2015 WATER RESOURCES MANAGEMENT PRACTICUM REPORT

Habitat Improvement in Agricultural Drainage Ditches in Wisconsin's Central Sands Region

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The Water Resources Management Practicum is a regular part of the curriculum of the Water Resources Management Graduate Program in the Nelson Institute at the University of Wisconsin-Madison. The practicum involves an interdisciplinary team of faculty members and graduate students in the analysis of a contemporary water resource problem.

The conclusions and recommendations are those of the graduate authors and do not necessarily reflect the official views or policies of any of the cooperating agencies or organizations, nor does the mention of any trade names, commercial products, or companies constitute endorsement or recommendation for use.

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PREFACE

The Water Resources Management (WRM) master's degree program in the Nelson Institute for Environmental Studies at the University of Wisconsin-Madison is an interdisciplinary program designed to prepare students for employment as water resources management professionals. Since the 1970s, the cornerstone of the WRM program has been a seminar focusing on current issues in Wisconsin water resource management. The seminar has developed into a year-long applied learning opportunity known as the WRM Practicum, which is the central requirement of the program's Master of Science degree.

The 2015 Practicum undertook a study of habitat improvement in agricultural drainage ditches in the Central Sands region of Wisconsin. For over a century, drainage ditches have played a vital role in supporting agriculture in the Central Sands. Today, these ditches are the center of an important nexus between human and natural systems, serving both as a tool for managing field drainage and as a refuge for freshwater species such as trout. The practicum investigated methods for physically altering agricultural drainage ditches to improve in-stream habitat while maintaining drainage function. Using a wide range of methodologies, including community surveys, hydraulic modeling, and habitat assessment, the practicum developed recommendations around using "patch" restoration to improve in-stream habitat.

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INTRODUCTION

The landscape of the Central Sands region of Wisconsin is dominated by agriculture, which in some areas is supported by a series of agricultural drainage ditches. Such landscapes are often ecologically characterized by habitat loss and fragmentation as well as reduced ecosystem services compared to pre-agricultural landscapes. Agricultural drainage ditches can provide important habitat area and connectivity for both aquatic and terrestrial species within an otherwise fragmented landscape (Herzon & Helenius, 2008), and in the Central Sands, several agricultural drainage ditches are Class I trout streams. However, these channelized streams offer limited habitat and ecological services compared to naturally meandering streams. Given the potential of the groundwater-fed streams to provide ecological benefits, there is interest in performing ecological restoration within the streams, with trout habitat improvement as one avenue for restoration.

Improving the health of drainage ditches, even on small scale, can provide benefits to both the landowner and the community. Though the primary focus is on improving habitat for trout, further improvements in water quality and stream health are also possible. A larger, healthier trout population serves as an economic resource by attracting anglers and other fish enthusiasts to the area. Environmental stewardship is an important aspect of many farmers' agricultural practices. Enhancing the aquatic habitat of the drainage ditches on their properties is a simple yet profound way to demonstrate this commitment. Through habitat improvement projects, which may be done at no cost to the landowner, landowners can also strengthen ties to their local communities and organizations.

Originally, this project was intended to consider a full-scale restoration of the Isherwood Lateral, an agricultural drainage ditch in the Central Sands. A full-scale restoration could include re-establishing a meandering stream channel, with the goal of improving in-stream habitat and other ecological services, and would involve significant physical alterations to the lateral from its present state. However, any restoration projects in the agricultural drainage ditches face other physical challenges, in addition to legal and social challenges.

The region's sandy substrate, because of its instability, poses physical challenges for any project that alters the channel geometry or surrounding land. It is difficult to maintain desired channel geometry in sandy substrate streams due to the tendency of sand to slump, and the sand is easily transported downstream, potentially creating drainage problems for downstream landowners. In addition, the drainage ditches in the region exist to support agricultural production by lowering groundwater levels in agricultural fields. Therefore, careful consideration must be given to how a restoration project might affect drainage. Legally, any alterations of drainage ditches in this area must obtain approval and permits from multiple entities, including the county drainage board and the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP). Finally, projects are not likely to succeed without social acceptance from landowners in the area. Without local support, projects will not receive the necessary resources to be implemented, and more importantly, maintained.

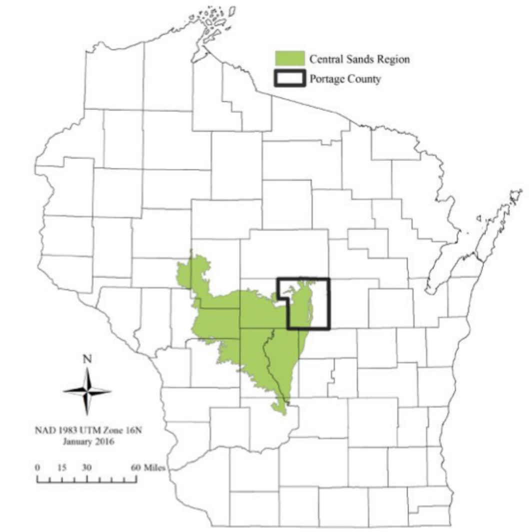


Figure 1: Map of Wisconsin's Central Sands region

In consideration of these challenges, this project incorporates several smaller goals into two broad outcomes: an interdisciplinary study of agricultural drainage ditches in the Central Sands, and a guide for stakeholders interested in improving habitat in agricultural drainage ditches by physically altering the ditches.

The overall goals of this project are to:

- Assess the feasibility of physically altering agricultural drainage ditches in the Central Sands region of Wisconsin to improve in-stream brook trout habitat while maintaining drainage function.
- Provide an informational guide to landowners and policymakers interested in pursuing a habitat improvement project in an agricultural drainage ditch.

Study Area

The Central Sands covers portions of several counties in the central part of the state (Figure 1). It occupies an area that was once the bed of glacial Lake Wisconsin. When the lake drained about 18,000 years ago, it left behind the deep sandy soils that characterize the region (Wisconsin Geological and Natural History Survey, 2013). Another characteristic feature of parts of the region is a high water table, notably in the approximately 87-square-mile Buena Vista Marsh in southwestern Portage County. Originally, the high water table made the area unsuitable for agriculture. By the late 1800s, landowners began digging drainage ditches to lower the water table enough to dry their land and make it suitable for agriculture. In 1903, the Portage County Drainage District (PCDD) was established to oversee drainage ditches in the Buena Vista Marsh area. Today, the PCDD covers the extent of the Buena Vista Marsh with a series of drainage ditches that flow from east to west (Figure 2). As the drainage ditches lower the water table in agricultural fields below the root zones of crops, they also allow farmers to take advantage of the sandy soils and precisely control water and fertilizer application through irrigation. The drainage ditches support production of potatoes, vegetables and cranberries, contributing to the $6 billion, 35,000-job agricultural economy of the Central Sands region (Wisconsin Institute for Sustainable Agriculture, 2016).

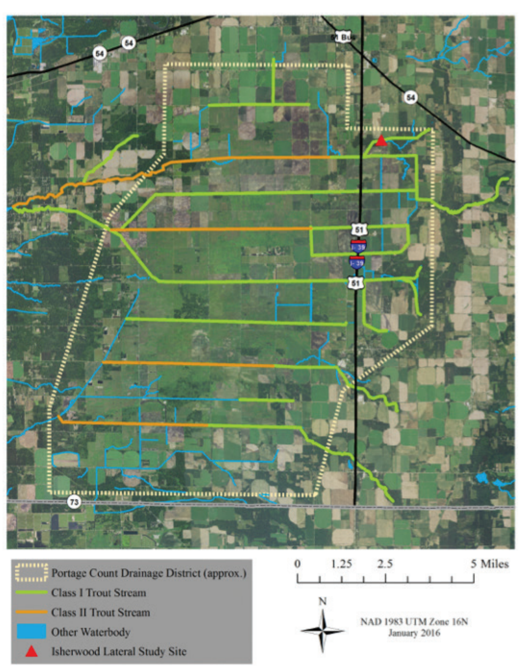


Figure 2: Map of Portage County Drainage District and its trout streams

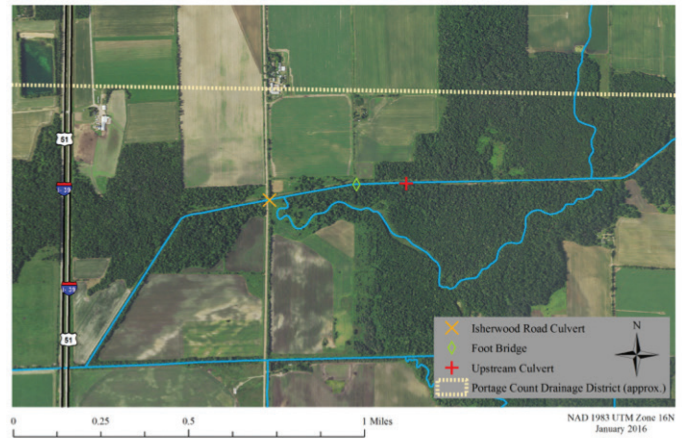


Figure 3: Map of study site at Isherwood Lateral, Portage County, Wisconsin

While many aspects of this project apply to the entire PCDD, the groundwater and in-stream assessments and hydraulic modeling aspects focused on the Isherwood Lateral. The Isherwood Lateral is a headwater stream located at the northeastern corner of the drainage district. Studies were done on a stretch of the Isherwood Lateral from a culvert located at the Isherwood Road crossing to a second culvert located approximately 2,100 feet upstream (Figure 3). Like the other drainage ditches in the PCDD, the Isherwood Lateral is a channelized stream (Figure 4). It is also one of several drainage ditches in the area that are classified as Class I trout streams by the Wisconsin Department of Natural Resources (WDNR), indicating that it is a high-quality trout stream.

Project Development

The Class I and II trout streams in the PCDD are valuable recreational and natural resources for the region and the state as a whole, contributing to the multi-billion dollar impact of trout fishing across Wisconsin. In the Central Sands, Class I trout streams contain naturally reproducing populations of brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*). Brook trout are Wisconsin's only native stream-trout species, and compared to the introduced brown trout, they are less tolerant of warm water, sedimentation and pollutants. Due to their strict habitat requirements, brook trout are susceptible to displacement by brown trout when habitat degradation occurs. Motivated by the opportunity to protect and enhance trout streams, this project focuses on physical alterations to drainage ditches that serve to improve in-stream habitat for brook trout.

Considering the physical, legal, and social challenges discussed above, it was deemed that a full-scale restoration, as originally envisioned, would not be the most appropriate alteration for these drainage ditches. Full-scale restorations can be costly to implement and can create significant physical changes to the ditches and the surrounding land. In addition, should the restoration negatively impact downstream drainage, it would be costly to ameliorate the problem. Instead, we consider "patch" restoration projects to be a more suitable alternative. Patch restoration projects are physically small, require fewer resources for implementation, and can be implemented within existing drainage ditch channels. Several structures and practices designed to improve in-stream brook trout habitat qualify as patch restoration projects and have the added benefit of being relatively easy to remove if they adversely impact drainage. Patch restoration projects also offer the chance to enhance trout habitat in several locations, which can help facilitate trout movement through the series of ditches and streams in the PCDD.

Figure 4: Isherwood Lateral in spring 2015

Overview of Work

The first sections of this report summarize our work in the PCDD. We explored legal issues associated with physically altering drainage ditches through a review of laws and a tour of the PCDD with the Portage County Drainage Board (PCDB). To understand the social concerns related to drainage ditch use and management, we surveyed residents of Portage County. We also undertook a detailed study of the Isherwood Lateral to better understand the physical challenges and opportunities present in the drainage ditches. Our efforts there included a physical habitat assessment, macroinvertebrate and fish surveys, water quality measurements and groundwater monitoring. We also report on hydraulic modeling that was performed to understand likely impacts of implementing patch restoration on surface water elevation within the drainage ditch.

The second part of this report offers recommendations and future opportunities based on the findings from our work in the PCDD. We propose several options for protecting and enhancing trout habitat within the drainage ditches. The options range from maintenance practices to installation of structures within the stream. We provide information and resources for people to consider before they implement an in-stream patch restoration project, and we suggest methods for monitoring patch restorations so that landowners and the PCDB can make informed decisions about ditch maintenance with patch restoration projects. Finally, we offer suggestions for future work related to trout habitat improvement in the PCDD.

POLICY

Introduction

State law pertaining to drainage ditches plays a large role in determining the feasibility of drainage ditch alterations. Before diving more deeply into other aspects of this project, we reviewed the legal issues guiding drainage ditch activities and visited the PCDB to understand what activities typically occur in the drainage district. This section highlights current drainage laws and their history, and explains the roles and interactions of relevant agencies.

History of Wisconsin Drainage Laws

The purpose of agricultural drainage ditches is to regulate the water table in adjacent fields by gravitationally draining groundwater from the land. However, doing this also has effects on the groundwater levels of downstream properties. In the past, this has caused disagreements among landowners, so the earliest drainage laws in Wisconsin, some of which predate statehood, were established to provide a structure for solving disputes among landowners who could not agree on where drainage ditches should be located (Wisconsin Department of Agriculture, Trade and Consumer Protection, 2015). To facilitate cooperation among landowners, organized drainage districts were established as early as 1891. In 1965, all prior forms of drainage organizations were combined under the regulatory overview of Wisconsin Statutes Chapter 88 (Figure 5). This has remained largely unchanged, with the exception that DATCP was given oversight of county drainage districts and the authority to develop drainage rules in 1991 (Kent & Dudiak, 2001).

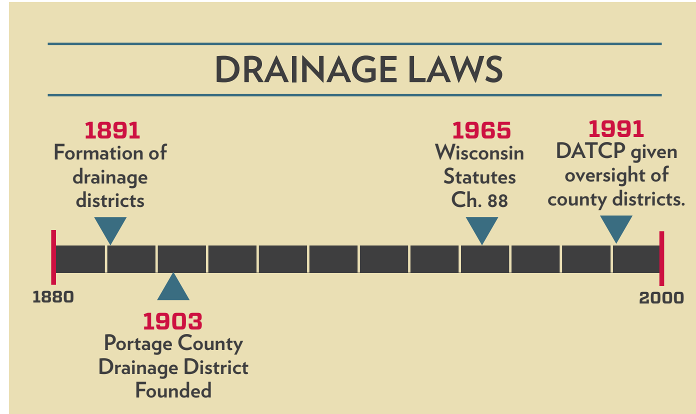


Figure 5: Timeline of Portage County drainage laws

Portage County Drainage District

The PCDD is the largest active drainage district in Wisconsin. Since drainage ditches in the district affect entities beyond agricultural production, including wetlands, navigable waters, endangered resources and trout streams, many agencies and organizations at federal, state and local levels are involved in activities within the drainage district:

- DATCP oversees drainage boards in the state, with duties such as assisting drainage boards in applying for permits, reviewing reports, and establishing performance standards for drainage district activities.
- The DNR, as the principal agency for protecting water quality, issues permits for all activities affecting navigable waters of the state or posing a threat to fisheries. The DNR also conducts reviews of activities that might impact endangered species, such as the Karner blue butterfly or the greater prairie chicken.
- For activities that might impact wetlands, both the DNR and U.S. Army Corps of Engineers review projects and issue permits.
- Circuit courts oversee the organization and dissolution of drainage districts.
- Landowners who benefit from the drainage ditches are assessed; the resulting money provides the sole financial support for activities carried out by the drainage board.
- Agencies such as Natural Resources Conservation Service (NRCS) and U.S. Geological Survey (USGS) participate in the monitoring of drainage ditches.
- Interest groups such as the Wisconsin State Cranberry Growers Association, the Wisconsin Potato and Vegetable Growers Association, and Trout Unlimited participate in drainage activities to advocate for their members' interests.

Ultimately, the PCDB has the most direct involvement with drainage activities. The PCDB is a three-member volunteer board that directs and oversees all aspects of drainage ditch construction and operation, working under DATCP supervision and in accordance with state law.

Current PCDD Activities

Given the size of the PCDD, a large portion of the PCDB's time is spent maintaining drainage ditches. Drainage ditches in the district have been constructed according to specific cross-section geometry and grade profile designed to lower the water table and keep it below a certain level. Maintenance of drainage ditches consists of returning the ditches to their original geometry, often using heavy equipment to clear a path on one side of the ditch to remove deadfalls within the ditch and to dredge out accumulated vegetation and sediment. Currently, reed canary grass is the primary maintenance challenge in the PCDD. It grows in the ditch channels and alters the flow of water by trapping sediment, eventually slowing or completely blocking the flow of water. This blocked water flow has the potential to raise the water table and damage crops in adjacent fields. The PCDB manages reed canary grass, an invasive plant species, with herbicide applications to temporarily impede its growth and with dredging when the reed canary grass has advanced to the point where it is blocking most of the ditch channel.

For any type of maintenance, the PCDB must coordinate with the other groups and agencies involved. For example, herbicides must be approved for aquatic use and must be used in such a way as to not negatively impact cranberry growers downstream. In addition, maintenance via dredging requires a Wisconsin Pollutant Discharge Elimination System (WPDES) permit from the DNR. Since the permitting process for a single ditch can take over a year, some ditches are severely blocked by the time dredging occurs.

Proposing a Project

The PCDD serves farmers who are producing high-value vegetable crops. In some cases, a farmer will ask to construct a new ditch that connects to an existing ditch in order to develop additional farmland. The PCDB collaborates with these landowners by reviewing and, if appropriate, approving new construction. However, drainage activities are not limited to the construction of new drains. Regulated projects include anything that alters the ditch beyond the specifications on record, obstructs or alters the flow of water into or from a drainage ditch, or increases erosion into a drainage ditch. If a landowner wishes to place a structure in a ditch or otherwise alter it, permission from DATCP and WDNR, via the PCDB, is required.

When a project is proposed, the PCDB must submit a permit application to the WDNR and seek final approval from DATCP before proceeding with the proposed action (Wisconsin Administrative Code § ATCP 48.34). The application requires detailed information about the project, including the objectives of the project, estimated cost, design specifications, analysis of affected lands and waters, and a hydrology analysis. In addition, the PCDB must publish a hearing notice and hold a public hearing on the proposed action. Ultimately, a landowner should plan to work with the members of the PCDB when planning a project that requires DATCP approval and discuss with the PCDB the process for planning and implementing the project.

LANDOWNER SURVEYS

Any type of modification to drainage ditches in Portage County needs approval from the PCDB, but it also needs support from local residents. Without local support, restoration efforts would be difficult to implement and almost impossible to maintain. With this in mind, one of our first steps was to determine the relationship residents of the county have with the drainage ditches, and whether or not a restoration effort would be supported or opposed. We developed a survey for residents of the county in order to understand more completely how residents used their drainage ditches, if they would consider naturalizing parts of their ditches, and whether they felt that naturalization efforts would negatively affect farming activities. (A copy of the survey, entitled "Agricultural Drainage Ditch Enhancement Questionnaire," can be found in Appendix A.) In an effort to maximize response rates, we administered the surveys in person rather than send them through the mail. Overall, we

Public participation is important if a project is going to be successfully implemented and maintained. We administered surveys to residents of Portage County to gauge their interest in stream restoration projects.

Residents of Portage County are generally in favor of stream restoration activities if the costs are low and the projects do not impact agricultural activities.

found that residents of Portage County were receptive to the idea of ditch restoration efforts.

We first administered surveys on July 25, 2015, at a Lions Club event in Almond, Wisconsin, called the "Tater Toot." The survey handed out at this event varied slightly from the survey found in Appendix A, as Question 1 ("I am aware of and familiar with the operation of the Portage County Drainage District") was not yet included. In all, we collected 30 responses: 7 from residents with drainage ditches on their property, and 23 from residents without drainage ditches on their property.

Shortly after the Tater Toot, we met with two members of the PCDB, Paul Cieslewicz and Kiley Stucker. After explaining the PCDB's role in the community and its relationship with landowners, the board members asked that we place a question in our survey asking if residents were aware of the PCDD and the board's actions in the county. The survey was adjusted accordingly to accommodate this request.

On August 9, 2015, we attended a Lions Club event in Bancroft, Wisconsin called "The Good Old Days." With the help of Paul Cieslewicz, we were able to identify more county residents with ditches on their property and encourage them to complete our survey. We collected 26 responses: 12 from residents with drainage ditches on their property and 14 from residents without drainage ditches on their property.

In total, we received 56 completed surveys: 19 from residents with ditches on their property and 37 came from residents without ditches on their property. Of the 26 surveys from the Good Old Days, 18 people knew of or were familiar with the operation of the PCDD. (Overall results from the survey are summarized in Table 1.) The results indicate that, in general, residents of Portage County use or would like to use drainage ditches for recreational activities and are willing to enhance parts of their ditches to a more natural state. Cost of naturalization does not seem to be a factor. Responses indicate that residents are neutral toward or slightly disagree with the belief that naturalization would negatively affect farming activities, and are neutral on current ditch maintenance practices (i.e., how the PCDB currently maintains the ditches).

1 = strongly disagree with the statement
3 = neutral
5 = strongly agree with the statement

	Mean	Median
I use or would like to use drainage ditches for recreational activities.	3.65	4
I would consider enhancing parts of my ditch.	3.31	4
I would consider enhancing only if the costs were low.	3.36	3
I am concerned about negatively affecting farming.	2.78	3
I believe that ditches should remain the way they are now.	3.21	3

Table 1. Overall results of landowner surveys

These results were further broken down into responses from landowners with ditches on their property and residents without ditches on their property (Table 2). In general, landowners with ditches on their property use or would like to use ditches for recreational activities and would consider enhancing parts to a more natural state. They would only consider this enhancement, however, if the costs were low or nonexistent. They are neutral on the question of whether naturalization would affect farming activities, and they agree that ditches should continue to be maintained according to current practices.

Portage County residents without drainage ditches on their property had slightly different responses (Table 2). In general, residents without drainage ditches on their property would like to use ditches for recreational activities and are in favor of enhancing drainage ditches. They are neutral on the issue of cost, and are not concerned that enhancement would negatively affect farming activities. They are neutral on current ditch maintenance.

The results from residents with ditches on their property and those without ditches on their property show few significant differences. Both groups seem to favor using ditches for recreational activities and would consider enhancing ditches if the costs were low. However, residents without ditches on their property are less concerned that ditch enhancement would negatively affect farming activities, and residents with ditches are more agreeable towards current ditch management practices.

These results, while indicative of some general feelings toward drainage ditches, do not encapsulate the views of every resident of Portage County. Future studies could include a more thorough survey of landowners with ditches on their property. Overall, we found that the residents of Portage County were either in favor of or neutral toward drainage ditch enhancement projects. With the general support of the public behind us, we continued our research to determine which types of projects would work best in Portage County.

HABITAT ASSESSMENT

In order to better understand the challenges and opportunities for patch restoration to improve brook trout habitat in

1 = strongly disagree with the statement
3 = neutral
5 = strongly agree with the statement

	DITCHES ON PROPERTY		NO DITCHES ON PROPERTY	
	Mean	Median	Mean	Median
I use or would like to use drainage ditches for recreational activities	3.44	4	3.76	4
I would consider enhancing parts of my ditch	3.41	4	3.17	3.5
I would consider enhancing only if the costs were low.	3.47	4	3.24	3
I am concerned about negatively affecting farming.	3.22	3	2.52	3
I believe that ditches should remain the way they are now.	3.53	4	3.03	3

Table 2. Breakdown of results between landowners with ditches on their property and those without

SUMMARY OF FINDINGS:

The channelized ditch lacks riffles, pools and other lasting cover for fish.

Water temperature and water quality meet are suitable for Brook Trout.

the Central Sands region, we researched the habitat requirements of brook trout and assessed the current ecological conditions of the Isherwood Lateral. Assessments included a survey of the physical habitats found within the ditch, as well as surveys of macroinvertebrates and fish found in the stream. These assessments can serve as baseline conditions for future assessments and patch restoration projects.

Brook Trout Habitat Needs

Brook trout are native to the northeastern and northern Midwestern states and the eastern two-fifths of Canada, though they have been introduced elsewhere throughout the world. While Wisconsin streams are home to many species of trout, brook trout are the only native stream trout species in the state (Wisconsin Department of Natural Resources [WDNR], 2008). Brook trout are a coldwater species that live in perennial streams and lakes with optimum water temperatures between 52 and 62 °F. Sustained temperatures above 68 °F can cause high mortality rates in hatchlings, and growth rates decline as temperature rises above 62 °F (Chadwick, 2012). Brook trout often migrate seasonally to avoid temperature extremes and into colder headwater streams for spawning.

Brook trout reproduction occurs in the fall when water temperatures are between 40 and 50 °F. Females dig spawning grounds in gravel patches called redds, where fertilized eggs are deposited. Therefore, substrate size is of great importance to brook trout. As accumulation of fine sediments increases, such as in areas invaded by reed canary grass, inter-gravel oxygen concentrations decline and spawning success decreases (Raleigh, 1982).

Other brook trout habitat needs include clear water, in-stream cover, and relatively stable water flow and temperature regimes. In addition, a dissolved oxygen level of no less than 5mg/L is required, with an optimum dissolved oxygen concentration near saturation. In a study conducted by Bousuu (1954), the number and weight of trout increased or decreased by adding or removing brush cover and undercut banks. However, people involved in previous stream restoration projects in Wisconsin have observed that non-native brown trout often thrive in areas of high vegetative, undercut, or structural cover, effectively outcompeting brook trout. On the other hand, brook trout often prevail where there are deep pools and water surface turbulence for cover (Mike Miller, personal communication 2015; Stu Grimstad, personal communication 2015).

Physical Habitat Assessment

In September 2015, we performed a habitat assessment of the Isherwood Lateral using the WDNR Wadeable Stream Quantitative Habitat Evaluation Form 3600-228 and the WDNR Guidelines for Evaluating Habitat of Wadeable Streams (WDNR, 2002). This allowed us to evaluate the physical and biological integrity of the ditch as well as its suitability for brook trout. (Full results of this assessment can be found in Appendix B.) The habitat assessment revealed a few key things:

- The vast majority of the cover for fish consists of in-stream aquatic vegetation. When the ditches are dredged, this vegetation is removed, leaving fish nowhere to hide.
- The substrate of the ditch is homogeneous and lacks pool and riffle structures that are used by brook trout for cover and spawning.
- The sandy substrate contains very little gravel, which is preferred by brook trout for spawning.
- The water temperature and water quality are suitable for brook trout.

Macroinvertebrate Survey

In addition to a physical habitat assessment, we also conducted a macroinvertebrate assessment in the Isherwood Lateral. This assessment had two main goals: first, to determine if there was enough food present for adult trout to survive in the area, and second, to determine the "health" of the stream with regard to stream water quality. Macroinvertebrates are an important part of the aquatic food chain and have varying degrees of sensitivity to changes in the quality of water (pollutants, dissolved oxygen levels, etc.). In this case, macroinvertebrates were used as a proxy to determine the health of the Isherwood Lateral.

Our first macroinvertebrate survey was performed in March 2015. We divided the Isherwood Lateral into two

Freshwater shrimp (scuds) were abundant in the Isherwood Lateral and should provide adequate food for the trout population.

Macroinvertebrates have varying levels of sensitivity to pollutants. Based on the macroinvertebrates found in the Isherwood Lateral, the stream is in good health with regard to pollutants.

stretches: the first began approximately 100 feet upstream of Isherwood Road and had predominately sandy substrate and no woody debris; the second was upstream of the footbridge (approximately 1,330 feet upstream of Isherwood Road) and contained woody debris in the form of downed logs or branches. We then broke each stretch into three reaches (~33 feet each) with buffers of at least 33 feet between reaches (Figure 6). For each reach, we first determined the proportion of microhabitats in terms of vegetation, sand or woody debris. Vegetated habitats included any areas that were covered by in-stream macrophytes (coontail, watercress, etc.), and woody debris included areas that were mostly covered by fallen trees or branches. We next collected macroinvertebrate samples based on the proportion of each microhabitat. For example, if a reach had 75 percent vegetated bottom and 25 percent sandy bottom (3:1 ratio), we took three samples in the vegetated area and one sample in the sandy area.

To collect macroinvertebrates, we used a D-frame net held by one person while a second person disturbed the substrate upstream of the net for 30 seconds with their feet. The net was then emptied into a white washbasin and macroinvertebrates were collected. Samples were preserved in ethanol on site to be sorted at a later date. Total counts of macroinvertebrates (sorted by family) can be found in Appendix C.

In our spring survey, we found small freshwater shrimp, commonly called scuds, to be plentiful in all sampled reaches of the Isherwood Lateral, with some sampled reaches yielding up to 1,328 scuds (Figure 7). Scuds are a natural food source for trout, and often trout fishing lures are made to look like the small freshwater shrimp (Rowley, 2016). With so many scuds present in the Isherwood Lateral, we believe that food abundance should not be a concern for the trout population. We also used a Citizen Monitoring Biotic Index (provided by the WDNR, Appendix D) to assess stream health. This index categorizes macroinvertebrates by their tolerance to low water quality. Our results indicated that the woody debris habitat had an "excellent" stream health rating, sand had a "good" health rating, and vegetation had a

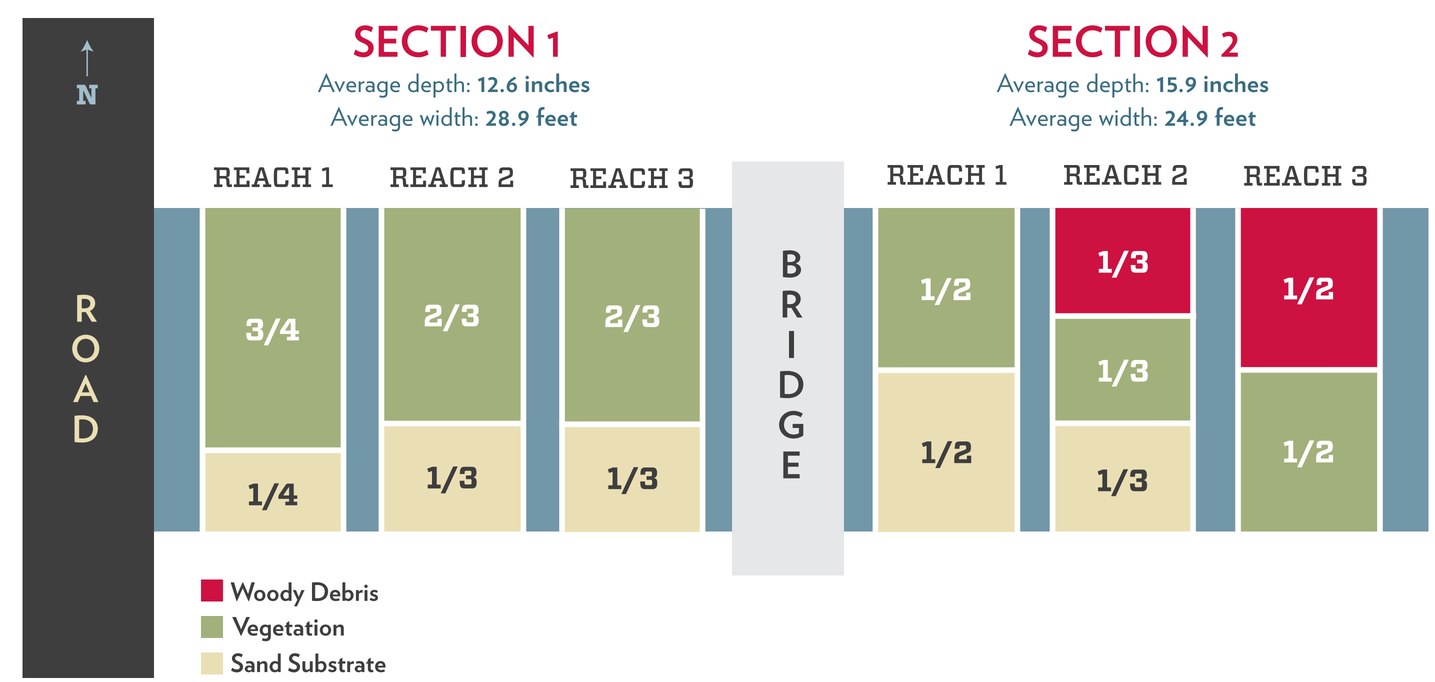


Figure 6: Macroinvertebrate sampling reaches and their relative proportions of microhabitats

Figure 7: Freshwater shrimp or "scud" (Redmond, 2016)

"fair" health rating (Table 3). Overall, the Isherwood Lateral supported a macroinvertebrate population that indicated that the ditch was in good health.

We sampled macroinvertebrates again in the beginning of fall 2015 (September) to assess the health of the lateral in different seasons. This time we did not preserve the samples for detailed counting, but rather adopted a catch-and-release protocol. Similar to our spring sampling, we employed the Citizen Monitoring Biotic Index to test for the presence or absence of different macroinvertebrates. The stream was again broken into two stretches (one downstream of the footbridge and one above), and the microhabitats were sampled in proportion to their prevalence in the stretch. We used the same sampling procedure as described above except after taking our counts we released the macroinvertebrates back into the stream. This time, the health readings for all three microhabitats were "good," though the index score for vegetated areas was slightly lower than for woody debris or sand (Table 3). Again, we observed an abundance of scuds in all habitat types.

Overall, we observed a large number of scuds present in fall and spring; these invertebrates should provide an adequate source of prey for trout. Additionally, the types of macroinvertebrates present indicated that the stream was in good health in terms of pollutants. In future studies, we suggest that macroinvertebrates be identified on a finer taxonomic scale, and that macroinvertebrates be studied in more drainage ditches throughout Portage County. It would be useful to compare the relative health of neighboring drainage ditches to determine if there are sufficient food sources for trout between the Isherwood Lateral and the streams that connect it to larger water bodies.

Fish Survey

Although the channelized Isherwood Lateral was constructed from the remnants of a stream that ran through what was once a wetland, it is classified by the WDNR as a Class I trout stream. This means that the natural reproduction of the trout in the stream is capable of sustaining the population without the stream being stocked (WDNR, 2016). In addition, it is classified by the WDNR as an "Exceptional Resource Water," meaning it provides recreational opportunities, supports valuable fisheries and wildlife habitat, has good water quality and is not significantly impacted by human activities (WDNR, 2013). During our spring 2015 macroinvertebrate sampling, we did, in fact, see brook trout in the Isherwood Lateral. To better understand the fish populations that are utilizing the ditch, we conducted an electroshocking survey in September 2015.

An electroshocking survey in the Isherwood Lateral revealed 54 brook trout, 14 brook stickleback and four mud minnows.

Over 94 percent of the brook trout found were young-of-the-year trout.

Electroshocking is a sampling method in which a low-voltage electrical current is sent through the water, temporarily stunning fish within the shocking range and allowing the fish to be caught, measured and released unharmed. This survey was performed following the WDNR's Guidelines for Assessing Fish Communities of Wadeable Streams in Wisconsin (WDNR, 2002). The survey began approximately 30 feet upstream of Isherwood Road and continued in an upstream direction. In accordance with WDNR protocols, the survey covered a stream length of 35 times the mean stream width: approximately 1,150 feet. The survey was performed using a battery-powered backpack shocking unit, which consisted of a wearable frame with a safety kill switch, an anode shocking arm with a manual switch, and a cathode tail that trailed behind the backpack wearer to complete the circuit.

The person wearing the backpack unit used the anode shocking arm to stun fish, which were then captured in a handheld dip net. Another person followed several feet behind with a bucket of stream water into which the fish were transferred to be held until they were measured. Once five to 10 fish had been caught, the surveying team paused in-stream to measure the fish on a field measuring board and record the data. The fish were then released downstream of the electroshocking area to avoid recapturing the same fish.

	SPRING			FALL		
	Sand	Vegetation	Wood	Sand	Vegetation	Wood
# of group 1 animals	1	2	1	2	2	1
# of group 2 animals	2	1	1	1	1	1
# of group 3 animals	1	1	0	1	1	0
# of group 4 animals	2	4	1	2	3	2
Index score	2.83	2.5	3.66	3	2.71	3
Health	Good	Fair	Excellent	Good	Good	Good

Table 3. Health of each habitat using the Citizen Monitoring Biotic Index (spring and fall)

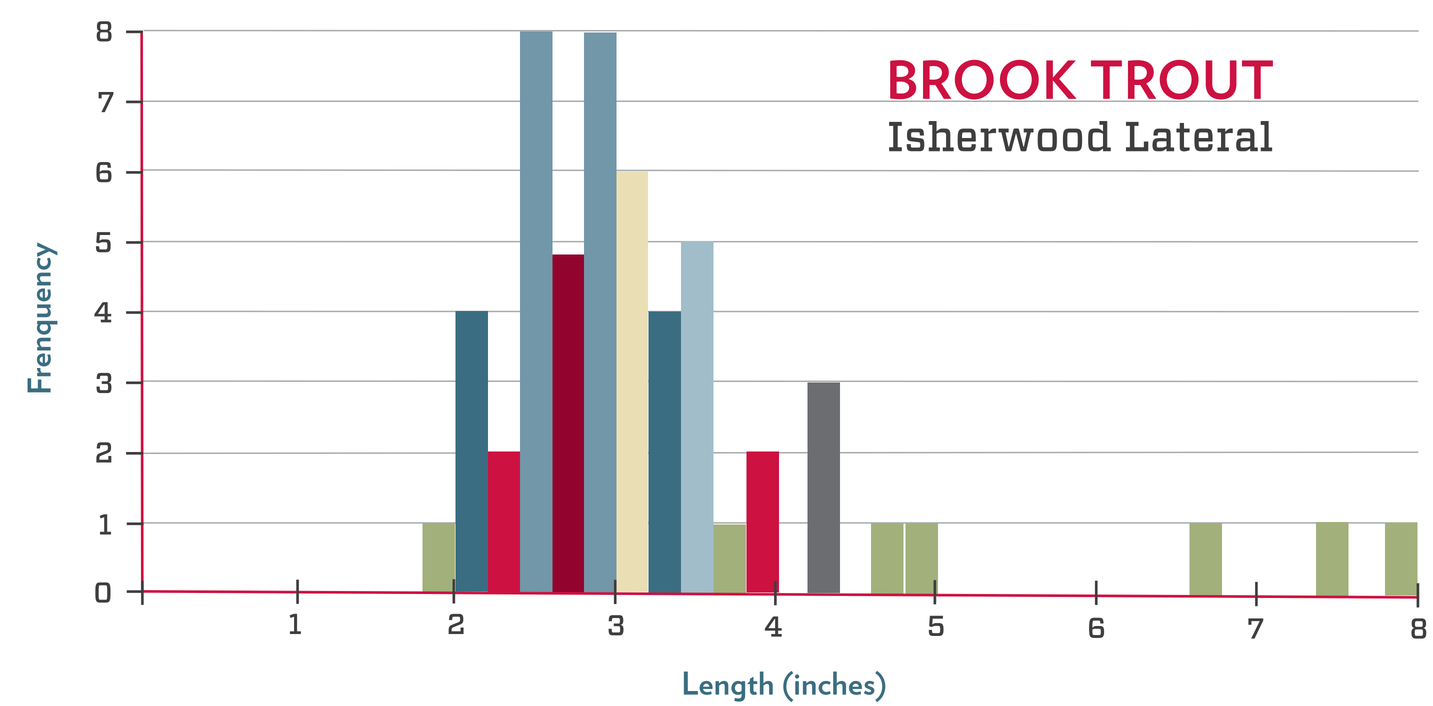


Figure 8: Brook trout in the Isherwood Lateral, September 2015

Our survey yielded 14 brook stickleback, four mud minnows and 54 brook trout (Appendix E). Brook trout in Wisconsin smaller than five inches are generally considered young-of-the-year trout. Of the 54 trout observed, 51 were less than five inches in length, indicating that the sample consisted primarily of young-of-the-year trout (Figure 8).

A number of factors could influence the high percentage of young-of-the-year trout we observed. The ditch may have little potential to support adult trout; this stretch of ditch may be preferred by young trout; or adult trout may utilize this area at a different time of year. Additional surveys during multiple seasons and over several years will clarify the use of the Isherwood Lateral by brook trout and other species.

WATER QUALITY

Water quality parameters were measured to gain a better understanding of the type of modifications that may be required in order to support in-stream habitat.

Some nutrient levels exceeded EPA recommendations for surface waters. However, temperature ranges remained favorable for brook trout throughout the study.

Introduction

The physical and chemical properties of the water in agricultural drainage ditches directly impact the types of macroinvertebrates and fish that inhabit them. Like the majority of drainage ditches in the Central Sands, the Isherwood lateral is almost entirely groundwater fed. We monitored groundwater and surface water conditions to gain a better understanding of the water quality of the lateral and the type of modifications that may be required in order to support in-stream habitat for brook trout.

Instrumentation

Three groundwater wells were installed adjacent to the lateral in early June 2015. The wells were constructed of two-inch diameter PVC pipe with 4.67-foot slotted PVC screens and installed 6.57, 6.37 and 6.06 feet below ground for wells 1, 2 and 3, respectively. Wells 1 and 2 are located on the north side of the Isherwood Lateral in primarily sandy soil. The south bank of the lateral, where well 3 is located, is comprised of much more humic soil (Figure 9). Water purged from well 3 was consistently darker and more tannic than that from wells 1 and 2.

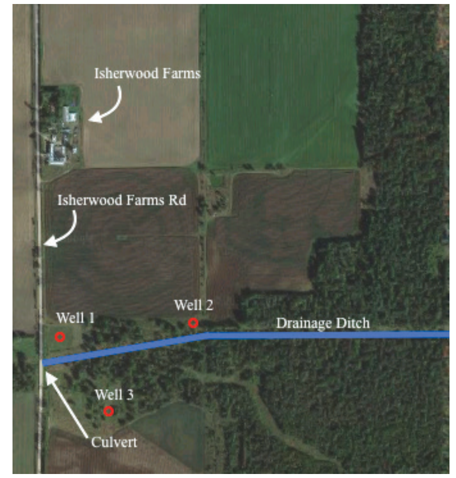
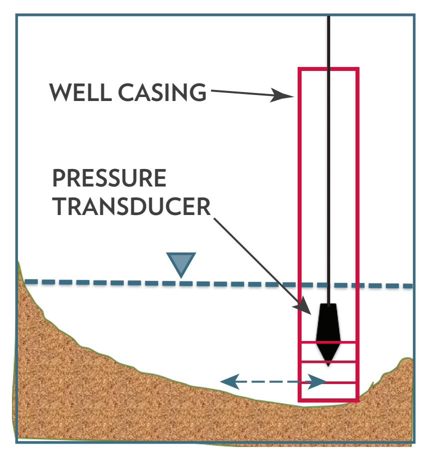


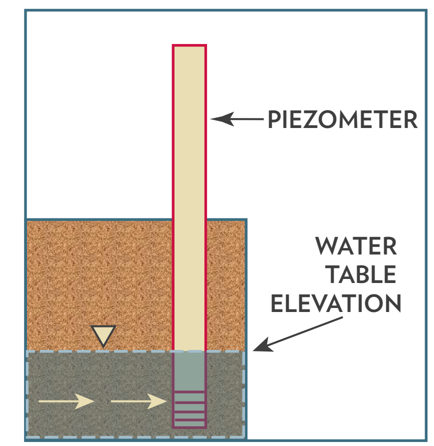
Figure 9: Aerial view of the Isherwood farm and well locations



Two stilling wells were installed at the base of the upstream side of the culvert at Isherwood Road and the base of the downstream side of the culvert east of the footbridge to monitor water levels in the Isherwood Lateral. Both of the wells were constructed of two-inch PVC pipe 5.07 feet in length. HOBOware pressure transducers were suspended within the stilling wells to record water levels and temperatures at one-hour intervals for periods lasting up to 2.5 months.

Physical Analysis

On June 4 and 5, 2015, we conducted a physical assessment of the discharge in the Isherwood Lateral to determine the amount and direction of flow. We measured water flow upstream of the road culvert using a mini-pygmy meter and found it to be 4.59 cubic feet per second (cfs). Two temporary mini piezometers were installed within the lateral – one upstream of the culvert at Isherwood Rd and a second upstream of the footbridge near well 2. Based on the hydraulic head measurements and water surface elevations, an upward hydraulic gradient of 0.224 at the downstream sampling site and 0.279 at the upstream sampling site were calculated, meaning that groundwater was flowing into the Isherwood Lateral in this area. Hydraulic conductivity values for the sediments below the streambed were estimated to be 5.507 feet/day (downstream site average) and 2.769 feet/day (upstream site average), which are characteristic values for sandy substrates. Water temperatures logged during the monitoring periods remained, for the most part, within the optimal range for trout (52-62 °F) (Figure 10). Within the monitoring period (June 19 – July 23 and August 18 – October 16, 2015), temperatures in the ditch peaked at 63.3 °F on June 21.



Hydraulic head is the combined measure of the elevation and the water pressure at a point in an aquifer (the saturated zone). It is measured using piezometers – mini wells with small screens that measure the water level in an aquifer at a discrete point.

Chemical Analysis

Nitrate-N, phosphate, and dissolved oxygen concentrations were measured in the Isherwood Lateral and the groundwater wells three times between June and August 2015, since these parameters play an important role in water quality. Measurements were made on-site using CHEMets colormetric test kits. Nitrate-N for the Isherwood Lateral far exceeded the U.S. EPA recommendations for controlling eutrophication in surface waters in this ecoregion (USEPA, 2000). Concentrations for the ditch were highest in June and decreased throughout the summer. Conversely, nitrate-N concentrations were lowest for the groundwater measurements in June and increased with time (Figure 11). Phosphate concentrations were below detection in the ditch with the exception of the June 4 and 25 sampling dates, where concentrations were still within the Wisconsin state-mandated levels for streams (Wisconsin Administrative Code, 2010) (Table 4, Appendix F). Dissolved oxygen levels ranged between seven and 10 mg/ L, consistently above the lower threshold of five mg/L for brook trout. Elevated levels of nutrients (specifically nitrate and phosphate) are linked to excessive metaphyton growth, low dissolved oxygen levels, and high conductivity, all of which negatively impact habitat quality for trout. However, eutrophication did not appear to be an issue for the Isherwood lateral based on the limited data collected.

Water temperature and conductivity were manually measured in the ditch and wells four times between June and August. Detailed results of the physical and chemical data collection for the wells and ditch can be found in Appendix F.

MODELING

Introduction

A patch restoration project in the Isherwood Lateral was modeled using HEC-RAS.

The results from that model were compared to the modeled conditions of the post-dredging design specifications of the Isherwood Lateral.

It was found that it is possible to perform patch restoration without increasing the water level in the ditch.

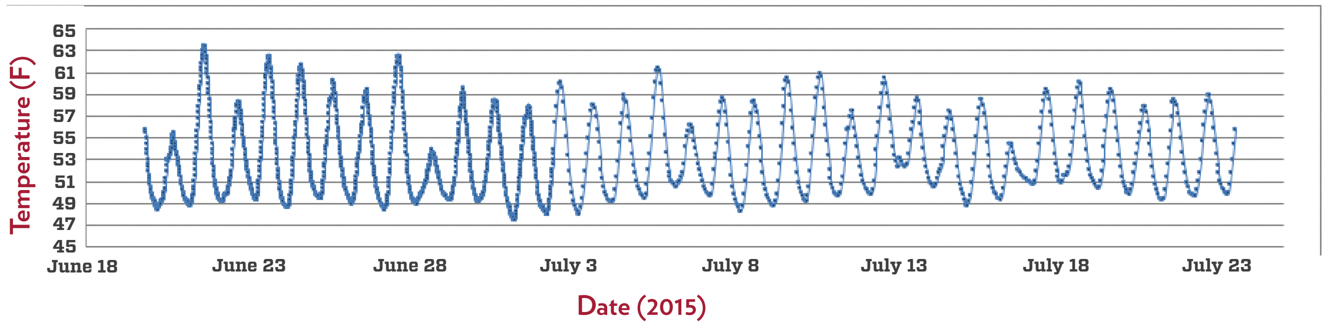


Figure 10: Summer temperature fluctuations for the Isherwood Lateral.

Because of the porous nature of the Central Sands region's soils, controlling the water table elevation is extremely important to farmers for managing crop health. Any alterations to the drainage ditches, which are used to drain the fields and manage water table elevations, must minimally impact groundwater levels. For this reason, hydraulic modeling of the study site was performed to assess the impact of implementing small-scale, in-stream restoration techniques in the Isherwood Lateral. A model of the ditch in its post-dredged state was compared to a model of the ditch in a state that simulated small-scale restoration. The model calculated values for the water surface elevation of the ditch under the different scenarios, with the understanding that changes in surface water elevation could impact the elevation of the water table in adjacent fields. (One objective of implementing patch restoration is to avoid significant fluctuations in the water table elevation.)

The following scenarios were modeled:

1. The post-dredging ditch geometry as specified by the PCDD.
2. The ditch geometry that would result from small-scale restoration techniques designed to deepen and narrow the flow area of the ditch.

Methods

In order to model the hydraulic impacts of small-scale restoration techniques on sandy-bed agricultural drainage ditches, we performed a one-dimensional, steady flow analysis using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software. HEC-RAS is a computer program developed by the U.S. Army Corps of Engineers that allows users to input stream cross-section data, parameters and boundary conditions in order to simulate the behavior of water in a channel under different conditions.

Modeling established cross sections

The PCDD has specifications for each drainage ditch showing the dimensions to which the ditches are dredged during maintenance. PCDD supplied us with a document

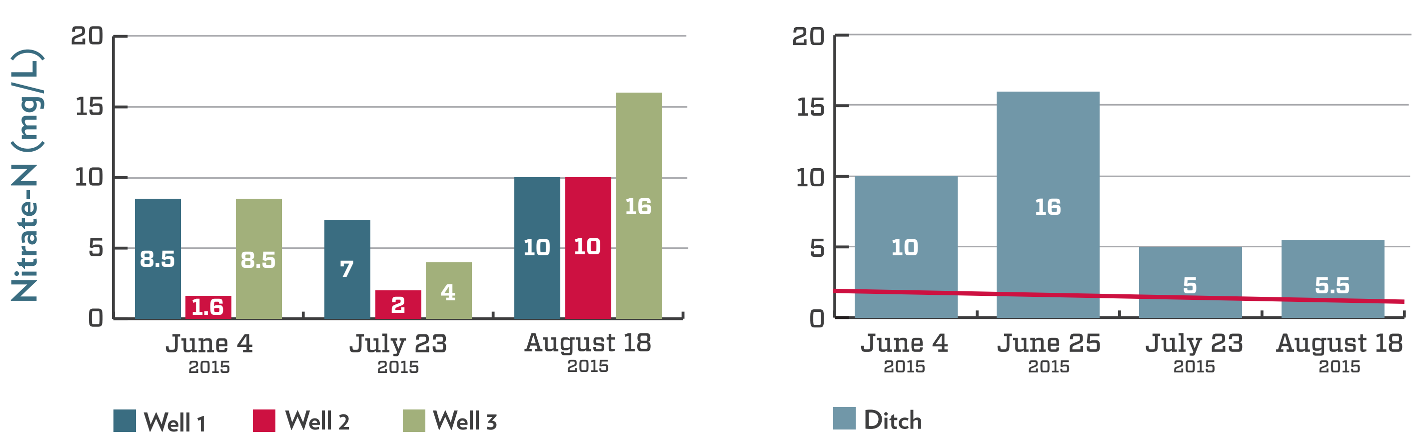


Figure 11: Nitrate-N concentrations measured in the groundwater wells and the Isherwood Lateral from June to August, 2015. The horizontal red line represents the maximum concentration recommended by the U.S. EPA for controlling eutrophication in surface waters (1.88 mg/L total N).

that detailed the channel geometry and slope requirements for the Isherwood Lateral for seven cross sections, each assigned an identifying station number, spanning 9,000 feet along the ditch. Profile views of cross sections along the Isherwood Lateral are seen in figures 12 and 13. (Hereafter, cross sections and their dimensions obtained from the PCDD specifications will be referred to as "established cross sections.") We used the elevation and dimensions for five of the seven cross sections; two were so far downstream from our study site that they were deemed irrelevant to our analysis.

Figure 12: Cross sectional view of station #4122 (PCDD, 2002)

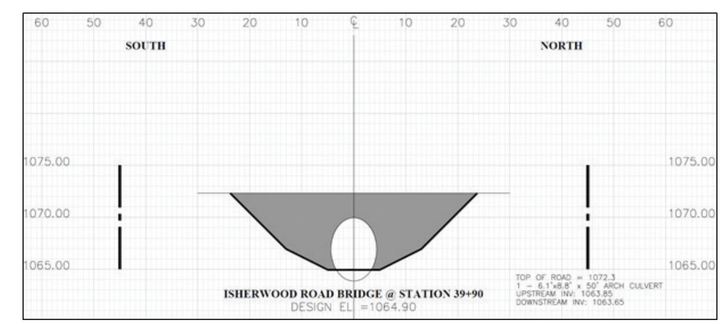


Figure 13: Cross sectional view of the Isherwood Road culvert (PCDD, 2002)

Our study site in the Isherwood Lateral comprises a stretch of the ditch from a culvert located at the Isherwood Road crossing to about 2,000 feet upstream of the road. Only two of the established cross sections were located within our official study site. Due to the limited number of cross sections in this area, we increased the model extent to include the next downstream cross section about 1,000 feet downstream of the culvert and the cross section about 5,000 feet upstream of the culvert. This allowed us to include a total of five established cross sections in the model.

After inputting data from the established cross sections, additional cross sections were added to the model to satisfy the culvert modeling requirements for HEC-RAS. We generated four new cross sections (two upstream and two downstream of the road culvert) based on the established cross-section data in order to provide the model with information about expansion and contraction properties of the culvert. In addition to the four extra cross sections around the culvert, we generated new cross sections between the established cross sections with the interpolation tool in HEC-RAS (Figure 14). It was assumed that the ditch geometry would not vary much between cross sections if the ditch were recently dredged to the PCDD specifications.

In order to set up the boundary conditions for the model, we conducted a hydrologic analysis of the Little Plover River. The Little Plover River was chosen because of its proximity to the study site and because it had the most complete record of gauge data available from the USGS web site. From a literature review, we found that the bankfull, or channel-forming, discharge for a sandy substrate, is somewhere between the one- and two-year flow event (Avery, 2004). We determined the one- and two-year flows and scaled them to the watershed of our study site. We used the program HY-8, a culvert hydraulic analysis program, to generate the rating curve (relationship between ditch water level and streamflow) necessary to run the model. We then ran the model at a prescribed flow of seven cubic feet per second, which we determined to be the bankfull discharge. The results of the run for the channel with the established cross-section specifications were treated as the "normal" conditions against which the restored conditions were compared.

Modeling Restoration Conditions

The purpose of the second HEC-RAS modeling scenario was to simulate the potential impact of patch restoration initiatives designed to deepen and narrow drainage ditch channels on ditch surface water elevation. Additional cross sections were added to the model between stations 5800 and 5504, spanning a length of about 300 feet. (A station number corresponds to main channel distance in feet from

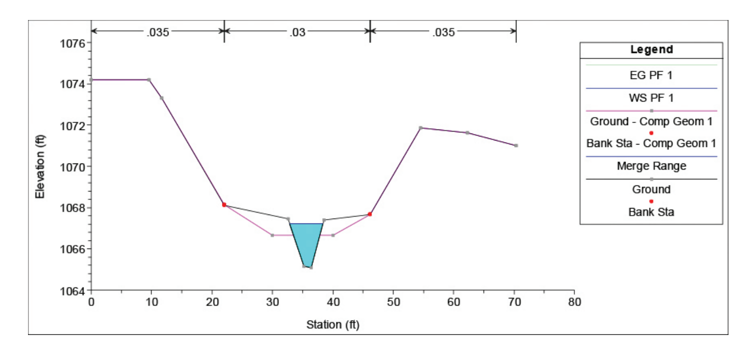


Figure 14: Comparison between cross sections for station 5603, where the original main channel width and elevation (pink line) were both decreased (black line).

the starting survey point for the Isherwood Lateral in the PCDD Ditch #2 plan set.) Interpolated cross sections were manually modified by decreasing the main channel elevation (deepening) and decreasing the distance between the left and right bank channel stations (narrowing). The cross sections were deepened and narrowed so that:

- Total Q (volumetric flow in cfs) was held constant
- Scenario 2 total flow area was less than or equal to scenario 1 total flow area
- Scenario 2 water surface elevation was less than or equal to scenario 1 water surface elevation
- Velocity (ft/sec) was increased
- Cross sections in the "patch restoration" length of the model were narrowed and deepened on average by about five feet and 1.5 feet, respectively.

Conclusions

The model results suggest that it is possible to narrow and deepen a 300-foot segment (in this case, about 15 percent of the total modeled ditch length) of the Isherwood Lateral without increasing the surface water elevation of the ditch (Figure 15). Patch restoration would likely improve habitat for trout and would likely not cause an increase in the water table elevation of adjacent agricultural fields.

LIMITATIONS OF SCENARIO 2:

The model does not account for changes in sediment transport due to channel modifications.

Only five cross sections from the PCDD document fell within the modeled section of the Isherwood Lateral requiring that a significant number of additional cross sections be constructed through interpolation to run the HEC-RAS model.

The amount of narrowing/ deepening resulting from the channel modifications was hypothesized due to lack of empirical data.

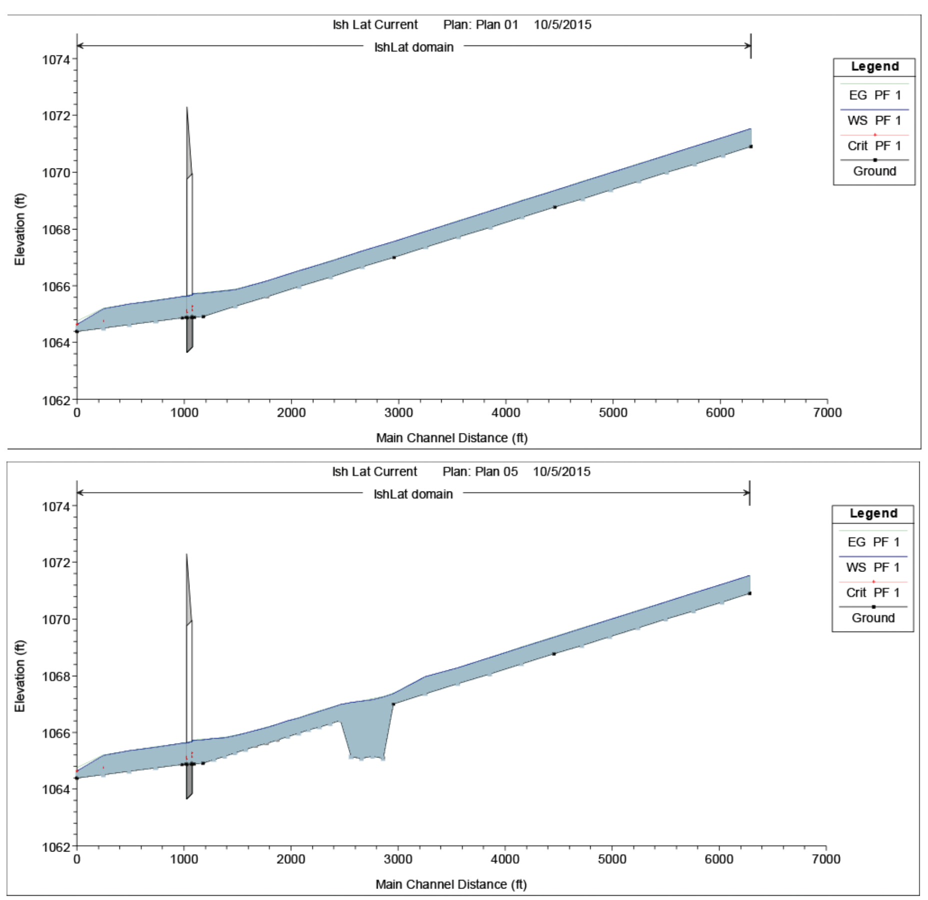


Figure 15: Comparison between profile plots of scenario 1 (top) and scenario 2 (bottom).

RECOMMENDATIONS

Introduction

This project investigated potential strategies to improve the habitat quality of agricultural drainage ditches in the Central Sands. These drainage ditches are used, regulated and studied by many different people who often have different priorities. Considering and understanding those priorities is vital for developing recommendations and strategies for improving in-stream trout habitat. To begin, we needed to determine which efforts would be feasible and have the greatest ecological impacts on the ditches. We researched the existing literature and spoke with natural resource experts to gain an understanding of which strategies and techniques may have the greatest utility in the drainage ditches. In addition, we sought to determine the feasibility of those strategies by speaking with state and local government officials, as well as by utilizing information from our surveys with landowners and other members of the community (Appendix A).

Project Feasibility

From the surveys and interviews, we identified several factors that affect the feasibility of different in-stream habitat improvement options and strategies. The priority of the PCDD is to keep the agricultural land within the district farmable. With this in mind, the primary physical feasibility concern for any habitat project is to ensure that drainage function is not negatively impacted. The PCDB would consider a project more feasible if it could be easily removed in the case that it negatively impacts drainage. Another physical feasibility consideration is the impact of a project on surface water elevation. A project is not feasible if it would significantly increase the surface water elevation such that it impacts the water table elevation in adjacent fields. Finally, restoration projects that require physical alteration beyond current ditch boundaries or impact currently farmable land would not be feasible.

Economically, costs for materials, implementation and maintenance factor into the feasibility of a project. Projects that would pose a significant financial burden on the landowner are considered less feasible. These considerations will play a larger role in higher-cost projects; the procurement of outside funding may be possible in these cases. For patch restoration projects, it is worth noting that lower-cost, higher-volume projects may be preferable as a larger "patch" can be created (Lyons et al., 2000).

Socially, landowners on both sides of the stream must be willing to allow patch restoration efforts to take place in the parts of the stream that run through their properties. Any efforts that do not have landowner support would likely not gain PCDB approval and would be nearly impossible to install in an efficient manner. Funding from outside organizations may require easements to allow public access to restored portions of trout streams. The terms of an easement depend on negotiations between the organization and landowner. However, an easement may be a point of contention that could cause project delays. The necessity of easements for some projects underscores the legal hurdles, including approval by a governing body, that may need to be cleared for a project to be implemented. Proposed projects must comply with all legal and regulatory standards for a given area to be considered feasible.

Patch Restoration Approach

Our recommendations are based on the feasibility concerns described above, in addition to ecological impact. In this case, the best strategy for improving in-stream habitat in the drainage ditches is to first protect intact habitats and then enhance lower-quality segments with physical alterations. Considering the importance of drainage to the value of the land, large-scale restorations would be cost-prohibitive and unpopular. With this in mind, along with feedback from local stakeholders and decision-makers, we recommend utilizing a patch restoration approach. This approach uses cost-effective, small-scale improvements to in-stream habitat that can be implemented within the existing ditch channel. It can improve in-stream brook trout habitat without the risks associated with a large-scale restoration.

Patch restoration consists of improving small areas within and around a stream and can apply to protecting intact habitats and enhancing lower-quality habitats. In-stream alterations can be done as individual patches along the stream or as a series of patches, which cumulatively provide greater habitat benefits. These patches can range from 10 feet to over 100 feet, depending on the strategies used and the resources available.

Brook trout in the drainage ditches have been observed to congregate in high-quality habitat areas characterized by in-stream woody debris and bank vegetation. The patch approach takes advantage of this behavior, as well as the ability of fish to migrate between different habitat patches. As found in the macroinvertebrate surveys, trout are not likely limited by food availability in the drainage ditches.

Therefore, providing better habitat structure for brook trout and their prey will help the ditches support a healthy, more resilient trout population.

Developing Recommendations

The following recommendations result from a comprehensive review of stream restoration and trout habitat restoration techniques. In addition to reviewing current literature, we interviewed experts with experience in trout habitat projects in the Central Sands region, including DNR fisheries biologists and Trout Unlimited members. The recommendations also consider the current state of the drainage ditches as determined by our habitat assessment of the Isherwood Lateral and observations from across the PCDD.

RECOMMENDATIONS

This section includes our recommended strategies for improving the habitat quality of drainage ditches in the Buena Vista Marsh area, as well as how those strategies were chosen and deemed feasible. We determined that the best strategy is to first protect intact areas, followed by enhancing in-stream habitats. We recommended a patch restoration approach in which smaller "patches" are improved across the drainage ditch system, leading to cumulative benefits for brook trout and the ditch ecosystems overall.

Protecting Intact Habitats

Protecting intact habitats is the top priority for stream rehabilitation plans, since it is the easiest and most cost-effective way to maintain high-quality streams and ecosystem processes (Beechie et al., 2008). Improving a degraded, low-quality stream requires time, money and other resources that could have been spared if preservation efforts were put in place earlier. Having a good foundation of intact habitats provides a starting point for subsequent rehabilitation actions. By acting as a refuge, these areas can be safe havens for organisms in an otherwise degraded landscape. In the drainage ditches, several steps can be taken to protect intact habitats, including maintaining canopy cover, limiting erosion and sedimentation, minimizing degradation of habitat, and maintaining native plant communities.

Maintaining Canopy Cover

Maintaining trees and other vegetation along the bank keeps the stream shaded. This keeps the water cool, which in turn supports higher dissolved oxygen levels, a requirement for brook trout. In addition, maintaining canopy cover provides potential inputs of coarse woody materials, which provides covered habitat for trout and their prey.

Limiting Erosion and Sedimentation

Erosion and sedimentation negatively impact brook trout by filling in spawning habitat and increasing the turbidity of the water. Erosion can be reduced in several ways. Runoff diversions and windbreaks are key practices that have been successful in the region and are already used in many areas. Diversions control and direct water flow in order to limit sedimentation. Field windbreaks help reduce wind erosion of soil from fields and subsequent deposition into the ditches. Planting and/or maintaining native vegetation along a bank creates a riparian buffer zone, which helps stabilize the soil and reduce soil transport by intercepting rainfall.

Minimizing Degradation of Existing Habitat

Many land-use practices can degrade trout habitats, putting brook trout at risk by reducing high-quality areas used for breeding and by limiting cover from predators. Fences bordering ditches, and signage warning of sensitive habitats, can reduce the risk of beneficial features being altered by roaming cattle or heavy machinery. Currently, cattle do not pose a concern in the PCDD.

Maintaining Native Plant Communities

Native flora supports diverse and healthy wildlife communities both in and around the ditches. Currently, many of the ditches in the PCDD are threatened by reed canary grass (*Phalaris arundinacea*). This invasive species establishes a monoculture within the channel, which both reduces flow and leads to a lower-quality, homogeneous plant community. Reed canary grass can be removed by herbicide application, excavation or mowing, but removal requires an intensive investment in repeated treatments. Planting native species in undisturbed and previously disturbed areas will help prevent invasive plants from establishing.

Enhancing In-stream Habitat

Patch restoration projects can be used to improve habitat in ditches or portions of ditches that are already degraded. Patch restoration projects primarily include adding structures to a ditch or altering a ditch to create more cover, deeper pools, and more in-stream heterogeneity for brook trout and other organisms. The best options for enhancing in-stream habitat in the drainage ditches are introducing coarse woody habitat and installing half-log structures or wing deflectors. These strategies are described in detail below, along with information regarding construction and associated costs.

The following options were selected based on their potential to maximize ecological improvement while minimizing construction and maintenance costs. These options were formulated with ease of removal as an especially important factor, since landowners may need to clear a ditch if there is an issue with drainage. The recommended patch restoration options below are all believed to be low cost, high benefit options. Cost, maintenance and ease of removal are all variables that can only be determined once a specific project has been proposed. However, our team believes that these options will have ecological benefits and be feasible options at any practicable scale within the drainage ditches of the Central Sands region.

Introducing Coarse Woody Habitat

Coarse woody habitat (CWH) consists of trees, limbs, branches, roots and/or wood fragments in a ditch or stream. These organic materials are a vital part of aquatic ecosystems. They provide food for invertebrates, serve as important habitat for both invertebrates and fish, and enhance the roughness and structure of the stream bottom (Shields et al., 2004).

Construction: CWH can enter ditches through natural or artificial processes. Canopy cover, as described above, can naturally add plant material, branches and roots as they fall into a ditch over time. Root wads and brush bundles can be added manually. These structures can consist of roots, logs, branches or small trees, which can be tied together. The bundles should then be placed between three wooden stakes that are driven into the streambed in a triangular orientation. Anchoring these bundles to the stakes and positioning them near the inside edge of a bank helps prevent them from being washed away during high-water events (Figure 16).

Cost: Costs associated with installing CWH include labor and materials for tying and anchoring the structures. Brush cuttings, branches, stumps and discarded trees can often be procured at no cost.

Ease of removal: CWH structures are compact and discrete, making them easy to remove if necessary. Smaller structures may be removed by hand, and larger ones can be dragged out with a tractor or other machinery.

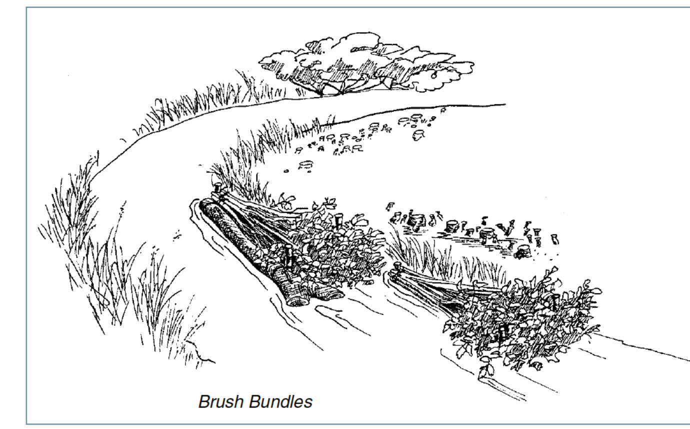


Figure 16: This image from Avery (2004) shows one example of a CWH installation. In this case, brush bundles were used. Root wads, tree bundles and log sections can also be installed. CWH structures must be anchored to the bank or ditch bottom to ensure that they do not float downstream.

Half-log Structures

Half-log structures are both simple and cost-effective. These structures consist of six- to 10-foot logs, which are cut longitudinally and anchored to the streambed (Figure 17). Half-logs provide cover for both yearling and adult trout. They are especially valuable where limited in-stream cover exists, as is the case in many drainage ditches (Avery, 2004).

Construction: Logs are cut longitudinally and steel rods are driven through both the logs and wooden spacers placed underneath. The entire structure is then anchored to the streambed via the steel rods sticking through the half-logs and spacers.

Cost: The lumber and steel rods for one half-log structure costs about $50-100. Logs can often be acquired at no cost or at very low cost from property owners. Drills and saws are required to prepare the planks and spacers, and heavy machinery (e.g., a hydraulic sign-post driver) is needed to drive in the rods.

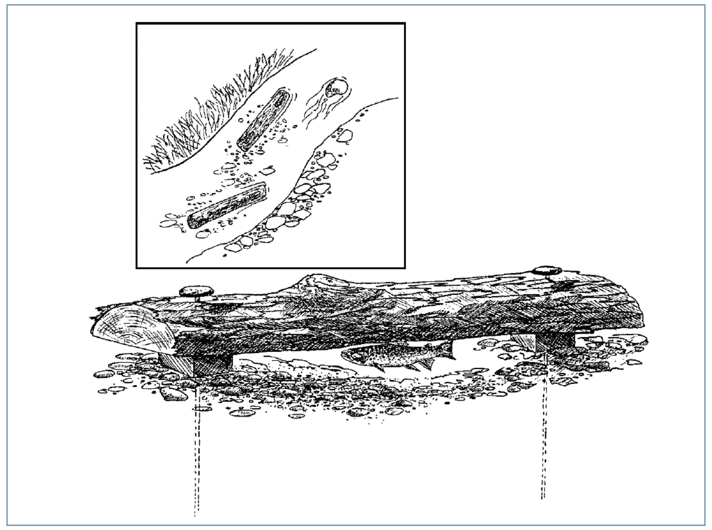


Figure 17: This illustration from Avery (2004) shows a typical half-log structure. The inset shows the in-stream position and orientation of structures.

Ease of removal: Half-logs can easily be removed by an excavator if necessary. Removing the rocks and soil from the top of the structure may be time-consuming.

Wing Deflectors

Single wing deflectors consist of one rock or segment of wood inserted into the stream at 30-45 degrees from the bank to constrict or divert flow (Figure 18). This creates meanders and pools by scouring, which creates high-quality breeding habitat for trout, as well as a more heterogeneous habitat overall.

Construction: A wing deflector consists of two four- to six-foot logs, which are nailed together at a 90-degree angle. The ends of the logs are buried into the bank so that the other connected ends jut into the stream. The space between the two logs and the bank is then filled with rocks and perhaps some organic material like CWH.

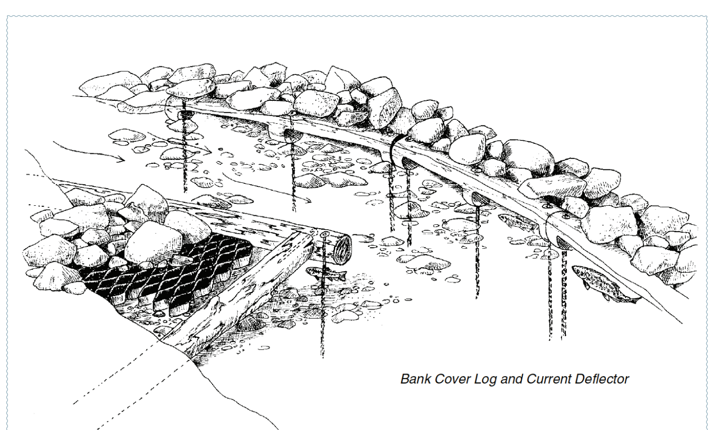


Figure 18: This illustration from Avery (2004) shows a typical wing-deflector structure to the left.

Cost: Wing deflectors can be constructed at low cost, since logs and rocks are often available on-site. Costs can rise if heavy machinery needs to be rented.

Ease of removal: Wing deflectors can be easily removed. An excavator or other piece of heavy machinery can pull or drag the logs out of the bank in which they are embedded.

In addition to those described above, we considered other strategies. We concluded that these strategies may not be as feasible in the Central Sands, but can still provide some benefit to brook trout habitats.

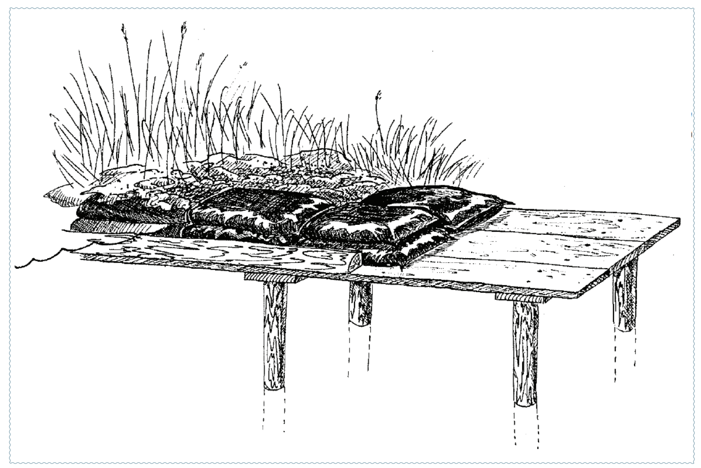


Figure 19: This illustration from Avery (2004) shows a bank cover structure with sandbags and vegetation on top.

Individual boulders can be placed in a ditch to provide cover for both fish and macroinvertebrates. Boulders can also redirect flow in a way that creates pools and a more heterogeneous streambed in general. Installing and removing boulders can be a challenge due to their size and weight.

Bank covers, like half-logs, are wooden structures anchored into a streambed. These structures consist of a wooden platform, which is elevated from the stream bottom by logs or wooden posts (Figure 19). Prior to installation, the channel is deepened near the bank using an excavator. Once installed and anchored in place above the deepened section, the platform is covered with sand bags, soil and native vegetation to help the artificial structure blend into the riparian ecosystem. The limitations of bank covers are that they are not as effective in narrow streams (such as ditches), and they are more resource and labor intensive.

The following strategies were deemed infeasible for the Central Sands region. These include LUNKER structures and two-stage ditch design.

LUNKER structures (Little Underwater Neighborhood Keepers Encompassing Rheotaxic Salmonids) are another popular trout stream rehabilitation technique. LUNKERs are crib-like wooden structures installed along a stream bank to create overhead cover and resting area for fishes (Figure 20). Although these structures work well in many streams across the state, the drainage ditches are too narrow for them to be effective. In addition, LUNKERs require more resources and are labor-intensive compared to other strategies.

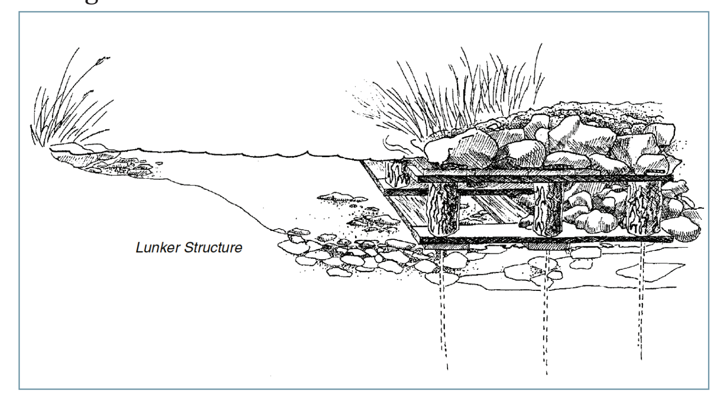


Figure 20: This is a depiction of a LUNKER structure from Avery (2004).

Two-stage ditch design has been shown to improve conveyance, enhance habitat, and require minimal maintenance over time. However, there are still a lot of questions about how effective this design would be in sandy areas. Most importantly, implementing this change would have very high construction costs, making it unpopular with landowners.

Implementation

In order to move forward with patch restoration efforts, it is necessary to develop a strategy, locate funding sources, and enlist the help of experienced restoration practitioners.

Strategy

Once restoration techniques have been chosen, prioritized, and considered for feasibility, a strategy must be developed to optimize ecological impacts. As described earlier, we recommend undertaking rehabilitation efforts in higher-quality reaches of ditches. Trout stream maps from the Wisconsin DNR can be used to determine if the ditch of interest supports, or is capable of supporting, trout populations (Appendix J). Therefore, Class I trout streams are most desirable, followed by Class II and Class III trout streams. People interested in pursuing restoration projects should identify high-quality trout streams bordered by land with property owners willing to undertake restoration efforts.

In developing a patch restoration strategy, it is also crucial to consider the target species of trout. Brook trout are native to the area and are generally considered the most desirable trout species. When planning a project, the best strategy is to consult biologists from the Wisconsin DNR and other experts to ensure the planned project will benefit the target species.

Agricultural ditches in the Central Sands are routinely dredged on approximately 20-year schedules. These schedules should be considered when deciding where a project will be implemented. We recommend undertaking in-channel rehabilitation efforts in ditches that have been recently dredged. In doing so, all restoration efforts that are undertaken will be preserved for as long as possible without the risk of being disturbed by dredging efforts. This would allow observation of how the rehabilitation efforts impact streamflow, channel geometry and sediment transport. This strategy also makes it more clear which impacts and changes result from the efforts. Projects such as bank covers or other bank modifications may require replacement within 20 years, and dredging may offer a convenient time to replace aging project structures.

Patch restoration is, by its very nature, a pragmatic approach that we recommend as a strategy for its ability to take advantage of restoration opportunities as they arise. Thus, the general strategy for those seeking to restore streams should be to use these recommendations when possible, but recognize that not all opportunities for restoration will perfectly align with these recommendations. Rather, each project will be different, and those working to implement restoration efforts should be mindful of this. The optimal strategy involves consulting with stakeholders and experts to create a feasible restoration project that will have the best results. Appendix K lists experts and organizations that may be of assistance to those who wish to enhance trout habitat in the agricultural streams of the Central Sands region.

Funding

Patch restoration techniques were chosen as a cost-effective solution to creating trout habitat in drainage ditches. Nevertheless, funding is an issue for any project. A variety

of funding options exist for any project in the region. Grants and cost-sharing may be available from any of the following organizations:
Trout Unlimited
Wisconsin DNR
Portage County Land and Water Conservation Department

Other non-profit conservation organizations or government agencies may be interested in assisting with the funding of restoration efforts. However, the three organizations mentioned above currently have programs in place or have expressed interest in assisting such projects.

Trout Unlimited is active in the Portage County area, and representatives from the organization have sought to fund past projects. They continue to look for opportunities to lend their expertise and financial backing to projects that enhance trout streams. The Wisconsin DNR has a multitude of grant programs that may apply depending on the scope and goals of a given project. Possible funding programs in the WDNR include the Knowles-Nelson Stewardship Fund or Surface Water Grants, which include aquatic invasive species control and river planning grants. The Portage County Land and Water Conservation Department offers cost-sharing opportunities for land owners for repairing and maintaining riparian buffers, stream bank restoration and other conservation programs. Through its Conservation Reserve Enhancement Program (CREP), the department also offers financial incentives for installing buffer strips along fields, thus protecting intact habitat or restoration projects.

MONITORING PATCH RESTORATIONS

Patch restoration projects offer a new opportunity to improve brook trout habitat while maintaining drainage function in agricultural drainage ditches. However, the impacts of physically altering the ditches with small projects are not well understood and have not been attempted to any significant extent in Portage County. Therefore, it is crucial that any patch restoration projects include pre- and post-implementation monitoring of drainage ditch characteristics. When possible, using recently dredged drainage ditches will make it easier to determine the success of the project. This monitoring will assist landowners, the PCDB, and other stakeholders with future decision-making concerning the appropriate use and advantages of patch restoration in the PCDD and in other nearby areas of Wisconsin. Assessment will also help determine the success of various restoration efforts and help identify options that are not as successful in the sandy substrate streams of Portage County.

The following is a list of suggested variables that should be monitored to assess the success of patch restoration efforts, and tools that can be used to complete this monitoring. (Note that this list is not meant to be comprehensive, and it will likely require modification over time to adapt to new restoration techniques, changes in stream-channel morphology, and stakeholder concerns.)

Groundwater levels: Patch restoration is meant to improve in-stream habitat without affecting agricultural drainage. If the groundwater level rises too much, it could cause problems with adjacent fields, in which case restoration efforts may need to be halted or reconsidered. Groundwater levels can be measured using piezometers and pressure transducers, which can be left in place over long periods of time and can provide a continuous measure of water level.

Ditch surface water elevation: Monitoring the surface water elevation is important in determining if in-stream water levels are being affected by patch restoration activities. Changes in the surface water level could impact bank stability or channel morphology. Surface water elevation can be monitored by placing stilling wells in the stream.

Water flow: Some restoration efforts may narrow the ditch width, causing the flow velocity to increase. The flow should be monitored to ensure that any increased velocity is not causing excess erosion or negatively affecting macroinvertebrates or small fish that may not be able to withstand such velocity. A flow meter should be used regularly throughout the year to determine the change in flow velocity from pre-project implementation to post-project implementation.

Channel morphology: The channel morphology should be thoroughly documented both before a project begins and after it is implemented. It is important to assess the morphology upstream of the project, at the project site and downstream from the project. Large changes in channel morphology may affect the PCDD's management regime and could have impacts on erosion control or culvert placement. Measuring the morphology of a channel will require a combination of surveying techniques and exact measures of length, width and depth of the channel.

Sediment transport: As mentioned in several of the suggestions above, erosion and sediment transport must be monitored closely. Patch restoration techniques should not negatively affect downstream reaches by causing deposition or siltation. Of special concern is siltation in or near culverts. Blockage of culverts could restrict trout movement and cause flooding in the ditches. Landowners should observe their ditches and report to the PCDD if they see build-up occurring.

Resident reactions: In addition to biological monitoring efforts, the social impacts of patch restoration projects must also be considered. This monitoring can be done through surveys, either in person or through the mail. Some important questions to consider are as follows:
Do you think the restoration effort is attracting more trout?
Do you believe the restoration activity is negatively affecting farming activities?
Do you believe the restoration activity is affecting recreational activities?
These questions will help determine public support for, and community interest in, restoration activities.

Fish populations: One of the main goals of patch restoration is to improve brook trout habitat. Fish surveys should be conducted throughout the year to determine the trout population demographics and whether more trout seem to be attracted to the patch restoration projects. This monitoring can be done through electroshocking surveys but can also involve citizen-monitoring both from landowners and local fishermen. These surveys can help identify the most successful types of restoration projects for the trout population in the Central Sands region and discourage projects that do not attract brook trout in any significant way. These surveys can also identify projects that attract non-native brown trout, which often outcompete brook trout.

Macroinvertebrate surveys: Macroinvertebrates must be closely monitored to ensure that the prey population is abundant enough to support brook trout. Patch restoration efforts may affect the population size and composition of the macroinvertebrate community, especially if woody debris is added to the stream. For this reason, samples should be taken pre- and post-project implementation to ensure that brook trout will have a sufficient food source. Macroinvertebrates also provide a way to assess the relative health of the stream in terms of pollutant and dissolved oxygen levels. Monitoring efforts would involve citizen-monitoring protocols such as the one employed in this study and encouraged by the Wisconsin DNR (see Appendix C for the monitoring form).

Vegetation: Vegetation is an important part of stream health, as it provides food and cover for many species. However, this vegetation can also present a challenge to the PCDD, especially invasive reed canary grass. When unchecked, vegetation can grow so abundant that it chokes off the flow of a stream. Vegetation must be constantly measured to ensure that water is able to move through the ditches and is deep enough for trout to be able to swim from patch to patch. Some patch restoration efforts may narrow the stream channel, in which case vegetation must be monitored even more closely to make sure water is still able to flow. Some native types of vegetation are essential to the health of the ditch and can provide shelter for trout and macroinvertebrates, but invasive plants should be eliminated as much as possible. Vegetation monitoring efforts would include transects or small patches monitored by experts throughout the year but could also utilize citizen-science techniques such as photographs or recorded observations.

Nutrients/pesticides: Nutrient levels in the water can dramatically change a stream ecosystem. Patch restoration efforts may affect the way the stream transports and processes pollutants or nutrients, and data should be gathered both pre- and post-restoration project implementation. This monitoring will likely require laboratory testing, though some field test kits could be used by landowners or citizen-scientists. Nutrient and pesticide levels should be measured at various times throughout the year.

Monitoring Conclusion

Ditch restoration efforts could have a variety of effects, both intended and unintended. As such, extensive monitoring should be done before patch restoration efforts are implemented, as well as after implementation. This monitoring data could help address stakeholder concerns about the effects of restoration efforts on stream health and agricultural activities, and assess the social and recreational effects of projects. With this data in hand, future restoration efforts may be easier, and quicker, to implement.

FUTURE OPPORTUNITIES

The drainage ditches in the PCDD have great potential for contributing to habitat and ecological processes while continuing to support agricultural production. In order to realize this potential, it will be necessary to establish a baseline understanding of the current physical and ecological properties of the drainage ditches by expanding the spatial and temporal scope of the assessments performed at the Isherwood Lateral. Additionally, implementing pilot patch restoration projects with follow-up monitoring will be the best method to understand the impacts of altering drainage ditches for improving habitat.

Prior to implementing a pilot project, gathering information will help identify the most appropriate site(s) for patch restoration. First, performing physical habitat assessments, fish surveys and macroinvertebrate surveys across several sites in the PCDD and over several seasons will establish much-needed baseline information. While the WDNR currently performs assessments in the PCDD, it does so with limited geographic and temporal coverage. By increasing the number of assessment sites and repeating assessments over seasons, it will be possible to prioritize sites for patch restoration based on current conditions. Continuing these assessments after implementing a pilot project will also help determine what changes patch restoration generates.

Using data collected from repeated assessments, along with other information, will enable the identification of high-priority project sites. Generally, habitat improvement projects are most successful when they preserve or enhance intact habitat. In addition, patch restoration projects in the PCDD will be most successful with landowner support, so it is important to identify landowners who are willing to grant access to their drainage ditches for project implementation, or who are willing to directly participate in project planning and implementation. We suggest using a GIS suitability analysis to combine information about site physical characteristics, macroinvertebrate populations, fish populations, ditch maintenance, and landowner involvement to prioritize potential restoration sites based on proximity to quality habitat.

One concern expressed by landowners is that altering drainage ditches with patch restoration may impact the water table (i.e., groundwater level) in adjacent fields. Therefore, prior to implementing a pilot project, it will be necessary to monitor groundwater levels in fields adjacent to priority sites, along with surface water elevation in the ditches. Continued monitoring after pilot project implementation will help determine whether it is possible to conduct habitat improvement without impacting drainage functions.

Finally, once the appropriate habitat assessments, site selection and groundwater monitoring have been conducted, we hope to see pilot projects implemented. While one project would vastly increase our knowledge of the effects of patch restoration on habitat and drainage, siting multiple projects across the PCDD, in upstream and downstream locations, will be the best way to understand whether the position of a patch restoration within a stream network affects its impact. Most importantly, any pilot project should be closely monitored using the guidelines detailed in this report to determine the impacts of patch restoration.

CONCLUSIONS

This practicum had two main objectives:

- To assess the feasibility of physically altering agricultural drainage ditches in the Central Sands region of Wisconsin to improve in-stream brook trout habitat while maintaining drainage function.
- To provide an informational guide to landowners and policymakers interested in pursuing a habitat improvement project in an agricultural drainage ditch.

Through our investigation, we were able to unpack the policies associated with this kind of work. We learned that several existing laws need to be considered, and working with the drainage board is vital for initiating and carrying out habitat improvement projects in drainage ditches. Based on landowner surveys, we determined that rehabilitation efforts would be socially feasible, as the survey responses were positive or neutral.

Our field assessments showed that rehabilitation efforts would be biologically and ecologically feasible. The water quality, physical habitat, food supply and existing trout populations were all adequate for supporting a healthier brook trout population.

Modeling showed that it is possible to do small-scale restorations without increasing water levels in the ditches or fields. In other words, the rehabilitation efforts would not impact or interfere with the drainage of agricultural fields.

The recommendation section lays out the different methods that can be used to improve brook trout habitat. This section provides detailed instructions and strategies to serve as a guide for undertaking an improvement project in an agricultural drainage ditch.

All of this work has led us to conclude that it is feasible to do patch restoration projects in drainage ditches. The improvements and strategies can be easily adapted for individual situations, one of the main factors favoring this approach.

In summary, enhancing the habitat in drainage ditches provides a great opportunity for environmental stewardship in a landscape dominated by agriculture. Rehabilitation projects can improve the aesthetics of an area, enhance recreation for landowners and visitors, and help ensure the long-term viability of brook trout populations and the ecosystem as a whole. We hope this report serves as a valuable resource for those interested in enjoying, studying or improving drainage ditches in the future.

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APPENDIX A: LANDOWNER SURVEY

Agricultural Drainage Ditch Enhancement Questionnaire

NELSON INSTITUTE FOR Environmental Studies
UNIVERSITY OF WISCONSIN–MADISON

The purpose of this survey is to gain further understanding of the roles of drainage ditches in Portage County and residents' opinions about ditch maintenance. In this survey, we refer to enhancing "parts" of the drainage ditches—by that, we mean focusing on localized areas within the established channel, such as adding coarse woody habitat to a small section of the ditch. We thank you for your honest answers, and please rest assured that your responses will remain anonymous.

Please circle the number most closely indicating how you feel about each statement.

1 = strongly disagree 2 = disagree 3= neutral 4 = agree 5 = strongly agree N/A = no opinion

1) I am aware of and familiar with the operation of the Portage County Drainage District. Yes No

2) I am a landowner with a drainage ditch on my property. Yes No

3) I use or would like to use drainage ditches for recreational activities, such as fishing, kayaking, or enjoying natural scenic beauty. 1 2 3 4 5 N/A

4) I would consider enhancing parts of my drainage ditch to a more natural state. 1 2 3 4 5 N/A

5) I would consider enhancing parts of my drainage ditch only if the costs were low or nonexistent. 1 2 3 4 5 N/A

6) I am concerned that enhancing parts of drainage ditches to a more natural state would negatively affect farming activities. Please list concerns on the reverse side. 1 2 3 4 5 N/A

7) I believe that the ditches should remain the way they are now and should continue to be maintained according to current practices. 1 2 3 4 5 N/A

8) If you would be willing to talk with us further about stream enhancement and the ditches on your property, please write your name and email address or telephone number below.

9) Please write anything you would like to share with us about your feelings on ditch enhancement on the reverse side of this page.

Thank you for your participation!

APPENDIX B: HABITAT ASSESSMENT

Distance from start (m)	0	Bankfull depth (m)	3.35	Bank slope (°)			
Stream width (m)	7	Bankfull width (m)	26	North	11		
Habitat type	run	Deepest water depth (cm)	33	South	10		

CHANNEL POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	33	25	27	24			
Depth of fines & water (cm)	41	42	43	30			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)				25	(These must total 100%)		
Gravel (2-64 mm)				25			
Sand (0.062-1.9 mm)	100	100	100	50			
Detritus							
Macrophytes		100	30				
Shading	0						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	2.7						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	100						
Shrubs							
Woodland							
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 1 of 12

Distance from start (m)	10	Bankfull depth (m)		Bank slope (°)			
Stream width (m)	9.5	Bankfull width (m)	17	North	30		
Habitat type	run	Deepest water depth (cm)	39	South	35		

CHANNEL POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	39	19	24	28			
Depth of fines & water (cm)	58	42	57	64			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	70	70	70			
Detritus		30	30	30			
Macrophytes		100	100	100			
Shading							

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	6.5						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	100						
Shrubs							
Woodland							
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 2 of 12

Distance from start (m)	40	Bankfull depth (m)	3.9	Bank slope (°)				
Stream width (m)	10	Bankfull width (m)	18	North	35			
Habitat type	run	Deepest water depth (cm)	32	South	45			

CHANNEL POSITION POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	32	18	19	18			
Depth of fines & water (cm)	68	49	23	21			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	80	10	10			
Detritus		20					
Reed canary grass roots			90	90			
Macrophytes	100	95	100	100			
Shading	50						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	6.5						
Emergent macrophytes	2						

BANK EROSION

	(These must total 100%)						
Meadow	100						
Shrubs							
Woodland							
Riparian buffer width (m)	Left:	10	Right:	10			

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 3 of 12

Distance from start (m)	70	Bankfull depth (m)	2.05	Bank slope (°)				
Stream width (m)	9	Bankfull width (m)	12	North	30			
Habitat type	run	Deepest water depth (cm)	31	South	5			

CHANNEL POSITION POSITION (FIFTHS OF STREAM WIDTH)

Water depth (cm)	29	26	31	7			
Depth of fines & water (cm)	62	62	62	8			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	90	70				
Detritus		10	30				
Reed Canary Grass Roots				100			
Macrophytes	10	100	100	100			
Shading	25						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Emergent macrophytes	1.5						

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	80						
Shrubs	10						
Woodland	10						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 4 of 12

Distance from start (m)	100	Bankfull depth (m)	3.9	Bank slope (°)			
Stream width (m)	7	Bankfull width (m)	17	North	40		
Habitat type	run	Deepest water depth (cm)	36	South	35		

CHANNEL POSITION POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	31	36	29	24			
Depth of fines & water (cm)	44	49	50	30			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	100	85	85			
Detritus			15	15			
Macrophytes	95	10	100	100			
Shading	35						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	4						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	65						
Shrubs	10						
Woodland	25						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 5 of 12

Distance from start (m)	130	Bankfull depth (m)	3.85	Bank slope (°)			
Stream width (m)	7	Bankfull width (m)	18	North	30		
Habitat type	run	Deepest water depth (cm)	28	South	40		

CHANNEL POSITION POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	26	18	21	28			
Depth of fines & water (cm)	42	41	57	86			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	100	100	50			
Detritus				50			
Macrophytes	10		40	100			
Shading	20						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	1.5						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	65						
Shrubs	10						
Woodland	25						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 6 of 12

Distance from start (m)	160	*Bankfull depth (m)	4	*Bank slope (°)			
Stream width (m)	9	*Bankfull width (m)	19	North	21		
Habitat type	run	Deepest water depth (cm)	29	South	47		
		* Measured by					

CHANNEL POSITION POSITION (FIFTHS OF STREAM WIDTH)

* Measured while kneeling, transects 7-12

Water depth (cm)	29	21	20	7			
Depth of fines & water (cm)	49	70	41	26			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	100	100	100			
Detritus							
Macrophytes		50	100	40			
Shading	40						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	8						
Emergent macrophytes	1.3						
Woody debris	1.8						

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	50						
Shrubs	20						
Woodland	30						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 7 of 12

Distance from start (m)	190	Bankfull depth (m)	3.8	Bank slope (°)			
Stream width (m)	10.5	Bankfull width (m)	20	North	43		
Habitat type	run	Deepest water depth (cm)	39	South	52		

CHANNEL POSITION POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	39	24	21	3			
Depth of fines & water (cm)	71	49	28	10			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	25	25	100			
Detritus		75	75				
Macrophytes		25	100	100			
Shading	40						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	1.8						
Emergent macrophytes							
Woody debris	2						

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	50						
Shrubs	20						
Woodland	30						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 8 of 12

Distance from start (m)	220	Bankfull depth (m)		Bank slope (°)			
Stream width (m)	8.5	Bankfull width (m)	16	North	35		
Habitat type	run	Deepest water depth (cm)	30	South	29		

CHANNEL POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	25	30	26	4			
Depth of fines & water (cm)	32	82	43	39			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	80	40	60			
Detritus		20	60	40			
Macrophytes	60	100	100				
Shading	50						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	2.1						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	33						
Shrubs	33						
Woodland	33						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 9 of 12

Distance from start (m)	250	Bankfull depth (m)	3.8	Bank slope (°)			
Stream width (m)	7	Bankfull width (m)	18	North	45		
Habitat type	run	Deepest water depth (cm)	40	South	35		

CHANNEL POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	4	9	20	40			
Depth of fines & water (cm)	6	25	47	58			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	80	100	80	100			
Detritus	20		20				
Macrophytes				25			
Shading	25						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	1						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	50						
Shrubs	25						
Woodland	25						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 10 of 12

Distance from start (m)	280	Bankfull depth (m)	3.9	Bank slope (°)			
Stream width (m)	8	Bankfull width (m)	18	North	37		
Habitat type	run	Deepest water depth (cm)	28	South	41		

CHANNEL POSITION (FIFTHS OF STREAM WIDTH)

	1/5	2/5	3/5	4/5			
Water depth (cm)	28	27	21	16			
Depth of fines & water (cm)	35	89	35	18			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)							
Sand (0.062-1.9 mm)	100	100	70	80			
Detritus			30	20			
Macrophytes	100		100	100			
Shading	25						

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	2.5						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	70						
Shrubs	10						
Woodland	20						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 11 of 12

Distance from start (m)	310	Bankfull depth (m)	3.95	Bank slope (°)			
*Stream width (m)	11-2.5=8.5	Bankfull width (m)	17	North	22		
Habitat type	run	Deepest water depth (cm)	41	South	55		

CHANNEL POSITION (FIFTHS OF STREAM WIDTH)

*this transect had a 2.5m island of RCG in the channel

	1/5	2/5	3/5	4/5			
Water depth (cm)	18	14	22	4			
Depth of fines & water (cm)	60	40	34	23			

PERCENT OF STREAM BOTTOM COVERED

Rubble/cobble (65-260 mm)					(These must total 100%)		
Gravel (2-64 mm)		15					
Sand (0.062-1.9 mm)	100	85	100	100			
Detritus							
Macrophytes	50	40	100	25			
Shading							

COVER FOR ADULT GAMEFISH (LENGTH OF TRANSECT WITHIN 0.15 M UP/DOWNSTREAM IN WATER AT LEAST 0.20 M DEEP)

Submerged macrophytes	1						
Emergent macrophytes							

RIPARIAN LAND USE (% OF BANK WITHIN 5 M OF STREAM EDGE ALONG TRANSECT)

	(These must total 100%)						
Meadow	60						
Shrubs	20						
Woodland	20						
Riparian buffer width (m)	Left:	10	Right:	10			

BANK EROSION

Length of bare soil within 1 m	Left:	0	Right:	0			
% of eroded bank	Left:	0	Right:	0			

Habitat assessment of Isherwood Lateral (Sept. 13, 2015) transect 12 of 12

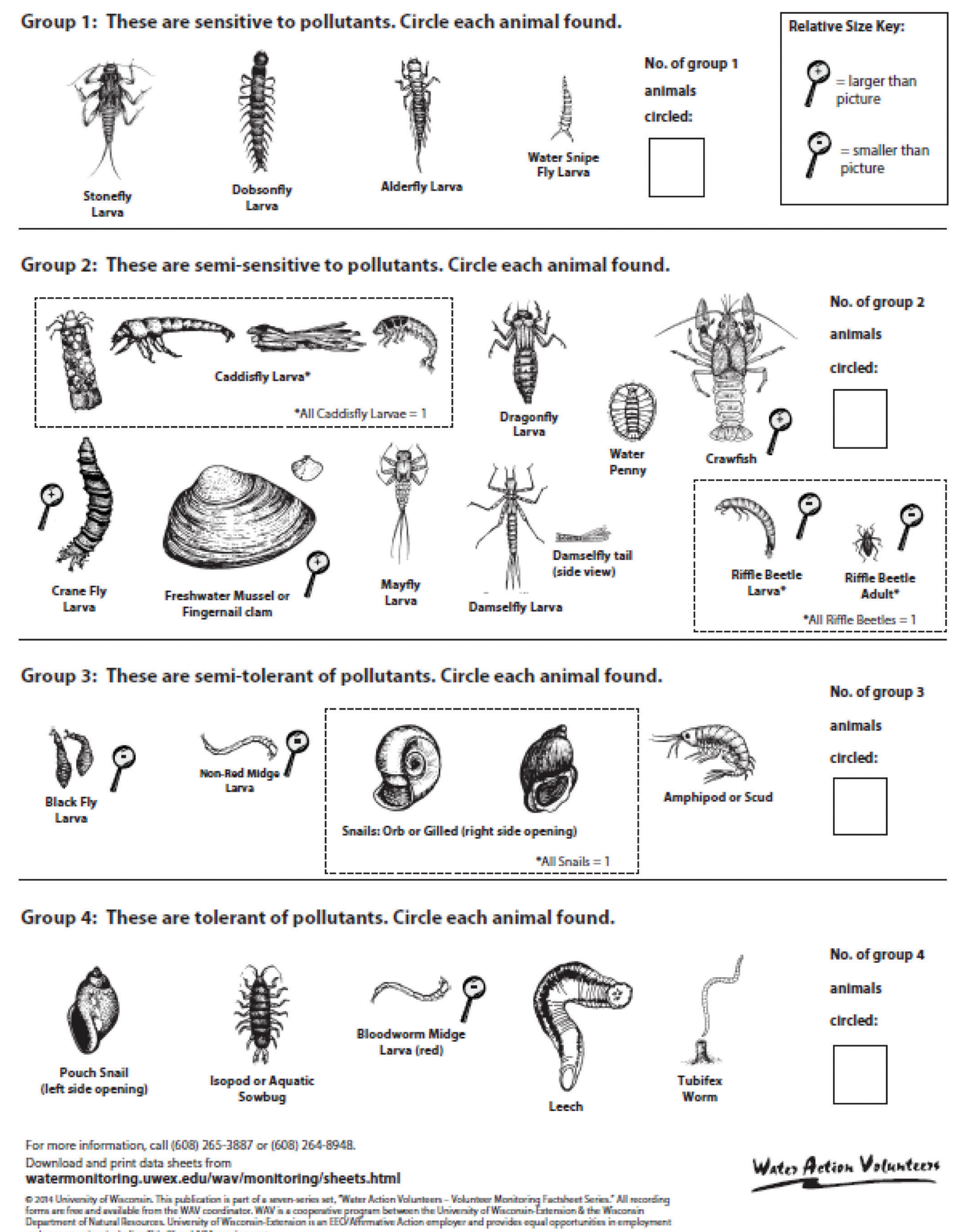
APPENDIX C: MACROINVERTEBRATE SURVEY DATA

Section Type	S1-R1	S1-R2	S1-R3	S2-R1	S2-R2	S2-R3
Veg Type	*All*	*All*	*All*	*All*	*All*	*All*
Alderfly Larva	0	0	0	0	4	0
Backswimmer	0	1	1	0	0	0
Caddisfly Larva	0	1	4	4	14	4
Cranefly Larva	1	0	1	1	0	0
Earthworm	1	0	0	0	0	0
Giant Water Bug	0	0	0	0	1	0
Horsefly Larva	0	0	0	2	10	0
Leech	2	0	0	0	0	0
Mayfly Larva	0	0	0	0	1	0
Midge (all stages)	107	12	24	38	69	27
Mosquito Larva	0	0	0	1	0	0
Predacious Diving Beetle	0	0	0	2	1	1
Scud	1328	1235	2440	75	302	251
Snail	7	8	13	0	0	5
Terrestrial Fly	0	0	0	2	1	0
Threadworm	6	1	0	0	9	0
Tubifex Worm	12	0	0	0	0	0
Water Boatman	2	6	0	0	0	2
Total Macroinvertebrates	**1466**	**1264**	**2483**	**125**	**412**	**290**

Raw data from spring collection of macroinvertebrates in Isherwood Lateral, listed alphabetically by family and ordered by stream stretch and reach.

APPENDIX D: CITIZEN MONITORING BIOTIC INDEX

Source: Wisconsin DNR



Recording Form for the Citizen Monitoring Biotic Index

Name: ______________________________ Date: ______________

Stream Name: ______________________________ Time: ______________

Location: ______________________________ Station Number: ______________

(County, Road, Intersection, Other)

At this point, you should have collected a wide variety of aquatic macroinvertebrates from your three sites. You will now categorize your sample, using the *Key to Macroinvertebrate Life in the River* to help you identify the macroinvertebrates found. **The number of animals found is not important; rather, the variety of types of macroinvertebrates and their tolerance to pollution tells us the biotic index score.** Before you begin, check off the habitats from which you collected your sample (see right).

- ☐ Riffles
- ☐ Undercut banks
- ☐ Snag areas, tree roots, submerged logs
- ☐ Leaf packs

1. You should have removed large debris (e.g. leaves, rocks, sticks) from your sample and placed this material in a separate basin (after removing macroinvertebrates from it).
2. Check the basin with the debris to see if any aquatic macroinvertebrates crawled out. Add these animals to your prepared sample.
3. Fill the ice cube tray half-full with water.
4. Using plastic spoons or tweezers, (be careful not to kill the critters – ideally, you want to put them back in their habitat after you're finished) sort out the macroinvertebrates and place ones that look alike together in their own ice cube tray compartments. Sorting and placing similar looking macroinvertebrates together will help insure that you find all varieties of species in the sample.
5. Refer to the *Key to Macroinvertebrate Life in the River* and the *Citizen Monitoring Biotic Index* to identify the aquatic macroinvertebrates:

   A. On the back of this page, circle the animals on the index that match those found in your sample.

   B. Count the number of types of animals that are circled in each group and write that number in the box provided. Do not count individual animals in your sample. Only count the number of types of animals circled in each group.

   C. Enter each boxed number in work area below.

   D. Multiply the entered number from each group by the group value.

   E. Do this for all groups.

   F. Total the number of animals circled.

   G. Total the calculated values for all groups.

   H. Divide the total values by the total number of types of animals that were found: **TOTAL VALUES (b.) / TOTAL ANIMALS (a).**

   I. Record this number.

   SHOW ALL MATH (Use space below to do your math computations)

No. of animals circled from group 1 ________ x 4 = ________

No. of animals circled from group 2 ________ x 3 = ________

No. of animals circled from group 3 ________ x 2 = ________

No. of animals circled from group 4 ________ x 1 = ________

TOTAL ANIMALS (a): ________ **TOTAL VALUE (b):** ________

Index score: ☐

How Healthy is the stream?	
Good ____________	2.6 - 3.5
Fair ____________	2.1 - 2.5
Poor ____________	1.0 - 2.0

Divide totaled value (b)______by total no. of animals (a) ______for index score:

Report your results online at **www.uwex.edu/erc/wavdb** *or submit your data to your local coordinator.*
Call your local monitoring coordinator if you have questions about sampling or determining the Biotic Index Score.

APPENDIX E: ELECTROFISHING SURVEY

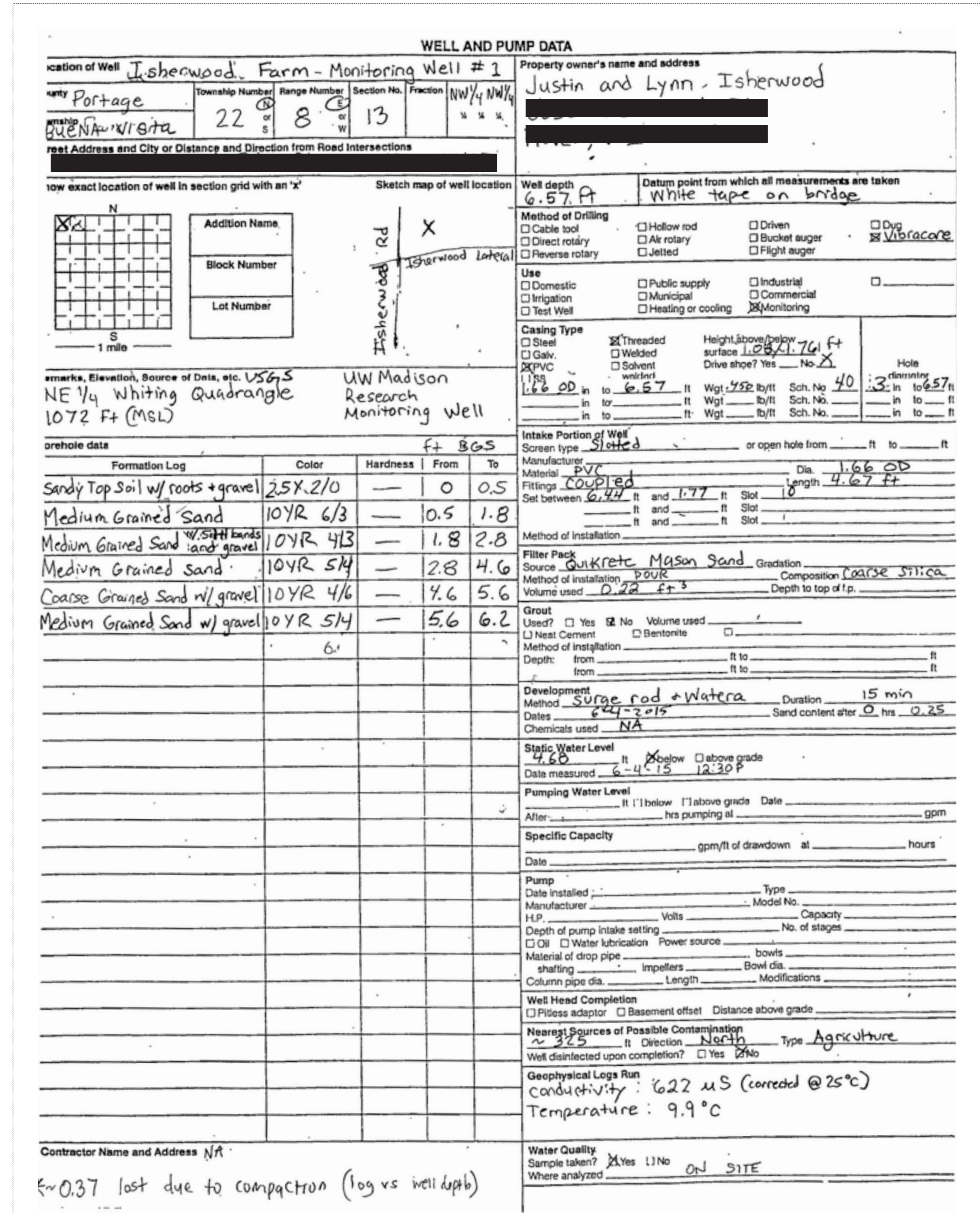
Species	Length (mm)	Quantity
Brook Trout	50	1
Brook Trout	52	1
Brook Trout	54	1
Brook Trout	55	1
Brook Trout	55	1
Brook Trout	60	1
Brook Trout	60	1
Brook Trout	64	1
Brook Trout	64	1
Brook Trout	64	1
Brook Trout	65	1
Brook Trout	65	1
Brook Trout	65	1
Brook Trout	65	1
Brook Trout	65	1
Brook Trout	70	1
Brook Trout	70	1
Brook Trout	70	1
Brook Trout	70	1
Brook Trout	71	1
Brook Trout	72	1
Brook Trout	74	1
Brook Trout	75	1
Brook Trout	75	1
Brook Trout	75	1
Brook Trout	75	1
Brook Trout	76	1
Brook Trout	76	1
Brook Trout	79	1
Brook Trout	80	1
Brook Trout	80	1
Brook Trout	80	1
Brook Trout	80	1
Brook Trout	81	1
Brook Trout	82	1
Brook Trout	82	1
Brook Trout	85	1
Brook Trout	85	1
Brook Trout	87	1
Brook Trout	90	1
Brook Trout	90	1
Brook Trout	90	1
Brook Trout	90	1
Brook Trout	94	1
Brook Trout	100	1
Brook Trout	100	1
Brook Trout	108	1
Brook Trout	110	1
Brook Trout	110	1
Brook Trout	120	1
Brook Trout	123	1
Brook Trout	170	1
Brook Trout	190	1
Brook Trout	200	1
Mud Minnow	n/a	4
Brook Stickleback	n/a	14

APPENDIX F: WATER QUALITY

Conductivity was measured using a handheld meter. Dissolved oxygen (DO), phosphate and nitrate tests were estimated using CHEMets colorimetric kits. The recommended nutrient concentrations for surface water bodies as set by the EPA and Wisconsin Legislature are .75 mg/L for total phosphorus (equivalent to 0.22 mg/L of phosphate) and 1.88 mg/L for total nitrogen.

	Date	Temperature (F)	Conductivity (corrected for temp - uS/cm)	DO (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
WELL 1						
	6-4-2015	50	622	4	7-10.	0.6
	7-2-2015	53.24	628			
	7-23-2015	57.2	637		7	0
	8-18-2015	57.38	697	0.3	10	0
WELL 2						
	6-5-2015	51.8	498	3 - 4	1.4 - 1.8	0
	7-2-2015	57.02	484.5			
	7-23-2015	59.36	487		0-4	0-0.1
	8-18-2015	58.82	490.4	0.4	10	0
WELL 3						
	6-4-2015	50.72	882	4	7-10.	1
	7-2-2015	52.34	866			
	7-23-2015	54.86	892		3.5-4.5	0
	8-18-2015	54.14	1142	1.5	14-18	0
DITCH						
	6-4-2015	54.32	510	10	10	0-0.1
	6-25-15			8-10.	14 - 18	0.1-0.2
	7-23-2015	56.66	530		5	0
	8-18-2015	52.7	532	7	4 - 7.	0

Well Construction Logs for Wells 1, 2, and 3



WELL AND PUMP DATA

Location of Well: Isherwood Farm - Monitoring Well # 1
County: Portage
Township: Buena Vista
Township Number: 22 N | Range Number: 8 E | Section No.: 13 | Fraction: NW 1/4 NW 1/4
Street Address and City or Distance and Direction from Road Intersections: [redacted]

Property owner's name and address: Justin and Lynn Isherwood
[redacted]

Show exact location of well in section grid with an 'x' — N, S, 1 mile
Addition Name / Block Number / Lot Number
Sketch map of well location: Isherwood Rd, Isherwood Lateral, X

Remarks, Elevation, Source of Data, etc.: USGS NE 1/4 Whiting Quadrangle 1072 Ft (MSL) — UW Madison Research Monitoring Well

Well depth: 6.57 Ft
Datum point from which all measurements are taken: White tape on bridge
Method of Drilling: ☒ Vibracore
Use: ☒ Monitoring
Casing Type: ☒ PVC, ☒ Threaded. Height above/below surface 1.08/1.76 ft. Drive shoe? No X
1.66 OD in to 6.57 ft, Wgt .450 lb/ft, Sch. No 40; Hole diameter .3 in to 6.57 ft

Borehole data (ft BGS)

Formation Log	Color	Hardness	From	To
Sandy Top Soil w/ roots + gravel	2.5Y 2/0	—	0	0.5
Medium Grained Sand	10YR 6/3	—	0.5	1.8
Medium Grained Sand w/ silt bands and gravel	10YR 4/3	—	1.8	2.8
Medium Grained Sand	10YR 5/4	—	2.8	4.6
Coarse Grained Sand w/ gravel	10YR 4/6	—	4.6	5.6
Medium Grained Sand w/ gravel	10YR 5/4	—	5.6	6.2

Intake Portion of Well: Screen type Slotted; Material PVC; Dia. 1.66 OD; Fittings Coupled; Length 4.67 ft; Set between 6.44 ft and 1.77 ft, Slot 10
Filter Pack: Source Quikrete Mason Sand; Method of installation Pour; Composition Coarse Silica; Volume used 0.22 ft³
Grout: Used? ☒ No
Development: Method Surge rod + Watera; Duration 15 min; Dates 6-4-2015; Sand content after 0 hrs 0.25; Chemicals used NA
Static Water Level: 4.68 ft ☒ below grade; Date measured 6-4-15 12:30 P
Pumping Water Level / Specific Capacity / Pump / Well Head Completion: (blank)
Nearest Sources of Possible Contamination: ~325 ft, Direction North, Type Agriculture; Well disinfected upon completion? ☒ No
Geophysical Logs Run: Conductivity: 622 uS (corrected @ 25°C); Temperature: 9.9°C
Water Quality: Sample taken? ☒ Yes; Where analyzed: On Site
Contractor Name and Address: NA
~0.37 lost due to compaction (log vs well depth)

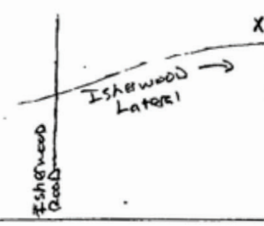
WELL AND PUMP DATA

Location of Well: Isherwood Farm Monitoring Well #2
County: Portage
Township: Buena Vista
Township Number: 22 N | Range Number: 8 E | Section No.: 13 | Fraction: NW¼ NW¼

Property owner's name and address: Justin /Lynn Isherwood
[redacted]

Street Address and City or Distance and Direction from Road Intersections: [redacted]

Show exact location of well in section grid with an 'x' — Sketch map of well location



Remarks, Elevation, Source of Data, etc.: USGS Whiting quadrangle 1074 Ft — UW-Madison Monitoring Research well

Well depth: 6.37
Datum point from which all measurements are taken: White Tape on East Side of Bridge

Method of Drilling: ☒ Vibracore
Use: ☒ Monitoring
Casing Type: ☒ PVC; Height above/below surface: 3.03/6.37; Drive shoe? No X
1.66 OD in to 0.34 ft; Wgt .450 lb/ft; Sch. No 40; Hole diameter 3 in to 9.81 ft

Borehole data (ft BGS)

Formation Log	Color	Hardness	From	To
Sandy Top Soil w/ roots + gravel	2.5Y 2/0	—	0	0.7
Oxidized Medium G. Sand w/ top soil traces	10YR 5/6	—	0.7	1.5
Medium Grained Sand w/ gravel	10YR 4/3	—	1.5	2.1
Medium Grained Sand w/ gravels	10YR 5/4	—	2.1	3.5
Coarse Grained Sand w/ gravel + silt pockets	10YR 4/2	—	3.5	4.0
Medium Grained Sand w/ Gravel	10YR 5/4	—	4.0	4.9
Coarse Grained Sand w/ Gravel	10YR 6/4	—	4.9	8.0

Intake Portion of Well: Screen type Slotted; Material PVC; Dia. 1.66 OD; Fittings Coupling; Length 4.67 Ft; Set between 5.16 ft and .234 ft; Slot 10; Method of installation Coupling

Filter Pack: Source Quickrete Mason Sand; Method of installation Pour; Composition Silica Coarse; Volume used .22 Ft^3

Grout: Used? ☑ No

Development: Method Peristaltic Pump/water / Surge Block; Duration 20min; Dates 6-4-2015; Sand content after 0 hrs; Chemicals used —

Static Water Level: 5.80 ft ☑ below; Date measured 6-4-2015

Pumping Water Level: ___ ft [ ] below [ ] above grade Date ___ After ___ hrs pumping at ___ gpm

Specific Capacity: ___ gpm/ft of drawdown at ___ hours Date ___

Pump: Date installed ___ Type ___ Manufacturer ___ Model No. ___ H.P. ___ Volts ___ Capacity ___ Depth of pump intake setting ___ No. of stages ___ ☐ Oil ☐ Water lubrication Power source ___ Material of drop pipe ___ bowls ___ shafting ___ impellers ___ Bowl dia. ___ Column pipe dia. ___ Length ___ Modifications ___

Well Head Completion: ☐ Pitless adaptor ☐ Basement offset Distance above grade ___

Nearest Sources of Possible Contamination: ~100 ft Direction N. Type Ag
Well disinfected upon completion? ☐ Yes ☒ No

Geophysical Logs Run: Conductivity – 498 uS 6-5-2015; T°C – 11.6

Contractor Name and Address: NA

Water Quality: Sample taken? ☑ Yes [ ] No; Where analyzed: Onsite

* ~1.63 gained due to infilling from side walls (log vs well depth)

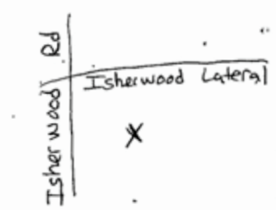
WELL AND PUMP DATA

Location of Well: Isherwood Farm - Monitoring Well #3
County: Portage
Township: BUENA VISTA
Township Number: 22 N | Range Number: 8 E | Section No.: 13 | Fraction: NW¼ NW¼

Property owner's name and address: Justin and Lynn Isherwood
[redacted]

Street Address and City or Distance and Direction from Road Intersections: [redacted]

Show exact location of well in section grid with an 'x' — Sketch map of well location



Remarks, Elevation, Source of Data, etc.: NE ¼ Whiting Quadrangle 1072 ft (MSL) — UW Madison Research Monitoring Well

Well depth: 6.06
Datum point from which all measurements are taken: White tape on bridge

Method of Drilling: ☒ Vibracore
Use: ☒ Monitoring
Casing Type: ☒ PVC; Height above/below surface: 3.04/1.25 ft; Drive shoe? No X
1.66 OD in to 1.26 ft; Wgt .450 lb/ft; Sch. No 40; Hole diameter 3 in to 6.06 ft

Borehole data (ft BGS)

Formation Log	Color	Hardness	From	To
Sandy Top Soil w/ roots	2.5Y 2/0	—	0	0.7
Sand w/ bands of Top Soil	10YR 3/2	—	0.7	1.3
Medium Grained Sand	10YR 6/3	—	1.3	1.9
Peat layer - visable organics	10YR 2/1	—	1.9	2.1
Coarse (cL) Grained Sand	10YR 5/4	—	2.1	3.1
Coarse (cL) Sand w/ silt bands	10YR 4/2	—	3.1	6.2
Coarse (cL) Grained Sand	10YR 6/3	—	6.2	7.4

Intake Portion of Well: Screen type Slotted; Material PVC; Fittings Coupled; Set between 5.93 ft and 1.26 ft; Slot 10

Filter Pack: Source Quikrete Mason Sand; Method of installation POUR; Composition Coarse silica; Volume used 0.22 ft^3

Grout: Used? ☒ No

Development: Method Surge rod + watera; Duration 15min; Dates 6-4-15; Sand content after 0 hrs 0.25; Chemicals used NA

Static Water Level: 5.04 ft ☒ below; Date measured 6-4-15

Pumping Water Level: ___ ft [ ] below [ ] above grade Date ___ After ___ hrs pumping at ___ gpm

Specific Capacity: ___ gpm/ft of drawdown at ___ hours Date ___

Pump: Date installed ___ Type ___ Manufacturer ___ Model No. ___ H.P. ___ Volts ___ Capacity ___ Depth of pump intake setting ___ No. of stages ___ ☐ Oil ☐ Water lubrication Power source ___ Material of drop pipe ___ bowls ___ shafting ___ impellers ___ Bowl dia. ___ Column pipe dia. ___ Length ___ Modifications ___

Well Head Completion: ☐ Pitless adaptor ☐ Basement offset Distance above grade ___

Nearest Sources of Possible Contamination: ~325 ft Direction SOUTH Type Agriculture
Well disinfected upon completion? ☐ Yes ☒ No

Geophysical Logs Run: Conductivity - 882 (corrected @ 25°C); Temperature - 10.4 °C

Contractor Name and Address: NA

Water Quality: Sample taken? ☒ Yes [ ] No; Where analyzed: ON SITE

* ~1.34 gained due to infilling from side walls (log vs well depth)

Table 4. Depth to water (DTW) manually recorded for well sites. "Stickup" refers to height of PVC pipe above ground.

Date	DTW Well 1 (ft)	Depth below ground surface	DTW Well 2 (ft)	Depth below ground surface	DTW Well 3 (ft)	Depth below ground surface	DTW Stilling Well 1 (ft)	DTW Stilling Well 2 (ft)
	Near gate entrance, north side of ditch	(=DTW-stickup)	Farthest from road	(=DTW-stickup)	South side of ditch	(=DTW-stickup)	Near road culvert	Near foot bridge
6/4/2015	5.76	4.68			5.04	2		
6/5/2015			7.91	4.47				
6/16/2015	5.74	4.66	7.83	4.39	5.86	2.82		
6/25/2015	5.84	4.76	8	4.56	6.24	3.2	3.32	3.3
7/2/2015	5.92	4.84	8.01	4.57	6.27	3.23	3.31	3.27
7/23/2015	6.069	4.989	8.12	4.68	6.335	3.295		
8/18/2015	6.5	5.42	8.46	5.02	6.68	3.64	3.54	3.6

APPENDIX G: MODELING

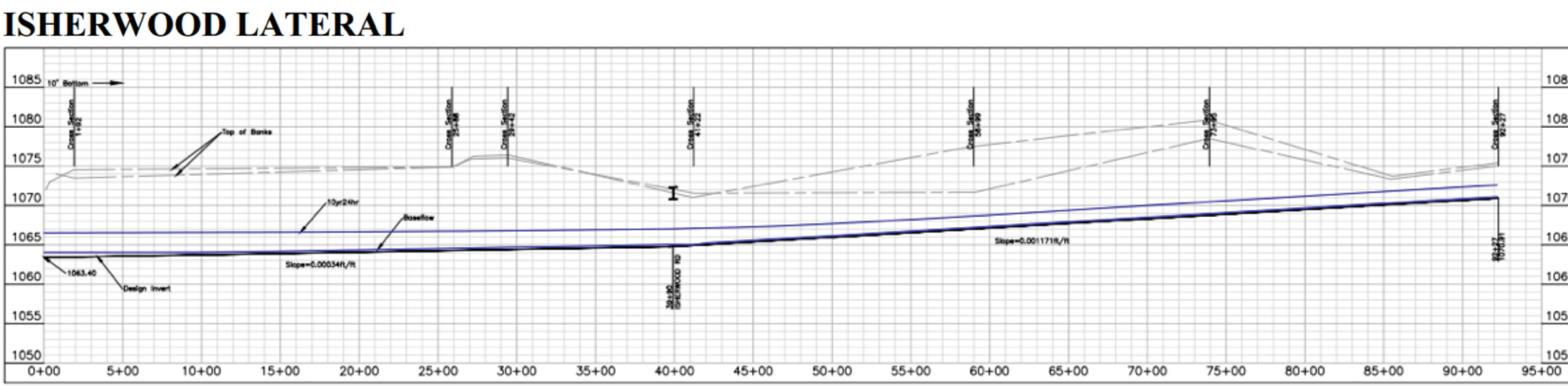


Figure 11: Profile view of Isherwood Lateral (PCDD)

APPENDIX H: NON-RECOMMENDED STREAM RESTORATION STRATEGIES

Strategy	Description	Construction	Effects	Costs	Comments
Two-Stage Ditch	Constructing an inset channel with floodplain benches on both sides	Requires heavy machinery; inset channel design must be based on regional curves	Improved streamflow conveyance and generally improved habitat; self-sustaining with minimal maintenance; may help inhibit reed canary grass growth	Larger upfront costs; earthworks on past projects range $5-20/linear foot	Promising strategy for drainage ditch enhancement, but many uncertainties on how it would perform in sandy soils; would involve largely permanent changes over a lengthy portion
LUNKERs	Installing wooden structures under-water along stream banks	Requires heavy machinery, drills, and saws to build and install; needs rocks, soil, and planted vegetation to stabilize	Provides cover and resting places for trout and other fish	Materials run $75-100 per LUNKER structure; machinery rental could run $500-1000	Popular and effective trout stream rehabilitation technique, but may be more favorable for brown trout than brook trout
New Canopy Cover	Installing/maintaining trees and other vegetation on banks to shade the channel	Planting new trees along banks	Supplies coarse woody habitat (CWH) to stream; roots can help stabilize banks; shade helps maintain cooler water temperatures	Planting trees can range $100s-$1000s depending on length of stream planted	New cover takes time and money to develop; water temperatures regulated by groundwater in Central Sands; desired outcomes achievable through other recommended strategies
Sediment Traps	Digging large pits into streambeds or installing turbidity curtains along banks	Requires heavy machinery to dig pits; curtains are anchored to banks/streambed using stakes	Captures suspended sediment and prevents its downstream movement; reduces turbidity	Medium costs for installation, but would require periodic emptying and maintenance	Generally used as temporary measure during construction projects, though can be used on a more permanent basis; sandy soils would lead to higher maintenance costs
Boulder Weirs	Small waterfalls installed in/across the stream channel	Placing large natural boulders or created concrete in stream; requires heavy machinery	Creates scouring pools and turbulence; increases oxygen content	Varies widely depending on size/type of boulder materials installed	Could create favorable habitat for trout, but slows water velocity and may be difficult to remove

APPENDIX I: PORTAGE COUNTY TROUT STREAM MAP

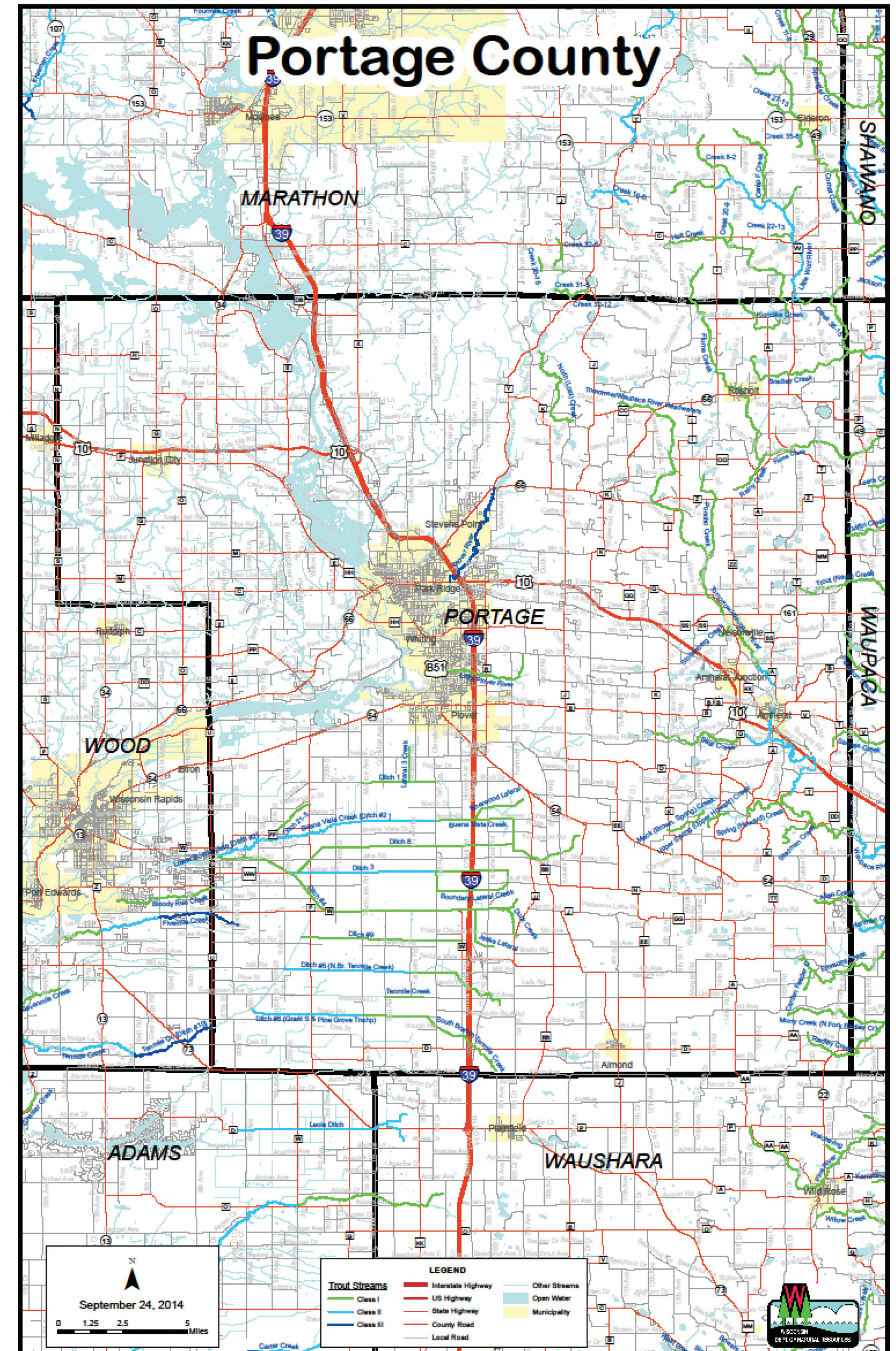


Figure 12. Source: Wisconsin DNR http://dnr.wi.gov/topic/fishing/documents/trout/trout_maps/Portage_color_portrait.pdf

APPENDIX J: EXPERTS AND ORGANIZATIONS TO CONSULT

PORTAGE COUNTY DRAINAGE DISTRICT
Area(s) of expertise:
State and local regulations, ditch maintenance, ditch design, local knowledge
Contact information:
Richard Raschke, Chairperson
Phone: (715) 340-5656

PORTAGE COUNTY PLANNING & ZONING DEPARTMENT
Area(s) of expertise:
State and local regulations, cost-sharing programs, conservation, grants, environmental planning
Contact information:
Steve Bradley, County Conservationist
Phone: (715) 346-1334
Email: bradleys@co.portage.wi.us
Website: http://www.co.portage.wi.us/planningzoning/new/land-conservation/index.html

WISCONSIN DEPARTMENT OF AGRICULTURE, TRADE AND CONSUMER PROTECTION
Area(s) of expertise:
State and local regulations, engineering, ditch design
Contact information:
Chris Clayton, Program Manager
Phone: (608) 224-4630
Email: Christopher.clayton@wi.gov
Website: http://datcp.wi.gov/Environment/Drainage_Programs/index.aspx

WISCONSIN DEPARTMENT OF NATURAL RESOURCES – WISCONSIN RAPIDS FIELD UNIT
Area(s) of expertise:
State and local regulationsregulations, fisheries management, stream restoration, conservation
Contact information:
Tom Meronek, Fisheries Biologist
Phone: (715) 359-7582
Email: thomas.meronek@wisconsin.gov
Website: https://hornberg-tu.org/

WISCONSIN TROUT UNLIMITED – FRANK HORNBERG CHAPTER
Area(s) of expertise:
Stream restoration, conservation easements, fish ecology, conservation
Contact information:
Matt Salchert, Chapter President
Phone: (715) 321-1394
Email: frankhornberg.tu@gmail.com
Website: https://hornberg-tu.org/

LIST OF ACRONYMS

CWH – Coarse Woody Habitat

DATCP – Wisconsin Department of Agriculture, Trade, and Consumer Protection

DNR – (Wisconsin) Department of Natural Resources

DO – Dissolved Oxygen

HEC-RAS – Hydrologic Engineering Center's River Analysis System

LUNKER – Little Underwater Neighborhood Keeper for Rheotactic Salmonids

NRCS – Natural Resources Conservation Service

PCDB – Portage County Drainage Board

PCDD – Portage County Drainage District

USACE – United States Army Corps of Engineers

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

WGNHS – Wisconsin Geological and Natural History Survey

WPDES – Wisconsin Pollutant Discharge Elimination System

GLOSSARY

Bank stability – the capacity of a stream channel to transport its water and sediment inputs without changing its dimensions

Bankfull discharge – the discharge that fills the active stream channel to bankfull stage

Biotic index – a scale showing the quality of an environment by the types of organisms that inhabit it; often used to assess water quality in bodies of water

Boundary condition – a stated restriction that limits the possible solutions to the differential equations used in mathematical modeling; used to determine what is and is not included in a study

Brook trout – Wisconsin's only native stream trout species and the focus of this report's restoration recommendations; its scientific name is Salvelinus fontinalis

Brown trout – a non-native stream trout species commonly found in the Central Sands; may compete with Bbrook Ttrout for habitat; its scientific name is Salmo trutta

Canopy cover – the percentage of a sample area shaded by trees and vegetation; plays an important role in stream water quality, but is less influential in groundwater-fed streams (such as those in the Central Sands) than other factors

Channel geometry – collectively, the dimensional characteristics that define a stream channel, including its width, depth, slope, and friction

Channel morphology – the shape of a stream channel and how it changes over time

Channelization – straightening and deepening a natural stream in order to increase the volume and speed of its flow

Class I trout stream – high-quality trout waters that have sufficient natural reproduction to sustain populations of wild trout, at or near carry capacity; requires no stocking of hatchery trout

Class II trout stream – may have some natural trout reproduction, but not enough to utilize available food and space; stocking is required to maintain a desirable sport fishery

Coarse woody habitat (CWH) – fallen dead trees and the remains of large branches in streams, wetlands, and forests; may also be called coarse woody debris (CWD)

Cross section geometry – the dimensions of a stream channel as viewed if "cut" vertically along a line perpendicular to its banks; used in hydraulic calculations

Culvert – a tunnel carrying a stream under a road

Deposition – the process in which soil or sediment that has been eroded from one place is transported by wind or water and laid down in another place

Dissolved oxygen (DO) – microscopic bubbles of gaseous oxygen (O_2) that are mixed in water and available to aquatic organisms for respiration; critical for almost all organisms

Dredging – underwater excavation performed for the purpose of removing sediments and debris from the bottom of the water body

Easements – the right to use or enter property belonging to another person, as granted voluntarily by the landowner; often employed as a method of conserving the property's natural resources

Ecosystem services – the benefits people obtain from ecosystems; includes resource provision, water filtration, recreation, and nutrient cycling (among many others)

Electroshocking – a common scientific survey method that uses electricity to stun fish so that they can be caught, measured, and released without being harmed

Eutrophication – the process in which a body of water becomes over-enriched by nutrients, leading to excessive algae growth and eventually the depletion of dissolved oxygen in that water body

Exceptional Resource Water – DNR designation for surface water which provides outstanding recreational opportunities, supports valuable fisheries and wildlife habitat, has good water quality, and is not significantly impacted by human activities; may also receive point-source pollutant discharge at the time of designation; receives Wisconsin's second-highest protection standards

Flow meter – a device that records the rate or quantity of flow of water through a pipe

Grade profile – refers to the slope of the streambed and thus its capacity for erosion or deposition; a graded stream is one which that is neither eroding nor depositing sediment

Heterogeneity – diversity; here, it refers to the variety of microhabitats within the stream

HOBOware – scientific software used to automatically log data

Homogenous – composed of all the same kind

Humic soil – soil composed primarily of dark organic matter (humus) formed by decayed plants or animals

Hydraulic conductivity – a measure of soil or sediment's capacity for transmitting water through its pores

Hydraulic gradient – a measure of the change in hydraulic head over a given distance

Hydraulic head – a measurement that represents the total mechanical energy of groundwater

Interpolation – a method of estimating unknown data points between known data points using numerical analysis

LUNKER structures – streambank installations used in trout streams to provide shelter for fish

Macroinvertebrates – animals without backbones that are large enough to be seen without a microscope

Macrophytes – aquatic plants large enough to be seen without a microscope

Metaphyton – algae living in the photic zone (the upper layer of water defined by the depth to which sunlight can penetrate) which are neither directly attached to the streambed nor freely floating

Mini-pygmy reader – a water current meter used to measure velocities less than 3 feet/second

Monoculture – the growth of a single kind of organism in a given area

Nitrate-N – an inorganic compound with negative water-quality impacts; may also be denoted as NO3-N or nitrate-nitrogen

Perennial stream – a stream that flows year-round in a well-defined channel

Phosphate – inorganic compounds containing phosphorous

Piezometer – a device that measures the pressure of groundwater at a certain point

Pressure transducer – a device that detects a fluid pressure and converts it to an analog electrical signal

Redds – a hollow in sand or gravel on a river bed, scooped out as a spawning place by trout, salmon, or other fish

Riparian – relating to land or wetlands adjacent to rivers or streams; the interface between land and a river or stream

Sediment transport – the movement of solid particles by water

Sedimentation – the process by which solid material settles to the bottom of a stream

Siltation – the "muddying" of water due to fine mineral particles suspended in the water column

Slump – the sudden downward movement of a large mass of unconsolidated material; in streams, this may be caused by erosional undercutting of streambanks

Stilling well – used to separate the main water-level fluctuations from the intermittent waves and surges so that more accurate water-level measurements can be obtained

Substrate – the sediment and material at the bottom of a stream

Tannic water – acidic water containing dissolved tannins from decaying organic matter; resembles dark tea

Taxonomy – the science of classifying organisms based on grouping them by shared characteristics

Volumetric flow – the volume of water that passes a given point per unit of time

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