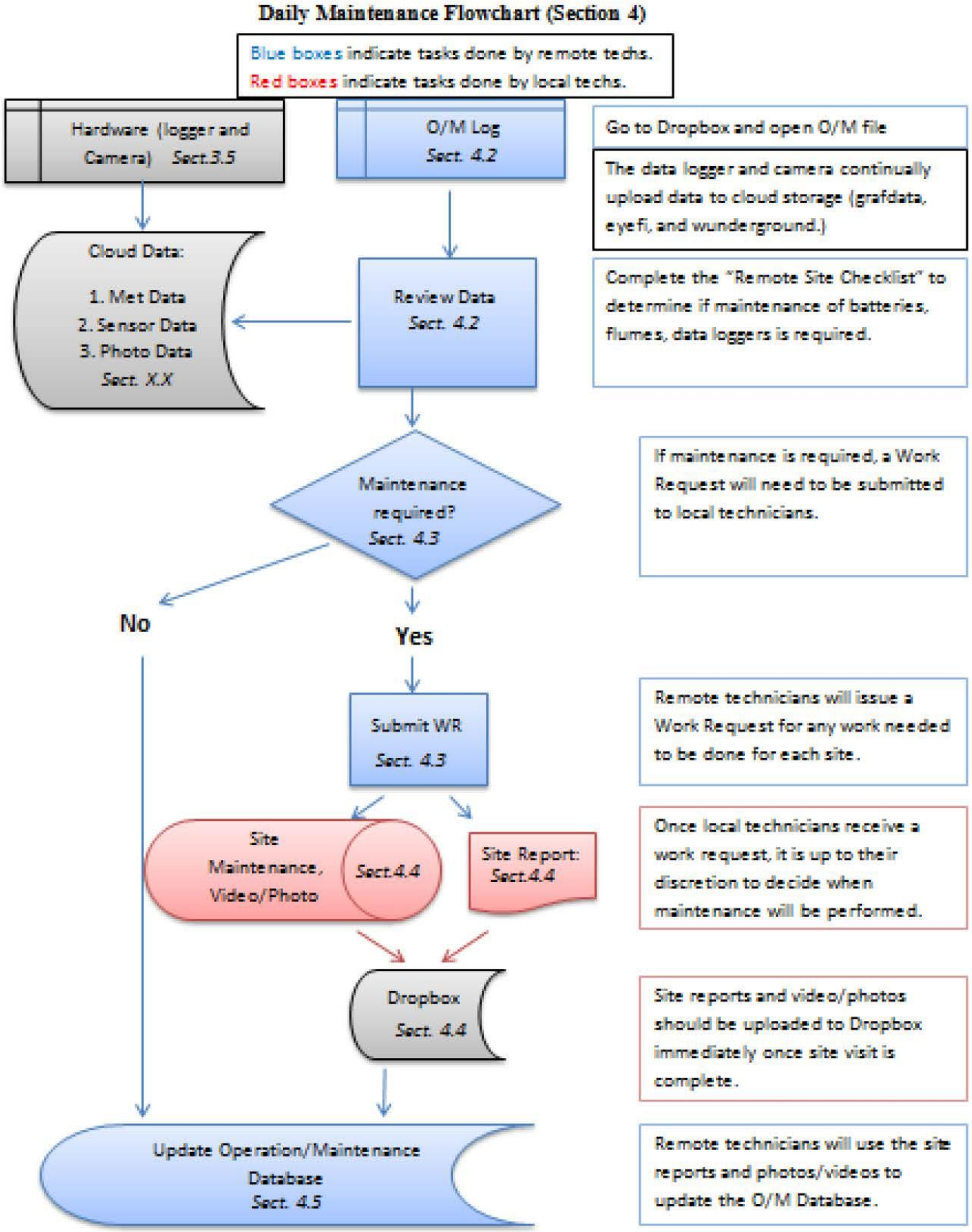



Figure 1. Daily Maintenance Flowchart.

### 4.1 Daily Maintenance

To ensure that sites are in proper working condition, it is essential that sites are checked daily. Remote techs will complete the "Remote Site Checklist", entering information into the Operations and Maintenance Log. If there is an issue that requires maintenance to the site (see Remote Site Checklist below), the remote tech will issue a Work Request to the local techs. A Work Request in the form of an email is then sent to the PI and local techs. Once the local technicians receive the work request, they will visit the site and fill out the Site Report on their tablet. After the Site report has been completed, it should be uploaded to Dropbox. Remote techs will take the information loaded to Dropbox and use it to update the Operations and Maintenance Database.

### 4.2 Operations and Maintenance Log

The Operations and Maintenance Log should be filled out first thing each morning. The remote tech will log into GrafData.com to get sensor data. Then they will check eyefi.com to get the time lapse photo information. While checking data, the technician will work through the Remote Site Checklist.

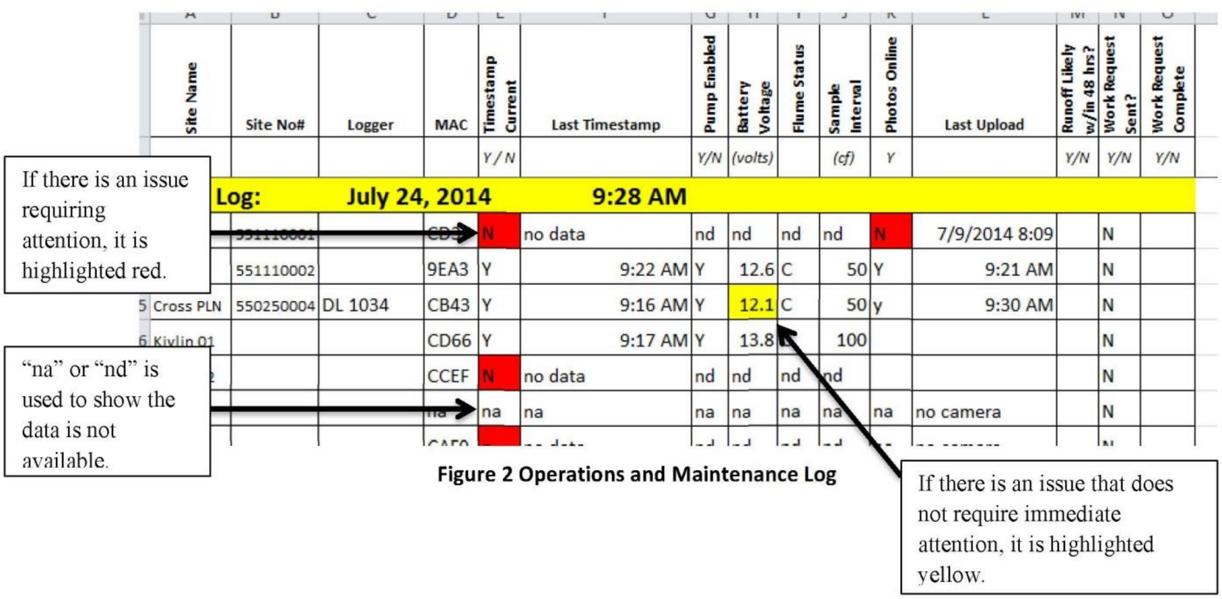



Figure 2 Operations and Maintenance Log

**Remote Site Checklist**

**Date:**______________ **Technician:**_____________ **Site:** _____________

| | Check | Submit a Work Request If… | Local Tech. Action |
|---|---|---|---|
| GrafData.com | Is the timestamp Current? | The timestamp is not current | 1. Determine status of data logger (frozen, working but offline, lost power, non-functioning?)<br>2. Power cycle the unit or replace if needed.<br>3. Verify that logger is working and uploading data.<br>4. Complete and submit Site Report. |
| | Is the Site ID correct? | The Site ID is not correct | 1. Modify Site ID.<br>2. Complete and submit Site Report. |
| | What is the Pump Status? | If needed enable pump via Grafdata.com. Work Request not needed. | None |
| | What is the Flume Status? | If flume stage is off by > 0.02' (compared to imagery) | 1. Modify flume stage offset.<br>2. Complete and submit Site Report. |
| | | If the flume needs to be cleared or ice, sediment, or debris. | 1. Clear flume or snow, ice, or debris if needed.<br>2. Ensure that the staff gauge is clean and clear.<br>3. Complete and submit Site Report. |
| | What is the Sample Interval? | If the interval needs to be changed. | 1. Modify sample interval.<br>2. Complete and submit Site Report. |
| | What is the Battery Voltage? | If the Battery Voltage is below 12 Volts | 1. Check charge controller, battery connections, panel output, and wiring.<br>2. Replace components as needed.<br>3. Complete and submit Site Report. |

**Figure 3 Remote Site Checklist**

| | Check | Submit a Work Request If… | Local tech Action |
|---|---|---|---|
| Eyefi.com | Is the Timestamp current? | If timestamp is not current and there is storage available on camera card. | 1. Determine status of camera (working but offline, frozen, lost power, non-functioning.)<br>2. Power cycle the camera. Replace if needed.<br>3. Complete and submit Site Report |
| | Is the Flume clear? | If there is ice, snow, or debris in the flume. | 1. Clear flume or snow, ice, or debris if needed.<br>2. Ensure that the staff gauge is clean and clear.<br>3. Complete and submit Site Report. |
| | Is there any flow through the flume? | If flume stage is off by > 0.02'(compared to sensors) | 1. Modify flume stage offset.<br>2. Complete and submit Site Report. |
| | Has there been a sample collected? | If a sample can be seen in the container and the runoff event is complete. | 1. Collect samples according to defined methods.<br>2. Complete and submit a Site Report. |
| | Is the interval between pictures consistent? | If the interval is not consistent. | 1. Determine status of camera (working but offline, frozen, lost power, non-functioning.)<br>2. Power cycle the camera. Replace if needed.<br>3. Complete and submit Site Report |
| | What is the photo resolution? | If the file size is > 100 KBytes | 1. Change settings to 640 x 480.<br>2. Restart camera.<br>3. Complete and Submit Site Report. |
| | Is the camera orientation correct? | If the orientation is off | 1. Reposition camera.<br>2. Complete and submit a Site Report. |

**Figure 4 Remote Site Checklist Continued**

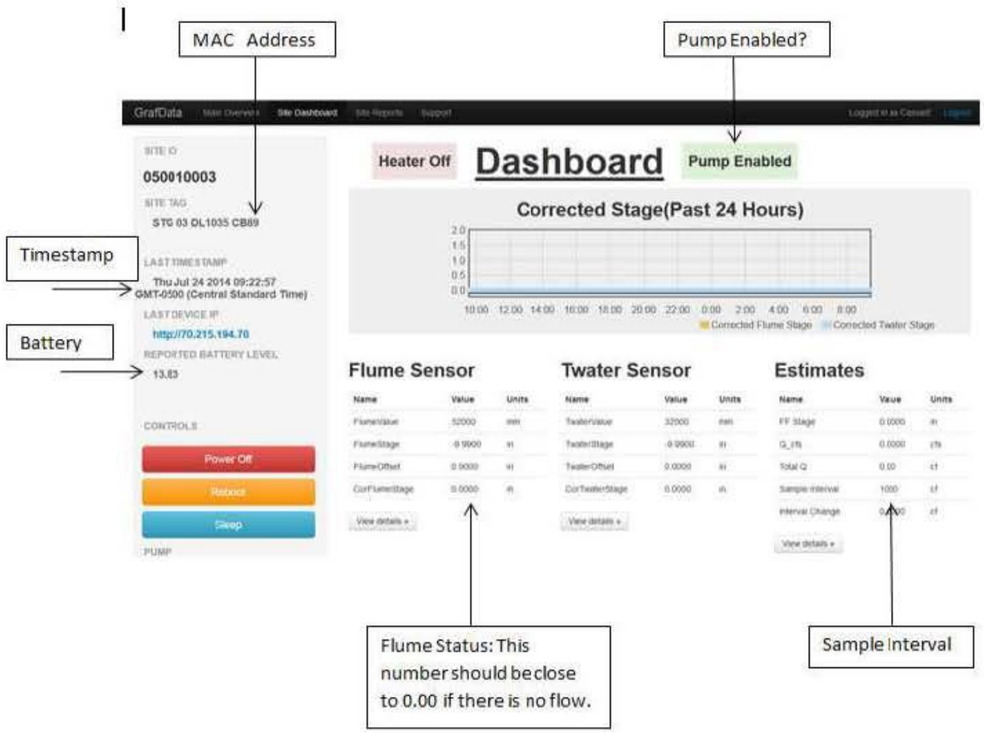



**Figure 5 GrafData Site Dashboard. This is where you get the information for the Remote Site Checklist, which is then entered into the O/M Log**

### 4.3 Work Requests

Once the Remote Site Checklist and the O/M log have been completed, the remote tech will send out any necessary Work Requests. The Remote Site Checklist is clear on what issues require maintenance, and what action the local techs should take. Work Requests will be to the PI and local techs from the remote tech email account, with the following format.

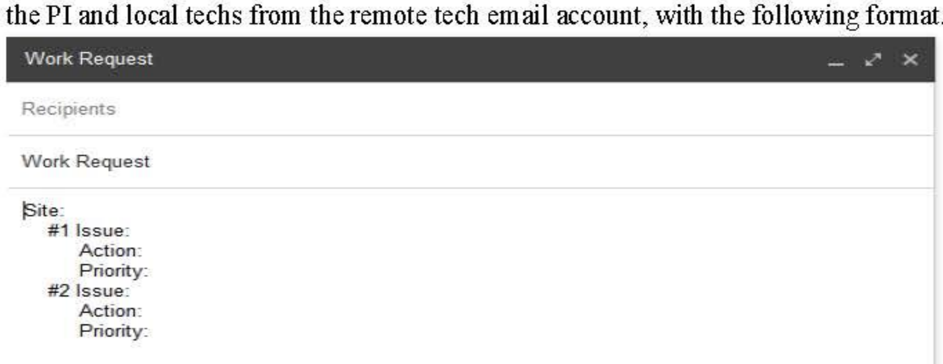



Figure 6. Email template.

### 4.4 Site Report

The Site Report (Appendix 4.4) was developed to ensure runoff monitoring stations are properly maintained between runoff events. Having site report ensures field staff checks all critical conditions and equipment, and serves as a maintenance record. After completing the Site Report, technicians will upload it to Dropbox.com to make it immediately available. Site Reports should be completed on every site visit.

The Site Report also includes a section on simulated events. By simulating runoff events, field staff can ensure that the runoff monitoring equipment will respond as expected during actual runoff events (Appendix 4.4). Simulated events should be conducted at least once per month, and any time equipment changes are made.

Ver 2014.06.25

**Site Report**

| | | | |
|---|---|---|---|
| **Site Name:** | | **Site Number:** | |
| Technician: | | Date: | |
| Logger No#: | | MAC: | |
| ***Is the data logger timestamp correct?*** | | | |
| Logger Timestamp: | | UTC Date and Time: | |
| Local Date and Time: | | Timestamp Adjusted? | Yes No |
| ***Is the flume stage correct?*** | | | |
| Observed Stage: | | Flume Cor. Stage: | |
| | | *If offset applied, record new offset and time applied:* | |
| ***Record Observations.*** | | | |

| | ***On Arrival*** | ***On Departure*** |
|---|---|---|
| Is Data Logger Online? | Yes No | Yes No |
| Is Data Current on Server? | Yes No | Yes No |
| Time lapse Camera Functioning? | Yes No | Yes No |
| Photos Current on Server? | Yes No | Yes No |
| Sample Line Clear | Yes No | Yes No |
| Sample Bucket Empty and In-Place | Yes No | Yes No |
| Flume Clear of Snow, Ice, Sediment | Yes No | Yes No |
| Entrance to Gauge Clear of Snow, Ice, and Sediment | Yes No | Yes No |
| Exit of Gauge Clear of Snow, Ice, and Sediment | Yes No | Yes No |
| Is flume level front to back*? | Yes No | Yes No |
| Is flume level left to right*? | Yes No | Yes No |
| **If flume is not level, describe in comments on back of sheet.* | | |

| | |
|---|---|
| ***Conduct a simulated event (anytime equipment is changed, or once a month.)*** | |
| Simulated Stage: | |
| Logged Stage: | |
| Discharge (cfs): | |
| Sample Triggered? | Yes No |
| Pump Cycle Correctly? (Purge/Collect/Purge): | Yes No |
| Sample Volume Collected: | |
| ***Complete the final check.*** | |
| Sample Line In Place · Sample Interval Correct · Sample Bucket In Place · Flume Clear | |
| ***Water Sample Collection*** | |
| Quantity of Sample Collected: | |
| Time and Date Sample was Collected: | |
| Sample Shipped on (date): | |
| Sample Shipped to: | |

Figure 7. Site report and simulated event form.

**Site Report Instructions**

1. Take notes: be sure site name is on note card
    a. Site Name, Site Number, date, and initials of technician, logger number, and MAC address across top of note sheet
    b. Any explanation of observations is helpful
2. Is the data logger timestamp correct?
    a. Check the local date and time, UTC date and time, and adjust timestamp as needed.
3. Is the Flume Stage correct?
    a. Staff Reading: Read staff measurements in thousandths (0.000). The staff tape is only accurate to hundredths, so the thousandths digit is a guess.
    b. Need wood engineers rule if flume not equipped w/ gauge
        i. Take reading to the thousandths at flume
        ii. Write staff reading on note card
        iii. Read stage height on Home screen of logger
        iv. Write data logger reading under staff reading
        v. Note the exact time this occurs
    c. If values are off by 0.010 re check readings and enter on notes w/ time read
        i. If stage is rising or falling quickly, it will be challenging to get stage measurements that match due to the time lag. In these situations, write down the stage both before and after getting the staff reading and take multiple staff readings over several minutes.
        ii. If stage is off by a value of 0.020 or greater, reset the flume offset

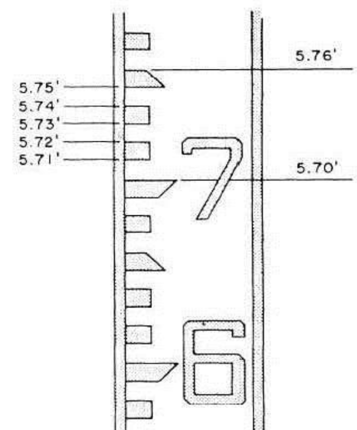


Figure 8. Staff gauge.

4. Record Observations
    a. Bring field digital camera on site visit and photo-document conditions
        i. Check the date and time on the field camera and ensure it is accurate
        ii. Check resolution setting (should be at least 1500 pixels on the shortest side)
        iii. Use appropriate flash setting
        iv. Overall view (think slideshow presentations, newsletters, etc). Turn off date/time stamp for photos taken for this purpose
        v. Observations – turn date/time stamp on
    b. Check sampler:
        i. Ensure that samples are being taken
        ii. Common problems
            1. Frozen sample line
            2. Disconnected Sample line
            3. Power Failure
    c. Check flume: draw flume level on notes (if equipped) w/ an arrow underneath to indicate the direction of flow

        i. Ensure proper flow
        ii. Common problems
            1. Ice in flume
            2. Sediment build up
            3. Debris blocking tip
            4. Backwater conditions
    d. Remedy any problems possible and note how and approximate time when remedied. If fixing flow problems, note measurement before and after fix.
5. Conduct a Simulated Event
    a. Simulate an event by placing a wood block in the flume under the sensors.
    b. Record the height of the block in the flume.
        i. This is the simulated stage height
    c. Record the stage height from the data logger
        i. This is the logged height.
        ii. If the stage height and log height are off by more than 0.02’, and adjustment needs to be made to the logger.
    d. Record the discharge value from the data logger.
    e. Place sampling line into a container of water and wait for the sampler to trigger an event.
        i. The sampling interval can be changed to a lower value if it is taking too long for a sample to be triggered. **Make sure to return the sampling interval back to the original value once the simulated event is complete.**
    f. Did the pump cycle correctly?
        i. Did it purge, pump, and then purge again?
    g. Record the sample volume collected.
6. Complete the Final Check
    a. Check if the sample line is in place, if the sample interval is correct, if the sample bucket is in place, and if the flume is clear.
7. Water Sample Collection
    a. Record the quantity of the sample
    b. Record the time and date that the sample was collected
    c. Record the date that the sample is shipped to the lab
    d. Record the name and location of the lab that the samples were shipped to.

Once complete, the Site Report should be submitted to the data manager for archiving and a copy of the Site Report uploaded to Dropbox.

### 4.5 Operations and Maintenance Database

The Operations and Maintenance Database is used to track any changes and events that have occurred onsite. Field notes and journal entries will be embedded into the database, while photos, videos, checklists, and Runoff Event Reports will be linked to the database.

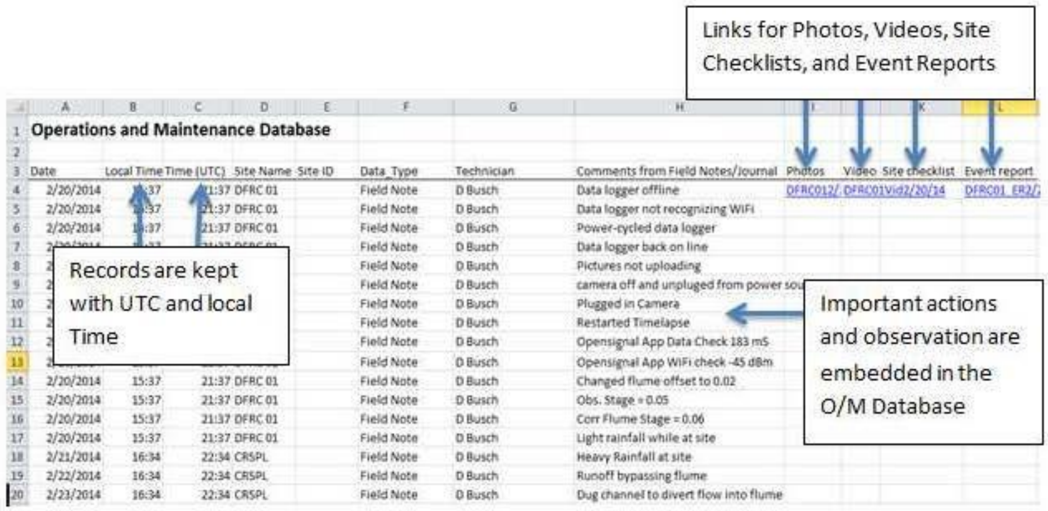



Figure 9. Database entries.

### 4.6 Calibration Procedures

The sensors are checked for accuracy by conducting a simulated event (see section 4.4.) The sample volume can also be checked for accuracy during a simulated event. Additionally, the photometric stage data can be checked on the time lapse photos on site.

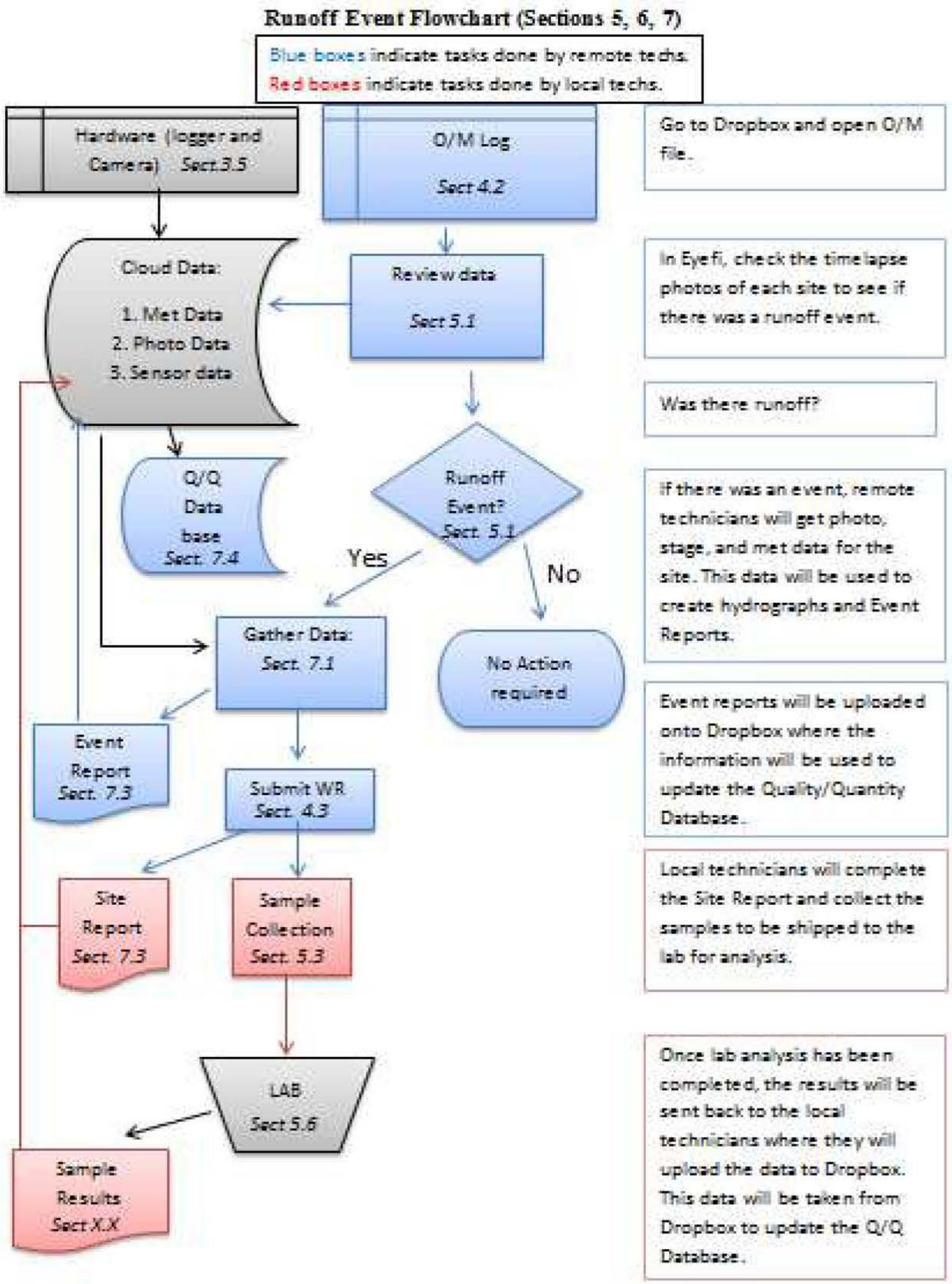



Figure 10. Runoff event flowchart. (ignore sample references)

## SECTION 5.0 SAMPLE PROCOCEDURES

| This section is not applicable as no samples were collected during this project. |
| --- |

### 5.1 Sampling Equipment

### 5.3 Sample Collection

### 5.3 Sample Quantities

### 5.4 Sample Containers

### 5.5 Sample Handling

### 5.6 Sample Analysis

### 5.7 Lab Analysis Protocol

## SECTION 6.0 QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

### 6.1 Field Blanks and Duplicates

Not applicable, no samples collected.

### 6.2 Calibration of Stage Sensors

The ultrasonic sensor is factory calibrated and rigorously tested such that it requires no calibration once its installed in the field. Periodic checks are performed to ensure stage accuracy. Sensors must be installed at least one foot above the maximum expected stage to account for the dead band.

### 6.3 Laboratory Equipment Calibration Procedures

Not applicable, no samples collected.

### 6.4 Post-Event Summary and Analysis

After each runoff event, data and observations are summarized in a Runoff Event Report, which summarizes the runoff event data and project data. Also included is a series of graphs that shows the raw and corrected data for the event, photos taken, and a table of data with discharge and time. Specifics about Runoff Event Reports can be found in Sect 7.3. Runoff Event Reports are archived in Dropbox.

## SECTION 7.0 DATA HANDLING PROCEDURES

### 7.1 Methods for Data Acquisition

#### A. Discharge Data

1. Log into Dropbox
   a. Open Project_Six Mile Creek DNR Folder
   b. Select appropriate folder (e.g. DFRC02)
   c. Open Discharge Data Folder
   d. Open Daily Log DFRC02.xlsx

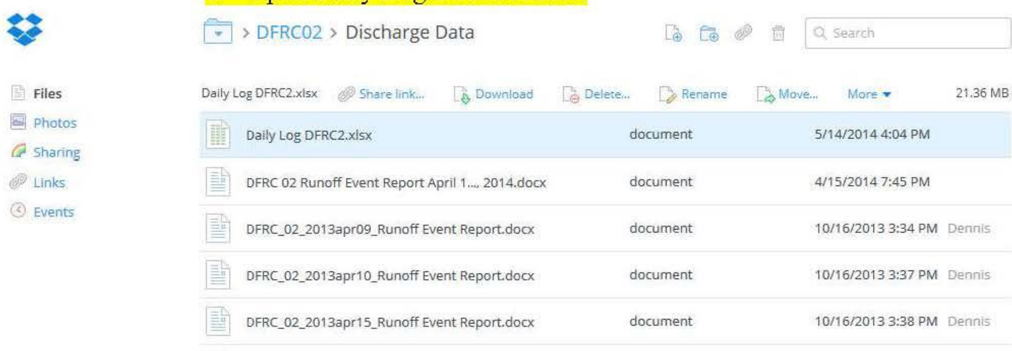



Figure 11. Dropbox file structure

2. Once excel file of Daily log is open, Create a copy of the event template, and move the tab into the correct chronological order.

   a. In the excel file, the font face should be "Calibri" and the font size should be '11".

3. Go to www.grafdata.com (this will give you your sensor data.)
   a. Log in and select the correct site (e.g. Cross Plains DL1034 CB43)
   b. Click on the Site Report tab on the top of the page.
   c. Enter the dates and times of the beginning and end of the event.
   d. Once the information is uploaded, click on Download CSV Report
   e. Open with Microsoft Excel.
   f. Highlight and copy the information from the Timestamp column to the Heater Status column.
   g. Paste these values into your newly created event tab in the excel file of the Daily Log in to columns A-Q.

Figure 12. Grafdata download window.

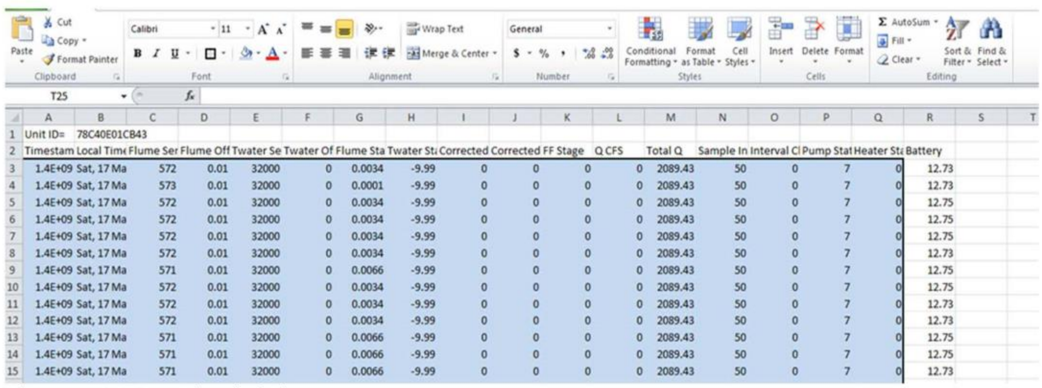


Figure 13. Downloaded data.

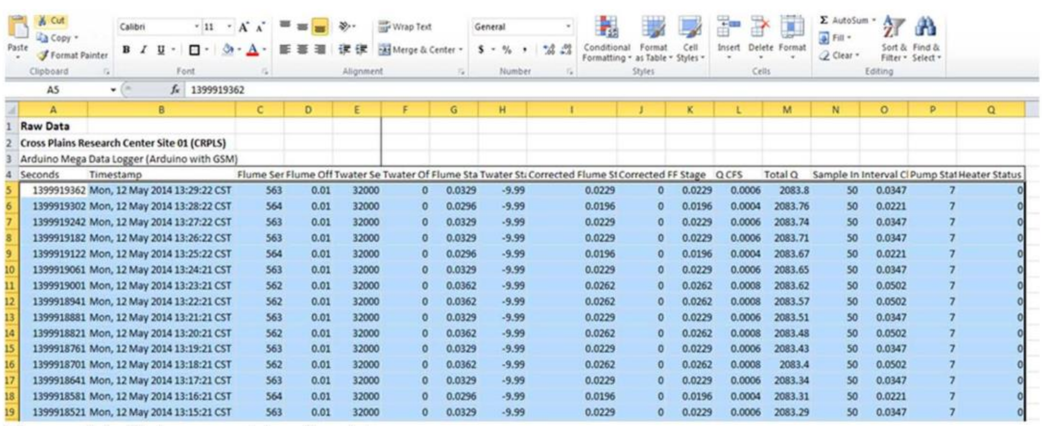


Figure 14. Column entries for data.

## B. Meteorological Data

4. Go to www.wunderground.com ( this gives you the meteorological data.)
   a. Enter city of site.
      i. DFRC01 and DFRC02 are both located in Prairie du Sac, WI.
      ii. CRPLS is located in Cross plains, WI.
      iii. Dumas 02 and Dumas 03 are both located in Dumas, Arkansas.
      iv. Wildy 09 and Wildy 10 are both located in Manila, Arkansas.
      v. Stu 02 and Stu 03 are both located in Stuttgart, Arkansas.
      vi. Elkins 02 and Elkins 03 are both located in Elkins, Arkansas.
   b. Scroll down to Nearby Weather Stations, and choose the corresponding station.
      i. DFRC01 and DFRC02 are the Baraboo/Sauk Prairie station.
      ii. CRPLN is the St. Francis/ Cross Plains station.
      iii. Dumas 02 and dumas 03 are the GOULD AR US UPR MUP499 station.
      iv. Wildy 09 and Wildy 10 are the
      v. Stu 02 and Stu 03 are the Shady Grove Road KARSTUTT2 station.
      vi. Elkins 02 and Elkins 03 are the Elkins / Durham KARFAYET15 station
   c. Click on the Graphs and History Tab on the left hand side
   d. Enter the day of the event. (If the event occurs over multiple days, you have to get the information for each day separately; otherwise it will only give you the average temperature and rainfall.)
   e. Select the Table option located next to the dates.

   f. Download Tabular Weather History (this will open in a new internet tab.)
      i. Hit Ctrl+a to select all the information, then copy the information.
      ii. In a new excel file, paste the information.
      iii. The information is located in one column, and needs to be reformatted.
      iv. Under the Data tab in excel, click on the Text to Columns button.
         1. Step 1 of the prompt, choose that the data is delimited, then hit Next.
         2. Step 2 of the prompt, set the delimiter of your data to Comma, and then hit next.

3. Step 3 of the prompt is a preview of how the newly sorted data will look. Hit Finish.

v. This data can now be copied and pasted into the newly created event tab in the excel file of the Daily Log into columns AA-AO

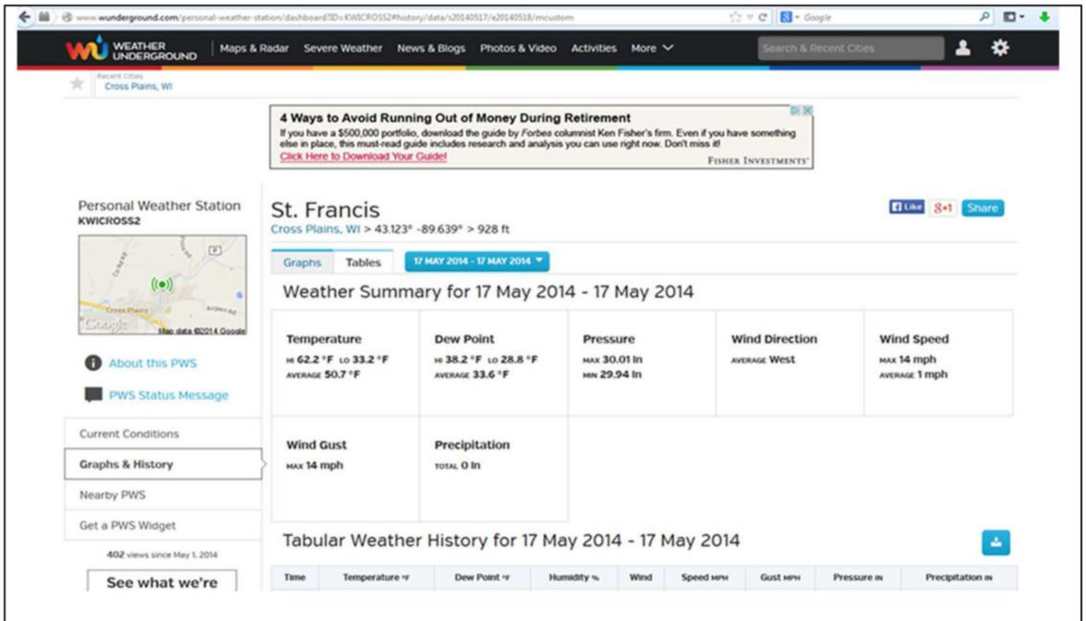


Figure 15. Weather Underground dashboard.

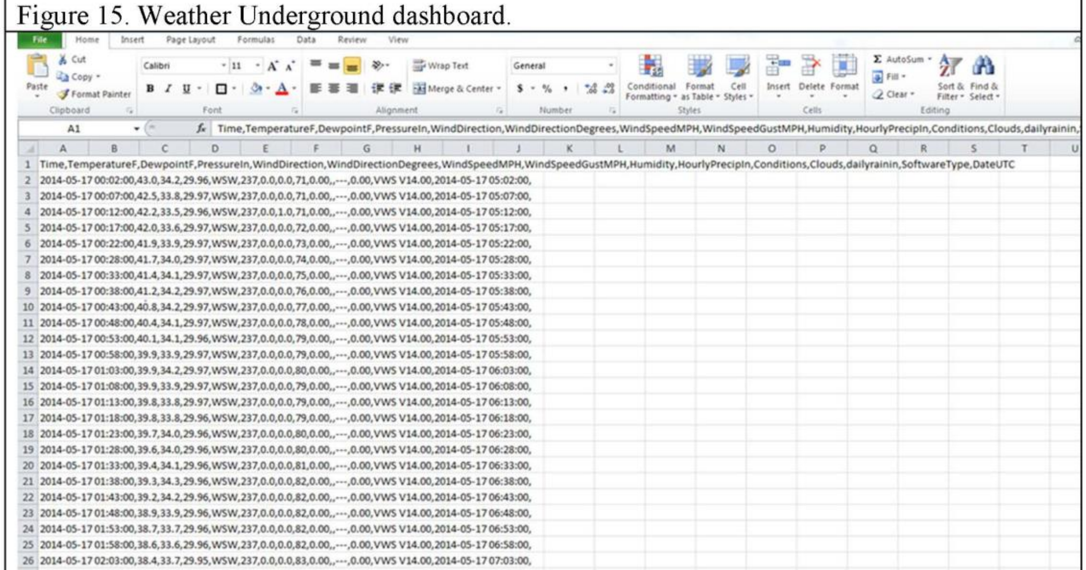


Figure 16. Download data from Weather Underground.

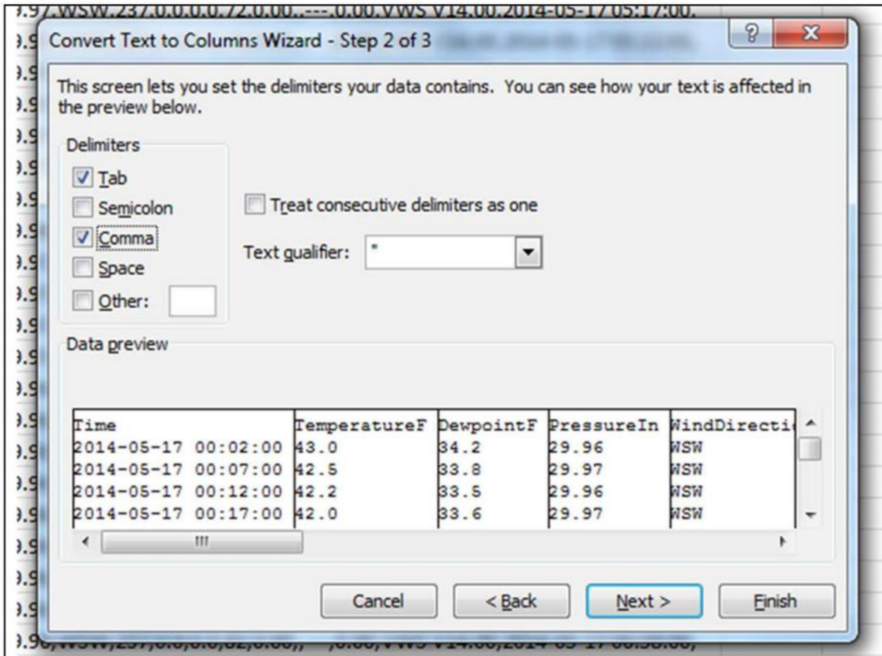
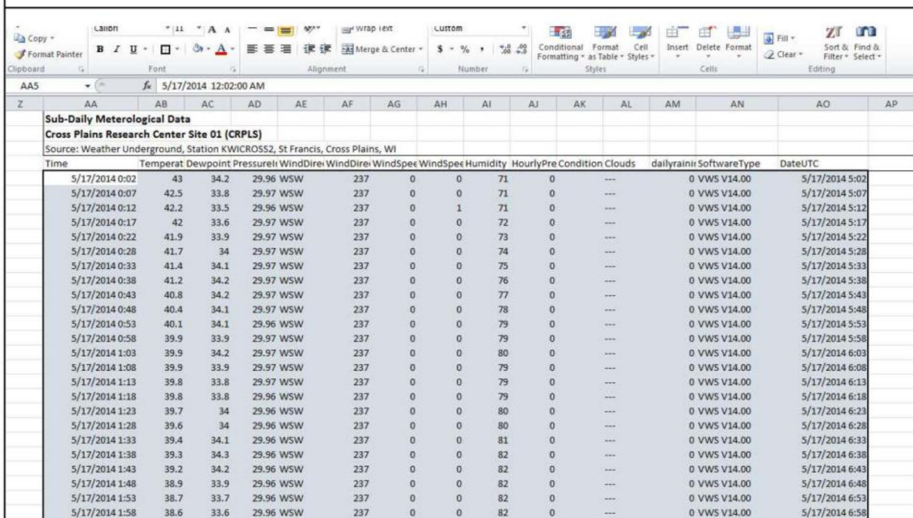



Figure 17. Convert text to columns.




**Sub-Daily Meterological Data**
**Cross Plains Research Center Site 01 (CRPLS)**
Source: Weather Underground, Station KWICROSS2, St Francis, Cross Plains, WI

| Time | Temperat | Dewpoint | PressureI | WindDire | WindDire | WindSpee | WindSpee | Humidity | HourlyPre | Condition | Clouds | dailyrainir | SoftwareType | DateUTC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/17/2014 0:02 | 43 | 34.2 | 29.96 | WSW | 237 | 0 | 0 | 71 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:02 |
| 5/17/2014 0:07 | 42.5 | 33.8 | 29.97 | WSW | 237 | 0 | 0 | 71 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:07 |
| 5/17/2014 0:12 | 42.2 | 33.5 | 29.96 | WSW | 237 | 0 | 1 | 71 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:12 |
| 5/17/2014 0:17 | 42 | 33.6 | 29.97 | WSW | 237 | 0 | 0 | 72 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:17 |
| 5/17/2014 0:22 | 41.9 | 33.9 | 29.97 | WSW | 237 | 0 | 0 | 73 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:22 |
| 5/17/2014 0:28 | 41.7 | 34 | 29.97 | WSW | 237 | 0 | 0 | 74 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:28 |
| 5/17/2014 0:33 | 41.4 | 34.1 | 29.97 | WSW | 237 | 0 | 0 | 75 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:33 |
| 5/17/2014 0:38 | 41.2 | 34.2 | 29.97 | WSW | 237 | 0 | 0 | 76 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:38 |
| 5/17/2014 0:43 | 40.8 | 34.2 | 29.97 | WSW | 237 | 0 | 0 | 77 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:43 |
| 5/17/2014 0:48 | 40.4 | 34.1 | 29.97 | WSW | 237 | 0 | 0 | 78 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:48 |
| 5/17/2014 0:53 | 40.1 | 34.1 | 29.96 | WSW | 237 | 0 | 0 | 79 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:53 |
| 5/17/2014 0:58 | 39.9 | 33.9 | 29.97 | WSW | 237 | 0 | 0 | 79 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 5:58 |
| 5/17/2014 1:03 | 39.9 | 34.2 | 29.97 | WSW | 237 | 0 | 0 | 80 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:03 |
| 5/17/2014 1:08 | 39.9 | 33.9 | 29.97 | WSW | 237 | 0 | 0 | 79 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:08 |
| 5/17/2014 1:13 | 39.8 | 33.8 | 29.97 | WSW | 237 | 0 | 0 | 79 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:13 |
| 5/17/2014 1:18 | 39.8 | 33.8 | 29.96 | WSW | 237 | 0 | 0 | 79 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:18 |
| 5/17/2014 1:23 | 39.7 | 34 | 29.96 | WSW | 237 | 0 | 0 | 80 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:23 |
| 5/17/2014 1:28 | 39.6 | 34 | 29.96 | WSW | 237 | 0 | 0 | 80 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:28 |
| 5/17/2014 1:33 | 39.4 | 34.1 | 29.96 | WSW | 237 | 0 | 0 | 81 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:33 |
| 5/17/2014 1:38 | 39.3 | 34.3 | 29.96 | WSW | 237 | 0 | 0 | 82 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:38 |
| 5/17/2014 1:43 | 39.2 | 34.2 | 29.96 | WSW | 237 | 0 | 0 | 82 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:43 |
| 5/17/2014 1:48 | 38.9 | 33.9 | 29.96 | WSW | 237 | 0 | 0 | 82 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:48 |
| 5/17/2014 1:53 | 38.7 | 33.7 | 29.96 | WSW | 237 | 0 | 0 | 82 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:53 |
| 5/17/2014 1:58 | 38.6 | 33.6 | 29.96 | WSW | 237 | 0 | 0 | 82 | 0 | | --- | 0 | VWS V14.00 | 5/17/2014 6:58 |

Figure 18. Met data in excel.

## C. Photometric Data

5. Go back into dropbox (this is where the time lapse photos are located.)
   a. Click on the Sharing button on the left hand side.
   b. Open the correct site file (e.g.DFRC02b)
   c. Open the last file (this will be the most recently updated time lapse photos.)
   d. Find the photo of the beginning of the event.
   e. Record the height of the water in the flume and correlate it to the timestamp on the photo.

Figure 19. Time lapse photo.

   f. Continue recording the height of water in the flume for each photo of the event.

g. Enter these values into the newly created event tab in the excel file of the Daily Log into columns AQ-AS.

| AP | AQ | AR | AS | AT |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | Photo Data | | | |
| | Time | Stage (ft) | PEC Photc | PEC Precipita |
| | 5/12/2014 10:10 | 0.02 | 0 | |
| | 5/12/2014 10:25 | 0.03 | 0.01 | |
| | 5/12/2014 10:40 | 0.07 | 0.05 | |
| | 5/12/2014 10:55 | 0.105 | 0.085 | |
| | 5/12/2014 11:10 | 0.085 | 0.065 | |
| | 5/12/2014 11:25 | 0.07 | 0.05 | |
| | 5/12/2014 11:40 | 0.058 | 0.038 | |
| | 5/12/2014 11:55 | 0.05 | 0.03 | |
| | 5/12/2014 12:10 | 0.045 | 0.025 | |
| | 5/12/2014 12:25 | 0.045 | 0.025 | |
| | 5/12/2014 12:40 | 0.045 | 0.025 | |
| | 5/12/2014 12:55 | 0.044 | 0.024 | |
| | 5/12/2014 13:10 | 0.043 | 0.023 | |
| | 5/12/2014 13:25 | 0.043 | 0.023 | |
| | 5/12/2014 13:40 | 0.04 | 0.02 | |
| | 5/12/2014 13:55 | 0.04 | 0.02 | |
| | 5/12/2014 14:10 | 0.04 | 0.02 | |
| | 5/12/2014 14:25 | 0.04 | 0.02 | |
| | 5/12/2014 14:40 | 0.04 | 0.02 | |

Figure 20. Time lapse stage data entries.

### 7.2 Runoff Data Analysis Methods

1) Column Headings and Calculations
   a. All of the excel data will be in font "Calibri" size 11.
   b. All of the column headings for the data collected will remain the same.
   c. Make the following headings in the columns between the sensor and weather data.
      i. Note, we need to make corrections to the sensor data timestamp because the sensor doesn't have a "sense of time," and has just been counting the seconds since January 1, 1970.

| S | T | U | V | W | X | Y |
|---|---|---|---|---|---|---|
| Data Corrections (timestamp, stage, discharge). | | | | | | |
| Dairy Forage Research Center Site 01 (DFRC 01) | | | | | | |
| PEC_RefDate | Days Since | PEC_UTCTime | PEC_LocalTime | PEC_FFStage | PEC_Qcfs | PEC_Qcf |
| 1-Jan-70 | 1/1/1970 | Timestamp | Corrected Timestamp | Stage (ft) | Q Rate (cfs) | Q Volume (cf) |
| 1-Jan-70 | 16173.641 | 4/13/14 15:23 | 4/13/14 10:23 | 0 | 0 | 0 |
| 1-Jan-70 | 16173.641 | 4/13/14 15:22 | 4/13/14 10:22 | 0 | 0 | 0 |
| 1-Jan-70 | 16173.64 | 4/13/14 15:21 | 4/13/14 10:21 | 0 | 0 | 0 |
| 1-Jan-70 | 16173.639 | 4/13/14 15:20 | 4/13/14 10:20 | 0 | 0 | 0 |
| 1-Jan-70 | 16173.638 | 4/13/14 15:19 | 4/13/14 10:19 | 0 | 0 | 0 |

Figure 21. Corrected data spreadsheet.

d. The first column will read January 1, 1970 for every row.
e. Calculate the days since January 1, 1970 (in the second column) using the seconds column (column A). Using row 5 as the example (e.g. "=A5/(60*60*24)")
f. Calculate the original UTC time in the third column (e.g. "=S5+T5")
g. Convert from UTC time to Central Standard time in the fourth column (e.g. "=U5-(5/24)")
h. Note, that when daylight savings occurs, the equation will need to change to "=U5-(6/24)."
i. Make any corrections that are necessary in the PEC_FFStage column, such as sensor errors or sediment in the flume. For example, the stage height isn't going to jump from 0.01ft to 0.3ft then jump back down to zero within minutes. This is an obvious error, and this needs to be corrected (See screenshot).
j. PEC_ Q RATE
k. PEC_ Q VOLUME

| Timestamp | Flume Ser | Flume Off | Twater Se | Twater Of | Flume Sta | Twater Sta | Corrected | Corrected | FF Stage |
|---|---|---|---|---|---|---|---|---|---|
| Thu, 24 Apr 2014 05:44:53 CST | 627 | 0.02 | 689 | 0 | -0.1771 | -0.3805 | 0 | 0 | 0 |
| Thu, 24 Apr 2014 05:43:53 CST | 701 | 0.02 | 688 | 0 | -0.4199 | -0.3772 | 0 | 0 | 0 |
| Thu, 24 Apr 2014 05:42:53 CST | 457 | 0.02 | 686 | 0 | 0.3807 | -0.3707 | 0.3607 | 0 | 0.3607 |
| Thu, 24 Apr 2014 05:41:53 CST | 457 | 0.02 | 687 | 0 | 0.3807 | -0.3739 | 0.3607 | 0 | 0.3607 |
| Thu, 24 Apr 2014 05:40:53 CST | 465 | 0.02 | 688 | 0 | 0.3544 | -0.3772 | 0.3344 | 0 | 0.3344 |
| Thu, 24 Apr 2014 05:39:53 CST | 563 | 0.02 | 688 | 0 | 0.0329 | -0.3772 | 0.0129 | 0 | 0.0129 |
| Thu, 24 Apr 2014 05:38:52 CST | 559 | 0.02 | 687 | 0 | 0.046 | -0.3739 | 0.026 | 0 | 0.026 |
| Thu, 24 Apr 2014 05:37:52 CST | 560 | 0.02 | 687 | 0 | 0.0427 | -0.3739 | 0.0227 | 0 | 0.0227 |

Figure 22. Stage correction entries in the database.

2) Event Information
   a. A runoff event is when the runoff reaches a FF Stage height of 0.03 ft or greater.
   b. From the data collected, choose a good point for the beginning and end of the event.

3) Graphing
   a. A set of graphs will be created which includes raw data of the stage height versus temperature, and the stage height versus precipitation.
      i. Create a graph which includes "PEC_LocalTime" vs "FFStage" on the primary axis (from data logger), "Time" vs. "Photo Data" on the primary axis, and "Time" vs "Temperature" on the secondary axis (from weather underground). Create a second graph which is the same except it has "Time" vs "dailyrainin" on the secondary axis. No corrections will be made to the data used (besides the timestamp).

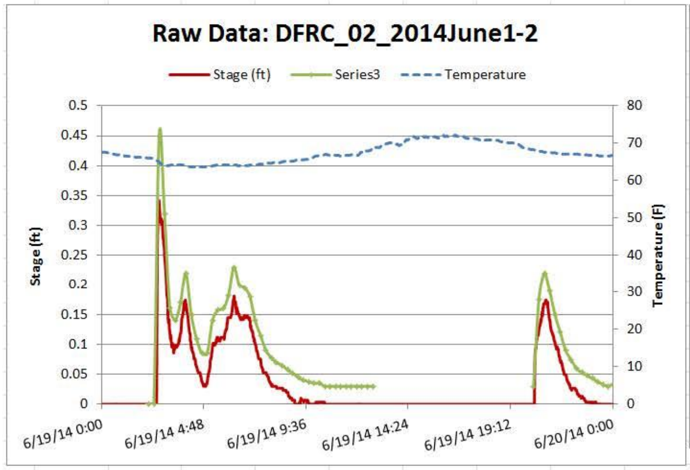



Figure 23. Plot of stage and temperature data.

ii. Graphs will be titled as "Raw Data: Site Name, Date"
iii. The primary axis title will be labeled "Stage (ft)."
iv. The secondary axis title will be labeled either "Temperature (F)" or "Precipitation (in)."
v. The primary axis will have a minimum value of 0, a maximum value of 0.5, and go up in increments of 0.05. If the stage values exceed 0.5 ft, change the maximum value as needed, then note this in the event report under the discussion.
vi. The secondary axis for Temperature will have a minimum value of 0, a maximum value of 60, and go up in increments of 10. It the temperature is higher than 60, change the maximum value as needed, then note this in the event report under the discussion.
vii. The secondary axis for Precipitation will have a minimum value of 0, a maximum value of 1, and go up in increments of 0.1. If the precipitation values are higher than 1 inch, change the maximum value as needed, then note this in the event report under the discussion.
viii. Stage data will be displayed as a solid red line.
ix. Temperature and precipitation data will be displayed as a dotted blue line.
x. The legend will be displayed on the top of the graph

b. On the graph with "Time" vs "Precipitation" indicate the start and end of the event, and any other relevant information (e.g. sediment in the flume).

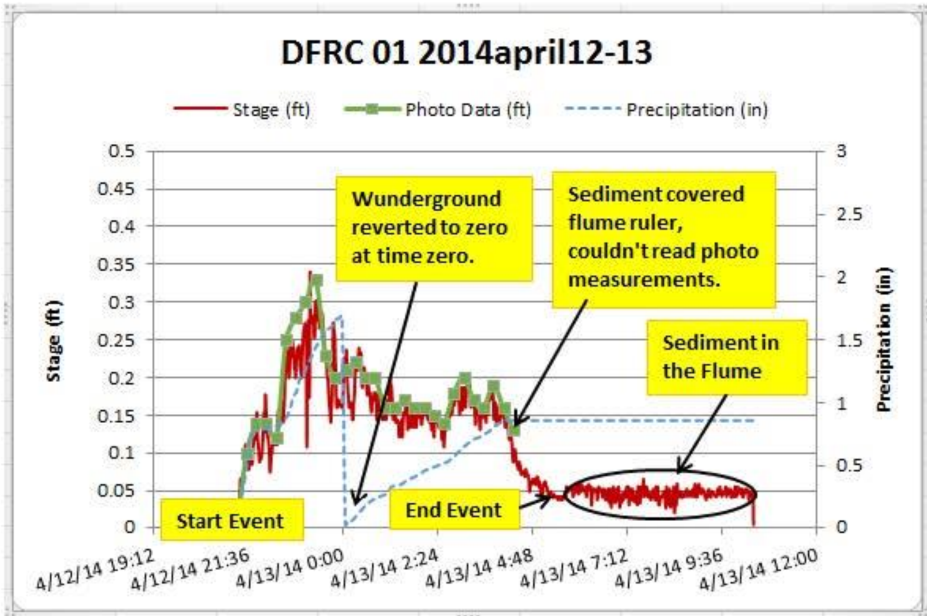



Figure 24. Annotated hydrograph with corrections.

c. A second set of graphs will be created which includes any corrections that needed to be made to the raw data. Correction of stage data is necessary under the following circumstances: ice or debris affected stage, flume was not level during the event, or the stage recorder was measuring stage inaccurately. If ice or debris affected stage, the hydrograph can usually be corrected by using cues in the field notes. Field staff should record stage both before and after removing any ice or debris in the flume. If stage is affected by being off-level or the stage recorder was off, an offset can usually be applied to the entire event. If the site was visited during runoff, and a stage discrepancy was noted, this can be used to apply the offset.

   i. Create a graph which includes "PEC_LocalTime" vs "PEC_FFStage" on the primary axis (from data logger), "Time" vs "Temperature" on the secondary axis (from weather underground), and "Time" vs "Photo Data (ft)" on the primary axis (from timelapse photos). Create a second graph which is the same except it has "Time" vs "dailyrainin" on the secondary axis.

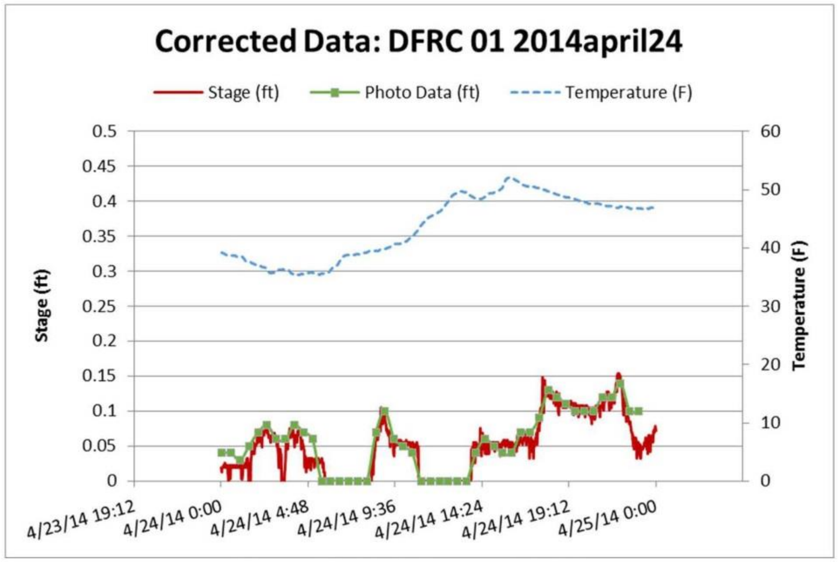



Figure 25. Plot of corrected data.

ii. Graphs will be titled as "Corrected Data: Site Name, Date"
iii. The axes will be titled the same.
iv. Photo data will be displayed as a solid green line with markers which will be green boxes (size 4)

d. A third set of graphs will be created which will be hydrographs.
   i. Create a graph which includes "PEC_LocalTime" vs "PEC_Qcfs" on the primary axis, "Time" vs "Temperature" on the secondary axis (from weather underground). Create a second graph which is the same except it has "Time" vs "dailyrainin" on the secondary axis.
   ii. Graphs will be titled as "Corrected Data: Site Name, Date."
   iii. The primary axis will be titled as "Discharge (cfs)."
   iv. The secondary axis will be titled the same.
   v. The primary axis will have a minimum value of 0, a maximum value of 2.5, and go up in increments of 0.5. If the stage values exceed 2.5 cfs, change the maximum value as needed, then note this in the event report under the discussion.

Discharge data will be represented by a solid purple line

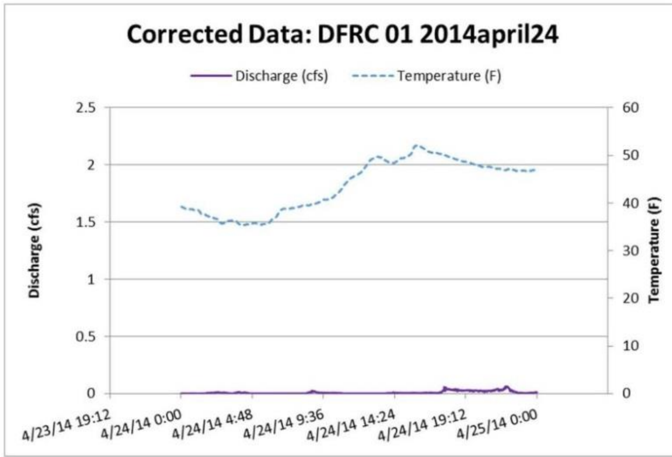



Figure 26. Corrected discharge versus temperature.

**Discharge Calculations**

The "Reformatted Data" tab already contains equations to convert stage to discharge. These equations were generated by plotting Tracom's H-flume discharge table in Excel and fitting a $3^{rd}$-degree polynomial to it (Appendix G). On a 2.5-foot H-flume the equation is:

$$0.5049(\text{stage})^3 + 1.8153(\text{stage})^2 + 0.0885(\text{stage}) = \text{discharge (cubic feet per second)}$$

The "edited data" section has equations that convert cfs into cubic feet per time interval (CF column). Sum all data in the "CF" column to get a total discharge in cubic feet. Divide the discharge by the area of the basin in square feet to get a runoff depth in feet, which can be converted to millimeters or inches.

**Compare Discharge**

Hydrographs for the Aquarod and ISCO ultrasonic meters can be generated using the same general methods described above. Once the discharge volume is calculated, a percent error can be calculated using the following equation:

(Alternative Discharge - EPA Discharge) / (EPA Discharge) = % error

**Calculate Loads and Yields**

Once concentration data is received from the lab, calculating loads and yields for the runoff event is very straightforward:

Concentration * Discharge = Load

Load / Area = Yield

### 7.3. Preparing the Runoff Event Report

1. Log into Dropbox.com
   a. Open Project_Six Mile DNR Folder
   b. Open correct folder for the site (e.g. Cross Plains).
   c. Open the Event Report folder.
   d. Download the Event Report Template (will open in Microsoft Word.)
   e. All event report data should be in the font "Calibri" and size 11.

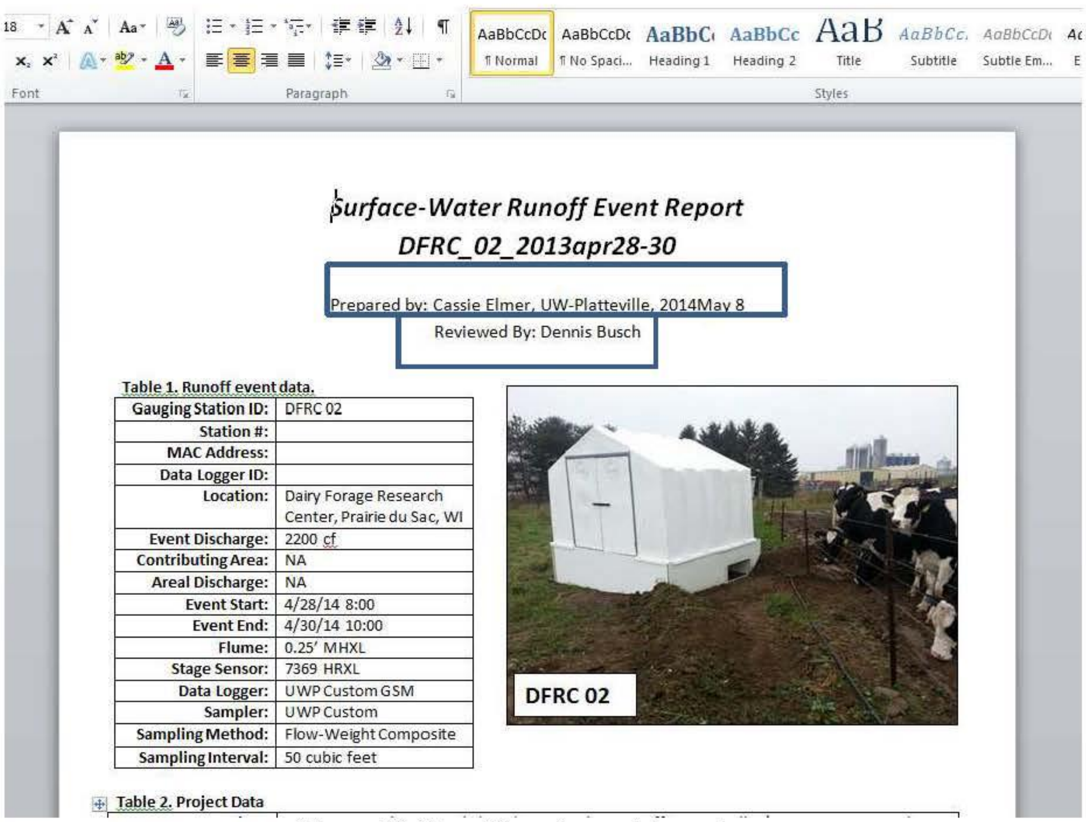



Figure 27. Runoff event report format.

2. At the top of the event report, enter the title dates and prepared by information.
3. Enter the Event Discharge
   a. This is the sum of the Correct Q Volume (column Y of the Daily Log)
4. Enter the Event Start and End times.
5. Enter the Sampling Interval
   a. This is column N of the Daily Log.
6. Enter and notable information into the Comments box.

a. This would include the total rainfall for the event, the duration of the event, if there was and sediment that accumulated in the flume, and if or when it was cleared out.

7. Figure 1
   a. Raw data of Stage vs. Temperature including photo data
      i. Copy the graph that was made in the Daily Log.
      ii. Paste it as a picture.
      iii. The dimensions for all Figures should be a height of 4" and a width of 6".
      iv. Add comments to Figures of raw data (1&2) by inserting shapes and text boxes.
         1. Examples of notable comments are the start of the event, end of event, and where sediment had accumulated in the flume.

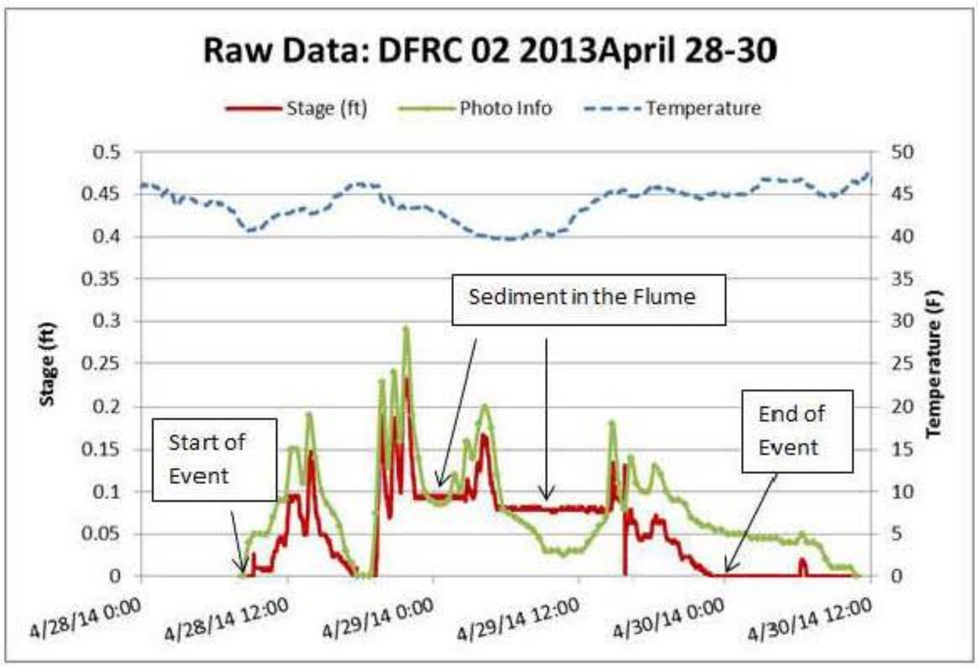
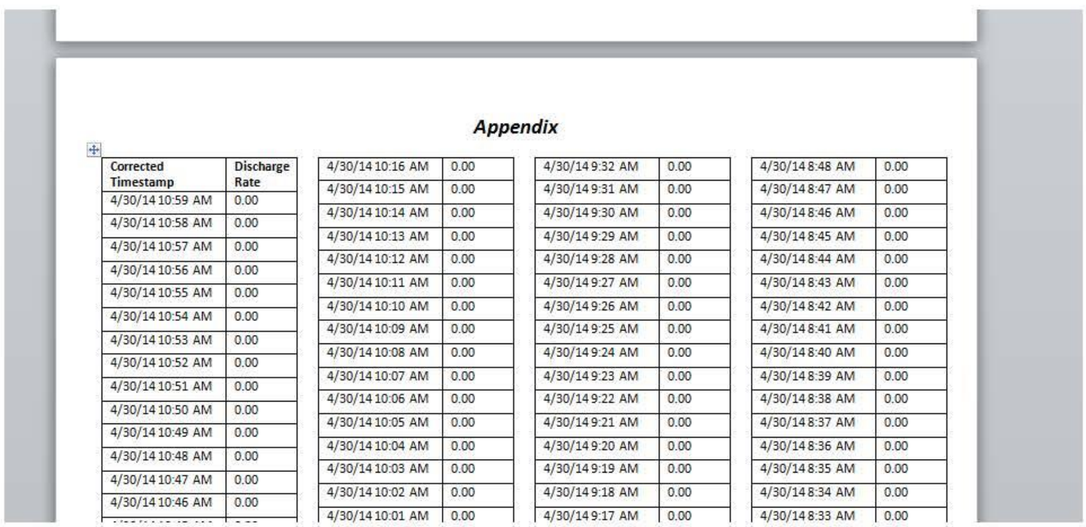



Figure 28. Annotated hydrograph.

8. Figure 2
   a. Raw data of Stage vs. Accumulated Precipitation including photo data
9. Figure 3
   a. Corrected data of Stage vs. Temperature including photo data
10. Figure 4
   a. Corrected data of Stage vs. Accumulated Precipitation including photo data
11. Figure 5

a. Corrected data of Discharge vs. Temperature

12. Figure 6
    a. Corrected data of Discharge vs. Accumulated Precipitation
13. Include any time lapse photos of interest, and comment on importance.
    a. Examples include maximum flow or accumulated sediment in the flume.
14. Appendix
    a. Corrected Timestamp and Corrected Discharge Rate
        i. This can be found in the Daily Log in Columns V and X
        ii. Make a table in excel with these values.
        iii. Change the format of the document to add multiple columns of a table
            1. Go to Page layout Tab click the Breaks button, and select column.
            2. Then click the columns button, go to more columns, and enter 4 into the number of columns.
            3. The text size for this table should be 9.
        iv. Copy and paste the table from excel into the Appendix.



**Appendix**

| Corrected Timestamp | Discharge Rate |
|---|---|
| 4/30/14 10:59 AM | 0.00 |
| 4/30/14 10:58 AM | 0.00 |
| 4/30/14 10:57 AM | 0.00 |
| 4/30/14 10:56 AM | 0.00 |
| 4/30/14 10:55 AM | 0.00 |
| 4/30/14 10:54 AM | 0.00 |
| 4/30/14 10:53 AM | 0.00 |
| 4/30/14 10:52 AM | 0.00 |
| 4/30/14 10:51 AM | 0.00 |
| 4/30/14 10:50 AM | 0.00 |
| 4/30/14 10:49 AM | 0.00 |
| 4/30/14 10:48 AM | 0.00 |
| 4/30/14 10:47 AM | 0.00 |
| 4/30/14 10:46 AM | 0.00 |

| | |
|---|---|
| 4/30/14 10:16 AM | 0.00 |
| 4/30/14 10:15 AM | 0.00 |
| 4/30/14 10:14 AM | 0.00 |
| 4/30/14 10:13 AM | 0.00 |
| 4/30/14 10:12 AM | 0.00 |
| 4/30/14 10:11 AM | 0.00 |
| 4/30/14 10:10 AM | 0.00 |
| 4/30/14 10:09 AM | 0.00 |
| 4/30/14 10:08 AM | 0.00 |
| 4/30/14 10:07 AM | 0.00 |
| 4/30/14 10:06 AM | 0.00 |
| 4/30/14 10:05 AM | 0.00 |
| 4/30/14 10:04 AM | 0.00 |
| 4/30/14 10:03 AM | 0.00 |
| 4/30/14 10:02 AM | 0.00 |
| 4/30/14 10:01 AM | 0.00 |

| | |
|---|---|
| 4/30/14 9:32 AM | 0.00 |
| 4/30/14 9:31 AM | 0.00 |
| 4/30/14 9:30 AM | 0.00 |
| 4/30/14 9:29 AM | 0.00 |
| 4/30/14 9:28 AM | 0.00 |
| 4/30/14 9:27 AM | 0.00 |
| 4/30/14 9:26 AM | 0.00 |
| 4/30/14 9:25 AM | 0.00 |
| 4/30/14 9:24 AM | 0.00 |
| 4/30/14 9:23 AM | 0.00 |
| 4/30/14 9:22 AM | 0.00 |
| 4/30/14 9:21 AM | 0.00 |
| 4/30/14 9:20 AM | 0.00 |
| 4/30/14 9:19 AM | 0.00 |
| 4/30/14 9:18 AM | 0.00 |
| 4/30/14 9:17 AM | 0.00 |

| | |
|---|---|
| 4/30/14 8:48 AM | 0.00 |
| 4/30/14 8:47 AM | 0.00 |
| 4/30/14 8:46 AM | 0.00 |
| 4/30/14 8:45 AM | 0.00 |
| 4/30/14 8:44 AM | 0.00 |
| 4/30/14 8:43 AM | 0.00 |
| 4/30/14 8:42 AM | 0.00 |
| 4/30/14 8:41 AM | 0.00 |
| 4/30/14 8:40 AM | 0.00 |
| 4/30/14 8:39 AM | 0.00 |
| 4/30/14 8:38 AM | 0.00 |
| 4/30/14 8:37 AM | 0.00 |
| 4/30/14 8:36 AM | 0.00 |
| 4/30/14 8:35 AM | 0.00 |
| 4/30/14 8:34 AM | 0.00 |
| 4/30/14 8:33 AM | 0.00 |

Figure 29. Data archive format.

### 7.3 Archiving Data

Photometric data is archived in Dropbox: when in Dropbox, choose the correct Project file, then choose the site file, then choose Time-lapse photos folder. Sensor data will be stored in the Quantity Database, where the project, site number, site name, timestamp, flume stage, tail stage, free flow stage, and flow will all be recorded. The Quality Database will consist of the project name, site name, site number, start of event, end of event, total discharge of event, and concentrations of tested constituents.

### 7.4 Quality/Quantity Database

Not applicable, no samples collected for quality analysis.

### 7.5 Data Reduction (Timelapse Photos)

1. Open Windows Explorer
2. Select "Details" View and Preview Pane
3. Select Appropriate Folder (e.g. Kivlin01_18)
4. Review Photos by day
    a. view photos in approximately 4 hour increments
    b. delete images except under the following circumstances:
        i. The first image of the day.
        ii. Timestamp photo (photograph of a watch or logger timestamp).
        iii. Runoff is Evident in the Flume (stage > 0.03)
        iv. Sediment, Ice, or Snow is Evident in the flume. If this occurs, redundant photos can be deleted. However, always keep photos before and after a transition. For example, if after an event sediment is observed in the flume, do not delete the first photo after the event, the last photo prior to cleaning flume, or the first photo after the flume has been cleared, see example below.
        v. Other unusual observations
5. Record actions and observations in the "Timelapse Photo Record" using the following abbreviations:

| | |
|---|---|
| D | Deletion: All photos deleted except the first of the day |
| Dp | Deletion partial: missing photos. All available photos deleted except first of the day. Create a comment to indicate what photos are missing. |
| S | Snow, Sediment, or Ice observed in Flume |
| RE | Runoff event: observed runoff >0.03' |
| R<3 | Runoff observed, but less than 0.03' (No Event Report will be Completed) |
| NA | Not available, no photos are available |
| TS | Timestamp photo |

| End of Event | Last Photo Before Clearing | First Photo After Clearing |
|---|---|---|

Figure 30. Time lapse photo examples.

## SECTION 8.0 ASSESSMENT AND OVERSIGHT

### 8.1 Post Surface Water Runoff Event Assessment of Discharge Data

After each runoff event, discharge data is reviewed using the Post Surface Water Runoff Event Assessment form (Appendix E). This form has three sections for reviewing discharge data. The first section documents whether discharge data from any of the three methods requires corrections. Correction of discharge data is only necessary if considerable flume tilt is observed, ice or debris artificially affects stage, or a stage sensor was observed measuring stage consistently high or low. The second section of the form addresses whether the discharge relationship is consistent with previous events. The expected outcome of regression analysis is a predictable, consistent discharge relationship. If an event has an unusually large regression residual, it should be noted and the cause recorded. The third section asks if samples were collected when the sample interval was exceeded. In certain large or flashy runoff events, flow-weight-composite samplers may need to collect samples faster than they are mechanically capable of. This portion of the form will document whether those conditions occurred. The bottom of the form provides space for additional comments.

### 8.2 Post Surface-Water Runoff Event Assessment of Concentration Data

After each runoff event, discharge data is reviewed using the Post Surface Water Runoff Event Assessment form (Appendix E). This form has four sections for reviewing yield (unit area load) data. The first section is for documenting whether samples were analyzed within the recommended holding times. Runoff samples can only be stored for a certain period of time (varies depending on the analysis) before the chemical makeup of the sample begins to shift. The second section addresses whether field duplicates are precise. All field duplicates should have a relative standard deviation of less than 10%. The third section provides space to record concentrations found in sampler blanks, potential contamination should be noted. The fourth section is for checking how consistent the concentrations are when compared to previous events. Each concentration is expected to have a consistent relationship when compared to other events. Large regression residuals should be noted. The bottom of the form provides space for additional comments.

### 8.3 Annual Audit

An annual audit is conducted at the end of each water year (Appendix F). The audit is conducted to determine if the methods outlined in the QAPP are followed and document the reasons why or why not.