DEMONSTRATION OF DRAINAGE CHANNEL RESTORATION TO IMPROVE STREAM INTEGRITY AND MAINTAIN FLOW CAPACITY

Final Narrative Report to the Great Lakes Protection Fund

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Overview

Highly modified channels drain extensive portions of productive agricultural land in the U.S.A. In many of these areas, most natural channels have been deepened and straightened to facilitate the flow of water from agricultural subsurface drainage outlets and to maximize conveyance. Work done periodically to maintain the drainage function typically includes removal of woody vegetation and deposited sediment. Ancillary work includes stabilizing bank slope failures and toe scour. Ditch form is a result of not only construction and maintenance but also, to verifying degrees, due to fluvial (flowing water) processes. The purpose of this project was to demonstrate through applied research and outreach education an alternative drainage channel form approach that incorporates naturalized fluvial features to enhance stream integrity and maintain or improve drainage capacity. The objectives of this project, addressed below, focused on understanding the conditions that favor such evolution and to determine the water quality, ecological and economical benefits of a two-stages ditches. Under specific hydrological conditions, highly maintained one-stage ditches can evolve into two-stages ditches that present more naturalized fluvial features. The project team evaluated conditions that favor such evolution and determined water quality, ecological and economical benefits of 2-stage ditches Northwest Ohio's Upper Portage River basin. Thirty+ ditch cross-sections and reaches were frequently sampled. N and P concentrations were similar, ditch-to-ditch. Biological processes might be limited by N:P ratios ranging from 50 to 800. Lab denitrification rates were similar to those in 1- and 2-stage ditches; denitrification potential was greater in 2-stage ditches. Macro-invertebrate biodiversity was strongly correlated with quality of benthic sediment, only partly responding to changes in ditch geomorphology. ICI suggested only poor to fair water quality throughout summer months. An engineering approach based on geomorphological principles, and regional curves that related bank-full width/depth to drainage area, were developed and tested to design 2-stage ditches, along with rapid-assessment methods for determining stream morphological parameters. Two-stage demonstration ditches were constructed in Wood County, OH and Hillsdale County, MI. Benefits and economic analyses are underway. Long-term monitoring is required to fully evaluate the impact of these modifications on stream ecology. Long-term funding is being sought.

Accomplishments

Objective 1 – Identify watershed and stream channel sites where the ecological benefits of alternative drainage channel forms can be assessed.

First through third order agricultural ditches were studied in the headwaters of the Portage and Sandusky River watersheds in Northwest Ohio. Both rivers discharge into Lake Erie. The Portage watershed lies almost entirely within the Huron-Erie Lake Plains Ecoregion, while the headwaters of the Sandusky River lie within the Eastern Cornbelt Plains Ecoregion. In both watersheds, the soils are poorly drained and the topographical relief is very low. Land use is primarily crop agriculture consisting of soybean, corn and wheat. Subsurface drainage has been extensively applied to enhance crop production. Extensive review of more than 50 sites and 130+ channel cross-sections was conducted; 35+ sites were selected for further study. Key GIS layers for the Portage River Basin were developed, as well as extensive channel morphological analyses.

Objective 2 - Evaluate the ecological benefits of alternative drainage channel forms as measured by aquatic habitat and water quality indicators.

Recent unpublished research from our GLPF team suggests that grassed agricultural one-stage ditches evolve toward a state of higher stability. More stable ditches are those that have developed low floodplain depositional areas (or benches) at the bottom of their channel. The result of this bench development is a two-stage ditch in which a narrow baseflow channel lies within the larger ditch. Two-stage ditches may reduce extremes in erosion and deposition if the presence of benches limit toe scour and provide areas for the deposition and storage of fine sediment. Stream benthic communities are strongly affected by substrate and disturbance regimes and may be improved if two stage channels provide a cleaner substrate and a reduction in the severity and frequency of disturbance events. Several component studies were conducted.

Ecological diversity in agricultural ditches:

Bouchard et al. focused on the potential link between ditch geomorphology (i.e., trapezoidal channel versus channel that had developed a bench) and structures of the ecological community, and hypothesized that management practices that allow the establishment of a bench and/or the development of a riparian tree communities would enhance the aquatic community. Bench and riparian trees would thus provide habitat and food resources, and would reduce flow velocity and excess of temperature. 21+ of the channel cross-sections/reaches were sampled in 2001 and 2002 for macro-invertebrates, amphibian and plant communities in three types of ditch reaches: ditches with riparian ecosystem (e.g., ditches with trees); ditches without riparian ecosystems but with a low narrow floodplain bench; and ditches without riparian ecosystems and without floodplain bench. Overall habitat quality was evaluated using the Qualitative Habitat Assessment Index, which considers bed substrate, in-stream cover, channel morphology, riparian conditions, riffle and pool development, and gradient in relation to habitat quality for fishes and macro-invertebrates. Several benthic macro-invertebrate assemblage metrics were calculated.

Preliminary data showed that macro-invertebrate richness and diversity did not differ significantly among the three types of ditches. However, the ditches with bench had the highest average richness and diversity while the ditches with trees had the lowest, suggesting that ecosystem productivity is lower in ditches with a riparian zone, as in-stream autotrophs are much less abundant due to shading by the tree canopy. Primary productivity might limit macro-invertebrate community development in such headwater systems. Additionally, substrate quality was positively correlated with macro-invertebrate richness. Bench width and the ratio of bench width to channel width were significantly higher in the Bench group than in both the Tree and Control groups. The overall QHEI score was significantly higher in the Bench group than in the Control group, but not significantly greater than in the Tree group. In-stream cover was significantly higher in the Bench group than in the Control group, but in-stream cover in the Tree group was not significantly different from either of the others. There were no other significant differences in individual QHEI metrics between the groups.

The M.S. Graduate Research Associate conducting a portion of this work will defend his thesis later this month.

Macro-invertebrate communities transect analyses:

Rife and Moody led efforts in 2001 and 2003 to quantitatively and qualitatively assess macro-invertebrate communities in the Portage River watershed. The emphasis was on identification and community structure of the macro-invertebrate biota resident in its smallest order streams and ditches. Hester-Dendy multi-plate samplers were used to assess the macro-invertebrate communities at 10 sites across the watershed. Dominant macro-invertebrates collected at greater than 70% of the sites included 54 species from 11 major taxa, with the highest diversity in the smallest order tributaries. The central area of the transect yielded lower numbers of species and densities than the eastern or western drainage areas, and Shannon-Wiener Diversity Indices illustrated this depressed community structure. Of the study sites, Rader Creek and the South Branch of the Portage were the most diverse, while Bull Creek was the least diverse. As was predicted from the physical appearance of the majority of the sites, the Portage River watershed macro-invertebrate communities were both depauperate and trophically simplistic. The ICI of the macro-invertebrate communities' resident suggested only poor to fair water quality at all locations throughout the summer. The impoverished state of the communities present in what is the most active time of the year suggests that steps to increase the health and complexity of the habitat would offer greater natural services to the watershed and drainage.

Water quality in drainage ditches:

With reductions in point sources over the last 30 years, non-point sources are now the most important contributors to nutrient pollution of rivers and streams in the Midwest. In Northwest Ohio, subsurface drainage of agricultural lands is an important source of water and nutrients to drainage ditches, which are the headwaters of rivers and streams. Richards and McCall focused on the characterization of water quality in typical drainage ditches at times when flow was dominated by inputs from subsurface drainage. These times are characterized by intermediate levels of flow, neither the highest, which are associated with storm runoff, nor the lowest, which typically occur during dry periods in the late summer and fall. Water samples were taken approximately once per month at sixteen sites within the upper Portage River watershed in northwest Ohio 2001 and 2002, and analyzed for suspended sediment, phosphorus and nitrogen species, and major ions. Nutrients concentrations were similar from ditch to ditch, and concentrations were generally comparable to those in larger rivers in the area, though concentrations of suspended solids were lower. Concentrations were similar from station to station: greater differences were seen from month to month than from station to station. Total nitrogen/total phosphorus ratios are much higher than would be ideal for biological assimilation of these nutrients, suggesting that nutrient uptake will be phosphorus-limited, and much of the nitrogen will not be taken up by the aquatic ecosystem. Unless denitrification is an active process at these times, substantial nitrogen export is to be expected.

Research, analysis, and discussions continue across all components.

Objective 3 - Evaluate sediment transport, deposition and sorting in alternative drainage channels.

Ward, Mecklenburg, Bouchard and others assessed drainage ditch form (pattern, profile, and dimension) on the project study sites in Northwest Ohio. Additional measurements and observations were made in the Wabash River, Great Miami River, Auglaize River, St Mary, and Big Walnut watersheds, as well as several locations in Minnesota and Illinois. Extensive measurements have also been made on natural streams throughout the state. Apparent benefits exist for incorporating fluvial process derived form into ditch construction and maintenance. All interesting reaches were surveyed to determine longitudinal profile and cross-sectional shape. Longitudinal elevations were measured along the thalweg of the channel and used to determine bed slope. Cross-sectional dimensions were measured at 2 to 4 transects per reach at locations that represented a significant proportion of the channel. The dimensions at each transect were averaged to give the final value used in the analyses. Bench development was assessed based on the ratio of the bench width to the baseflow channel width. Bench width was determined as the distance from the edge of the baseflow channel to the break in slope that ascends to the top of the ditch.

The quality of sediment was highest in the two-stage channels as there was less fine sediment and more gravel. Other studies conducted in agricultural landscapes that have compared grassed and forested streams suggest that substrate quality is higher with grassed riparian zones. However, the Control reaches - which had grassed riparian zones - were also dominated by fine sediment. Substrate quality, therefore, may be related more to bench development than riparian vegetation. The strong positive relationship between bench development (measured as bench width / total width) and gravel, and the negative relationship between bench development (measured as bench width / total width) and silt/clay, both with bench development support this hypothesis. The absence of significant bench development within both the Tree and Control study reaches may have precluded the deposition of fine material outside of the baseflow channel, resulting in greater amounts of fine bed sediment. Additionally, bench development may have reduced erosion within these ditch reaches and limited the amount of fine sediment available for deposition. Currently, research is underway that may provide insight to bench formation and function within agricultural ditches.

Objective 4 - Determine the potential for flood peak attenuation and storm water storage.

Historically, there are many examples of stream modifications that paid little attention to the discharges that naturally shape a stream. To some extent this oversight has been alleviated in the last decade by also considering a *bankfull* or *effective* discharge. These discharges are sometimes incorrectly identified or evaluated and we have a societal fixation in tying them to a 1 to 2 year recurrence interval. Inadequate attention has been paid to reports in the literature by eminent geomorphologists who provide extensive discussion on the relationship between the effective discharge, bankfull discharge, other discharges, sediment transport, and recurrence interval. For the Ohio streams that were studied there was close agreement between bank-forming discharges associated with effective discharge and bankfull discharge concepts. All of the streams suggested that the bank-forming discharges are associated with a range of discharges. Calculation of the effective discharge was sensitive to the subdivision of the sediment and discharge data into unequal bin sizes. The bank-forming discharges were primarily related to the transport of the middle 50% of the total sediment load. The recurrence interval of the bank-forming discharges generally ranged from 0.8 to 1.0-years. A study of the frequency of daily discharges that equal or exceed the bank-forming discharges suggests that for these streams these flows occur several times annually and the annual peaks approach is a poor indicator of the actual frequency of the flows.

Ward, Mecklenburg, and others focused on determining the relationship between benches, floodplains and other fluvial features for watersheds with drainage areas less than 1000 square miles. They evaluated the recurrence interval and relationship between bank forming discharges, sediment transport and measured bankfull channel dimensions, and the USGS rural and urban regression methods for estimating peak discharge, and incorporated knowledge from these evaluations into the development and enhancement of a suite of Excel spreadsheet design tools. This work has lead to the development of regional curves that relate bank full width and depth to drainage areas. Curves have been developed for several watersheds in Ohio including Broken Sword Creek, Upper Great Miami River, Loramie Creek, Upper Olentangy River, Paint Creek, the Portage River, St Joseph River, and the Wabash River. A new rapid measurement protocol has been used to develop these regional curves. A small loss in accuracy is offset by the ability to develop relationships within 1 or 2 days compared to many days or weeks of work using conventional methods.

Ward and Mecklenburg evaluated methods to estimate the hydrologic response of a piece of land such as a field, land parcel, subwatershed or watershed, including the USGS approach based on a statistical analysis of stream discharge data (rural regression equations are available for all fifty States, Puerto Rico, and American Samoa), and other approaches contained in the National Flood Frequency (NFF) Program that attempt to address rural and urban interfaces. A problem with the urban and rural equations is that they do not provide a smooth transition from a rural land use to an urban land use. Typically, discharge estimates for a Basin Development Factor (BDF) of 0 (the lowest values used in the Urban Equations) will be much higher than those obtained by using the rural equation. In contrast the rural equation cannot be used to evaluate land use changes. Therefore there is a need to develop an interface between the two approaches to better reflect land use changes from a rural setting to an urban setting. An additional problem with both sets of equations is that they were developed for use on watersheds with areas less than a few square miles. Observed discharge data that might be used to calibrate the models is normally only available on larger watersheds and for planning purposes there is often a desire to make assessments on these large watersheds. A student is evaluating the application of these methods to drainage areas of a few hundred square miles and is also evaluating how a seamless transition from a rural to an urban land use might be considered with these methods.

Objective 5 – Conduct an economic cost-benefit analysis related to the design, implementation, construction, and maintenance of two-stage channel forms, water quality, and storm water management.

Benefits and Costs:

Benefits of a two-stage ditch over a conventional ditch are potentially both improved drainage function and ecological function. Drainage benefits may include increased ditch stability and reduced maintenance. First, as mentioned above, ditches are often constructed with a base width greater than that of a channel formed by fluvial processes, making the effective discharge wide and shallow, effectively reducing the channels ability to transport sediment. Evidence and theory both suggest ditches prone to filling with accumulated sediment may require less frequent “dipping out” if constructed in a two-stage form. Second, channel stability may be improved by a reduction in the erosive potential of larger flows as they are shallower and spread out across the bench. Stability of the ditch bank may also be improved where the toe of the ditch bank meets the bench rather than the ditch bottom. Here the bank height is effectively reduced and the shear stress (erosive force) on the toe of the bank is less. Also, this bank material will be dryer, not being in contact with low flow. However, where the main channel meanders to the toe of the ditch bank this would not be the case and bank erosion might even be induced.

The two-stage ditch has the potential to create and maintain better habitat. The narrow deep main channel provides better water depth during periods of low flow. Grass on the benches can provide quality cover and shade. The substrate in the main channel is improved as the two-stage form increases not only sediment conveyance but also sorting, with fines deposited on the benches and courser material forming the bed. Two-stage ditches might also be useful in improving water quality particularly for nutrient assimilation. Work has been initiated on the ecology of these ditches and the role of the channel and benches in improving water quality and habitat.

The primary costs of two-stage ditches are increased width and more initial earthwork. Creating a low bench typically requires the top width of ditch to be greater. If a two-stage ditch is commonly in the range of 10-20 feet wider then the loss of potentially farmable land might be 1 to 3 acres per mile of ditch, depending on watershed size and the size of the existing ditch. The increased width however, will usually increase the capacity (amount of flow it can carry) by 25 to 100 or more percent. With the loss of farmable acreage in mind, we have proposed that the establishment of the low bench be included in the same way as establishing a grass filter adjacent to the top of the ditch. It is probable that establishment or retention of this feature will have a similar or greater benefit than a grass filter. However, it does not negate the benefit of also having a grass filter along the top bank of the ditch.

Economic analysis of the benefits and costs:

Sohngen and others are evaluating the benefits and costs of naturalizing streams and drainage ditches in Northwest Ohio through channel modification, in collaboration with other team members focusing on the engineering methods for altering ditch design. We proposed that two-stage drainage ditches can be designed and implemented in Northwest Ohio to maintain runoff during storm events, and to improve environmental conditions in the streams. Currently, we are considering the costs of channel modification and the potential environmental benefits. While the estimated environmental benefits in economic terms have yet to be realized so early in this long-term study, scenario analysis is being used to provide estimates of costs across alternative modification regimes that would have different environmental benefits.

The hypothesis of the economic study is that a two-stage drainage channel design for naturalizing channelized streams will improve the integrity of self-maintaining benches. The proposed designs will: Increase the amount of water storage for large storm events thereby reducing the risk of flooding, decrease the need for ditch dipping of sediments, improve the biodiversity of the streams, increase the aquatic habitat for sustainability by improving the water quality, and finally act as a buffer to filter upstream pollution from downstream areas. This design is hypothesized to be more cost effective than using riparian buffer zones and grass filter strips. Thus, the key issue for economists is to analyze the benefits and costs of the naturalization of channelized streams in northwest Ohio.

There are two components to the economic analysis. The first component is to estimate the potential costs of converting stream reaches to the two-stage ditch design proposed in the engineering aspects of this research. Cost elements include machinery and labor costs during the work period, permit costs, and future maintenance costs (which may actually decline with the proposed ditch designs. Because the proposed designs also allow for sinuousity in the streams to improve environmental conditions, they may require additional land to be allocated to the ditches. An important additional cost included in this analysis is the opportunity cost of converting productive farmland near existing drainage ditches to the new, two-stage ditch design. The second component of this research is to apply optimization techniques to assess the benefits and costs of converting stream reaches to the two-stage ditch design by exploring the most cost effective placement of widening the ditches in a particular area. The optimization program focuses on determining which parcels to convert to two-stage ditches, taking into account land values, construction costs, optimal size of ditch width to accommodate a longer lag time for water retention. This analysis compares the cost effectiveness of constructing many small benches upstream or constructing a large bench downstream. Cost effectiveness will be measured in terms of sediment control and other environmental outcomes, such as stream biotic integrity.

The model focuses on the area along Needles and Radar Creek. This area was chosen by the project team as the primary area for studying ditch processes. The economic analysis considers specifically naturalization scenarios near several selected research sites. The economic model is static, and thus considers flow regimes under three storm events, the 1-year storm event, the 10-year storm event, and the 50-year storm event. Using data from the Drainage Ditch Model Study Sites excel file the model was used to find figures for increasing ditch widths by 15, 30, and 45 feet. The model also calculates the velocity differences of the water at each width and storm event level. This information has been used to find the relative water levels in the ditch, to understand the capacity of the ditch, and to optimize the construction of the ditches to be able to withstand at least a 50-year storm without flooding. The optimization model calculates the total costs of ditch improvement project by calculating the sum of each parcel's cost of widening the bench in 15-foot increments by multiplying the parcel stream frontage length, the rental price of the land and the bench width. These same dimensions are multiplied by the variable costs for conversion and then the total is added to the fixed costs of conversion. Areas in-between the study sites are modeled by using actual site values and extrapolating values for flow characteristics from the study sites. A budget is imposed on the optimization program to find the lowest cost placement of two-stage ditch designs to meet environmental and cost constraints.

A number of different scenarios are currently being explored with the economic model. The results will be assessed, and optimal ditch placement strategies will be discussed. The results will help policy makers understand the potential trade-off's between the costs of improving environmental conditions within streams and maintaining stream flow. The M.S. Graduate Research Associate conducting the benefits/cost analysis as a portion of this objective has yet to defend her thesis – possibly this summer.

Objective 6 – Develop an implementation guide bulletin, and conduct field-days and a workshop to illustrate and teach the design, implementation, construction, maintenance, and drainage capacity and ecological benefits of two-stage channel forms, and prepare the final project report for Phase I.

The Ohio Department of Natural Resources (Mecklenburg) in collaboration with the Ohio State University (Ward) have developed several ditch, channel, and stream system evaluation and design tools. The goal of the work on ditches is to develop a procedure that can be used in the Midwest to correctly size the fluvial channel, to provide a minimum bench width for stability, and to size the cross-sectional capacity of the second stage to carry a design discharge based on a recurrence interval that satisfies local, county, watershed, or state requirements. Other spreadsheets facilitate evaluation of the impact (positive and negative) of sediment agradation, bench development, and channel geometry on flow and sediment transport in a channel. Tools have also been developed to evaluate the benefits of floodplains, to evaluate measured information on channel geomorphology, to calculate the effective discharge, and to evaluate storm water management strategies. Many of the tools are available through the ODNR Soil and Water Conservation Division website. The tools have been used to design several channel systems and use of the tools has been presented in several workshops and in a Stream geomorphology course that is taught at The Ohio State University.

It is anticipated that two-stage ditches will have improved conveyance capacity, will be more self-sustaining, will create and maintain better habitat, and will improve water quality. The construction of two-stage ditches requires capital investment to create a wider surface width and more earth moving. Case studies have been developed for recently constructed two-stage channels in Michigan and Ohio. In on-going research these ditches will be monitored to evaluate their potential to reduce the export of sediment and agricultural chemicals.

Presentations, workshops, papers, fact sheets, etc., other outreach products and activities:

Various aspects of the project concepts and results have been presented at 50+ county- and watershed-level to international professional meetings, including virtually every Extension outreach meeting/program under the heading of "agricultural water management" in Ohio, Illinois, Indiana, conducted or attended by project principals; and 10+ national and international professional meetings (including Canada and South Africa). The estimated numbers of stakeholders reached through these efforts may exceed 2000.

Workshops, and lectures at workshops included: Workshop on Surveys and Measurements for Drainage Channel Restoration, a 1-day session at Ohio State University's Overholt Drainage School in 2003; Workshop on the ODNR Natural Channel Design Tools presented at The STREAMS Channel Protection and Restoration Conference in 2003; Workshop on Helping Nature Improve the Function of Ditches and Streams, sponsored by the Nature Conservancy in 2003; Meeting for Drainage Commissioners in Champaign County, IL, on ditch maintenance and the Endangered Species Act Sponsored by NRCS and the Farm Bureau in 2003; A Rapid Regional Curve Assessment Technique for 100-1000 square mile watersheds at the Great Lakes Commission Workshop on Bringing It Home: Lessons from the Field for Making Watershed Management Work in 2002; Two-stage ditch design at Ohio NRCS Engineers' Workshop in 2002; and others.

Posters developed and presented at 12+ meetings/conferences: Two-Stage Agricultural Ditch Design; Tile Drainage WQ in the Portage River Basin; Drainage Channel Restoration Construction.

Publications: Designing Two-Stage Agricultural Drainage Ditches published in the Proceedings of the ASAE 8th International Drainage Symposium, March 2004; article in the Drainage Contractor Magazine, with international circulation exceeding 10,000.

Publications in development, review, etc.: Two-Stage Ditch Design (fact sheet and journal articles); 8-page fact sheet/work sheet product on the design of two-stage ditches; *Aquatic macroinvertebrate communities from the Portage River watershed headwater streams (Wood County, Ohio*) in review for publication in The Ohio Journal of Science; development of a new chapter on Two-Stage Ditches in the National NRCS Handbook NEH Part 654 Stream Design Handbook (publication in 2004); Water Quality in Drainage Ditches Influenced by Agricultural Subsurface Drainage (fact sheet).

Information exchange and websites: Developed and maintain streamnet list server; Lunched two project related websites/pages at: http://www.ag.ohio-state.edu/~streams/ and http://www.ag.ohio-state.edu/~ncd/.

Assistance to other GLPF projects: Members of our project team made a site visit to the Ives Road Fen project in Southern Michigan to review and advise on the removal of the old subsurface drainage system as part of their restoration project, in collaboration with Sherri Laier.

Co-Organized and hosted the Restoring Natural Flows: Building Capacity in the Great Lakes Third Meeting, October 21-23, 2001, for Projects Funded through the Great Lakes Protection Fund, held at Sauder Village, Ohio.

Objective 7 – Initiate the process to design and implement a construction demonstration of an actual drainage channel restoration construction project (start of Phase II).

A drainage channel reconstruction project was designed and completed in 2002, well ahead of the proposed Phase II activity that was to follow Phase I.

Wood County Construction Demonstration Project:

The new design method developed by Mecklenburg and Ward was incorporated with knowledge of bench and channel features in the ditch; drainage area (watershed) size information; and equations based on a study of ditches in the upper reaches of the Portage River Basin. The project was Joint County Ditch number 2458, petitioned by Mary E. Smith in Wood County, Ohio. The Rosengarten Construction, Inc., was employed for the work of reconstructing this project. The overseer of construction was D.J. Mears, Office of the Wood County Engineer. The Wood County Engineer staff developed the project design by applying the new design method. Thirty cross-section stations were surveyed along the waterway and the data used to develop the final engineering design of the reconstructed ditch. Project construction began on May 6, 2002 and ended on June 6, 2002, with several days of downtime because of wet weather. Bench formation and earth removal took approximately 6 days: 3 days for 6,000 linear feet of bench construction, and 2.5 days to dip 4,400 linear feet of earth. Bench work progressed by approximately 1,475 feet per day, more than double the expected daily amount. Outlet installation was completed in 2 days and rock removal in 2 days. Construction, engineering and associated costs totaled approximately $40,335. Process and engineering costs included advertisement, mailings, materials, construction staking, inspection, engineering design, contingencies, and the initial maintenance fund ($24,865). Construction costs included excavation, tree and debris removal, rock work, subsurface drain outlet replacement and splash apron, seeding, fertilizer, etc. ($13,606). All but approximately $6,000 of the cost of this project was assessed to the benefiting landowners, with the $6,000 being the project's cost of the construction demonstration. The $6,000 was approximately the increase in costs over that for a traditional ditch construction.

Building on the project's results as supported by the GLPF, project collaborators and principals obtained additional, and separate funding to conduct a similar drainage channel reconstruction project in Wood County in cooperation with ODNR Division of Wildlife (Needles Creek at Sands Road, constructed in October 2003 as single-sided construction, with 1500 lineal ft of channel and 13,000 CY of sediment excavated, at a cost of approximately $33,000). Other grants have been received by several organizations and individuals to construct two-stage ditches in Hillsdale County, Michigan, and Mercer, Shelby, Union and Wood Counties in Ohio, all with the cooperation and design helps from this project. The Hillsdale County, Michigan two-stage ditch design was developed by Ward as part of a demonstration project for the Nature Conservancy, Upper St. Joseph River Project Office, and is funded with a grant from the Great Lakes Commission, with construction in 2003.

Continuation of research:

Because of the large number of interrelated components to this project, we plan to continue discussions of the results from the component research in the context of the larger system. Also, we plan to continue to monitor the sites that were evaluated as part of the Phase I project efforts. Long-term monitoring and evaluation of the Wood County and Hillsdale County sites is extremely important. Additional funding will be required, and several proposals will be developed to continue this work.

Related project funding obtained:

OARDC Seed Grant awarded to Bouchard to help support graduate student working on nutrient in the drainage ditches in Northwestern Ohio, $30,000.

Fluvial Geomorphology and Nutrient Processes in Low Order Streams in Midwestern Tile-Drained Agricultural Landscapes. USDA/EPA Nutrient Science for Improved Watershed Management Program, $690,000. *Investigators*. A. Ward, V. Bouchard, B. Sohngen, P Richards. Fall, 2002 – Fall, 2005. The study addresses regional and national concerns regarding high nitrogen loading to the Great Lakes and Gulf of Mexico. Our goal is to quantify the extent that agricultural drainage ditches can reduce nitrogen loading, and to identify management practices that increase nitrogen removal while maintaining economic viability. To achieve our goal, we will study: (1) the geomorphic evolution of ditches in response to their hydrologic regimes; (2) their ecological function and how it can be improved; and (3) the quantity, quality, and temporal distribution of discharges to agricultural ditches. We will also evaluate the economic and water quality tradeoffs between improving the assimilative capacity of ditches versus using less fertilizers and incurring more risk and lower yields or less profitability from crop production. The study will build on the knowledge base and research infrastructure developed during on ongoing study in Ohio. That study has identified the role of fluvial processes in establishing more natural channel and bench features in ditches. Of particular importance is that the formation of these features is predictable and they are associated with high tile discharge events. The study will be conducted by an inter-disciplinary team of faculty at The Ohio State University, Heidelberg College, the University of Illinois, and the University of Minnesota. Results of the study will be disseminated through outreach education programs, a website, facts sheets, presentations at meetings, and in refereed papers. These activities will be facilitated by an established network of collaboration that includes stakeholders at the state and local level.

Great Miami River Watershed Project. US EPA Watershed Initiative Grant Program $700,000 with an additional $600,000 of matching funds. Award Recipients: Miami Conservancy District. 8/1/2003-7/31/2006. PROJECT 2 of this initiative will: Reduce nutrient/sediment impairment in Loramie Creek sub-watershed. Install Two-Stage Ditch Design in highly visible sediment prone area as demonstration, $151,500 and $41,480 of matching funds. Co-PI: A Ward. This project will design and construct innovative two-stage ditches using an approach developed by The Ohio State University and Ohio Department of Natural Resources. A two-stage ditch can decrease sediment and nutrient transport, improve drainage and ecological function, increase ditch stability, and reduce maintenance. In August 2003, we assisted the Miami Conservancy District in two drainage ditches that could be re-designed to accommodate the Two-Stage design. The survey work and a conceptual design have been developed for one

of these ditches. Construction is targeted for the Spring of 2004. The project will evaluate the ecology of Two-Stage Ditches and the role of the channel and benches in improving water quality and habitat. The project will provide the participating landowner with appropriate payment for land taken out of production as well as paying for the ditch design and construction costs. The project will monitor water quality benefits by taking appropriate water quality samples throughout the project timeframe upstream and downstream of the constructed two-stage ditches. Samples will be collected and analyzed by a certified water analysis laboratory. A quality assurance/control plan, for data collection and analysis activities, will be developed prior to initiation of the project to ensure the scientific usefulness of the data.
The Watershed Initiative was conceived to encourage successful community-based approaches to restore, preserve, and protect the nation's watersheds. This new competitive grant program is a bold approach to watershed management in that it will provide needed resources to those watershed organizations whose restoration plans are ripe, and who are anxious to achieve quick, yet tangible environmental change. EPA conducted a national competition to select up to 20 of the nation's most deserving watersheds to receive this funding through Watershed Initiative grants. In August 2002, EPA invited Governors and Tribal Leaders to nominate their most meritorious watersheds. In response, EPA received 176 nominations including projects in every state, Puerto Rico and the Virgin Islands. Regional and National experts reviewed and evaluated the nominations from this highly competitive field. The watersheds were chosen based upon the watershed organization's demonstrated ability to achieve on-the-ground environmental results in a short time frame. Each proposal also had to exhibit strong partnerships with support, show innovation in their watershed plans, and demonstrate compatibility with existing governmental programs.

Problems Encountered and Solutions

Three members of the initial project team (technical staff, part- and full-time, temporary) identified in the proposal left soon after GLPF funding was obtained. Brown requested an adjusted project start date of February 1, 2000. Brown later requested a no-cost extension from February 2003 to November 2003 – the GLPF approved this extension.

The interdisciplinary focus of this project and the large number of interrelated components led to a lot of extra work, just to coordinate project activities. However, we successfully addressed these challenges due to the commitment of the project team members. We often forget that large project with many disciplines mandates greater management to be fully successful.

After the first year of the project, the project team at times began to be inundated with requests for help on similar efforts in a number of watersheds across Ohio, Michigan, and Illinois. We have made every effort to accommodate all requests, but this has had its impact on project progress. We finally had to put limits on how much time we could commit to other projects, unless funding was provided to support technical staff and graduate students. The demand for help continues to increase, and we now at a point where we are not able to help stakeholders as much as is necessary for a broader implementation of this concept. This lack of sufficient technical support for such efforts will have to be addressed now, and technical training of existing NRCS/SWCD staff is only one of the answers.