b. Project Narrative: Demonstrating Nitrogen Treatment Effectiveness through Innovative Bench Wetland Systems

Project background:

Surface drainage ditches and subsurface drainage tiles are important components of agricultural production in low-gradient regions of the Upper Midwest. Nutrient uptake in traditional ditches is very low, while sediment and turbidity levels are high. Recent evidence has shown that the two-stage ditch has great potential to improve nutrient processing compared to conventional ditches, by creating an in-ditch bench that facilitates denitrification and nutrient uptake while enhancing the stability of the channel and reducing sediment movement. This relatively new practice has been incorporated conservation practice standards, but not yet nationally.

Limited studies have begun to quantify the hydraulic and geomorphic impacts of this new ditch management strategy, but data quantifying the nitrogen reduction mechanisms and the cost-effectiveness of nitrogen treatment are very scarce. We will quantify the water quality benefits, as well as other ecosystem services, of two-stage ditches, and specifically the potential to increase nitrogen reduction efficiency by managing the benches as constructed wetland features.

As implemented, the practice includes a rock pad for erosion protection at tile drain outfalls. We believe the nutrient benefits could be enhanced by managing these bench areas as **constructed wetland** features, and have termed them "bench wetlands" (Figure 1). Vegetation establishment is a challenge in this wet environment, resulting in dominance by invasive species such as reed canary grass. Currently, a standard grassland mix for erosion control and nitrate uptake is used on vegetated benches, and we will compare its establishment and uptake to vegetation used in constructed wetlands.

A **bioreactor** consisting of an excavated trench filled with an organic matter source such as wood chips and water table control structures to enhance denitrification will be installed at the outlet of the largest subsurface drainage system. The remaining subsurface outlets will be enhanced to improve the wetland hydrology of the benches on one side of the ditch. Rather than a traditional rock pad to prevent erosion at tile outlets discharging perpendicular to the channel, the tile outlets will be redirected parallel to the channel, with positive grading to enhance flow dispersal to encourage the infiltration and denitrification potential.

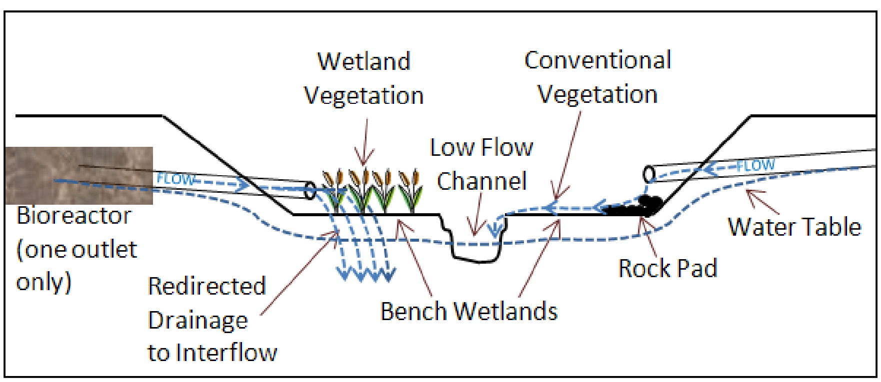


Figure 1: **A bench wetland system** refers to our innovative conservation practice including a two-stage ditch with bioreactor and constructed wetland features.

We have a unique opportunity to measure the overall effectiveness of this innovative system of practices at a reduced cost. The Land Improvement Contractors Association has committed to working with University to install a bench wetland system on a research farm in the summer of 2011. Earth-moving equipment as well as labor will be donated by the contractors as part of an educational field day, further enhancing the transferability of this technology. No CIG program funding is requested for construction, but funding will instead be used for monitoring to determine nitrogen reduction efficiency and other ecosystem services; analysis of the potential for NRCS and others to use the results; and information transfer. The opportunity for the public to participate in the Field Day just prior to the start of the grant will increase interest in the outcomes of the CIG project, and since we will have managed all aspects of the construction, we will know the cost and be able to determine the cost per pound of reduction.

Project objectives:

The overall goal of this project is to demonstrate treatment effectiveness and efficiency for nitrogen contaminants in watershed runoff with an innovative bench wetland system, including a two-stage ditch with wetland features together with a bioreactor. A secondary goal is to quantify the other ecosystem services provided by the practice as noted below.

Specific objectives include:

1) *Determine the cost, total reduction and cost per pound of nitrogen reduction through the entire bench wetland system.*
2) *Quantify additional ecosystem services provided within the bench wetland system, including*
    a. *Bench wetland vegetation establishment and monitoring*
    b. *Wetland hydrology and nitrogen reduction potential of managed bench wetlands*
    c. *Geomorphic stability and aquatic habitat creation*
    d. *Fish habitat utilization, including a new technique for monitoring.*
3) *Facilitate the transfer of this system to other locations by simulating the nutrient reduction of each component of the two-stage ditch system through physically-based models and effective information and outreach.*

We consider this project to be innovative for several reasons. We are:

1) demonstrating the potential to improve performance of an accepted conservation practice (Open Channel Standard 582) by managing the ditch benches as constructed wetland features,

2) leveraging existing monitoring at the practice location to monitor changes in fish species richness and habitat utilization following practice implementation and

3) quantifying total nitrogen reduction through a linked system of practices, including a two-stage ditch, bioreactor and constructed wetland features.

The proposed project directly addresses three of the four Mississippi River Basin Healthy Watersheds Initiative (MRBI) objectives by reducing nutrient loading and enhancing wildlife and other ecosystem services, while maintaining agricultural productivity, one of the 12 states of consideration. The **primary program area** addressed is **Water Management**, through demonstration of treatment effectiveness and efficiency of nitrogen contaminants in runoff or drainage water using innovative practices. In addition, by leveraging other on-going efforts, the proposed project will address many other topics within the MRBI initiative, including:

- *Wildlife Habitat Improvement* - Demonstration of new technique for monitoring fish habitat
- *Vegetative Practices* – Demonstration of the efficacy of reconnecting subsurface drainage to interflow for enhanced denitrification of shallow groundwater; Demonstration of how placement of appropriate perennial vegetation can bolster nutrient management;
- *Adaptive Management* - Developing models to evaluate the effects of MRBI initiated systems of practices at watershed scales.
- *Program Outreach* - Creating a MRBI demonstration and program outreach site.

Project methods:

Our overall strategy is to employ multiple monitoring and modeling techniques to quantify the treatment effectiveness of an innovative bench wetland system and to demonstrate the related ecosystem services. Our analysis methodology will consist of continuous upstream/downstream monitoring in a newly constructed two stage ditch reach (Marshall Ditch, in Tippecanoe County, IN). Periodic sampling of other nutrient sources and sinks will be used to better understand the mechanism of nutrient reduction through the system. The overall technical approach will contain the following elements: 1) water quality monitoring, 2) cost and reduction efficiency estimation, 3) vegetation establishment and monitoring, 4), monitoring of wetland hydrology, 5) fish monitoring, 6) geomorphologic stability and habitat monitoring, 7) hydraulic and water quality modeling and 8) information transfer. These are described in more detail below.

Task 1, Water Quality Monitoring: The experimental design will consist of collecting flow and water quality data upstream and downstream from the new bench wetland system (two stage ditch, bioreactor and bench wetlands). We will deploy two data sondes, one upstream and one downstream of the bench wetland system, to continuously measure water quality parameters at 15 minute interval including temperature, conductivity, salinity, turbidity, and dissolved oxygen. Streamflow will be measured continuously using a pressure transducer and established stage-discharge relationship (upstream) and velocity-area meter (downstream). We will measure flow-proportional sediment, nutrient (nitrate and total nitrogen, dissolved and total phosphorus) concentrations two times every week for two years, when water is present and air temperatures are warm enough for active biologic processing of the nutrient inputs. All samples will be collected immediately upstream and downstream of the two-stage ditch and will be analyzed using standard method of analysis. In addition, the approximately six lateral subsurface drainage tiles that enter the bench wetland system will be sampled monthly during the same period, with the monthly sampling dates targeted to follow fertilizer application and a variety of high flow/low flow conditions. Seasonal and annual nitrate load reductions will be calculated, as well as total nitrate load reduction over the life of the project.

The proposed monitoring program benefits greatly from a previous EPA-funded project in this location, which resulted in established streamflow monitoring stations, ISCO water samplers and supporting infrastructure, including batteries, dataloggers and solar panels.

Task 2, Estimation of Cost and Nitrogen Reduction Efficiency: Because the project will be built with donated labor, machinery, and materials, cost will be based an engineer's estimate of takeoff quantities (pre-construction) and the tracking of actual quantities during construction. Cost basis for construction include excavation (per cubic yard); seeding and seed (per acre), bioreactor installation (per cubic yard excavation plus materials), tile outlet relocation (based on pipe size), bank stabilization matting (per linear foot), and safety fencing (per linear foot) and will be based on Land Improvement Contractor 2011 prices. The nitrate load reduction efficiency and price per pound of nitrogen reduction will be calculated relative to total costs (installation plus maintenance) and maintenance costs calculated over an appropriate project lifetime (20 years) using the net present value of money to determine cost reduction efficiency.

Task 3, Establishment and Monitoring of Wetland Vegetation: We will compare the establishment, competitiveness, resilience and nutrient uptake of the standard grassland mix traditionally used in vegetated ditches to a wetland vegetation mix on the benches. Plant choice can influence many aspects of the nitrogen transformation process, through both plant uptake and assimilation and by enhancing conditions for denitrification in the soil, through infiltration, soil temperature regulation, anaerobic root zones and organic carbon supply (NEH-651, 1999). We will use a paired design where the right bank and bench will be seeded with a standard grassland mix, while the left bank and bench will be seeded with a native wetland vegetation mix. Appropriate erosion suppression methodologies will be used during the establishment phase of both vegetation types. Wetland plants will be selected based on their tolerance of saturated soil, soil and light preference, nitrogen uptake potential and ability to generate from seed. Vegetation establishment (stand density and diversity) and invasive pressure will be monitored monthly by visual survey to determine if moisture tolerant plants will establish more readily and demonstrate greater ability to withstand invasives. Surveys will be within 1 m^2 sample boundaries, with three replicates for each vegetation type. Vegetation biomass will be sampled from the same locations bi-monthly from April-November and analyzed for Total Nitrogen content to estimate the nitrogen uptake potential of alternative vegetation systems.

Task 4, Monitoring Wetland Hydrology: The wetland hydrology of the benches will be monitored using one piezometer in each bench (left and right) fitted with automatic water level recorders for continuous measurements. These will be used to calculate the annual and seasonal hydroperiod of the bench wetlands. The ability of the bench wetlands to support microbial processes such as nitrogen transformation will be assessed using IRIS (Indicator of Reduction in Soils) tubes. IRIS tubes are 1/2" PVC pipes coated with an iron oxide paint. In the presence of reducing conditions, the iron oxide paint will dissolve, exposing the underlying white tube (Jenkinson and Franzmeier 2006). IRIS tubes provide a low cost, alternative method of assessing the denitrification potential of hydric soils. Three tubes will be installed for overlapping time periods in the left and right benches to compare the seasonal variability of reducing conditions in each bench.

Task 5, Geomorphologic Stability and Habitat Monitoring: Topographic surveys of the ditch plan, profile, and cross-sectional dimensions will be carried out both pre-construction and annually post-construction to monitor changes in ditch geomorphology. Profile monitoring will be used to measure channel aggradation/degradation and sediment transport. Cross-sectional monitoring will assess bank and channel stability and erosion. Wolman pebble counts (Wolman, 1954) will be performed at permanent cross section locations pre- and post-project to monitor the transport and size of sediment in the reach. Performance criteria for stream restoration also include the degree to which the system is more self-sustaining and resilient to external perturbations (Powell et al., 2007). We will measure instream habitat characteristics (e.g., depth, substrate composition, channel wetted width, etc.) during each sampling event to quantify fish habitat availability and change. This data will also be used to extend our knowledge of habitat change due to the change in flow hydraulics in conjunction with the modeling, Task 7.

Task 6, Fish Monitoring: We have been monitoring fish in this ditch since 2008, and baseline monitoring will be relative to both past fish community richness and a nearby traditional trapezoidal ditch which will be used as a control for fish community sampling. Fish communities will be sampled on a bimonthly basis from April through November at both the treatment and control ditches to determine patterns of species richness and seasonality of habitat use. Stream fish are highly mobile, and fish movements can provide insights into the habitat viability of a site. In addition to baseline sampling, target fish monitoring will take place during three moderate to high flows per year (ditch stage above the bench, but still accessible on foot). Fish communities will be sampled using a backpack electroshocker ((ETS, Madison, WI) and the exact locations of sampled fish will be demarcated using survey flags deployed during the sampling. Habitat characteristics, including substrate, water depth, and water velocity will be recorded at each survey flag to determine the preferred habitats of fish by species. We will use the locational information and habitat descriptors to determine if fish species and communities are preferentially using the benched areas as refuges during high flow events.

Task 7, Hydraulic and Water Quality Modeling: The monitoring results will be used to parameterize the representation of this ditch reach in the Hydrologic Engineering Center River Analysis System (HEC-RAS) model (CPD-69, 2010), which will enable us to understand the results in a broader context and predict the transferability of results. HEC-RAS will be used to simulate hydraulic changes within the two stage ditch reach. The one-dimensional chemical transport algorithm in HEC-RAS version 4.1 will be used to simulate the water quality impact of different portions of the treatment system, including the channel, bioreactor, modified and unmodified benches. The simulation will aid in transferring the lessons learned to other locations. In particular, the quantification of channel velocity and stage modifications within the two stage ditch will be used in conjunction with the habitat utilization monitoring (Task 6). The monitoring and HEC-RAS modeling results will be used to parameterize the representation of these practices in the Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998), enabling us in the future to compare the effectiveness of various locations in the landscape for this practice, and determine cumulative benefits that could result from its use in combination with other conservation practices at locations throughout the watershed. The SWAT model has already been developed and calibrated for this watershed (McCahon, 2010). We will modify the SWAT model to include bench wetland systems as one of the conservation practices and will use the modified model to quantify watershed scale benefits of this innovative conservation practice.

Task 8, Information Transfer: Results will be shared through field days, workshops, scientific publications and presentations, fact sheets, a web site, and reports. Because of the highly-accessible location adjacent to University, we expect that field days and educational workshops at this location will be a particularly effective means of sharing information. In fact, the project will serve as a demonstration and program outreach site for a number of MRBI practices. We expect broad and sustained interest in this project because of widespread involvement in the construction in an earlier field day. We will document the construction through photos, videos, and a web site that will promote sustained interest among the drainage industry and the public. We will develop at least two fact sheets on the results of this project, covering (1) the nitrogen reduction and costs, and (2) the additional ecosystem services of the bench wetland system. Our Extension experience and support from communications specialists will ensure that these address the needs of clientele who will use them. We will also present the results in scientific papers where other scientists can learn from the results. We will participate in at least one NRCS CIG Showcase, and in addition will present the results at state and national conferences

Location and size of project or project area:

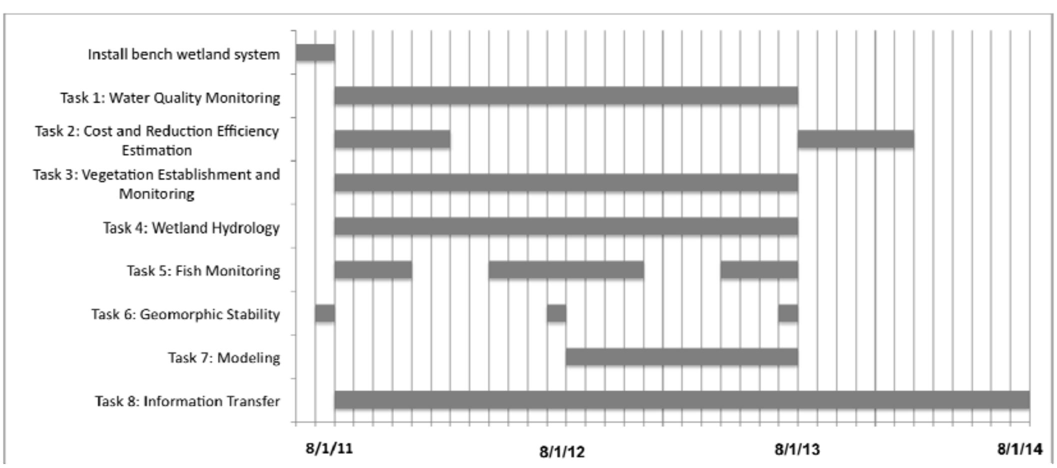
The project location is in the Little Pine Watershed (12-digit HUC 051201080202), a tributary of the Wabash River (Figure 1). This watershed is being monitored by the USGS and is a key subwatershed in a watershed project funding by a USEPA/Department of Environmental Management 319 grant (http://wabashriver.net). This means that the conservation practices installed at the site, and the ecosystem services they provide, will be viewed in the context of a larger watershed landscape. The conservation practice location is at the headwaters of Marshall Ditch, typical of many low-gradient highly-agricultural drainage ditches in the Midwest. Located on the University Animal Sciences Research and Education Center, this ditch section has been monitored for many years by various research projects, providing a rich record of pre-construction data (http://tinyurl.com/DitchMonitoring).

Figure 2: Project Location

Producer participation:

Producers visit the University farm where the bench wetland system will be located regularly to attend field days highlighting new research. We will conduct outreach on the bench wetland system at these field days, emphasizing the treatment of field drainage through bioreactors. The decision-makers for these systems are primarily contractors and the ditch authorities, rather than producers, however. These groups are participating in project planning. Conservation agencies at the state and local levels who work directly with producers will be additional target audiences for workshops, field days, and educational materials.

Project Action plan and timeline



Project management:

The project team has worked together extensively, and will hold regular project meetings to ensure good communication and progress.

Table 1: Project personnel and their roles

Key project personnel	Roles and Responsibilities
Dr. will serve as the Project Director. She is an Associate Professor of watershed hydrology in the Department of Agronomy . She has experience with the monitoring, model development and simulation of wetland water quality, biogeochemistry and hydrology in diverse wetland systems in the Midwest, Alaska and Siberia.	As Project Director, will be responsible for overall progress, reports, and all communications with NRCS. In addition, she will have primary responsibility for monitoring of wetland hydrology and vegetation (Tasks 3 and 4) and participate in all other tasks.
Dr. is an agricultural engineer and extension specialist working in agricultural conservation . She leads the Cooperative Extension Service program in soil and water engineering, and is author or co-author of 38 extension publications dealing with watershed management and assessment, drainage management for water quality, and drinking water quality.	Dr. will lead the estimate of costs (Task 2) and geomorphology and habitat monitoring (Task 5). She will lead Task 8, information transfer, with participation from the entire team in ensuring that project results are documented and made available to NRCS, producers, and the public
Dr. is associate professor of ecohydrology in the Departments of Agricultural and Biological Engineering and Earth and Atmospheric Sciences , and is a nationally recognized expert on evaluation of conservation practices using watershed and field scale models and water quality monitoring and tools.	Dr. will lead the water quality data collection and modeling described in Tasks 1 and 7.
Dr. is an assistant professor of aquatic community ecology in the Department of Forestry and Natural Resources . Dr. is an expert in fish ecology, focusing on responses of stream biological communities to varied human land uses.	Dr. will lead the fish sampling in Task 6.

Other participants

The Land Improvement Contractors Association is working with us to plan and construct the bench wetland system. Equipment dealers will also participate in the construction phase. **The Nature Conservancy** will provide seeding, fuel costs of construction, planning assistance, and will share results from other projects to determine lessons learned.
ASREC staff will ensure that we have access to the field site and perform basic maintenance.

Project deliverables/products

This project adapts a proven technology in an innovative conservation approach to improve performance and encourage adoption. The following products are anticipated from the objectives in this project:

Objective 1:

- Benchmark data related to water quality, management, and efficiency of a combined bench wetland/ two-stage ditch and bioreactor system implemented in a drained agricultural watershed.
- Treatment effectiveness and efficiency (cost per pound of reduction) of nitrogen contaminants in the drainage water.

Objective 2:

- Assessment of ancillary ecosystem services provided by the innovation conservation system.
- Suggested improvements to the two-stage ditch conservation practice standard for enhancing wetland function.

Objective 3:

- Estimation of the individual and combined impact of each practice in the conservation system through a parameterized and validated HEC-RAS.
- Recommendations for conservation system design that will improve both water quality and ecosystem services in drained agricultural watersheds

In addition, the following deliverables will be submitted, as required:

- Semi-annual reports and final report
- Supplemental narratives to explain and support payment requests
- Performance items: *See Table 2, page 10 for a complete list.*
- Fact sheets: Two-stage Ditches with bioreactors; Benched wetlands
- Participation in at least one NRCS CIG Showcase or comparable NRCS event

Benefits or results expected and transferability:

The deliverables described above will be transferred to and benefit numerous entities. The benchmark data and treatment effectiveness estimation will be useful to NRCS and other conservation agencies in determining the benefits of this practice and making decisions about adopting it more widely. These values could be used in future nutrient trading, and would thereby benefit municipalities who seek quantified benefits. EPA's Hypoxia Task Force can use the results in assessing practices that can be used to reduce hypoxia in the Gulf of Mexico.

The assessment of ancillary ecosystem services will provide more insight into the practice, and could be used by the USDA Office of Environmental Markets as it develops ways to quantify ecosystem services for use in developing markets. The geomorphic stability analysis will be particularly useful to ditch managers who are responsible for periodic dredging of drainage ditches. Groups such as The Nature Conservancy will use it in targeting practices, while anglers and groups supporting fish habitat will use information on habitat utilization to potentially promote it as a new practice.

Our demonstration of modeling two-stage ditches with the industry standard HEC-RAS model will benefit other groups that regularly use the model in conservation planning. Modeling will be useful in showing how two-stage ditches can be used in TMDL implementation, particularly where sediment and/or nitrogen are targeted pollutants. The modeling results will be beneficial to understand the relationship between benefits in this watershed and elsewhere, and understand how widely they can be transferred. They will provide an estimate of effectiveness over a longer time period than our monitoring, and can be used in a watershed-scale assessment to estimate the effects of multiple bench wetland systems.

Project evaluation:

Evaluation will be a key part of the project. Measures of success that will be used in the evaluation are described below.

1. Successful completion of all tasks following the timeline on page 6, including delivery of all products on pages 7-8.
2. Demonstration of overall technical feasibility of the bench wetland system through quantifying nitrogen efficiency and costs.
3. Final report quantifying results from all tasks.

Table 2: Summary of how the project meets the merit criteria.

Merit Criteria	How the proposed project meets the criteria
Purpose, Approach, and Goals	
Design and implementation of project based on sound methodology and demonstrated technology.	The two-stage ditch design method developed at University will be followed, and NRCS engineers will collaborate in finalizing the design. The wetland features will be designed based on known techniques
Promotes environmental enhancement in conjunction with agricultural production.	Bench wetland systems will provide the same drainage as conventional ditches, so agricultural production will not be affected adversely. Environmental enhancement includes nutrient reduction, habitat improvement, and increased stability.
Project outcome is clearly measurable.	See page 7 for deliverables and benefits, and page 8 for measures of success.
Potential for successful completion.	Potential is high, based on the expertise of the project team in monitoring, modeling, and outreach, and the collaboration of key partners.
Both beneficial & adverse impacts considered; acceptably significant improvement	Potential minor adverse impacts will be minimized as shown on page 11. Improvement will likely be modest, but if replicated throughout the Midwest has the potential to result in significant nutrient reduction.
Innovative Technology or Approach	
Project is innovative (national, regionally, and local in nature).	Management of the ditch benches as constructed wetland features will improve the performance of an accepted conservation practice (two-stage ditch)

Project conforms to description of innovative projects	The project adapts a proven technology to improve performance, and will demonstrate effectiveness and transferability.
Project Management	
Timeline & milestones clear, reasonable.	See timeline on page 6.
Project staff has technical expertise needed.	The project team is well qualified, as detailed in the brief summaries of qualification on pages 6-7.
Budget adequately explained and justified.	The modest budget leverages contributions of others, and is explained in detail on pages 10-11.
Experience and capacity to partner with and gain support of other organizations.	The project team has successfully collaborated in numerous projects with partners listed on page 7.
Transferability	
Potential for producers and landowners to use the innovative technology;	Economic advantages to the two-stage ditch include reduction in ditch cleaning due to improved bank stability
Potential to transfer the approach to a broader audience;	The project will provide an excellent demonstration site for this and other MRBI practices.
Potential for NRCS to successfully use the innovative approach.	We have discussed this project with NRCS, and have worked with NRCS staff on other projects such as drainage water management.
Will result in the development of technology transfer materials	Objective 3 (Task 8) focuses on technology transfer, described on page 5. Our Extension experience and numerous previous publications provide evidence that information will be provided effectively to people who can use it.

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c. Assessment of Environmental and Social Impacts

We are modifying an accepted practice, and our improvements will not change the approved standard. Monitoring follows accepted procedures, and is not likely to have any impact.

	Adverse Impacts	Plans for Minimizing Adverse Impacts	Beneficial Impacts
Soil	Soil in adjacent field could be degraded by spoil from bench construction/excavation.	The poor-quality existing soil may be improved by the channel sediments, which will be feathered into field.	Erosion and sediment loss from ditch banks will be reduced due to the innovative channel design.
Water	During construction, the two-stage ditch system may have a slight negative impact on water quality due to sediment movement.	We will take measures to minimize water quality impacts during construction by staying out of the channel and timing the construction when flow conditions are optimal (late summer).	Nitrogen concentration will decrease due to denitrification and plant nutrient uptake. Sediment concentration will be reduced due to increased bank and channel stability and more natural channel design.
Air	No impact expected		No impact expected
Plants	Existing ditch vegetation will be disrupted. Approximately 1 acre of land taken out of crop production.	The cropland will be replaced by benches with wetland vegetation, improving the current invasive reed canary grass.	New wetland vegetation will provide denitrification, nutrient uptake, aquatic habitat, and bank stability.
Animals	Some small mammals may be displaced by bench construction.	No threatened or endangered species have been identified.	Fish populations will benefit from the improvements in habitat
Social	No impact expected		No impact expected