

**South Dakota Water Research Institute
Annual Technical Report
FY 2012**

Introduction

South Dakota Water Resources Institute's (SDWRI) programs are administered through the College of Agricultural and Biological Sciences at South Dakota State University (SDSU). Dr. Van Kelley has been the Director for the Institute since August 1, 2000. Dr. Kelley is also the head of the Agricultural and Biological Engineering Department. In addition to the Director, the Institute's programs are administered and executed by a staff consisting of an Assistant Director, a Program Manager, a Program Assistant, an Assistant Professor and a Research Associate. During FY 2012 the SDWRI supported, through its base funding or through externally funded projects, three graduate research assistants and four undergraduate research assistants.

The annual base grant from the United States Geological Survey (USGS) and a South Dakota legislative appropriation form the core of the SDWRI budget. The core budget is supplemented by research grants from a state and federal agencies as well as private organizations and industry interested in specific water-related issues.

The mission of the South Dakota Water Resources Institute is to address the current and future water resource needs of the people, industry and the environment through research, education, and service. To accomplish this mission, SDWRI provides leadership by coordinating research and training at South Dakota State University and other public educational institutions and agencies across the state in the broad area of water resources. Graduate research training, technology transfer, and information transfer are services which are provided through the Institute.

This report is a summary of activities conducted by the SDWRI during the period March 1 2012 through February 28 2013.

Research Program Introduction

Water is one of the most important resources in South Dakota. Together with the state's largest industry, agriculture, it will play an important role in the economic future of the state. Enhancement of the agricultural industry and allied industries, the industrial base and, therefore, the economy of South Dakota all depend on compatible development of our water resources.

During 2012-2013, the South Dakota Water Resources Institute (SD WRI) used its 104B Grant Program funds to conduct research of local, state, regional, and national importance addressing a variety of water problems in the state and the upper Midwest region.

The WRI 104B External Review Panel reviewed 17 grant applications and recommended 5 projects for funding that addressed research priorities that had a good chance of success, and would increase our scientific knowledge. The projects were titled - Identifying barriers for adopting new drainage technology among agricultural producers. PI's N. Benesh, J. Kjaersgaard and C. Hay, South Dakota State University. - Subsurface Drainage Impacts on Evapotranspiration and Water. PI's C. Hay, J. Kjaersgaard, T. Trooien and G. Sands, South Dakota State University. - Evaluating the Nitrate-Removal Effectiveness of Denitrifying Bioreactors. PI's J. Kjaersgaard, C. Hay, T. Trooien, South Dakota State University. - Evaluation of the performance of two vegetated treatment systems. PI T. Trooien, South Dakota State University. - Evaluation of wastewater produced in biomass pyrolysis process. PI's L. Wei, T. Trooien, South Dakota State University.

In addition, the following project selected for funding during FY2011 was granted an 18 month no-cost extension: - Life Cycle Assessment Analysis of Engineered Stormwater Control Methods Common to South Dakota. PI's Molly Gribb, James Stone and Jennifer Benning. South Dakota School of Mines and Technology.

Progress and completion reports for the five projects selected for funding during FY 2012 and the one project from FY 2011 operating under a no-cost extension are enclosed.

Life Cycle Assessment Analysis of Engineered Stormwater Control Methods Common to South Dakota

Basic Information

Title:	Life Cycle Assessment Analysis of Engineered Stormwater Control Methods Common to South Dakota
Project Number:	2011SD195B
Start Date:	3/1/2011
End Date:	1/31/2014
Funding Source:	104B
Congressional District:	SD First District
Research Category:	Water Quality
Focus Category:	Surface Water, Models, Non Point Pollution
Descriptors:	None
Principal Investigators:	Molly Gribb, Jennifer L Benning, James Stone

Publications

There are no publications.

South Dakota USGS 104B 2013 Annual Report

Title: Life cycle assessment analysis of engineered stormwater control methods common to South Dakota

Investigators: Dr. James Stone, South Dakota School of Mines & Technology
Tyler Hengen, South Dakota School of Mines & Technology
Maria Squillace, South Dakota School of Mines & Technology
Dr. Molly Gribb, South Dakota School of Mines & Technology
Dr. Jennifer Benning, South Dakota School of Mines & Technology

Introduction:

The following report addresses the progress to date and findings of significance related to the project titled “Life cycle assessment analysis of engineered stormwater control methods common to urban South Dakota watersheds” during the funding period of December 2012 to May 2013. Funding from this project has support two life cycle assessment (LCA) research efforts, including

1. LCA of urban stormwater treatment; and
2. LCA of acid mine drainage (AMD) treatment

The objective of both studies were to comparatively assess the life cycle impacts of various treatment options that are common for South Dakota municipalities (stormwater) and mining operations (AMD). The LCA of urban stormwater treatment focus was presented in the previous annual funding report, therefore the focus of this annual report will be providing an update on our AMD LCA research.

AMD results from oxidation processes where sulfide minerals (eg. pyrite) become exposed to water and oxygen during coal or ore extraction, resulting in acidity that activates metal leaching from overburden material. AMD generation continues until either the pyrite is exhausted (typically millennia) or oxygen is prevented from reacting with the pyritic ore (near impossible in mines). Acidic mine water enriched with dissolved metals and sulfates is therefore treated through conventional lime-dosing (or lime-slaking) practices, or through more passive engineering means employing bioreactors relying on biogeochemical processes. Seven treatment scenarios were assessed including both active and passive approaches: (1) mussel shell bioreactor (2) bioreactor utilizing mined limestone in place of mussel shell substrate (3) mussel shell bioreactor using purchased energy rather than being gravity fed, (4) mussel shell bioreactor using modified transport distances, (5) lime-dosing treatment utilizing ultra-fine limestone (UFL), (6) lime slaking using hydrated lime, and (7) mussel shell “leaching beds”. Preliminary design flows and unit operations considered were based upon existing and proposed site treatment operations, with all design considerations based upon a 16.9 year design life.

Research Objectives:

AMD is currently the largest environmental challenge facing the mining industry. And while the acid mine drainage can certainly be mitigated through the use of many different treatment approaches, no

LCA to date has been documented for the actual treatment systems, despite the widespread implementation of these treatments throughout the world.

The general system boundary is shown in Fig. 1.

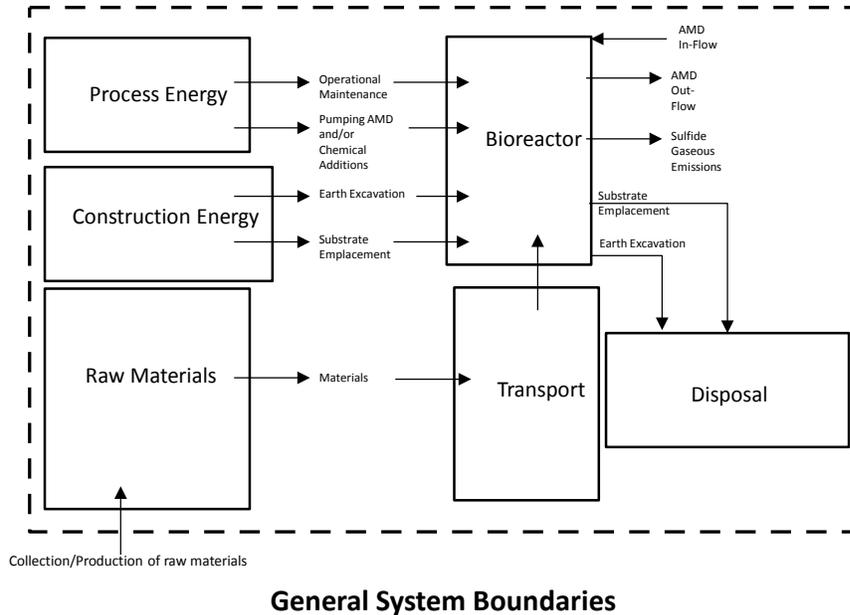


Figure 1: General system boundaries for AMD treatment methods

Included within the system boundaries were: raw materials including extraction and processing for mined materials, transportation for all materials, construction including earth excavation or substrate emplacement, and process energy such as pumping. Not included were man hours associated with operation and maintenance of the systems. For any materials that were assumed to be “waste” materials, no process energy was taken into account for the materials, therefore the system boundary for these materials began at the transportation of the materials to the AMD treatment site. These recycled materials are denoted with dashed arrows in Appendix A.

In the case of the mussel shells for the leaching bed, a separate process was modeled that included the mussel shell processing such as crushing of the mussel shells (assumed similar to gravel crushing). In addition, since mussel shells were considered a waste product, so as such, the system boundaries did not account for or allocate impacts associated with harvesting or the filleting of the mussel meat.

Methodology:

The life cycle assessments were conducted using SimaPro 7.3 LCA modelling software (PRé Consultants, Netherlands) and life cycle inventory database EcolInvent, produced by the Swiss center for life cycle inventories (Frischknecht, Althaus et al. 2007) following ISO 14040 protocols. Results were quantified using ReCiPe ‘hierarchist’ midpoint and endpoint methodologies.

Principal Findings:

The key midpoint impact categories evaluated in the AMD LCA were climate change (kg CO₂ eq), terrestrial acidification (kg SO₂ eq.), agricultural land occupation (m²a), urban land occupation (m²a), fossil depletion (kg oil eq.), water depletion (m³), and particulate matter formation (kg PM10 eq.). As was the case in the stormwater study, the endpoint impacts evaluated were: Damage to Human Health (DALY), Damage to Ecosystems (species.yr), and Damage to

Resources (\$). The figures in Appendix B show the values of each of the midpoint impact categories for each scenario, while figures in Appendix C demonstrate the endpoint impact categories for each scenario.

Climate Change

Generally, results indicate that climate change impacts increased with increasing energy requirements, and to a lesser degree, increased transport requirements. The two active systems (lime slaking and lime-dosing) emissions were higher than all passive treatment systems except for the bioreactor utilizing purchased energy which required 3800 kWh of pumped energy per kg acidity removed per day compared to lime slaking (911 kWh) and lime-dosing (83 kWh). Lime slaking still demonstrated 4.9 times higher climate change impacts than the bioreactor utilizing purchased energy (1160 kg CO₂ eq.) and 8.8 times higher climate change impacts than lime-dosing (652 kg CO₂ eq.) due to the high processing energy embodied within lime slaking.

Terrestrial Acidification

For terrestrial acidification, the passive treatment systems' terrestrial acidification impacts were generally lower compared to active systems. The SO₂ emissions that contribute to terrestrial acidification are primarily from transportation and industrial processing, so scenarios incorporating higher levels of materials processing, as was the case with the active treatment, as well as scenarios incorporating higher transport tended to show higher levels of SO₂ emissions. As an example of this, reducing the transportation distances by ½ in the case of the mussel shell bioreactor with modified transport scenario reduced the kg SO₂ eq. emissions by 33.5%, when compared to the original mussel shell bioreactor scenario.

Agricultural Land Occupation

The passive treatment systems showed lower values of agricultural land occupation compared to the active treatment scenarios

The bioreactor with modified transport showed the largest difference compared to both active treatment scenarios, with 56 times fewer m² per year of agricultural land occupation compared to lime-dosing, and 870 times fewer m² of agricultural land occupation than lime slaking. Between lime slaking and lime dosing, lime dosing showed 93% fewer m² per year of agricultural land occupation

Urban Land Occupation

Within the passive treatment, the bioreactor with mined limestone as the primary substrate had the highest contribution and the mussel shell leaching bed had the least urban land occupation contribution. The bioreactor utilizing purchased energy demonstrated a 17% increase in m² per year, occupation compared to the standard mussel shell bioreactor. Within the active AMD treatment methods the urban land occupation impacts were over 48 times larger for lime slaking compared to lime-dosing. The primary active treatment contributor, lime slaking, is 177 times greater than the largest passive treatment contributor, the bioreactor with mined limestone.

Fossil Depletion

Within the fossil depletion category the bioreactor with purchased energy was the largest contributor for the passive treatment scenarios. The values between the mussel shell leaching bed and the bioreactor with mined limestone were nearly identical, while there was a 40% decrease in fossil depletion impacts in the bioreactor with modified transport. The gap between lime-dosing and lime slaking was reduced in this category, with contributions from lime slaking being 3.6 times larger than lime-dosing. An interesting trend noted is that the bioreactor with purchased energy was 200% larger than the lime-dosing scenario, a trend that again reflects the large difference in the amount of necessary kWh per kg acidity removed per day between the bioreactor with purchased energy and the lime-dosing, as the main contributor for fossil depletion is the use of coal.

Water Depletion

Water depletion showed very similar trends to fossil depletion. The bioreactor with purchased energy was again the highest contributor for passive treatments' water depletion, while the bioreactor with mined limestone had the second highest passive treatment contribution. Lime slaking again had higher contributions compared to lime-dosing by 5 times.

Particulate Matter Formation

The bioreactor with purchased energy was the lead contributor to particulate matter formation within the passive treatment scenarios, while the bioreactor with modified transport had the lowest particulate matter formation values of any of the scenarios. Lime-dosing had 50% fewer impacts than lime-slaking, which produced 12 times the particulate matter of the bioreactor with modified transport.

Total Damage Assessment

The endpoint impacts for all of the categories showed very similar results. In the case of lime slaking, materials and the embodied energy within the processing of materials dominated the endpoint categories. Transport dominated the endpoint impacts in the rest of the scenarios, with the exception of the bioreactor with purchased energy, which was mainly influenced by the energy used for pumping in the system.

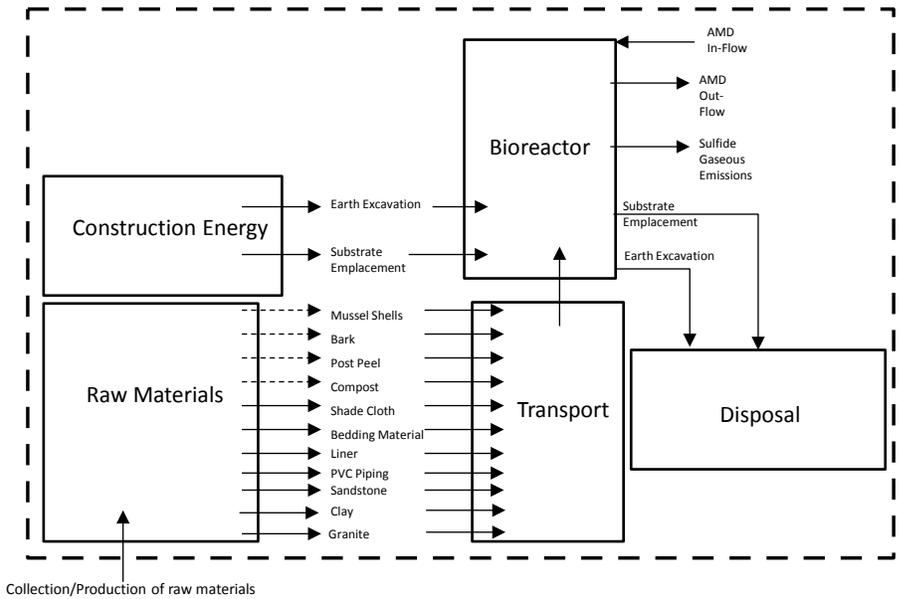
Summary

To date, we have looked at the life cycle assessment of stormwater management BMP's and coal mine acid drainage treatment. Little to no LCA evaluation and documentation has been undertaken in either field to this point. However, the results found have supported what we expected to find from the outset of these studies, with passive treatment and low-impact development treatment methods generally showing lower environmental impacts. Significantly, though, our study has been able to emphasize that not all of the low-impact and passive treatment systems demonstrate the same environmental benefit, and that the environmental impacts of treatment methods are highly variable and dependent on the entire cradle-to-grave process.

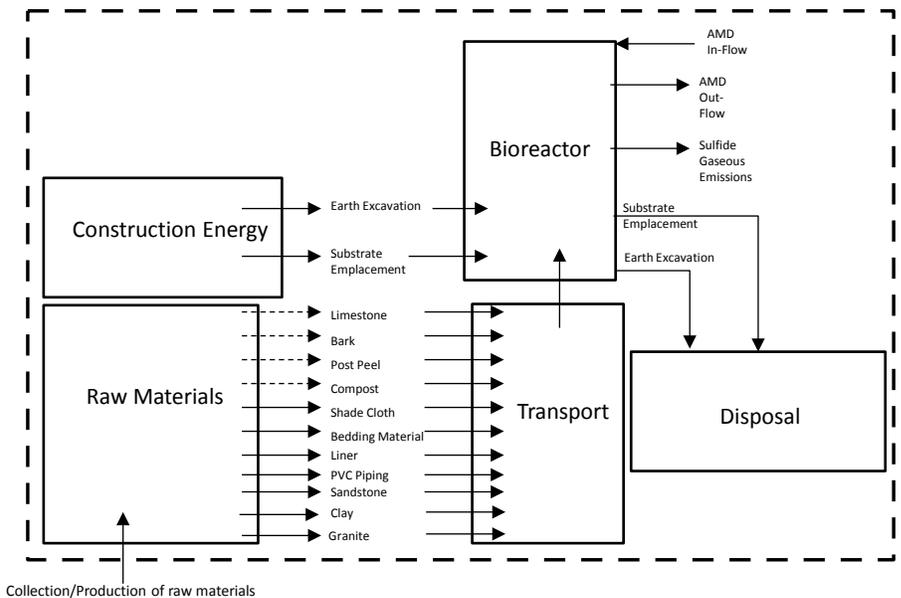
The next step of the process for these LCA studies is to look at the economic aspect of these treatment methods. When that is complete, a full analysis of the "triple bottom line", which incorporates the environmental, economic, and societal impacts of a scenario, will be able to be quantified, and the true sustainability of these treatment methods can be assessed.

Appendices

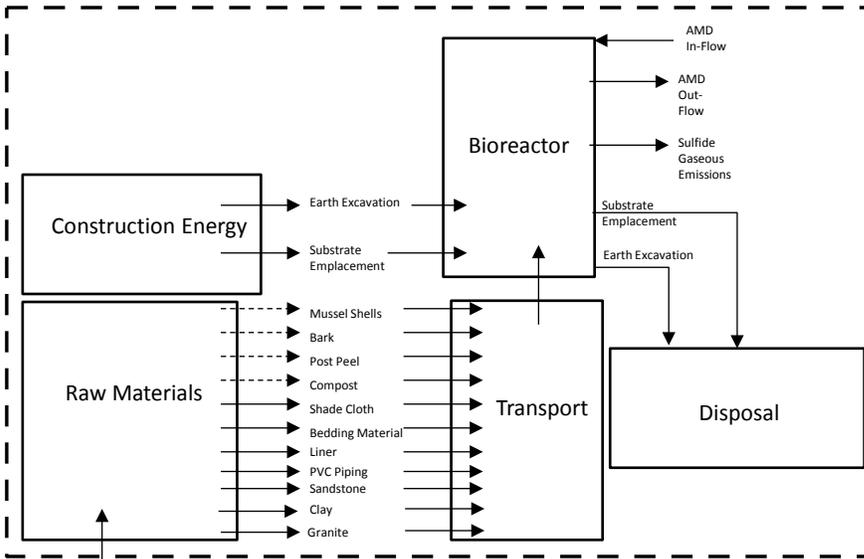
Appendix A: AMD System Boundaries



Scenario 1.a -- Bioreactor

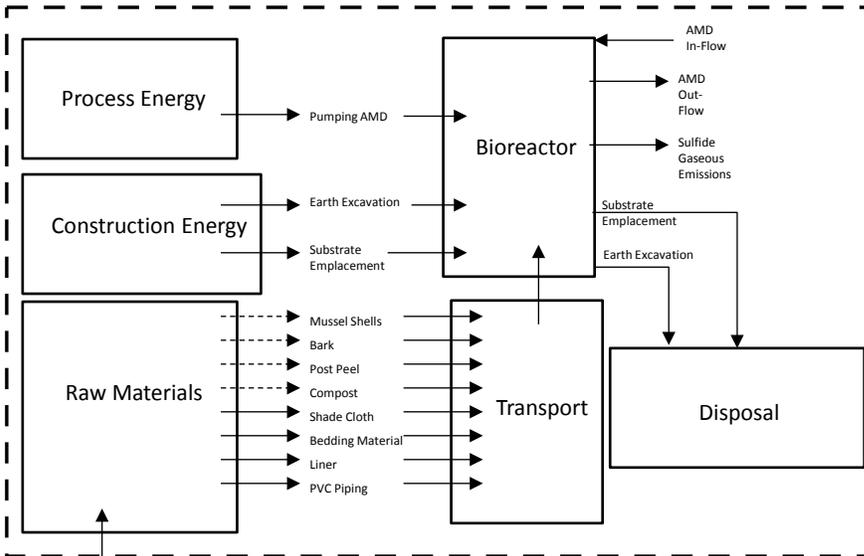


Scenario 1.b -- Bioreactor with Modified Substrate



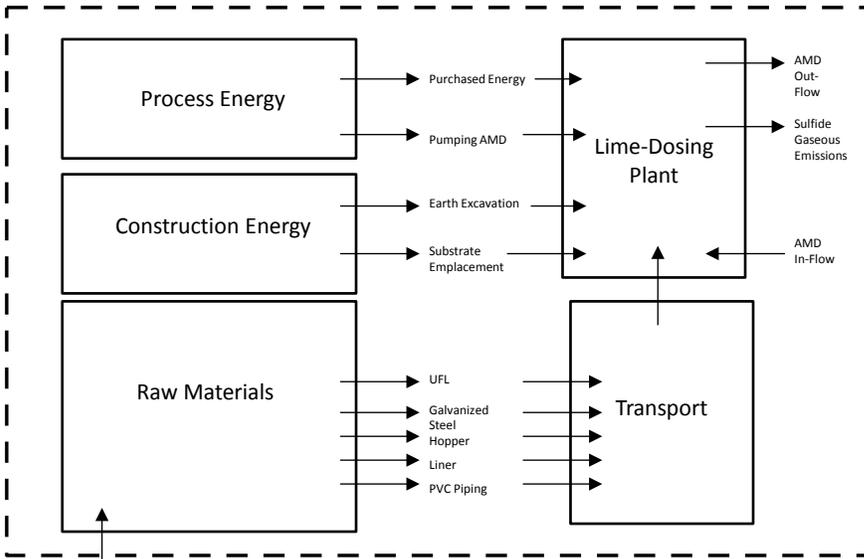
Collection/Production of raw materials

Scenario 1.c – Bioreactor with Modified Transport Distances



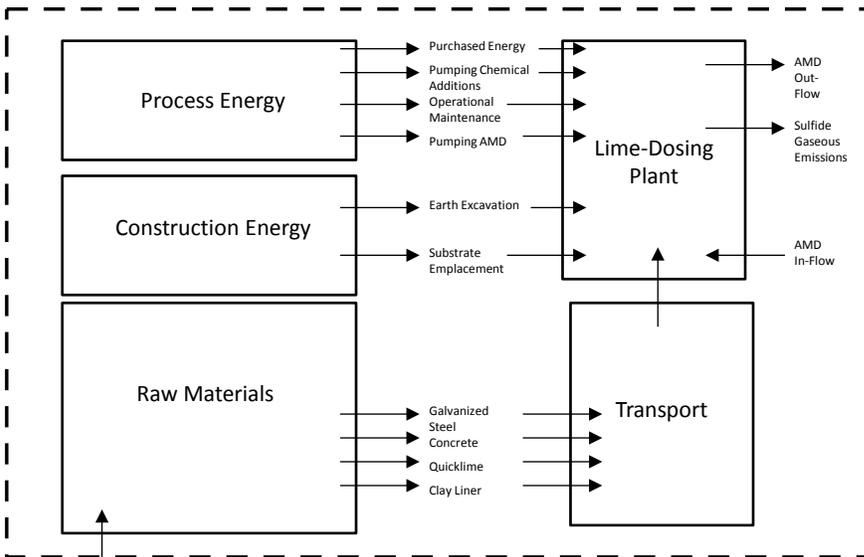
Collection/Production of raw materials

Scenario 1.d – Bioreactor with Purchased Energy



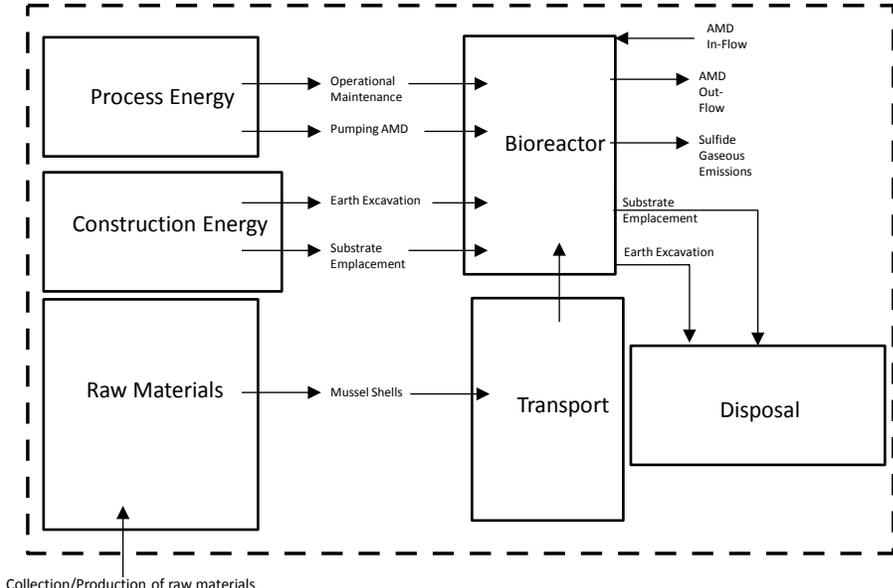
Collection/Production of raw materials

Scenario 2 – Lime-Dosing Plant



Collection/Production of raw materials

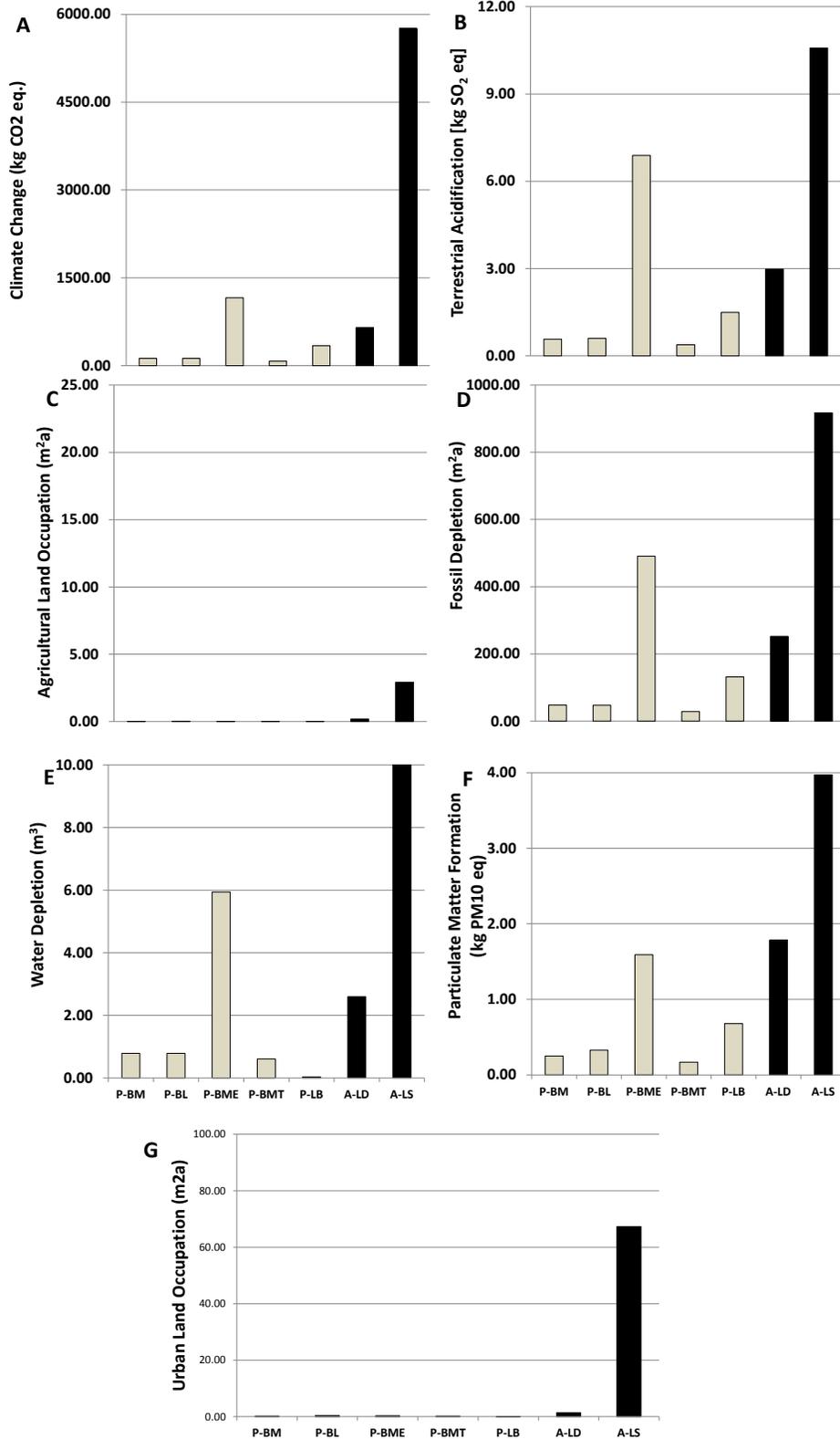
Scenario 2 – Lime Slaking



Collection/Production of raw materials

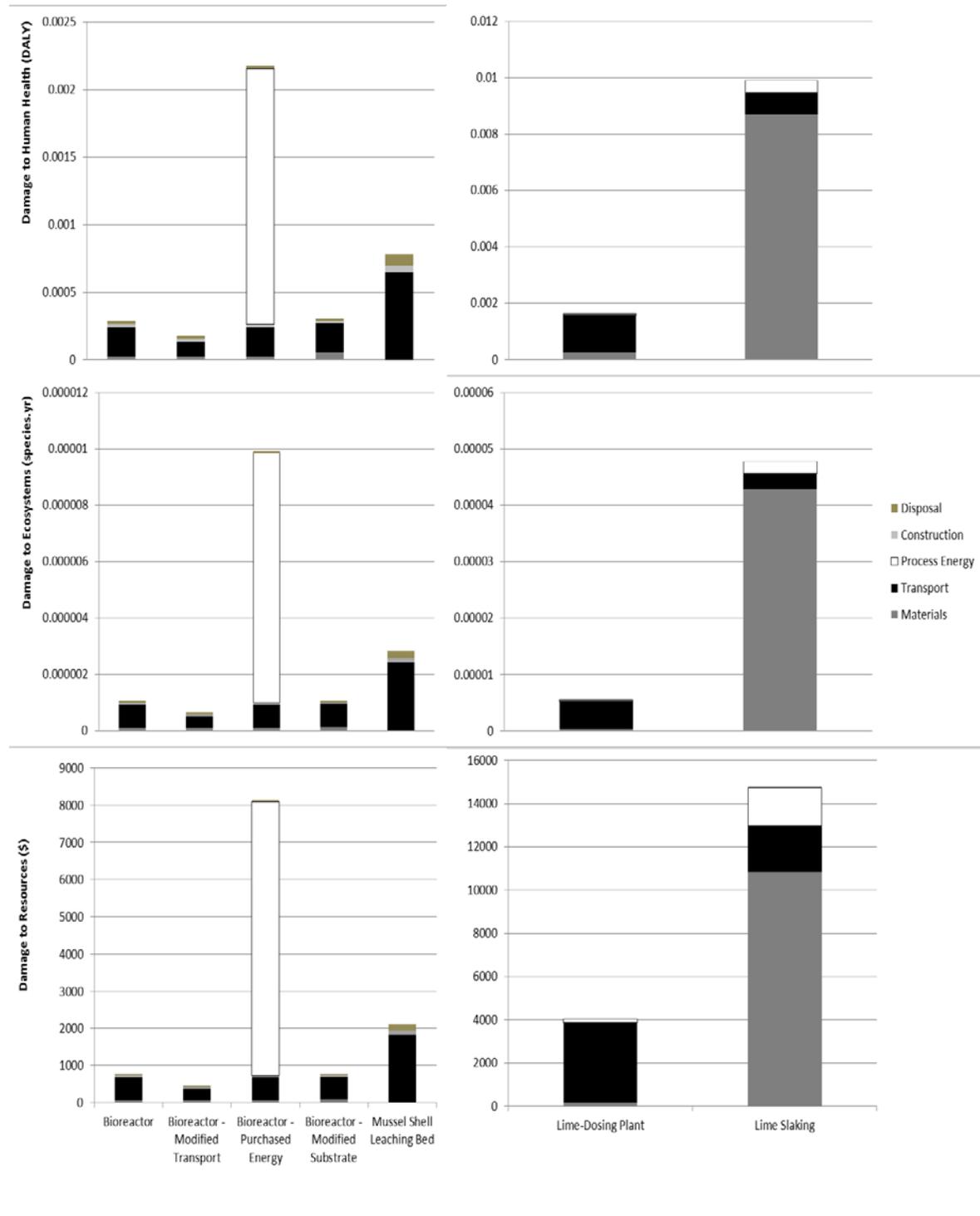
Scenario 3 – Mussel Shell Leaching Bed

Appendix B: AMD Midpoint Results



AMD scenarios (abscissa): Mussel shell bioreactor (P-BM), bioreactor with mined limestone (P-BL), bioreactor utilizing purchased energy (P-BME), bioreactor modified transport (P-BMT), mussel shell leaching bed (P-LB), lime-dosing (A-LD), lime slaking (A-LS)

Appendix C: AMD Endpoint Results



Works Cited

Conservation, N. D. o. E. (2010). "New York State Stormwater Management Design Manual." 78-191.

Frischknecht, R., et al. (2007). "The environmental relevance of capital goods in life cycle assessments of products and services." International Journal of Life Cycle Assessment 12: 7-17.

Goedkoop, M., et al. (2009). "ReCiPe 2008: A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level." report I: Characterisation.

Evaluation of the performance of two vegetated treatment systems

Basic Information

Title:	Evaluation of the performance of two vegetated treatment systems
Project Number:	2012SD210B
Start Date:	3/1/2012
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	First
Research Category:	Engineering
Focus Category:	Acid Deposition, Water Quality, None
Descriptors:	
Principal Investigators:	Todd P. Trooien

Publications

There are no publications.

Project Annual Report

Project Title: Evaluation of the performance of two vegetated treatment systems

PI: Todd P Trooien

Reporting Period: March 1, 2012 to Feb. 28, 2013

Date of Report: May 1, 2013

Written By: Todd P Trooien

Executive summary

The major accomplishments completed in the reporting period include:

- Collected baseline soil samples from the VTA at the Southeast Research Farm.
- Analyzed a subset of the soil samples for pH, total nitrogen, and phosphorus concentrations.
- Trained two undergraduate Agricultural and Biosystems Engineering (ABE) students.

Background

Animal agriculture seeks efficient production of economical food by placing many animals together in animal feeding operations (AFO). These operations make efficient use of space, labor, and investments in technology and other capital such as vehicles, feeders, storage, and infrastructure. But these operations also concentrate the animal waste products such that they could be deleterious to the environment if not managed properly.

Beef feedlots are an example of animal feeding operations. The runoff from open feedlots must be controlled and managed properly to prevent adverse impacts on the environment. The standard runoff control system for beef feedlots is collection of the runoff into a holding pond or lagoon. This technology is routinely accepted by USEPA and state regulatory agencies. Design and management guidelines for holding ponds are well established.

Holding ponds are not optimal for every site, however. Alternative technologies that perform as well as or better than holding ponds would be useful to many producers and regulatory agencies, as long as they manage the runoff well enough to protect the environment. This project is designed to monitor one alternative technology for beef feedlot runoff, the Vegetated Treatment System (VTS).

A VTS, as used in this proposal, consists of a solids settling basin (SSB), a distribution method to apply the runoff, and a Vegetated Treatment Area (VTA) to receive the runoff. This project will test two different distribution methods- (1) gravity flow through multiple outlets and (2) sprinkler distribution.

Previous research has shown that a gravity-driven VTS, if properly designed and managed, has the potential to prevent surface water release. Two of the system requirements for a properly designed and managed system are: (1) active control of the SSB outlet to delay the application of water to the VTA and (2) water spreading methods to apply runoff to the entire VTA.

A sprinkler VTS can adequately address both of the requirements but that technology has not been tested in South Dakota. Tests in Nebraska have shown that a sprinkler VTS can control runoff and apply it effectively. But the harsher weather of South Dakota may make sprinkler VTS management more difficult, especially at the beginning and end of the growing season. Thus, sprinkler VTS technology should be tested in South Dakota.

Our hypothesis is that a gravity-driven or sprinkler vegetated treatment system can successfully control and manage the runoff from a beef feedlot. The goal of this study is to evaluate the performance of two vegetated treatment systems, one gravity system and one sprinkler system, in their control and management of surface water.

The objectives of this project are to measure and sample the surface water flows at two VTS sites to document the effectiveness of the VTS at each site in managing the feedlot runoff.

Planned activities:

Table 1. Timeline of activities

Activity	Months
Install monitoring equipment at both VTS sites	March to April
Test pump flow rates at sprinkler VTS	May
Monitor surface water flows at both sites, collect VTA inflow samples	March to October
Transport VTA inflow samples to lab	When collected

Actual Accomplishments:

1. Install monitoring equipment at both VTS sites

Surface water monitoring equipment at the gravity site included turbine flow meters at each of the 7 inlets to the larger VTA. At the single inlet of the smaller VTA, an ISU low-cost monitoring system (LCMS), a modified H flume with float switches and timers, was used to measure inflow and collect samples.

Water sampling at the sprinkler VTS site was to be accomplished by dipping a sample from the solids settling basin at the time of pumping.

Soil samples were collected at the sprinkler VTS site during October 2012. Four diagonal transects between adjacent sprinklers were chosen. Along those transects, samples were collected from five equally-spaced locations. Sample depths were 0 to 15, 15 to 30, 30 to 60, 60 to 90, 90 to 120, and 120 to 150 cm. Two cores were collected and a composite of the two cores was kept as the sample. Only 3 of the core profiles were analyzed. The remaining soil samples are in storage and may be analyzed if future research requires the information.

The application amounts during 2012 were so small that the soil samples collected in October could be considered the baseline conditions with little or no affect by the applied runoff water. The nitrate-nitrogen (Fig 1), phosphorus (Fig 2), and total nitrogen (Fig 3) concentrations

decreased with depth. There are few differences of nutrient concentration among the three locations. The nitrate-N concentration was slightly reduced near sprinkler 1 but the phosphorus concentration was reduced near the midpoint. Historically, the land containing the VTA was in crop production.

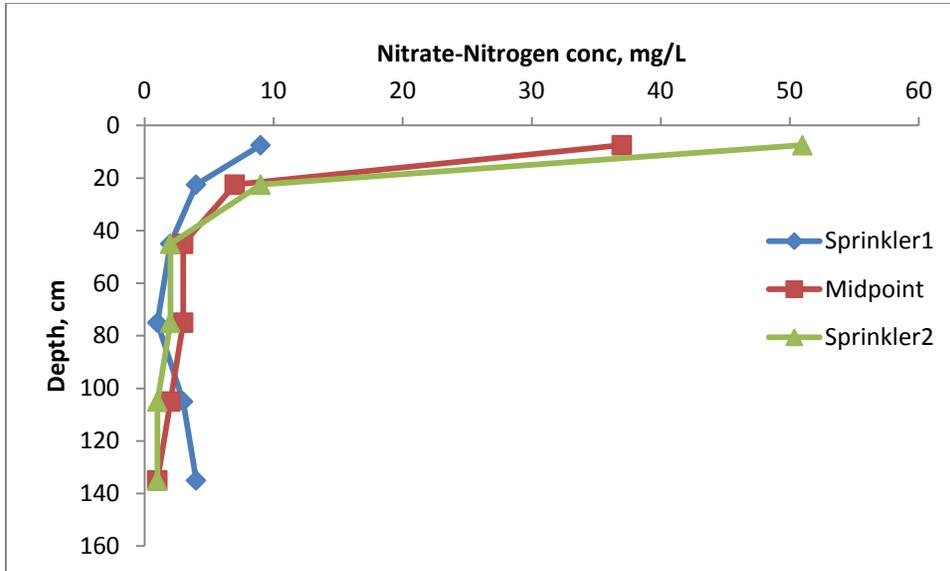


Figure 1. Nitrate-nitrogen concentrations with depth at three locations within the VTA at the sprinkler VTS site, October 2012.

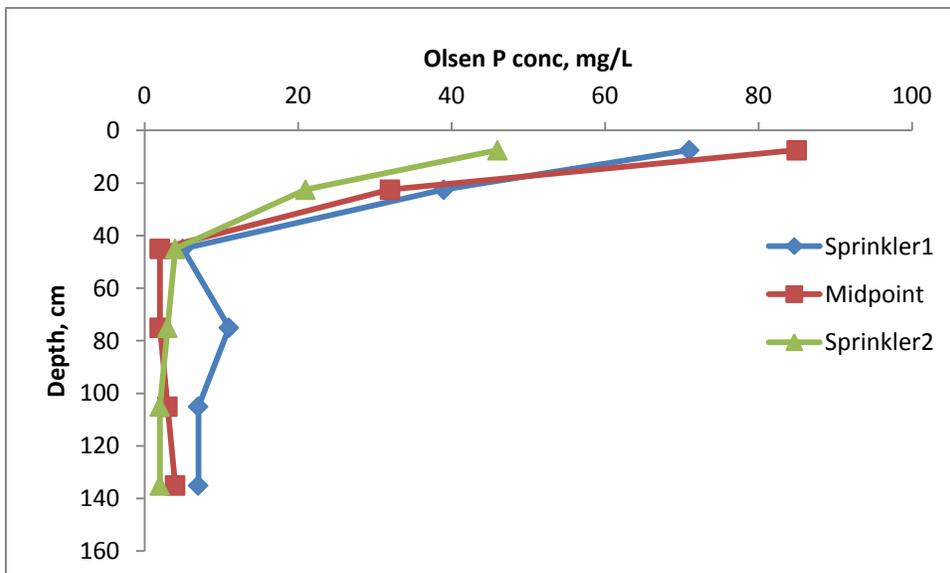


Figure 2. Olsen P concentrations with depth at three locations within the VTA at the sprinkler VTS site, October 2012.

1. Test pump flow rates at sprinkler VTS

After the spring melt, there was no feedlot runoff during the entire monitoring season at the sprinkler VTS site. The pump flow rate was not measured. Future studies at the sprinkler VTS

site will use pressure-flow relationships for the installed pump and sprinklers to estimate flow rates and volumes.

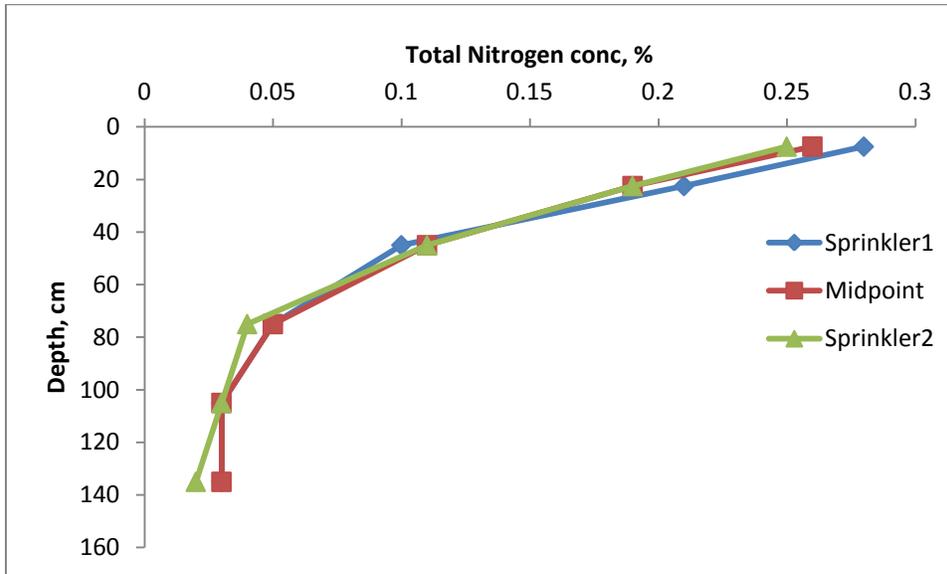


Figure 3. Total nitrogen concentrations at three locations within the VTA at the sprinkler VTS site, October 2012.

2. Education and training

There were two undergraduate ABE students, Patrick Hofer and Lane Stockland, trained in this project. One was paid directly by this project and the other student was paid from other grant funds. They were trained in surface water measurement and sample collection, plant biomass sampling and processing, groundwater measurement and sampling, and preliminary data analysis with spreadsheets. Not all of these tasks were related to this funded 104 b project but all were related to research efforts at the two VTS sites.

3. Project outcomes and challenges

The outcomes of this project included:

- Collected baseline soil samples from the VTA at the Southeast Research Farm.
- Analyzed a subset of the soil samples for pH, total nitrogen, and phosphorus concentrations.
- Trained two undergraduate ABE students.

There are still some challenges for the use of VTS as a routine method for feedlot runoff management.

- Because of the historically dry conditions at the sprinklers VTS site, the actual performance of the system is still unknown.
- Weather varies from year so multiple years of monitoring are required to adequately and confidently characterize the long-term performance of VTS.

4.Plans for the 1-year non-cost extension

- Complete a chemical and nutrient analysis of a runoff (VTA inflow) sample from the sprinkler VTS site to estimate nitrogen, phosphorus, and salt inflows to the VTA.
- Explore external funding support and collaborations to improve the research

Summary

Two students were trained in VTS monitoring at two sites. The sprinkler VTS site was historically dry and no runoff samples were collected at that site. Baseline soil samples were collected. A subset of the samples was analyzed for N and P and showed little or no difference among the analyzed locations.

Identifying barriers for adopting new drainage technology among agricultural producers

Basic Information

Title:	Identifying barriers for adopting new drainage technology among agricultural producers
Project Number:	2012SD211B
Start Date:	3/1/2012
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	First
Research Category:	Social Sciences
Focus Category:	Management and Planning, Agriculture, Water Quality
Descriptors:	
Principal Investigators:	Nickolas Benesh, Jeppe H Kjaersgaard

Publications

1. Kjaersgaard, Jeppe, Benesh, Nicholas, Hay, Chris, 2012, Identifying barriers for adopting drainage technology among agricultural producers, 2012 Western South Dakota Hydrology Conference. Rapid City, SD
2. Davis, Molly, Goodale, Brooke, Kjaersgaard, Jeppe, Benesh, Nicholas, Hay, Chris, 2012, Measures of innovation diffusion of sub-surface drainage in South Dakota, Poster session presented at the Eastern South Dakota Water Conference. Brookings, SD.

Annual report for 104b subawards for FY 2012

Title: Identifying Barriers to Conservation Drainage Water Management among Agricultural Producers

Dr. Nick Benesh

Dr. Jeppe Kjaersgaard

Dr. Chris Hays

Brief Summary

Goal of project was to explore reasons why agricultural producers in the SD area may be slow to adopt a new innovation, such as filtration for subsurface water drainage tile. The researchers developed a preliminary set of questions to assess the target population. Based on the pilot study results and guided by Innovation Diffusion Theory, a questionnaire was created to acquire information that should be useful to future innovators when attempting to get their technology or technique into mainstream usage. Currently formatting and analyzing data from questionnaire, with plans to submit final results to Journal of Environmental Psychology.

Introduction

The diffusion of innovations is something that can happen seemingly overnight like television programming or take decades to be fully accepted as in seat belt usage. Research on this suggests that persuading people to use an innovation is not as straight forward as simply telling them it is better (Rogers, 2003). The decision to use something new involves not only internal considerations (usefulness, ability to use, etc.), but also external considerations (environment, social norms, etc.). Whether the user finds the innovation useful or not will depend on a person's perceptions of the innovation. However, there are models and theories that assist in understanding the likelihood of adoption; specifically, Everett's (2003) Innovation Diffusion Theory (IDT) has been influential in this area for more than half a century.

Diffusion of innovation can be broadly defined as a change that alters structure and function of a social system (Rogers, 2003, 6). The different rates of diffusion of innovations are difficult to predict due to the varying contexts of them. Rogers' (2003) IDT involves four elements: innovation, communication channels of diffusion, timing, and current social system. Each element can be adapted to the context and further broken down into more specific aspects and functions each play in the broader concept of innovation diffusion.

The first step of diffusion is getting users to want the innovation. Rogers (2003) outlines five components of the first step: 1) perceived relative advantage, 2) compatibility with norms and values, 3) opportunity to try innovation to reduce uncertainty, 4) observability of a change to the current system, and 5) perceived difficulty of use. The first four components are theorized to be positively related to rates of adoption, while the fifth is theorized to be negatively correlated. On the other hand, when the innovation is perceived as complex and difficult to implement, the theory would predict the adoption rate to be low or

slow. Lee, Hsieh, and Hsu (2011) applied the five IDT components in regards to using and promoting online learning systems. They found that people's perceptions of usefulness were influenced most by the compatibility and relative advantage of the innovation. In addition, ease of use perceptions were influenced positively by relative advantage and trialability, but negatively by perceived complexity. Their overall findings suggest the components are not all equally related, but instead cover a variety of variables related to innovation adoption behavior.

While IDT is useful at a broad level of investigation, it is also helpful in categorizing adopters of innovations. Early adopters begin using an innovation soon after it has been created or tested. These users are typically more venturesome, higher educated, and/or social leaders. Majority adopters are generally more skeptical, less financially secure, and have contact with early adopters. Laggards typically are adverse to change, have less diversity in social connections, and experience higher anxiety when dealing with debt. Ideally, it is the early adopters that need to be targeted to get innovations to spread. Studies suggest that specific information about potential adopters can impact potential adoption rates (Edward-Jones, 2006; Quazi & Talukder, 2011). Quazi and Talukder (2011) compared perception of innovation adoption based on age, education, training, and attitudes. They found that training is a strong predictor for perception and usage of innovations. Edward-Jones (2006) advocates the importance of an individual's unique attitudes in regards to innovation adoption, suggesting they are tightly coupled with decision making processes. For example, crop farmers make large decisions that have long term and geographical implications. These implications mean they must carefully consider multiple factors before selecting a course of action. As a result, Edward-Jones has encouraged researchers to examine the importance of identifying norms locally and personally.

Innovation Context

Recently the U.S. Department of Agriculture (2011) revised its nutrient management conservation practices to promote use of technology and local information. It calls for stricter water management to reduce the loss of nutrients from water runoff, specifically in the Upper Mississippi Basin. To address this, researchers are looking into innovation diffusion from many perspectives and in various areas of application. Each local area has its own norms/values, ways of implementation, outcomes, and audience. More specifically, soil nutrient runoff has become an issue in South Dakota (Bartos, 2012) with the recent increase in subsurface tiling (Johnson, 2012).

Due to the need to increase food production to feed the world's growing population, there is a requisite for more effective yet sustainable methods of food production. One such method of promoting this is the installation of subsurface, or tile, drainage systems to maximize land usage.

The use of subsurface drainage on agricultural land with poor natural drainage allows more timely access for field operations and leads to improved crop yields. Subsurface drainage has become

increasingly popular in eastern South Dakota in recent years. Increasing trends in precipitation, high agricultural commodity prices, rising land prices and the advent of computer-aided tile drain installation equipment all contribute to the increased interest in tile drainage. However, studies have found elevated nitrogen (in the form of nitrate) concentrations in tile drainage water (e.g. Randall and Goss, 2008) compared to surface runoff.

Nitrogen is an essential plant nutrient. However excess nitrogen leads to nutrient enrichment, algae growth and hypoxic conditions in which aquatic organisms can no longer survive. Current tile drainage systems can increase the nitrate concentration in water that comes off of crop fields, which then flows into larger river systems impacting their quality level. David et al. (2010) found that fertilized crops on tile drained lands were the greatest contributing factor for riverine nitrate yields in the Mississippi River basin. Studies looking at the nitrogen transported by the Mississippi River have been linked to the ‘dead zone’ found in the Gulf of Mexico (USEP, 2007). In addition, exposure to elevated nitrate levels in drinking water is a public health concern as it may reduce adequate amounts of oxygen in organs and lead to acute methemoglobinemia (*blue-baby syndrome*) in infants.

Elevated nitrate levels create a critical need among water managers and policy makers for strategies to minimize nitrate losses through subsurface drainage of agricultural land. This is done in order to balance profitable agricultural production with clean drinking water needs, environmental sustainability and the security of future ecosystem services. There are several effective management practices for reducing the amount of nitrate in drainage water available, including good management of nitrogen fertilizer, changes in cropping systems or optimization of the drainage system design. However, these practices are often not enough, and it is necessary to have an edge-of-field treatment system to reach the goals for decreasing the amount of nitrogen that is discharged into waterways to acceptable levels. Several studies show that installing edge-of-field treatment systems are effective technologies for reducing nitrate concentrations of drainage flow (e.g. Luo et al., 2010). Currently, the most common treatment systems include controlled drainage water management using drainage control structures, denitrifying bioreactors as filters for nitrates, and wetlands.

Study Goal

Treatment technologies that were developed several decades ago have not been widely adopted by the agricultural landowners. The goal of the project is to explore the barriers and identify incentives that may increase the adoption rate of innovations, specifically drainage water treatment systems by agricultural landowners. Our hypothesis is that the very modest adoption rate for these nitrate treatment systems relates to producers either: 1) Are not informed about nitrate problems related to tile drainage, 2) Are not informed about treatment options, 3) Feel environmental concerns regarding tile drainage are unwarranted or 4) lack incentives.

Methodology

Edwards-Jones (2006) points to five non-financial variables influencing producer decision making: personal characteristics, household characteristics, farm structure, social milieu and characteristic of the innovation. We used two rounds of questionnaires to determine agricultural producers' use of drainage technology and motivations to adopt new ones.

Pilot Study

In spring 2012, questionnaire was presented at a South Dakota subsurface tile drainage workshop. The questions explored reasons and likeliness for adopting recent innovations in general, social influences, recent technology for drainage management, years of agricultural experience, and which basin the drained acreage primarily resides (see Appendix 1). Questions were displayed using PowerPoint and participants used TurningPoint Clickers to respond.

Results: An exploratory analysis of the nominal data was evaluated visually looking for large patterns demographic or tile drainage opinion. Knowledge of Soil Science and Impact of Drainage on Environment were strongly correlated, $r(164)=.47$, $p<.01$. This suggests or confirms that extension workshops are fulfilling a need. A moderate correlation was found for relying on Own Experience and Experts' recommendations, $r(161)=.15$, $p<.05$. Suggesting agricultural producers may seek out expert opinions and compare it with their own experiences. Another moderate correlation was found for relying on Experts' recommendations and neighbors' opinion on tiling, $r(161)=.21$, $p<.01$. This may suggest that agricultural producers are just as likely to rely on experts as their neighbors opinions.

Main Study

For the main study we created over 40 questions to address the range of possible influences on adopter behavior. However, it was believed that the participants would be unlikely to answer all of them with the limited time they have (Rogelberg, 2005). Therefore, the list of questions was streamlined to 14 (mix of multiple choice, and open-ended). In the winter of 2013, the second questionnaire was distributed at a South Dakota subsurface tile drainage workshop. It focused on specific motivational aspects as based on the information collected in the initial questionnaire, along with a brief personality assessment (see Appendix 2).

The expected results from this second questionnaire will consist of information on possible motivational incentives, together with personality traits of early adoptive agricultural producers. This data will be analyzed and organized in the hopes that extension program organizers, managers and policy makers can use it to benefit agricultural producers and their immediate communities.

Discussion

These results should provide an initial representation of agricultural producers in the regional area. This information could be useful for those interested in extension programs and working with local agricultural producers, in order to facilitate meeting their needs. The long-term goal of this study is to collect preliminary information that could be applied in future project proposals (such as to USDA NIFA Integrated Grants). These topics might include similar water resource management areas and populations addressing both economic feasibility of implementation and societal impacts on water resource problems, such as agricultural waste land application or agricultural and environmental resilience towards variations in climate and changes in policies and economics.

Student Involvement in Project

Two undergraduate students were heavily involved in the overall process of the project. They searched out articles and assisted in writing up the literature review. Assisted in going through multiple iterations of the questionnaires, and collection of data. One of the students presented the pilot study results at the Eastern SD Water conference. In the next month they will go through the final set of data and write it up for publication submission.

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Appendix 1: Pilot Questionnaire Questions

- 1) What is your main occupation?
 - I farm my own farm
 - I manage a farm but I am not the owner
 - Farm worker
 - Drainage contractor
 - County agency/policymaker
 - State agency/policymaker
 - Federal agency/policymaker
 - Other, farm related
 - Other

- 2) How many years have you been doing your main occupation?
 - 0-5 years
 - 5-10 years
 - 10-15 years
 - 15-20 years
 - 25-30 years
 - More than 30 years

- 3) In which river basin is most of your land or business located?
 - Big Sioux River Basin
 - James River Basin
 - Minnesota River Basin
 - Red River Basin
 - Vermillion River Basin
 - Other basin in SD
 - Other basin in ND
 - Other basin in MN
 - Other basin in NE
 - Other basin

- 4) If you own or manage a farm,
 - I have no tile
 - I have no tile but I consider putting some in myself

I have no tile but I consider having a contractor putting some in
I have some tile, and would like to put in more myself
I have some tile and I consider having a contractor putting in more
None of the above
I do not own or manage a farm

5) How many acres do you farm?

1-199
200-399
400-599
600-799
800-999
1,000-1,199
1,200-1,399
1,400-1,599
1,600+

6) How much of a concern is excess water on fields compared to other crop concerns?

1 - Not at all important
2
3
4 - Just as important as others
5
6
7 - Most Important

7) What is the biggest challenge for you relating to tile installation

I am not sure tiling will benefit me
I am not sure how to design the tiling system
Cost of installation
Getting a wetland determination done by the NRCS
Getting a tiling permit
Downstream neighbors
Environmental concerns, nitrogen management
Public perceptions
Other

8) What is the second biggest challenge for you relating to tile installation?

I am not sure tiling will benefit me
I am not sure how to design the tiling system
Cost of installation
Getting a wetland determination done by the NRCS
Getting a tiling permit
Downstream neighbors
Environmental concerns, nitrogen management
Public perceptions
Other

9) How much do you feel you know about tiling and its benefits/drawbacks?

1 - Not informed at all
2
3

- 4 – Informed enough to talk about it
- 5
- 6
- 7 – Very informed

10) How familiar are you with soil science in general?

- 1 - Not informed at all
- 2
- 3
- 4 – Informed enough to talk about it
- 5
- 6
- 7 – Very informed

11) How aware are you of the impact tiling drainage has on the immediate environment?

- 1 - Not informed at all
- 2
- 3
- 4 – Informed enough to talk about it
- 5
- 6
- 7 – Very informed

12) How aware are you of the impact tiling drainage has on the environment at large?

- 1 - Not informed at all
- 2
- 3
- 4 – Informed enough to talk about it
- 5
- 6
- 7 – Very informed

13) Tile drainage typically increases the amount of nitrate coming off a field compared to surface runoff. Some negative impacts of tile drainage can be reduced by implementing conservation drainage (CD) practices (practices to keep the benefits of drainage while minimizing negative impacts). Would you be willing to implement CD practices?

- I was not aware of any negative impacts of tiling
- I think the environmental concerns relating tiling are unwarranted
- I would implement CD practices but I am not aware of how they work
- I have implemented CD practices already
- Other

14) Would you be willing to implement in-field or end-of-tile Conservation Drainage (CD) practices if it does not interfere with the tile system efficiency?

- I would not install CD practices
- I would install CD if they are available at no cost to me
- I would install CD if they are available at less than 5% of the cost of tile installation
- I would install CD if they are available at 5-10% of the cost of tile installation
- I would install CD if they are available at 10-15% of the cost of tile installation
- I would install CD if they are available at 15-20% of the cost of tile installation
- I would install CD if they are available at 20% or more of the cost of tile installation
- Other

15) What would motivate you to implement Conservation Drainage (CD) management practices?

- I would not implement CD practices
- Reduce the environmental footprint
- Being a good steward of the environment
- Help with public perception of farming
- My neighbors are doing it
- It can help me manage soil moisture better
- Other

16) How frequently do you interact with the closest neighbors to your fields?

- 1 - Never
- 2
- 3
- 4 – Every other week
- 5
- 6
- 7 – Every 1-2 days

17) How important are the opinions of your closest neighbors' when making your decisions on tiling?

- 1 - Not at all important
- 2
- 3
- 4 - Just as important as others
- 5
- 6
- 7 - Most Important

18) How important is the cost-to-benefits ratio in your consideration for using tiling?

- 1 - Not at all important
- 2
- 3
- 4 - Just as important as others
- 5
- 6
- 7 - Most Important

19) How would you feel about possible future regulations on tiling?

- 1 – Very negative
- 2
- 3
- 4 – Depends on the regulations
- 5
- 6
- 7 – Very positive

20) I view more crops as more profit to help sustain my operation and employees.

- 1 – Strongly disagree
- 2
- 3
- 4 – Unsure
- 5

6
7 – Strongly agree

21) I view more crops as contributing more resources to the world at large that can be used by others.

1 – Strongly disagree
2
3
4 – Unsure
5
6
7 – Strongly agree

22) Do you feel that farming innovations are beneficial?

1 – Rarely
2
3
4 – Occasionally
5
6
7 – Always

23) I primarily rely on my experience to make judgments about trying new things.

1 – Never
2
3
4 – Somewhat
5
6
7 – A great deal

24) I primarily rely on experts' explanations and recommendations about trying new things.

1 – Never
2
3
4 – Somewhat
5
6
7 – A great deal

Appendix 2: Main Questionnaire

1) What river basin is the majority of your land in?

- a) Big Sioux River Basin
- b) James River Basin
- c) Minnesota River Basin
- d) Red River Basin
- e) Vermillion River Basin
- f) Other _____

2) How many years of experience do you have working in farming or other agricultural production?
_____ years.

- 3) Who do you consult anyone before using a new technique, method or other innovation?
(Circle all that apply)
- a) No one
 - b) Other producers
 - c) Friends
 - d) Family
 - e) Neighbors
 - f) Employees
 - g) Outside consultants
 - h) Extension specialist
 - i) Other _____
- 4) How often do you attend meetings/presentations/demonstrations on agricultural innovations?
- a) Never
 - b) Yearly
 - c) Quarterly
 - d) Monthly
 - e) Every couple weeks
- 5) Have you or any of your friends/neighbors already tiled some fields?
Yes or No
- 6) When did you first hear about or start using tiling?
_____(year)
- 7) One is concern about tiling is nitrate losses from the drains. Conservation drainage (CD) practices are one way to address these concerns. Would you be willing to implement CD practices?
(Circle best one)
- a) I was not aware of any negative impacts of tiling
 - b) I think the environmental concerns relating tiling are unwarranted
 - c) I am ready to implement CD practices
 - d) I would implement CD practices but I need more information
 - e) I would implement CD practices if there were financial incentives to do so
 - f) I have implemented CD practices already
 - g) Other _____
- 8) If you implemented field tiling, would you also be willing to implement in-field or end-of-tile Conservation Drainage (CD) practices if it does not interfere with the tile system efficiency?
(Circle best one)
- a) I would not install CD practices
 - b) I would install CD if it was no additional cost to me
 - c) I would install CD if it was only an additional 1-5% of the cost of tile installation
 - d) I would install CD if it was only an additional 5-10% of the cost of tile installation
 - e) I would install CD if it was only an additional 10-15% of the cost of tile installation
 - f) I would install CD if it was only an additional 15-20% of the cost of tile installation
 - g) I would install CD if it was an additional 20% or more of the cost of tile installation
 - h) Other
- 9) What would motivate you to implement Conservation Drainage (CD) management practices?
(Circle all that apply)
- a) I would not implement CD practices
 - b) Reduce the environmental footprint

- c) Being a good steward of the environment
- d) Help with public perception of farming
- e) Cost share or other financial incentives
- f) My neighbors are doing it
- g) It can help me manage soil moisture better
- h) Other

10) What are some of the biggest challenges for you relating to tile installation?

11) How do you interact with the wildlife and environment near and on the farm?

(Circle all that apply)

- a) Recreational hunting, fishing or other outdoor activities
- b) Leave food plots for wildlife
- c) Maintain habitat areas for wildlife
- d) Other _____

12) How concerned would you say others in your community are about agricultural impacts on the local environment?

- a) Not interested
- b) Not worried
- c) Indifferent
- d) To a certain extent
- e) Greatly concerned

13) Are you involved in local community organizations? (Ex. school board, Scouts, church committee, 4-H, township board etc.)

TUPI

Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

There are no right or wrong answers. Your responses are kept anonymous.

Rating Scale

- 1 = Disagree strongly
- 2 = Disagree moderately
- 3 = Disagree a little
- 4 = Neither agree nor disagree
- 5 = Agree a little
- 6 = Agree moderately
- 7 = Agree strongly

I see myself as:

- _____ Extraverted, enthusiastic.
- _____ Critical, quarrelsome.
- _____ Dependable, self-disciplined.
- _____ Anxious, easily upset.
- _____ Open to new experiences, complex.
- _____ Reserved, quiet.
- _____ Sympathetic, warm.
- _____ Disorganized, careless.
- _____ Calm, emotionally stable.
- _____ Conventional, uncreative.

Subsurface Drainage Impacts on Evapotranspiration and Water

Basic Information

Title:	Subsurface Drainage Impacts on Evapotranspiration and Water
Project Number:	2012SD212B
Start Date:	3/1/2012
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	First
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Agriculture, Water Quantity
Descriptors:	
Principal Investigators:	Christopher Hay, Jeppe H Kjaersgaard, Todd P. Trooien

Publications

There are no publications.

Subsurface Drainage Impacts on Evapotranspiration and Water Yield

Progress Report: March 1, 2012 to February 28, 2013

Investigators:

Christopher Hay, South Dakota State University
Jeppe Kjaersgaard, South Dakota State University
Todd Trooien, South Dakota State University
Gary Sands, University of Minnesota

Introduction

Subsurface drainage has increased dramatically in eastern South Dakota with increases in precipitation, commodity prices, and land prices. Subsurface drainage improves agricultural production by increasing yields and reducing risk, but there are concerns about its environmental impacts. A key concern is to what extent does subsurface drainage contribute to downstream flow alterations and flooding through changes in the amount and timing of water leaving the field. Changes in evapotranspiration (ET), as a result of drainage, are a primary determinant of the hydrologic alterations from subsurface drainage. However, the impacts of drainage on ET are not yet well understood. Lack of such knowledge is an important problem, because without it, we are limited in our ability to accurately quantify the impacts of subsurface drainage on watershed hydrology and flooding.

Project Information

The overall goal of this project is to develop a method to account for the impact of yield reductions from poor drainage on evapotranspiration in drainage model simulations. Our central hypothesis, based on water productivity functions that relate crop yield and ET, is that current drainage model simulations overestimate ET under undrained or poorly drained conditions. The rationale for the proposed research is that once we are able to accurately simulate ET under undrained and poorly drained conditions, we can then better estimate the impacts that subsurface drainage development will have on hydrology. Our contribution here is expected to be an improved understanding of the impacts of subsurface drainage on ET. Once such knowledge is available, we can better evaluate the hydrologic impacts of increased subsurface drainage in eastern South Dakota.

There are three research objectives for this project:

1. Evaluate ET estimates from DRAINMOD in relation to estimates using the FAO 56 dual-crop coefficient approach that uses water balance to account for water limitations on ET.
2. Develop crop stress coefficients that account for excess water stress reductions on ET based on relative yield estimates from DRAINMOD.
3. Evaluate the magnitude of excess water stress reductions of ET on water yield estimates for undrained scenarios in DRAINMOD.

A graduate research assistantship (MS-level) was awarded for this project in August 2012. The student has been undergoing the necessary training in order to accomplish the project objectives. The student is enrolled in the graduate-level DRAINMOD course at North Carolina State University (where DRAINMOD was developed). Dr. Hay has been training the student on ET calculation, and Dr. Kjaersgaard has been training the student on the use of the METRIC (Mapping

EvapoTranspiration at high Resolution with Internalized Calibration) model for computing ET from remotely-sensed imagery. The METRIC model will be used for direct comparisons of ET between similar fields with and without drainage. Two field sites, one in Minnesota and one in North Dakota, have been identified for use with METRIC to evaluate the impacts of drainage on ET. Additional field sites are being investigated in South Dakota and Iowa.

Evaluating the Nitrate-Removal Effectiveness of Denitrifying Bioreactors

Basic Information

Title:	Evaluating the Nitrate-Removal Effectiveness of Denitrifying Bioreactors
Project Number:	2012SD215B
Start Date:	3/1/2012
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Agriculture, Non Point Pollution
Descriptors:	
Principal Investigators:	Jeppe H Kjaersgaard, Christopher Hay, Todd P. Trooien

Publications

There are no publications.

Demonstrating the Nitrogen-Removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management

Progress Report: March 1, 2012 to February 28, 2013.

By J. Kjaersgaard, C. Hay, T. Trooien, E. Cortus and C. Partheeban, South Dakota State University. January 2013.

Report submitted to the South Dakota Water Resources Institute under the USGS 104b program.

Introduction

This report summarizes the project activities during March 1, 2012 to February 28, 2013 for the project titled *Demonstrating the Nitrogen-Removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management*. The project is a collaborative effort between South Dakota State University and partner organizations, industry, government agencies and landowners. A list of project sponsors is available at <http://www.sdstate.edu/abe/wri/research-projects/upload/Project-Sponsors.pdf>.

This project has the overall goal of demonstrating and evaluating denitrifying drainage bioreactors placed near field edges to reduce nitrate export through subsurface (tile) drainage systems to receiving waters in eastern South Dakota. A factsheet about bioreactors is attached in Appendix A.

The objectives of the project are to:

1. Demonstrate and evaluate four field-scale bioreactor designs by installing, monitoring, analyzing and documenting their effectiveness for removing nitrate from subsurface drainage water in South Dakota; evaluate the transferability of this method and these designs to South Dakota
2. Evaluate the potential for nitrous oxide emission to the atmosphere
3. Estimate the cost per pound of nitrate removed
4. Support the development of NRCS Conservation Practice Standards and Best Management Practices (BMPs) for management of nitrate in subsurface tile drainage water
5. Transfer information about the bioreactor design and performance through outreach and demonstration activities, factsheets, and train one or two undergraduate research assistants in environmental and agricultural water management.

More information about the project, including background information about denitrifying bioreactors, is available at <http://www.sdstate.edu/abe/wri/research-projects/bioreactors.cfm>.

Bioreactor Installations

At this time we have installed two bioreactors, one near Baltic and one near Montrose. Two additional bioreactors are scheduled to be installed during the spring of 2013. The approximate location, county, watershed and installation dates for the four bioreactors are shown in Table 1.

Table 1. Approximate location, county, watershed and installation dates for the four bioreactors.

Location	County	Watershed	Installation date
Baltic	Minnehaha	Silver Creek	July 23-24 2012
Montrose	McCook	Skunk Creek	December 5-6 2012
Arlington*	Brookings	Lake Sinai	Scheduled spring 2013
Beresford*	Clay	Vermillion River	Scheduled spring 2013

*Scheduled location

Bioreactor Design

The designs of the Baltic and Montrose bioreactors are based on the Iowa subsurface drainage bioreactor design method as outlined in Appendix B.

The following section summarizes and documents some of the technical aspects of the Baltic and the Montrose bioreactor installations. Pictures showing the step-by-step installation process are enclosed in Appendix C.

Baltic Bioreactor

The Baltic bioreactor was installed on a drainage system with a 6-inch main line draining approximately 40 acres. The drainage system consists of lateral lines installed in the swales of adjacent fields and smaller pattern tiled portion. The bioreactor is located east of the drainage system at the outlet as shown in Figure 1. The outlet of the drainage system discharges into an open waterway running east through a pasture/wetland area.

The upstream 3-chamber control structure (used to divert the tile water through the bioreactor) was installed directly on the 6-inch main line near the outlet. Ten feet of non-perforated 6-inch pipe were used at all three connectors to prevent tile water bypassing the control structure. During the installation of the bioreactor the original tile system outlet was maintained to be used as the outlet structure for the overflow bypass. The bioreactor was installed parallel to the open waterway.

The bioreactor trench was excavated using a backhoe. A skid steer loader was used to move and pile the spoil away from the excavation. The trench was 115 feet long, 18 feet wide and 4 feet deep with a water level height of 2 feet above the bottom at the inlet and an outlet water level of 0.46 feet above the bottom. The bottom of the trench was constructed on a gentle slope. For this design, the estimated hydraulic retention time at design flow is 5.4 hours, and it is estimated that the bioreactor can handle up to 25% of the peak flow water volume (see Appendix B). Following excavation, the trench was lined with a plastic film liner and backfilled with woodchips to within approximately 1 foot of the ground surface. The chips were covered with a geotextile and topsoil was used to cover the trench at a thickness of about 1 foot along the edges and 1.5-2 feet near the center of the trench to account for subsidence of the chips as they decompose.

The downstream 2-chamber control structure was installed 10 feet from the collector manifold in the downstream end of the bioreactor. The terrain near the outlet has varying levels of slope so to ensure sufficient elevation drop and prevent backflow into the bioreactor when the water level in the open waterway is high, the outlet for the bioreactor was extended approximately 400 feet east of the reactor using non-perforated pipe.

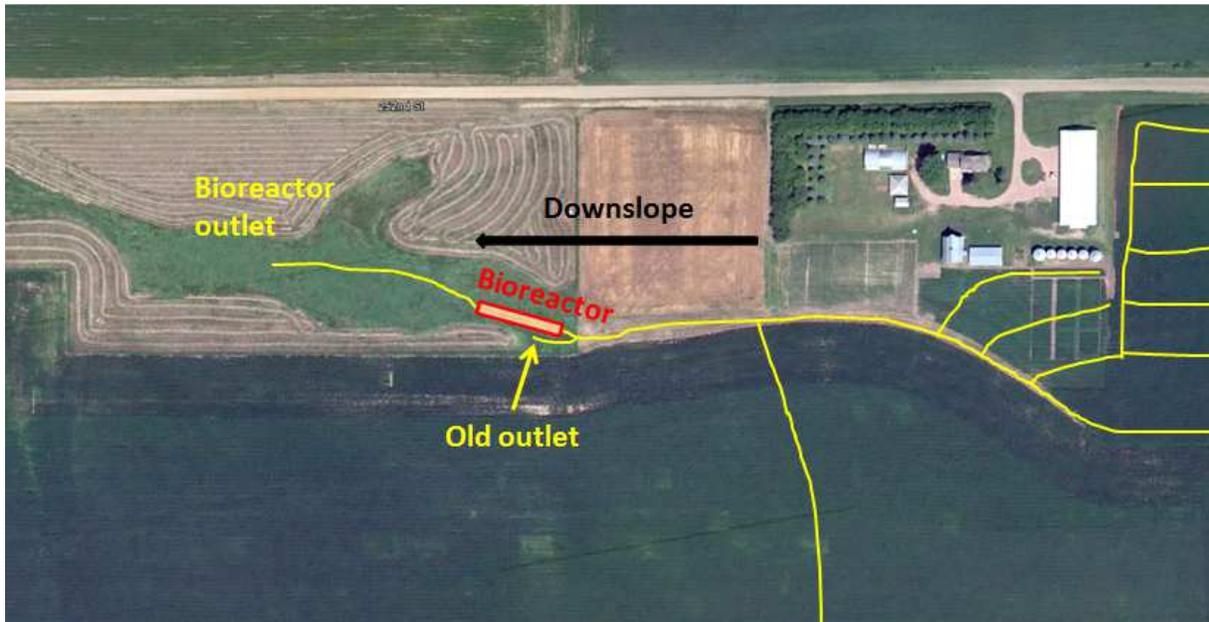


Figure 1. Location of the Baltic bioreactor (red rectangle), the overflow outlet (old outlet) and bioreactor outlet relative to the drainage system and farmstead overlaid on 2010 NAIP Aerial Photography.

We acquired services and supplies needed for the installation locally whenever possible. An overview of our direct installation costs (excluding sales tax) for the Baltic bioreactor is shown in table 2. Although these costs provide an indication of the installation cost of a bioreactor, the actual costs will vary depending on local price and access to the services and supplies needed for the installation.

Table 2. Approximate direct costs (excluding sales tax) for the installation of the Baltic Bioreactor.

Cost Category	Quantity	Vendor	Total Cost	Comment
Earth work and backfilling	2.5 days	Vandersnick Excavation	\$1900	Backhoe and skid steer
Wood Chips	250 yd ³	Golden Valley Hardscapes	\$3925	Includes transportation
Control Structures ¹	2	Agridrain Corp., Adair, IA	\$1675	A 3-chamber a 2-chamber structure
Plastic Liner ²	1liner	Runnings Farm and Fleet	\$500	6 mil plastic film
Tile, joints and elbows ³		ADS and Hefty Seed	\$0	Donated by ADS and Hefty Seed
Personnel Transportation		SDSU Motor Pool	\$300	
Misc. supplies		Runnings and Lowes	\$200	
Labor ⁴	2 laborers	SDSU students	\$500	
Total Installation Cost			\$8800	

¹The indicated cost includes a 20% discount from Agridrain Corp.

²A liner is not needed if the bioreactor is installed in stable soil (high clay content).

³Advanced Drainage System (ADS) donated a roll of 6 inch tile and Hefty Seed donated all pieces of connectors, elbows, tee's, tape etc.

⁴SDSU hourly student labor. Labor costs for local collaborators, SDSU graduate students and faculty are not charged to the project.

The Baltic bioreactor was our first installation. Despite our best efforts in planning the installation, there was somewhat of a learning curve relating to the installation. The learning curve will likely be less steep for an individual with extensive tiling installation experience.

Because of the learning curve and because the installation doubled as an educational exercise for undergraduate and graduate students from SDSU, we likely spent more time installing the Baltic bioreactor compared to the time requirement of an experienced installation crew. During the installation, up to 10 individuals were assisting, but most of the time 2 or 3 helpers would suffice. The approximate amount of time we spent on the installation was

- Assessing potential installation location and initial surveying: 2 hours
- Bioreactor design and planning, including procurement of materials and supplies: 10 hours,
- Bioreactor installation personnel:
 - o Backhoe operator (excavation, trenching, backfill woodchips and topsoil): 1 person for two days,
 - o Skid steer operator (excavation, backfill woodchips and topsoil): 1 person for two days,
 - o Installation crew (surveying, assembling pipe, install control structures, miscellaneous labor etc.): 2-3 persons for 2.5 days.

Montrose Bioreactor

The Montrose bioreactor was installed on a drainage system draining approximately 35 acres. The drainage system was installed in the fall of 2012. The bioreactor was installed “in-line”, i.e. parallel to the existing tile line approximately 400 feet from the outlet of the drain tile, figure 2.

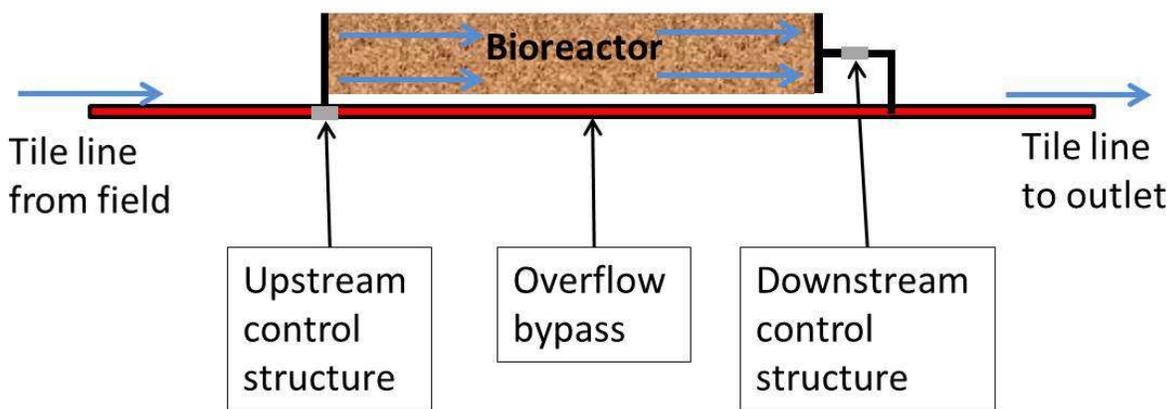


Figure 2. Schematic representation of the Montrose bioreactor location relative to the red-striped main tile line. The bioreactor was installed parallel to the existing tile line approximately 400 feet from the outlet. The upstream control structure routes water from the main line into the bioreactor. The overflow bypass diverts excess water past the bioreactor when the flow exceeds the bulk hydraulic conductivity of the reactor.

The upstream 3-chamber control structure, which diverts the water from the main line into the bioreactor, was installed directly on the 8-inch main line. Ten feet or more of non-perforated 8-inch pipe were used at all three connectors to prevent tile water bypassing the control structure. During the installation of the bioreactor, the existing 8-inch main line along the bioreactor was retained to function as the overflow bypass pipe.

The trench was excavated using a backhoe. A skid steer loader was used to move the spoil away from the backhoe and to keep the top soil and the sub soil separated. The trench was 130 feet long, 21 feet wide and 5 feet deep with an inlet water level of 2.6 feet above the bottom and an outlet water level of 0.46 feet above the bottom. The bottom of the trench was horizontal (no slope). The estimated hydraulic retention time is 4.9 hours, and it is estimated that the bioreactor at design flow can handle up to 25% of the peak flow water volume. Following excavation, the trench was lined with a plastic film liner (6 mil) and backfilled with woodchips to within approximately 2 feet of the surface. The chips were covered with a geotextile and topsoil was used to cover the trench at a thickness of about 2 feet.

The downstream 2-chamber control structure was installed 5 feet from the collector manifold in the downstream end of the bioreactor. The outlet from the control structure was connected back onto the main tile line.

As with the Baltic bioreactor, we acquired all services and supplies locally whenever possible. An overview of our direct installation costs (excluding sales tax) for the Montrose bioreactor is shown in table 3. Again, although these costs provides an indication of the installation cost, the actual costs associated with installing a bioreactor will vary depending on local price and access to the services and supplies needed for the installation.

Table 3. Direct costs (excluding sales tax) for the installation of the Montrose Bioreactor.

Cost Category	Quantity	Vendor	Total Cost	Comment
Earth work and backfilling	2 days	Vandersnick Excavation	\$2000	Backhoe and skid steer
Wood Chips	300 yd ³	Golden Valley Hardscapes	\$4500	Includes transportation
Control Structures ¹	2	Agridrain Corp., Adair, IA	\$2100	3-chamber and 2-chamber struct.
Plastic Liner ²	1liner	Lowes	\$500	6 mil plastic film
Tile, joints and elbows		Prinsco and Hefty Seed	\$800	
Personnel Transportation		SDSU Motor Pool	\$300	
Misc. supplies		Runnings and Lowes	\$200	
Labor ³		SDSU students	\$0	
Total Installation Cost			\$10400	

¹The indicated cost includes a 20% discount from Agridrain Corp.

²A liner is not needed if the bioreactor is installed in stable soil (high clay content).

³Labor costs for local collaborators, SDSU graduate students and faculty are not charged to the project.

The Montrose bioreactor was our second installation and we were able to complete the installation in 2 days. The approximate amount of time we spent on the installation was:

- Assessing potential installation location and initial surveying: 3 hours
- Bioreactor design and planning, including procurement of materials and supplies: 8 hours,
- Bioreactor installation personnel:
 - o Backhoe operator (excavation, trenching, backfill woodchips and topsoil): 1 person for two days,
 - o Skid steer operator (excavation, backfill woodchips and topsoil): 1 person for two days,

- Installation crew (surveying, assembling pipe, install control structures, miscellaneous labor etc.): 2-3 persons for two days.

Bioreactor performance

The growing season of 2012 was characterized by unusually dry conditions for south-eastern South Dakota. As a result, the crops depleted the root zone for moisture and there were no water flowing in the drainage systems. We were therefore unable to collect information relating to the nitrate removal efficiency of the bioreactors during the reporting period.

Wood chips

Of special note is that the wood chips to be used in a bioreactor should be relatively uniform in size (preferably between ¼ to 2 inches with the majority being around 1 inch) and free from soil, leaves, needles, saw dust, small bark fragments and similar. Also, prior to installation it may be necessary to determine the hydraulic conductivity of the wood chips, as this value is an important parameter when designing the bioreactor. The hydraulic conductivity for the woodchips of 0.31 ft./s we used in our design are based on the value determined by the Porous Media Lab at Iowa State University for woodchips from Golden Valley Hardscapes (our supplier of wood chips).

Depending on the moisture content of the woodchips, a truckload holds approximately 100 cubic yards. With multiple truck loads needed for each bioreactor, truck access or other means of moving woodchips to the site is a factor when deciding on a reactor location.

For the Baltic and the Montrose bioreactors the price of the wood chips broke down as \$10/cubic yard for the chips and approximately \$5/cubic yard for the transportation. The chips were delivered from the Golden Valley Hardscapes distribution center in Sioux City, Iowa.

Artificial N sink community

An artificial N sink community was formally established under the auspices of the American Society of Agronomy (ASA) at the ASA international meeting in Cincinnati, OH on October 23, 2012. The overall goal of the community is to formalize and solidify the collaborations and interactions among researchers, practitioners and the NRCS. The overall objective of the community is to define research questions, identify knowledge gaps and assist the NRCS in developing national or regional (Northern Great Plains region) standards for bioreactors and wetlands.

The community is currently chaired by Dr. Mark David from the University of Illinois while Drs. Louis Schipper from the University of Waikato, New Zealand and Tom Moorman from USDA-ARS in Ames, Iowa serve as vice chairs. PI Kjaersgaard serves as secretary for the community and will coordinate a poster session on case studies of bioreactors and wetlands at next year's ASA meeting held in Tampa, FL on November 3-7 2013.

Outreach and education

We have presented or discussed information relating to this project at the following events: 07/27/2012, **Ag Phd Field Day** demonstrating the on-site Baltic bioreactor, 3400 attendants of which we discussed bioreactors with an estimated 300 individuals, Baltic SD (Figure 3). 07/30/2012, **Drainage Field Tour and Workshop**, 180 attendants, Granite Falls, MN.

08/06-8/2012, **Farmfest**, demonstrating scale model of bioreactors, we discussed bioreactors with an estimated 100 individuals, Redwood Falls, MN.
08/17/2012, **Fish Lake Conservation Drainage Field Day**, 60 attendants, Windom, MN.
08/21-23/2012, **Dakotafest**, demonstrating scale model of bioreactors, we discussed bioreactors with an estimated 150 individuals, Mitchell SD.
09/20/2012, **East Dakota Water Development District** board meeting project update, Brookings, SD.
12/05-06/2012, **Bioreactor installation ‘open house’**, 20 attendants, Montrose, SD.

We have initiated an informal collaboration with Bruce Shewfelt, Evan Derdall and Erin Zoski from Agri-Food Canada. The Canadian group is in the process of installing and monitoring bioreactors to remove nitrate from tile drainage water in the Canadian provinces of Manitoba, Ontario and Prince Edward Island. The collaboration includes the sharing of ideas, experiences, tips and hints relative to bioreactor siting, design, installation, monitoring, and management, as well as sharing of results, design evaluations and conclusions and site visits. Because of the overlap in the objectives and scope of the Canadian bioreactor project and our project, we hope this collaboration will help provide additional information relative to the use of bioreactors in northern climates.



Figure 3. Demonstrating the Baltic bioreactor at the Ag Phd Field Day on July 27 2012.

Bioreactors for Drainage Water Treatment

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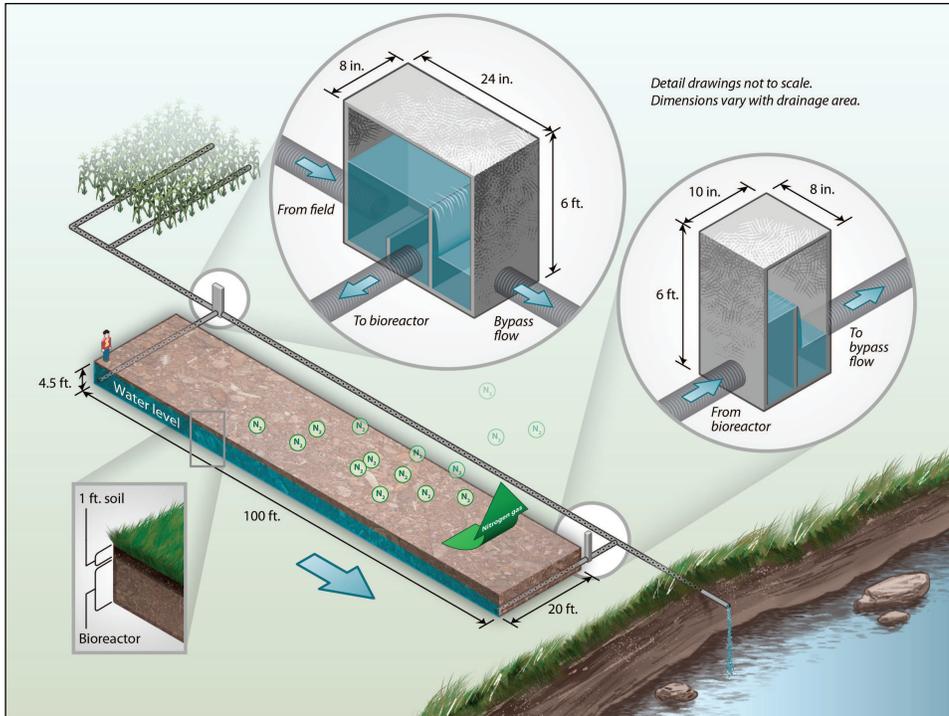


Diagram courtesy of Matt Helmers and Laura Christianson, Iowa State University. Illustration by John Peterson.



Photo courtesy of Mark Dittrich, Minnesota Department of Agriculture.

What is a bioreactor?

Bioreactors are one of a number of emerging conservation drainage practices (see Conservation Drainage box) for reducing the amount of nitrate in drainage water before it is released to surface waters. A bioreactor is a subsurface trench located along the edge of a field and filled with a carbon source, typically wood chips, through which the drainage water is passed. Control structures are used to control the flow of water through the bioreactor and to allow excess flows to bypass the system so that drainage isn't restricted.

How do bioreactors work?

The carbon source in the trench serves as a material for soil microbes to colonize. The microbes feed on the carbon source and 'breathe' the nitrate converting it into nitrogen gas. This process is called denitrification. The nitrogen gas is then released harmlessly into the atmosphere.

How effective are bioreactors?

Results of research on pilot scale and field scale bioreactors indicates that they can reduce nitrate levels in drainage water by 30 to 70%.

Advantages of bioreactors

- Based on proven technology
- Little or no land needs to be taken out of production
- Do not require a change in drainage practices
- Can be retrofitted to existing drainage systems
- No reduction in drainage effectiveness
- Require little maintenance (changing control structure levels a few times a year)

How much do bioreactors cost?

The average cost of field scale bioreactors installed by the Iowa Soybean Association for 40 to 80 acre drainage areas have averaged \$8,000. Although there is currently no financial incentive for producers to install bioreactors, it is hoped that as more is learned about these systems, they will be considered worthy of public funding. In Iowa, the EQIP program currently offers a 50% cost-share for bioreactor installations.

How long do bioreactors last?

The wood chips in the bioreactor should last for 10 to 20 years. At that time the wood chips can be replaced to restore the bioreactor function, or if the producer chooses not to replace the chips, the stop logs can be removed from the control structures and drainage will continue normally.

Bioreactor design criteria

The USDA NRCS in Iowa has an interim conservation practice standard for denitrifying bioreactors (Interim IA-747) that provides some design criteria. The interim standard calls for a design capacity to treat a flow equivalent to a drainage coefficient of 1/8" per day or 20% of the calculated peak flow from the drainage system. Bioreactors should be designed to meet the capacity requirements with a hydraulic retention time (the time it takes for water to pass through the bioreactor) sufficient to achieve the desired nitrate reduction. Current recommendations are for a retention time of 4 to 8 hours. Iowa State University has developed a spreadsheet calculator to assist with bioreactor design (see example spreadsheet).

Why is nitrate in drainage water an issue?

- Although subsurface drainage generally reduces sediment and phosphorous pollution, it often increases losses of dissolved pollutants such as nitrate-nitrogen
- Nitrate is both a human health concern (drinking water) and a cause of surface water impairments
- Excess nitrogen from agricultural land in the Mississippi River basin, particularly from more heavily drained states in the Midwest, is a leading contributor to the hypoxic (dead) zone in the Gulf of Mexico
- EPA has a goal for a 45% reduction in annual nitrogen deliveries to the Gulf by 2015

Subsurface Drainage Bioreactor Design

Developed by M. Helmers, ABE Iowa State University
Instructions: Enter values in gray cells

Field Information:	
Tile Size (in)	5
Tile Grade (%)	1
Dual Wall	no
Velocity in Pipe (ft/s)	2.20
Peak Flow from Tile Size (cfs)	0.30
Media Information:	
Conductivity of Wood Media (ft/s) (K)	0.31168
Porosity of Wood (p)	0.7
Bioreactor Inputs and Calculations:	
Flow Length (ft) (L)	80
Trench Width (ft) (W)	30
Depth of Trench below Inlet (ft) (d _t)	0
Head Drop (ft) (DH)	1
Flow Depth (ft) (d)	0.5
Hydraulic Gradient (i)	0.0125
Results:	
Bioreactor Flow Rate (cfs) (Q)	0.06
Hydraulic Retention Time (hours) (HRT)	4.0
% of peak flow that can be passed through bioreactor	19.5

Example spreadsheet calculator for bioreactor design. Bioreactor dimensions and water control elevations are chosen such that at least 20% of the peak flow can be treated with a hydraulic retention time of 4 to 8 hours. Spreadsheet courtesy of Matt Helmers, Iowa State University.

Conservation Drainage

Conservation drainage is the use of practices designed to maintain the benefits of drainage while minimizing negative environmental impacts, including:

- Nutrient best management practices
- Shallow drainage
- Drainage water management (controlled drainage)
- Bioreactors
- Reduced drainage intensity
- Treatment wetlands and saturated buffers
- Cover crops
- Including perennials in the crop rotation
- Sediment trapping for surface inlets
- Two-stage ditches



South Dakota
Cooperative Extension Service



Appendix B

Iowa Subsurface Drainage Bioreactor Design for rectangular bioreactors

Design template introduction

The Iowa template was developed by Dr. Matt Helmers and Laura Christianson at Iowa State University. It is based on treating a percentage of the maximum potential flow of the tile outlet pipe (depending on the diameter, slope and material of the drainage pipe) for a certain residence time. Residence time is estimated using the design inlet flow, the head drop between the upstream and the downstream control structures and the hydraulic conductivity of the media (typically woodchips) in the reactor. These quantities are normally known or can be determined using information about the tile system design and the topography where the bioreactor is to be installed. The hydraulic conductivity of the woodchips, however, is based on lab-scale testing of similar woodchips in Iowa. After defining these input parameters, the dimensions of the bioreactor are iteratively determined based on the desired residence time of the water in the reactor and the percentage of peak flow (i.e. the tile line is full) that should be treated. The chosen percentage of peak flow treated and hydraulic residence times are a balancing act among nitrate removal performance, practical and economic decisions (land area required, volume of excavation and woodchips needed, cost, level of management required, etc.) and avoidance of possible negative side effects (nitrous oxide emissions or methylation of mercury from the woodchips). Fine-tuning the design criteria is an area of continuing research. The currently recommended design criteria in Iowa are treatment of 20% of the peak flow at a retention time of 4-8 hours.

The advantages of the Iowa design template are that it is relatively easy to set up and use, and the required input information are somewhat readily available. The disadvantage is that the system is based on the tile size, which may or may not be an accurate indicator of how much water will flow through the tile under “typical” conditions.

The Iowa design template has been developed into an Excel Spreadsheet and is recommended by the Iowa NRCS for bioreactor design.

Design template overview

Table A-1 shows the required input, intermediate calculation results and output from the Iowa subsurface drainage bioreactor design template. A side-view schematic of a bioreactor providing an overview of the parameters required for the parameterization is shown in Figure A-1.

Table A-1. Overview of the needed input provided by the user, intermediate calculations and output from the Iowa subsurface drainage bioreactor design template.

Field Information:	Data Source	Comment
Tile Size (in)	User	Known from site
Tile Grade (%)	User	Known from site
Dual Wall pipe (yes/no)	User	Known from site
Velocity in Pipe (ft/s)	Calculation	Calculated using Mannings Flow Eq.
Peak Flow from Tile Size (cfs)	Calculation	Calculated as Velocity X Area of Tile
Media Information:		
Conductivity of Wood Media (ft/s) (K)	User	Value determined at Iowa State Univ.: 0.311 ft/s
Porosity of Wood (ρ)	User	From Van Driel et al., 2006: 0.7 cm ³ /cm ³
Bioreactor Inputs and Calculations:		
Flow Length (ft) (L)	User	Choose iteratively
Trench Width (ft) (W)	User	Choose iteratively
Depth of Trench below Inlet (ft) (d_i)	User	Adjust depending of site specs.
Head Drop (ft) (DH)	User	Adjust depending of site specs.
Flow Depth (ft) (d)	Calculation	Calculated for the bioreactor center
Hydraulic Gradient (i)	Calculation	Head Drop / Flow Length
Results:		
Bioreactor Flow Rate (cfs) (Q)	Calculation	Calculated using Darcy's Law
Hydraulic Retention Time (hours)	Output	Target: 4-8 hours
% of peak flow that can be passed through bioreactor	Output	Target: 20 %

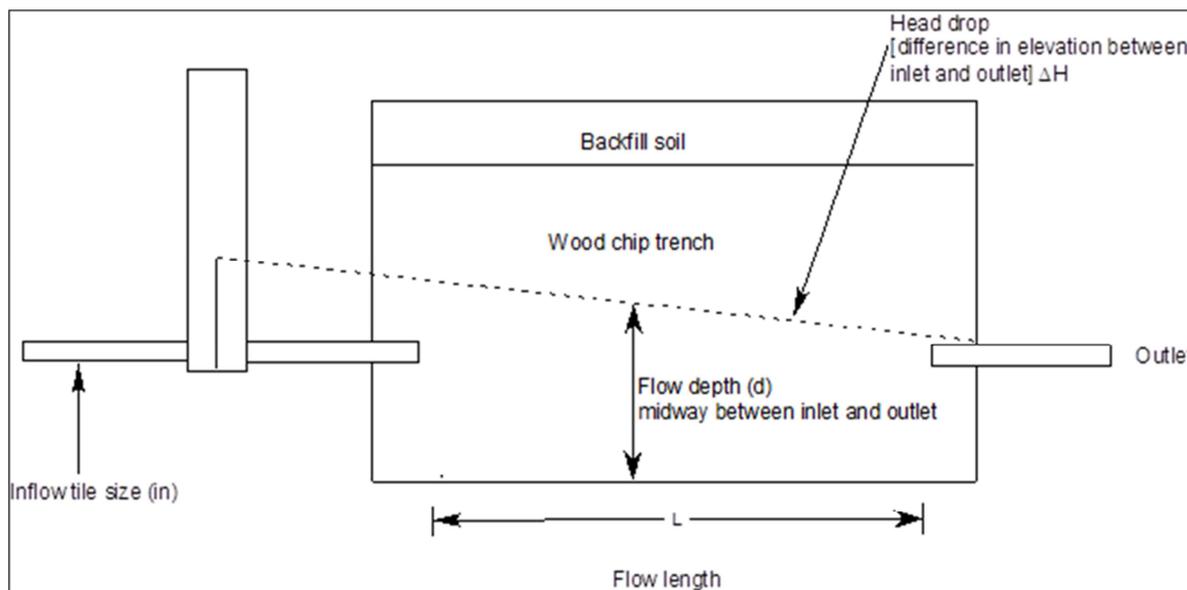


Figure A-1. Side-view of a bioreactor showing some of the parameters needed to parameterize the Iowa subsurface drainage bioreactor design template. Graphic by Dr. Matt Helmers, Iowa State University.

Design template parameterization

The parameterizations of the Baltic and the Montrose bioreactors are shown in Figures A-2 and A-3. Because the tile grade at the Baltic site was unknown, the grade was determined by

comparing the tile depth approximately 100 ft. upstream of the bioreactor to the tile depth at the bioreactor. At Montrose, information about the tile grade was available from the tile map.

Subsurface Drainage Bioreactor Design	
Developed by M. Helmers and L. Christianson, ABE Iowa State University	
Instructions: Enter values in gray cells	
Field Information:	
Tile Size (in)	6
Tile Grade (%)	0.6
Dual Wall	no
Velocity in Pipe (ft/s)	1.92
Peak Flow from Tile Size (cfs)	0.3777
Media Information:	
Conductivity of Wood Media (ft/s) (K)	0.31168
Porosity of Wood (p)	0.7
Bioreactor Inputs and Calculations:	
Flow Length (ft) (L)	115
Trench Width (ft) (W)	18
Inlet height (ft)	2
Outlet height (ft)	0.46
Head Drop (ft) (ΔH)	1.54
Flow Depth (ft) (d)	1.23
Hydraulic Gradient (i)	0.013391
Results:	
Bioreactor Flow Rate (cfs) (Q)	0.09
Hydraulic Retention Time (hours) (HRT)	5.36
% of peak flow that can be passed through bioreactor	24.47

Figure A-2. Design template parameterization for the Baltic Bioreactor.

Subsurface Drainage Bioreactor Design	
Developed by M. Helmers and L. Christianson, ABE Iowa State University	
Instructions: Enter values in gray cells	
Field Information:	
Tile Size (in)	8
Tile Grade (%)	0.4
Dual Wall	no
Velocity in Pipe (ft/s)	1.90
Peak Flow from Tile Size (cfs)	0.6641
Media Information:	
Conductivity of Wood Media (ft/s) (K)	0.31168
Porosity of Wood (p)	0.7
Bioreactor Inputs and Calculations:	
Flow Length (ft) (L)	130
Trench Width (ft) (W)	21
Inlet height (ft)	2.6
Outlet height (ft)	0.46
Head Drop (ft) (ΔH)	2.14
Flow Depth (ft) (d)	1.53
Hydraulic Gradient (i)	0.016462
Results:	
Bioreactor Flow Rate (cfs) (Q)	0.16
Hydraulic Retention Time (hours) (HRT)	4.93
% of peak flow that can be passed through bioreactor	24.82

Figure A-3. Design template parameterization for the Montrose Bioreactor.

Appendix C

Pictures from the bioreactor installations



Figure B-1. Excavation begins (top left), trench halfway completed (top right), trench completed (center left), the wood chips are unloaded (center right), lining the trench (bottom left) and backfilling the trench with woodchips (bottom right)



Figure B-2. The collector manifold is installed (top left), installing a control structure (top right), backfilling nearly complete (center left), rolling out the geotextile (center right), backfilling topsoil (bottom left) and bioreactor after completion before reseeding (bottom right).

Evaluation of wastewater produced in biomass pyrolysis process

Basic Information

Title:	Evaluation of wastewater produced in biomass pyrolysis process
Project Number:	2012SD216B
Start Date:	3/1/2012
End Date:	2/29/2014
Funding Source:	104B
Congressional District:	First
Research Category:	Engineering
Focus Category:	Acid Deposition, Water Use, Treatment
Descriptors:	
Principal Investigators:	Lin Wei, Todd P. Trooien

Publications

There are no publications.

Project Annual Report

Project Title: Evaluation of wastewater produced in biomass pyrolysis process

PI: Dr. Lin Wei; Co-PI: Dr. Todd Trooien

Reporting Period: March 1st, 2012 to Feb. 20th, 2013

Date of Report: April. 28th, 2013

Written By: Dr. Lin Wei, Dr. Todd Trooien

Executive summary

To evaluate the quantity and characterize the wastewater produced in catalytic pyrolysis of various biomass feedstocks, the research team has completed catalytic pyrolysis tests of corn stover and sawdust to produce crude bio-oil and upgraded the bio-oil to drop in fuels. The test results showed that 40 – 50% (w.t.) of wastewater would be generated when quality liquid biofuels were produced. Wastewater samples were collected and partially completed the characterization of the wastewater due to limited access to analytic instruments, which has resulted in the wastewater evaluation delayed. But new analytic instruments have been purchased and installed in the labs recently. The new equipment would help the team finish the project within the 1-year no-cost extension. The research project has provided a platform to train four PhD/M.S. graduate students (Yijing Wang, Parvathi Jampani, Dan Liu, and Xianhui Zhao) and two postdocs (Zhongyi Ma and Chunkai Shi) for biomass thermochemical conversion and wastewater analysis and provide useful information for future bio-refinery industry.

Background

Our future requires secure and affordable energy supplies but fossil fuel reserves are finite. We must find and develop alternative energy without disrupting food supplies or causing environmental degradation. Currently biomass is the only known source for the production of renewable liquid transportation fuels. Pyrolysis has been shown to be a very promising process to convert biomass materials such as corn stover, cord grass, wood residues, etc. to liquid transportation fuels. The National Renewable Energy Laboratory (NREL) estimated that industrial scale production costs of renewable transportation fuels produced from biomass pyrolysis range from \$2.10 to 3.10 per gallon (Wright et al., 2010), which may compete with fossil fuels if petroleum prices were higher than \$100 per barrel. Properly utilizing biomass resources can significantly contribute to national energy security, local economic growth, and environmental improvement.

Nonetheless biomass pyrolysis may also produce wastewater during bio-fuel production, as much as 20 to 60% of the volume of bio-fuel produced, depending on the biomass pyrolysis and bio-oil upgrading technologies used. Millions of gallons of wastewater will be produced if we achieve the goal of “25x25”, in which we get 25 percent of our energy from renewable resources in America by the year 2025. It is necessary to explore effective solutions for wastewater utilization for future biofuels industries and biomass feedstock producers before the impacts occur.

Biomass materials may contain various traces of chemical elements or metals such as Mg, Fe, Cu, Zn, Na, K, Mo, or Mn and many catalysts that contain Al, Cu, Fe, Ni, Pt, Pd, Rh, or Rb are involved in catalytic pyrolysis and bio-oil upgrading reactions for biofuel production. These elements or their compounds may be left in the wastewater and ash residues during

processing. The wastewater contaminants can be divided into two subcategories: organic and inorganic. The main organic contaminants may include acetic acids, phenols, alcohols, polyaromatic compounds, etc. The main inorganic residues may include ammonia, H₂S, chlorides, and traces of platinum group metals (Pt, Pd, Rh, or Ru) from the catalysts. These contaminants may make the wastewater unusable for some purposes. Even after processing for extra value-added products, many of these compounds may still left behind and resist biological degradation or exert significant toxicity towards environments. But the wastewater may be usable for other purposes or treatments may be available to make the wastewater usable for still other purposes. The goal of this study is to evaluate the quantity and characterize the wastewater produced in catalytic pyrolysis of various biomass feedstocks. The specific objectives are:

- 1) Conduct catalytic pyrolysis for converting various biomass feedstocks into liquid biofuels.
- 2) Characterize of the wastewater from the catalytic pyrolysis and evaluate the potential impact of wastewater on biomass refinery and environment.
- 3) Explore possible solutions for wastewater utilization.

Planned activities:

Table 1 Planned tasks to be completed in this study

Task 1	Set up pyrolysis reactors and prepare biomass feedstocks including corn stover, wood sawdust, and cordgrass.
Task 2	Conduct pyrolysis tests for converting the feedstocks into bio-oil. Evaluate the bio-oil and collect the wastewater generated for analysis.
Task 3	Upgrade the bio-oil to drop-in fuels. Evaluate the drop-in fuels and collect the wastewater generated for analysis.
Task 4	Characterize the pyrolysis wastewater generated and evaluate its potential
Task 5	Characterize the bio-oil upgrading wastewater and evaluate its potential
Task 6	Based on the results of characterization and analysis of the wastewater, the study will provide suggestions for renewable energy industries, biomass producers, and/or lawmakers and the research team will search more external funds for further research.

Actual Accomplishments:

1. Set up catalytic fast pyrolysis systems and conduct biomass pyrolysis and bio-oil upgrading tests

A liquid biofuels production system including a catalytic fast pyrolysis (CFP) reactor and a bio-oil upgrading HDO reactor was set up in the Advanced Biofuel Development Laboratory (ABDL) in the Ag. and Bio. System Dept. on SDSU campus. This system can convert various biomass materials to bio-oil and then upgrade the bio-oil into liquid biofuels (mixed hydrocarbons) that are compatible to petroleum hydrocarbons and can be directly dropped into existing petroleum refinery for production of “green” gasoline, diesel, and jet fuels. This liquid biofuel is so called “drop-in fuel”. The corn stover obtained from a corn farm at

Brookings, SD 57006, and the pine wood shavings bought from a lumber company, Hills Products Group at Spearfish SD 57783, were used as feedstocks in this study. These feedstocks were first air-dried and then ground into powder. The pine shavings powder is called sawdust. The moisture content and particle size of the powders were determined and the results are showed in Table 2. Analysis of particle size distribution is shown as Figure 1 and 2 respectively.

Table 2 Moisture Content of Feedstock

Feedstock	Corn Stover	Sawdust
Moisture Content (wt %)	6.05	7.15
Particle Size < 1mm (wt %)	87	85

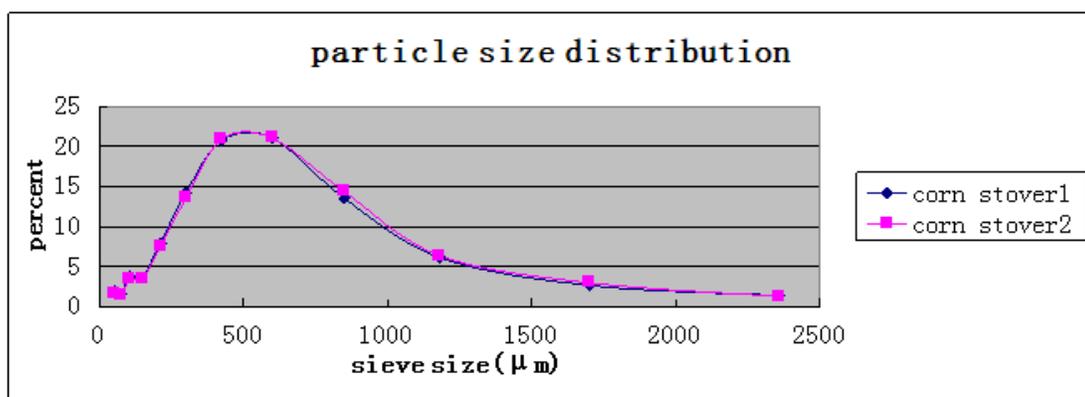


Figure 1 Particle size distribution of the corn stover powder

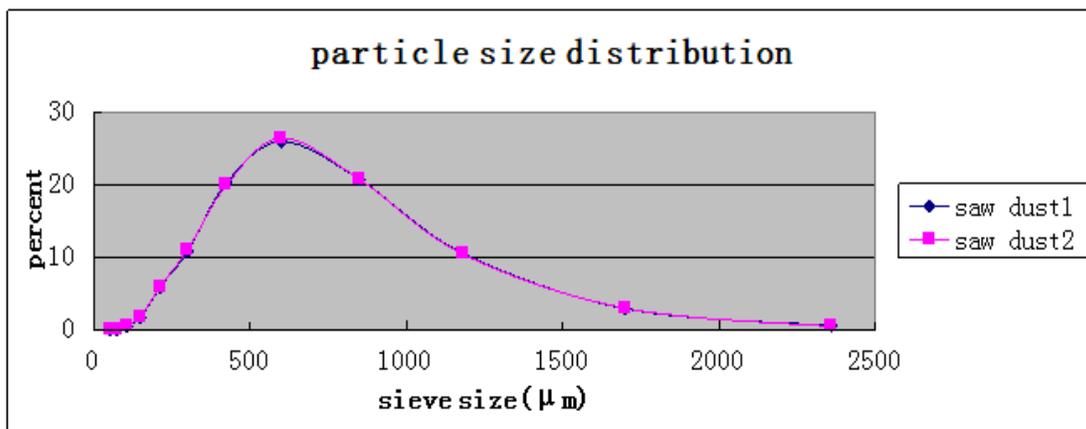


Figure 2 Particle size distribution of the pine sawdust

The prepared biomass feedstocks were fed into the CFP reactor to produce bio-oils at three different temperatures. Sawdust was tested at 648°C/1200°F and 760°C/1400°F. Corn stover was tested at 537°C/1000°F, 648°C/1200°F, and 760°C/1400°F respectively. 2 kg/h of biomass feedstock feeding rate was used for each test. After each test run, bio-oil samples were immediately characterized. Bio-oil density, pH value, dynamic viscosity, heating value,

water content, organic elemental content, etc. were determined. The chemical composition of bio-oil was also analyzed by using a Gas chromatography/mass spectrometry (GC/MS) system (Agilent model 5890 with DB-5 column). The yield rate of bio-oil and wastewater produced were also calculated. Up to 65% of bio-oil yield from sawdust has been achieved. The characterization results are showed in Table 3. The bio-oils' chemical composition profiles are shown as Figure 3. The compounds having high peaks in the profiles were identified by an internal data library (NIST08).

Table 3 Properties of bio-oil produced

Properties	Corn Stover	Sawdust
Density (g/ml)	1.048	1.045
pH	2.7- 3.5	2.0-2.9
Viscosity (cp at 20°C)	3.2	9.8
Moisture Content (wt%)	54.88	47.04
Heating Value (MJ/Kg)	10.19	13.81

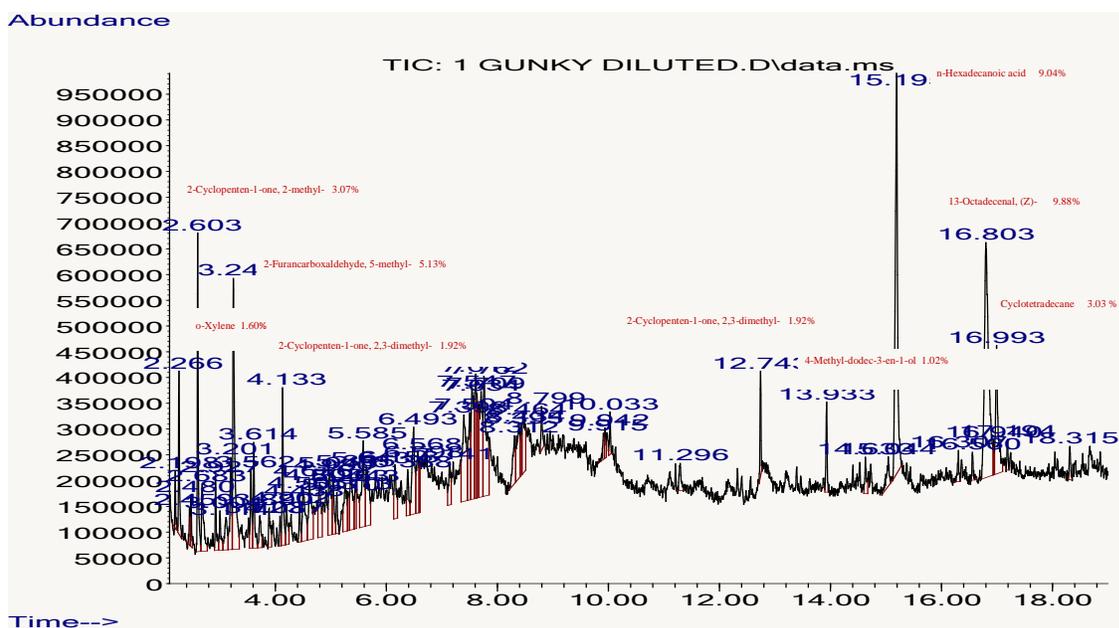


Figure 2. GCMS analysis of raw bio-oil

The bio-oils produced from corn stover and sawdust were fed into the bio-oil upgrading HDO reactor to be converted into liquid bio-fuels (mixed hydrocarbons). Zeolite based and activated carbon based catalysts were prepared and used in the bio-oil upgrading process. After bio-oil upgrading, good quality drop-in fuel was obtained. The drop-in fuels' properties are shown in the table 4. The results indicated that the liquid mixed hydrocarbons are compatible to petroleum-based hydrocarbons and very close to gasoline and diesel. They can

be compatible to petroleum hydrocarbons and can be dropped into existing petroleum refinery.

Table 4 Comparison of raw bio-oil and upgraded bio-oil, produced from corn stover, and petroleum based gasoline, diesel and jet fuel

Properties	SDSU Raw bio-oil	SDSU Upgraded bio-oil	Gasoline	Petro-diesel
pH value	2.8 – 3.2	5.0 – 5.6		
Viscosity cSt @20°C	20 – 50	1.2 – 1.88	0.4 – 0.8	1.9 – 4.1
Density, Kg/L	0.9 – 1.06	0.8 – 0.85	0.745	0.832
Heating value, MJ/kg	16 – 23	41 – 45	43	42
Carbon content, % w.t.	24 – 28	84.59 – 85.12	85 – 88	87
Hydrogen content, % w.t.	8.5 – 10.1	10.9 – 11.26	12 – 15	13
Oxygen content, % w.t.	35 – 40	1.4 – 1.72	0	0
Water content, % w.t.	35 – 47	< 0.2%	0	0

2.Collection and characterization wastewater samples

After bio-oil upgrading, the wastewater produced was 40 to 50% (w.t.) of the bio-oil. The wastewater samples produced in different biomass pyrolysis tests were collected and characterized. The wastewater pH value, dissolved oxygen (DO), and salinity, measured as electrical conductivity (EC) were measured with portable probes. The test results are shown in table 5. GC/MS analysis was also carried out for the wastewater sample produced from sawdust pyrolysis (Figure 5).

Table 5 Properties of the wastewater produced from different biomass pyrolysis tests

Wastewater sources	pH	DO, Mg/L	EC, uS/cm	Salinity hazard rating for irrigation
Sawdust 1	3.6	5.5	380	Medium
Sawdust 2	3.3	6.6	810	High
Corn stover 1	3.1	5.8	660	Medium
Corn stover 2	2.4	6.8	670	Medium
Corn stover 3	2.7	6.5	620	Medium

Note: the wastewater produced from sawdust tested at 1200°F and 1400°F is named sawdust 1 and 2. The wastewater produced from corn stover tested at 1000°F, 1200°F, and 1400°F is named corn stover 1, 2, and 3.

The five samples with EC values of less than 750 uS/cm would be considered medium salinity hazards for use as irrigation water. Values greater than 750 uS/cm would result in salinity hazard ranking in the low end of the High hazard ranking. Assuming any irrigated soils would have reasonable permeability and allow at least some drainage and salt leaching, the salinity risks posed by these wastewater samples are less than many irrigation water sources used in the region. The results of GC/MS analysis indicate that there were still some water solvable organic compounds/hydrocarbons left in the wastewater. There may be still potential for harnessing value-added products from the wastewater if properly treated.

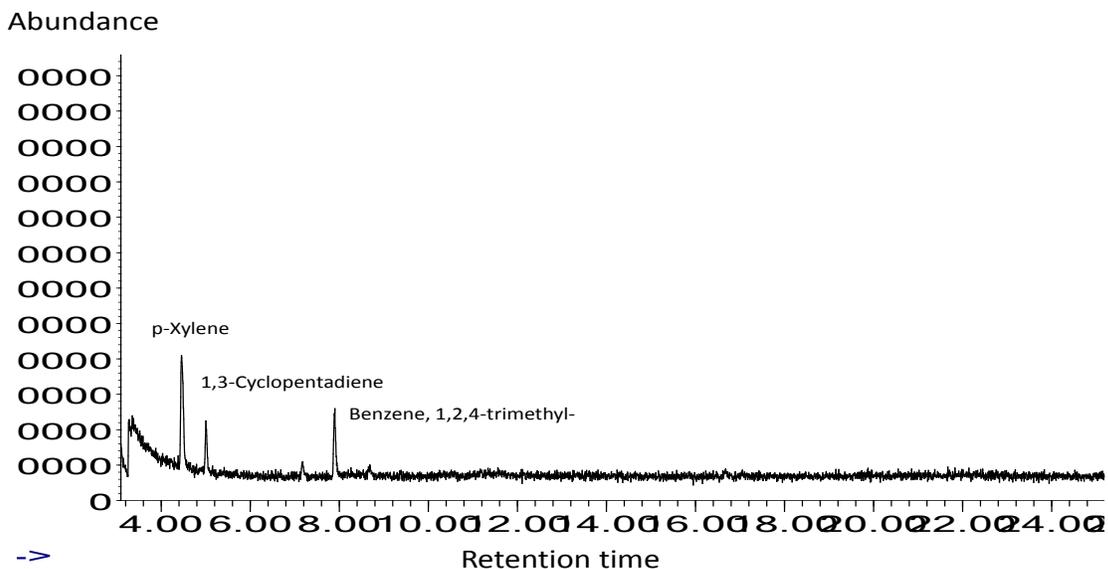


Figure 5 GCMS analysis of wastewater produced from bio-oil upgrading,

The research were not able to conduct comprehensive evaluation for the wastewater since there are still some wastewater parameters that haven't been measured in the project period due analytic instrument access limitation. For instance, the chemical quantification of wastewater, metal element content, etc. have resulted in the inability to finish the project in the expected time. Supported by the ABE Dept. the research team has recently purchased an organic elemental analyzer and an auto Calorimeter and obtained an Atomic Absorption Spectroscopy from Plant Science Department in SDSU. These analytic instruments will help the team to finish the project in near future.

3. Education and training

There were four PhD/M.S. graduate students (Yijing Wang, Parvathi Jampani, Dan Liu, and Xianhui Zhao) and two postdocs (Zhongyi Ma and Chunkai Shi) have been involved in the projects. The two PhD students and two Postdocs were supported by the funds from DOE (DE-FG36-08GO88073) and USDA projects (2011-67009-20030). They have been working on the biomass pyrolysis and bio-oil upgrading. Two M.S. students (Yijing Wang, Parvathi Jampani) mainly focused on wastewater collection and characterization. These two students were supported by the 104b funds for working in summer 2012. They have gained knowledge and skills to work on biorefinery wastewater for data collection and laboratory analysis of the samples. Both of them graduated in Fall 2012.

4. Project outcomes and challenges

The outcomes of this project included:

- Completed catalytic pyrolysis tests of corn stover and sawdust to produce crude bio-oil and upgraded the bio-oil to drop in fuels.
- Completed the characterization of bio-oil and drop-in fuels produced.
- Collected the wastewater samples and partially completed the characterization of the wastewater.
- Used the preliminary data to support a new proposal for USDA NIFA funding support.

- Trained four PhD/M.S. graduate students (Yijing Wang, Parvathi Jampani, Dan Liu, and Xianhui Zhao) and two postdocs (Zhongyi Ma and Chunkai Shi) for biofuel production and wastewater analysis.

There are still some challenges for the bio-refinery process and wastewater study.

- There are still some wastewater parameters that haven't been measured in the project period due analytic instrument access limitation. For instance, the chemical quantification of wastewater, metal element content, etc. have resulted in the inability to finish the project in the expected time.
- The information provided in this research is still limited due to lack of research funding and short research time period. A 1-year no-cost extension request has been approved. The research will go on until 2/28/2014. A proposal has been submitted to USDA NIFA to request \$1 million research funding for the research of water resource sustainability in different bioenergy platforms and the impacts of thermochemical biomass conversion wastewater on agricultural irrigation and the environment.

5.Plans for the 1-year non-cost extension

- Continue to complete the characterization of wastewater, including metal element analysis, quantification of chemical compounds, etc. Provide useful information for future research, biofuel industrial, government, and the public.
- Evaluate the potential of harnessing value-added chemicals from the wastewater. Suggest/develop innovative processes for the wastewater disposal.
- Publish research results, new finding, or new technologies in professional conferences or journals.
- Explore external funding support and collaborations to improve the research

Summary

The research team has completed catalytic pyrolysis tests of corn stover and sawdust to produce crude bio-oil and upgraded the bio-oil to drop in fuels. The test results showed that 40 – 50% of wastewater would be generated when quality liquid biofuels were produced. The wastewater samples were collected and partially completed the characterization of the wastewater due to limited access to analytic instruments, which has resulted in the wastewater evaluation delayed. But new analytic instruments have been purchased and installed recently in the labs. The new equipment would help the team finish the project within the 1-year no-cost extension. The research project has provided the platform to train four PhD/M.S. graduate students (Yijing Wang, Parvathi Jampani, Dan Liu, and Xianhui Zhao) and two postdocs (Zhongyi Ma and Chunkai Shi) for biomass thermochemical conversion and wastewater analysis and provide useful information for future bio-refinery industry.

Reference:

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Information Transfer Program Introduction

The Information Transfer Program includes public outreach, interpretation of laboratory analysis results, active participation in the annual Dakotafest farm show, steering committee representation and leading involvement in the Big Sioux Water Festival and in The Eastern South Dakota Water Conference, interactions with extension agents and local, state and federal agencies, participation and presentations at regional and national conferences, youth education, adult education and university student training and education. Publications, such as pamphlets, educational materials, reports and peer-reviewed journal entries are made available in paper format and electronic through the Institute's website and are designed to support the mission of the Institute.

FY12 Information Transfer Program

Basic Information

Title:	FY12 Information Transfer Program
Project Number:	2012SD217B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	First
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, Water Use
Descriptors:	Outreach, Information, Communication, and Collaboration
Principal Investigators:	Van Kelley, Kevin Dalsted, Jeppe H Kjaersgaard, Trista Marie Koropatnicki

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FY12 Information Transfer Program

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SD WRI 2012-2013 Information Transfer Program
South Dakota Water Resources Institute

The Information Transfer Program includes public outreach, interpretation of laboratory analysis results, active participation in the annual Dakotafest farm show, steering committee representation and leading involvement in the Big Sioux Water Festival hosting 1,000 fourth grade students and in The Eastern South Dakota Water Conference, which is the largest water conference in Eastern South Dakota with 200 participants, interactions with extension agents and local, state and federal agencies, participation and presentations at regional and national conferences, youth education, adult education and university student training and education. Publications, such as pamphlets, educational materials, reports and peer-reviewed journal entries are made available in paper format and electronic through the Institute's website and are designed to support the mission of the Institute.

PUBLIC OUTREACH

Public outreach and dissemination of research results are cornerstones of the South Dakota Water Resources Institute's (SD WRI) Information Transfer Program. The Institute distributes information through a variety of outlets, including interactive information via the Internet, pamphlets and reports, direct personal communication, hands-on demonstrations and through presentations and discussions at meetings, symposia and conferences. In addition, the SD WRI actively uses its Facebook page for two-way communication on water-related topics. These outlets are described below.

Water News Newsletter

The South Dakota Water Resources Institute *Water News* quarterly newsletter is in its ninth year of publication. Water-related research including updates on present projects, notification of requests for proposals, state-wide water conditions, conferences, and youth activities are common topics featured in each issue of the newsletter.

The newsletter is an effective method to disseminate information about activities in which the Institute participates, funds, and promotes. The newsletter is distributed at no cost via e-mail to nearly 200 subscribers across the United States. Current and past issues of the newsletter are available through the SD WRI website (<http://sdstate.edu/abe/wri>) in PDF format. The website additionally has a subscription request form where interested individuals can sign up to receive the newsletter.

SD WRI Website

During the past years, substantial efforts have gone into updating and redesigning the SD WRI website which is accessible through <http://www.sdstate.edu/abe/wri/>. The website continues to be updated to contain information relating to water resources, current and past research projects, reference material and extension publications. The website content is updated to reflect current conditions relating to water issues, such as water quality impact during drought situations. Since redesigning the website, the Institute has actively used the website as the entry portal relaying information relating to the Institute and water topics. As a result, we continue to see increased traffic to the website. One feature of the SD WRI website is it allows users access to updated links which include publications and on-line tools to help diagnose and treat many water quality

problems. The site allows the public access to information about the activities of the Institute, gather information on specific water quality problems, learn about recent research results and links with other water resource related information available on the Internet. The “Research Projects” section of the SD WRI web contains past and present research projects, highlighting the Institute’s commitment to improving water quality. An extensive library of information relating to water quality has been developed and continues to be updated on-line.

Water quality analysis interpretation

SD WRI staff continues to provide interpretation of analysis and recommendations for use of water samples submitted for analysis. Assistance to individual water users in identifying and solving water quality problems is a priority of the Institute’s Information Transfer Program. Interpretation of analysis and recommendations for suitability of use is produced for water samples submitted for livestock suitability, irrigation, lawn and garden, household, farmstead, heat pump, rural runoff, fish culture, and land application of waste. Printed publications and on-line information addressing specific water quality problems are relayed to lab customers to facilitate public awareness and promote education. SD WRI conducted approximately 50 interpretations during the reporting year.

SD WRI staff also routinely responded to water resource questions unrelated to laboratory analysis from the general public, other state agencies, livestock producers, and SDSU Extension Specialists. These inquiries include water quality and quantity, stream monitoring, surface water/ground water interactions, livestock poisoning by algae, lake protection and management, fish kills, soil-water compatibility, irrigation and drainage.

Eastern South Dakota Water Conference

SD WRI staff chaired the seventh annual Eastern South Dakota Water Conference (ESDWC) held on October 30, 2012 to provide a forum for water professionals to interact and share ideas. Water is an important piece of the economic future of South Dakota, and this conference serves as a mechanism to educate participants on this resource. Sessions throughout the conference offered information important to a wide array of stakeholders including engineers, industry, public officials, agricultural producers, and conservation groups. Speakers highlighted the importance of the scientific method to determine the state of our water resources. The Eastern South Dakota Water Conference was started in 2006 to serve as a mechanism to educate participants on water resource issues in South Dakota.

The goal of the 2012 Eastern South Dakota Water Conference was to bring together federal, state, and local governments, along with university and citizen insights. The event, in its fifth year, and included speakers and presenters from South Dakota State University (SDSU), South Dakota School of Mines and Technology, The Day Conservation District, South Dakota Department of Water and Natural Resources, North Dakota State University and many others.

The call for abstracts was released in June 2012. Attendees registered and submitted their conference payment directly through the conference website hosted by the website. A registration fee of \$65 was charged for individuals attending the 2012 ESDWC in a professional capacity. Students and citizens attending the conference in a non-professional capacity attended for free.

In 2012 there were 145 registered attendees and an estimated additional 50 non-registered attendees, mostly students. A breakdown of the background of the 145 registered attendees is shown in Figure 1.

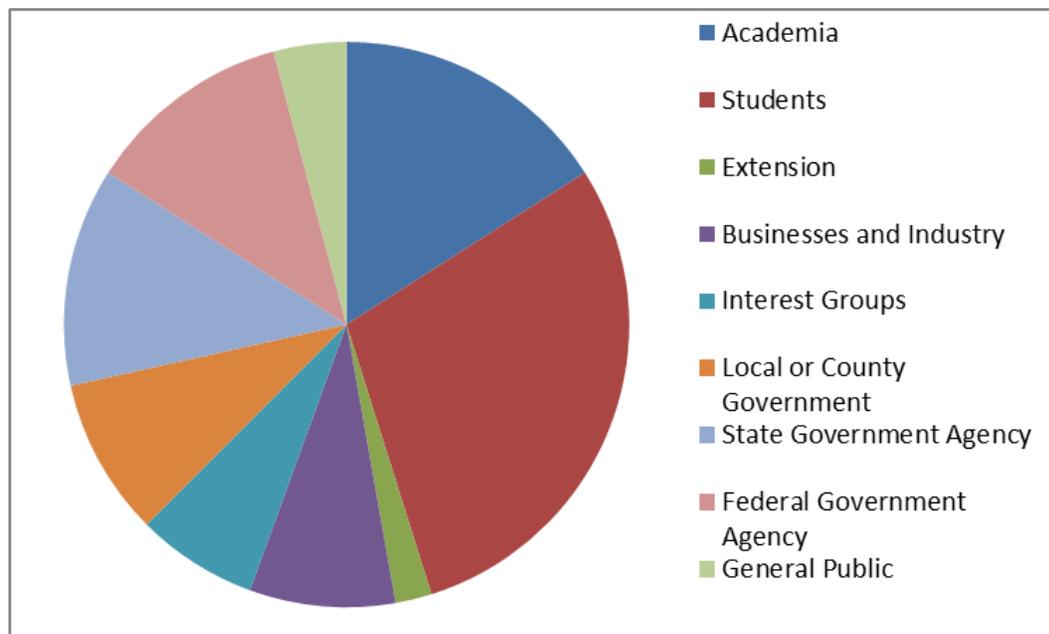


Figure 1. Background of the 145 registered attendees at the 2012 ESDWC.

A poster competition for college students was held in which ten student posters were presented. The posters were assessed by 4 judges, who scored each poster and provided written feedback to the student presenters. A first prize of \$200 and a second price of \$100 were awarded to the two highest ranked poster presentations.

Mark Anderson, Director of the USGS South Dakota Water Science Center in Rapid City, SD opened the conference with a plenary presentation addressing differences in runoff between the water years 2011 and 2012. Tim Cowman, Director of the Missouri River Institute at University of South Dakota, Vermillion, SD, discussed the impacts of the 2011 flood on the Missouri River Channel. David Ganje, Esq., from Ganje Law Offices in Rapid City, SD and Albany, NY was the lunch keynote speaker. He discussed the legal steps for obtaining an irrigation permit in South Dakota.

The conference featured a workshop titled “Geospatial Data Use and Access – How do I find and use maps and other spatial information in water resources management?” The workshop was held on October 30 2012 from 4:00 – 6:00 PM on the campus of South Dakota State University. The workshop was led by Mary O’Neill from the SD WRI while Dr. Jeppe Kjaersgaard from the SD WRI assisted. In the first part of the workshop Ms. O’Neill identified sources of geospatial information and demonstrated, through hand-on activities, how to acquire and manipulate the information. In the second part of the workshop, Ms. O’Neill led hands-on training in the use of GIS cloud computing using ESRI’s ArcGIS platform. Each participant received an unlocked 1.8 GB thumb drive to download the projects they were working on during class. The drive was pre-loaded with the course materials. The course materials included:

1. A dataset downloaded from the USDA NRCS Data Gateway for Brookings County. Brookings County was selected for example purposes only. Workshop participants were guided through the process of downloading the same datasets for any county,
2. ArcGIS 10 and 10.1 map document files for viewing and analyzing the Brookings County datasets,
3. A spreadsheet listing all of the datasets that were downloaded along with filename information, and
4. A document titled “Cool Geospatial Websites” that list several additional sources of geospatial information and datasets.

Participation in regional water outreach and experience-sharing activities such as the Eastern South Dakota Water Conference is cost-prohibitive for several agencies and organizations resulting in geographical areas or population groups being underrepresented and underserved by these activities. These agencies and organizations include members of county or tribal government, local and regional interest groups, students and others. To enable their participation, travel stipends covering travel, registration and accommodation costs for representatives from underserved agencies and organizations from South Dakota were provided. The travel stipends were announced on the conference website and promoted in emails sent to the conference attendees. The announcement from the website is attached as Appendix E. An award committee consisting of Trista Koropatnicki and Jeppe Kjaersgaard from the SD WRI was appointed by the Steering Committee of the ESDWC. The stipends were awarded based on a stated interest and gain for the organization or agency resulting from participation in the conference. The awards were relatively popular and a total of eight stipends were awarded.

Additional information including detailed program about the conference is available at <http://www.sdstate.edu/abe/wri/activities/ESDWC/past-con/2011.cfm>.

iGrow Publications

SD WRI staff authored or coauthored several SDSU iGrow extension publications, including “Nitrates in South Dakota Drinking Water” (<http://igrow.org/up/resources/07-2000-2012.pdf>), “Watershed Management” (attached as Appendix A) and “iGrow Wheat: Best Management Practices for Wheat Production” (<http://igrow.org/product/igrow-wheat-best-management-practices-for-wheat-production/>).

AGENCY INTERACTIONS

The SD WRI Information Transfer program includes interaction with local, state, and federal agencies in the discussions of water-related problems in South Dakota and the development of the processes necessary to solve these problems. One of the most productive agency interactions is with the state Non-Point Source (NPS) Task Force, where the SD WRI is represented as a non-core member. The NPS Task Force is administered by the SD Department of Environment and Natural Resources which coordinates, recommends, and funds research and information projects relating to non-point water pollution sources. Participation on the NPS Task Force allows SD WRI input on non-point source projects funded through the task force and has provided support for research in several key areas such

as soil nutrient management, agricultural water management, biomonitoring, and lake research. Many of the information transfer efforts of the Institute are cooperative efforts with the other state-wide and regional entities that serve on the Task Force.

SD WRI personnel additionally served on several technical committees and boards, including

- the Central Big Sioux Master Plan Technical Review Committee, overseeing the monitoring and implementation of the Central Big Sioux water quality master plan for the city of Sioux Falls,
- Member of the steering committee of the EPA Region 8 Northern Plains and Mountains Regional Water Program,
- South Dakota NRCS Technical Committee, and
- Member of the steering committee for the 2012 NIFA National Water Conference

Several other local, state and federal agencies conduct cooperative research with SD WRI or contribute funding for research. Feedback to these agencies is often given in the form of reports and presentations at state meetings, service through committees and local boards, and public informational meetings for non-point source and research projects.

YOUTH EDUCATION

Non-point source pollution contributes to the loss of beneficial uses in many impaired water bodies in South Dakota. An important part of reducing non-point pollution is modifying the behavior of people living in watersheds through education. Programs designed to educate youth about how their activities affect water is important because attitudes regarding pollution and the human activities that cause it are formed early in life. For these reasons, Youth Education is an important component of SD WRI's Information Transfer Program.

Water Festivals provide an opportunity for fourth grade students to learn about water. Since they began in 1992 Water Festivals have been held in seven towns in South Dakota: Spearfish, Rapid City, Pierre, Huron, Vermillion, Brookings and Sioux Falls. SD WRI personnel were part of the organizing committee for the 2012 Big Sioux Water Festival held on May 8 2012 where 999 fourth grade students participated from eastern South Dakota. SD WRI was responsible for coordination of volunteers and helpers, and co-coordinating the exhibit hall.

Staff from the SD WRI served as judges at the annual Eastern South Dakota Science and Engineering Fair where 650 middle and high school students showcase projects scientific and creative ideas. The students test theories, perform experiments, test theories and learn about the scientific process. During the fair, the judges have the opportunity to discuss the students' projects and what they have learned from the experiments.

ADULT EDUCATION

As part of SDWRI's outreach to the agricultural community, staff hosted a booth at Farmfest and at DakotaFest, each a three-day agricultural fair held in August each year near Redwood Falls, MN and Mitchell, SD, which each draws approximately 30,000 people. A selection of literature and displays regarding water quality is available for distribution and SD WRI staff members field a variety of questions concerning water quality and current research for farm and ranch families. SD WRI staff also hosted a booth at the AgPhD field day held on July 29 near Baltic, SD and the Conservation Connection day held at Bramble Park Zoo in Watertown, SD.

South Dakota has experienced hydrologic extremes over the past decade that demonstrates the susceptibility of the state's water resources to climate extremes. The NSF funded project "Development of conceptual and mathematical models to understand and describe the uncertainty of hydrological events in the changing conditions of the state of South Dakota" was completed from March to September 2012. The basic principles of the hydrologic theory which needed to be developed to deal with hydrologic events were considered. The results obtained by international team from fifteen multi-discipline scientists were presented on one International (Moscow, Russia, 2013), one National (Washington, DC, 2012) conferences, one National colloquium (Boulder, CO, 2012), on two regional conferences (Vermilion, SD and Rapid City, SD) and three workshop-seminars (Iowa City, IA, 2012, Brookings, SD, 2012, and Rapid City SD, 2012).

SD WRI personnel additionally participated in and presented at several regional and national meetings and conferences, including

- Missouri River Research Symposium, Vermillion, SD held April 5 2012,
- Western SD Hydrology Conference, held April 19 2012,
- Land Grant and Sea Grant National Water Conference, Portland, OR held May 20-24,
- ASA, CSSA, and SSSA International Annual Meeting, Cincinnati, OH held October 21-24 2012,
- Western States ET Workshop, Boise, ID held October 24-26 2012, and
- Eastern South Dakota Water Conference held October 30 2012.

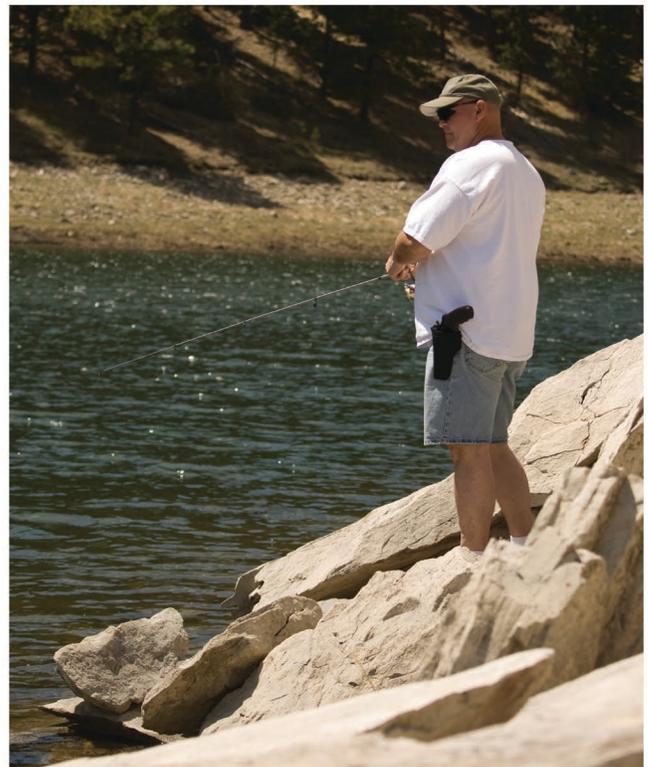
Watershed Management

Jeppé Kjaersgaard | SDSU Assistant Professor, South Dakota Water Resources Institute

Dennis Today | SDSU Associate Professor & State Climatologist, South Dakota Climate Office

Christopher Hay | SDSU Assistant Professor & Extension Specialist, Dept of Ag & Biosystems Engineering

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What is Watershed Management?

South Dakota has more than 95,000 miles of streams, of which over 9,000 miles are perennial. South Dakota also has almost 200,000 acres of classified, publicly owned lakes and reservoirs. Wherever you live, you are in a watershed, and you contribute to the quality and quantity of the water that enters South Dakota's lakes, reservoirs and streams.

A watershed is a land area that contributes all of the runoff to a point of interest, such as a lake or the mouth of a stream or river. Watershed management refers to land use practices that ensure effective stewardship of water quality and quantity. A watershed management plan is a roadmap for how to manage a watershed in order to meet the water quantity and quality requirements for its intended beneficial uses.

Nationwide, watershed management plans have typically been developed in watersheds where the water quality had already degraded below a threshold level for its use or where there were limited water supplies. In such cases, implementing a watershed management plan has often been very costly and in some cases, because of lack of transparency, resulted in a lack of trust among watershed stakeholders. Therefore, rather than reacting to existing problems, taking a proactive approach to address emerging water resource problems by preemptively developing a watershed management plan with stakeholder input requires fewer resources and is less costly compared to waiting for the problems to get worse.

Successful watershed management needs local support and engagement through the involvement of citi-

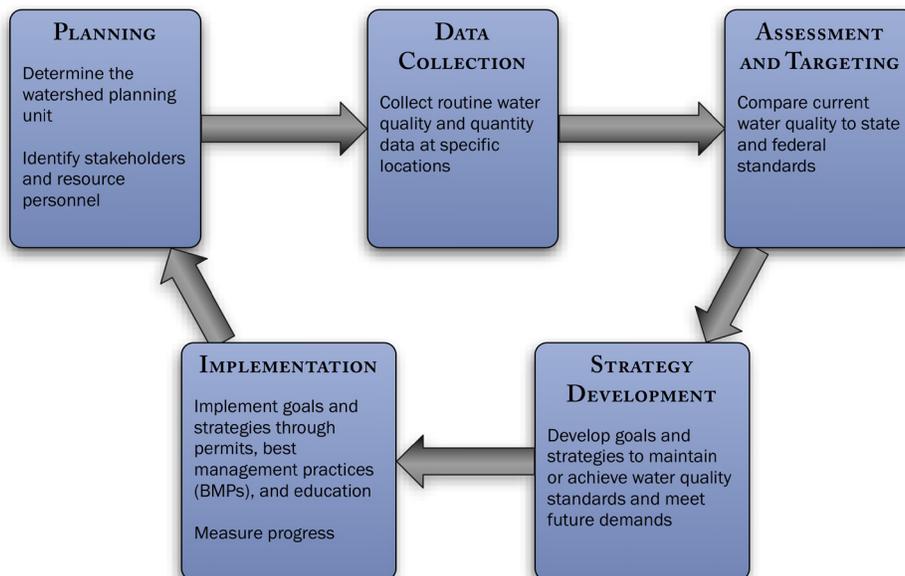


Figure 1: The watershed management cycle.

zens and stakeholders representing the watershed’s population. Stakeholders throughout a watershed will benefit from becoming familiar with the steps involved in developing a watershed management plan, in order to influence the outcome of the process. The approach currently recommended by the Environmental Protection Agency (EPA) includes five steps: 1) planning; 2) collecting data; 3) assessing current water quality and targeting desired standards; 4) developing goals and strategies to reach those standards; and 5) implementing strategies and measuring their effectiveness. Figure 1 graphically outlines this process and will serve as a guide to the rest of this publication which discusses these steps from the viewpoint of watershed stakeholders and from a water quality perspective.

1. Planning

1.1 Determine the watershed planning unit

When delineating the boundaries of a watershed it is necessary to consider which scale you will be working at; for example, whether a watershed management plan is to be developed for a large river basin, for a tributary, a smaller stream, or closed basin with a lake.

The size of a watershed influences stakeholder roles in all steps of the watershed management cycle. Also, the size of a watershed determines which government unit exercises authority over a particular land area. For example, a state or federal agency may be the lead stakeholder in a large river basin (1,000 to 10,000 square miles in area), while local government agencies may play the larger role in a smaller watershed (0 to

1000 square miles in area). Watershed unit size also determines the focus of management strategies ranging from, implementations of local best management practices to planning for the entire river basin. Table 1 gives an overview of watershed characteristics along with primary planning agency.

South Dakota’s Water Resources

South Dakota’s surface water network consists of 14 major river basins (Figure 2). All but three of these are shared with neighboring states. These river networks supply South Dakotans with part of their water needs. The surface water quality varies within these watersheds due to both natural processes and human activities.

Hydrologic Unit Codes

Because it is necessary to be able to accurately delineate and identify watersheds, the United States Geological Survey (USGS) has developed a system of hydrological land ‘units’, each identified using a unique numerical code. The unit boundaries are developed so that all surface drainage within each unit converges at a single outlet point such as a lake or the mouth of a stream or river. There may be ‘non-contributing areas’ located within a unit that do not drain to the outlet such as potholes or smaller closed basins, which do not drain to the common outlet.

Each hydrological unit (HU) delineates the boundaries of a watershed. The hydrologic unit codes (HUC) are organized in a hierarchy where more digits are added to the code as watersheds are being divided into smaller units:

Watershed Management Unit	Typical Area, mi ² (Acres)	Primary Planning Authority
Catchment	0.05-0.50 (32-320)	Property owner (local)
Subwatershed	1-10 (640-6,400)	Local government
Watershed	10-100 (6,400-64,000)	Local (or multi-local) government
Subbasin	100-1,000 (64,000-640,000)	Local, regional or state governments
Basin	1,000-10,000 (640,000-6,400,000)	State, multi-state or federal governments

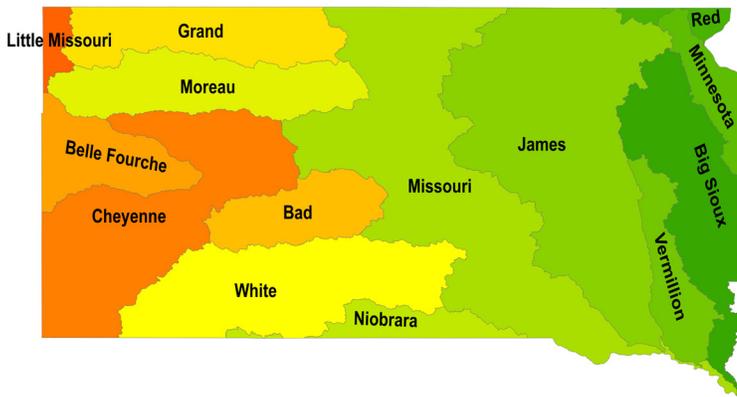


Figure 2: Major South Dakota river basins.

Want to find your watershed?

See the Environmental Protection Agency (EPA) Web site “Surf Your Watershed” at:

<http://www.epa.gov/surf/>

Region. Under the HUC the system, the US has been divided into 21 regions based on the nation’s major river watersheds. Each region has been assigned a two digit number between 01 and 21. For example, the Missouri River Basin has been assigned the code 10.

Subregion. Each region is subdivided into subregions. Each subregion is contained entirely within a region. A four-digit code is used to identify a subregion, of which the first two digits are the code for the region and the last two are the subregion identifier.

Basin. Each subregion is subdivided into basins. A six-digit code is used to identify a basin, of which the first two digits are the code for the region, the two middle digits are for the subregion and the last two are the basin identifier.

Subbasin. Each basin is subdivided into subbasins. An eight-digit code is used to identify a basin.

Watershed. Each subbasin is subdivided into watersheds. A ten-digit code is used to identify a watershed.

Subwatershed. Each watershed is subdivided into subwatersheds. A twelve-digit code is used to identify a subwatershed.

The hydrologic unit code (HUC) system levels are summarized in Table 2 with example names and codes for commonly identified regions. Figure 3 shows the HUC system’s levels and their characteristics using the Big Sioux River Basin in eastern South Dakota as an example.

The USGS HUCs are widely accepted as the norm for identifying watershed boundaries and are commonly used in the watershed planning process. Maps and descriptions of the HUCs are available at no cost for download from the USGS or from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Data Gateway. The addresses for these websites are included at the end of this publication.

Name	Level	Digits	Number of HUs Nationally (approx.)	Example Name	Example Code (HUC)
Region	1	2	21	Missouri Region	10
Subregion	2	4	221	Missouri-Big Sioux	1017
Basin	3	6	378	Big Sioux	101702
Subbasin	4	8	2264	Lower Big Sioux	10170203
Watershed	5	10	22000	Skunk Creek	1017020311
Subwatershed	6	12	160000	Beaver Lake	101702031101
14-digit HUC	7	14	Not Completed	-	-

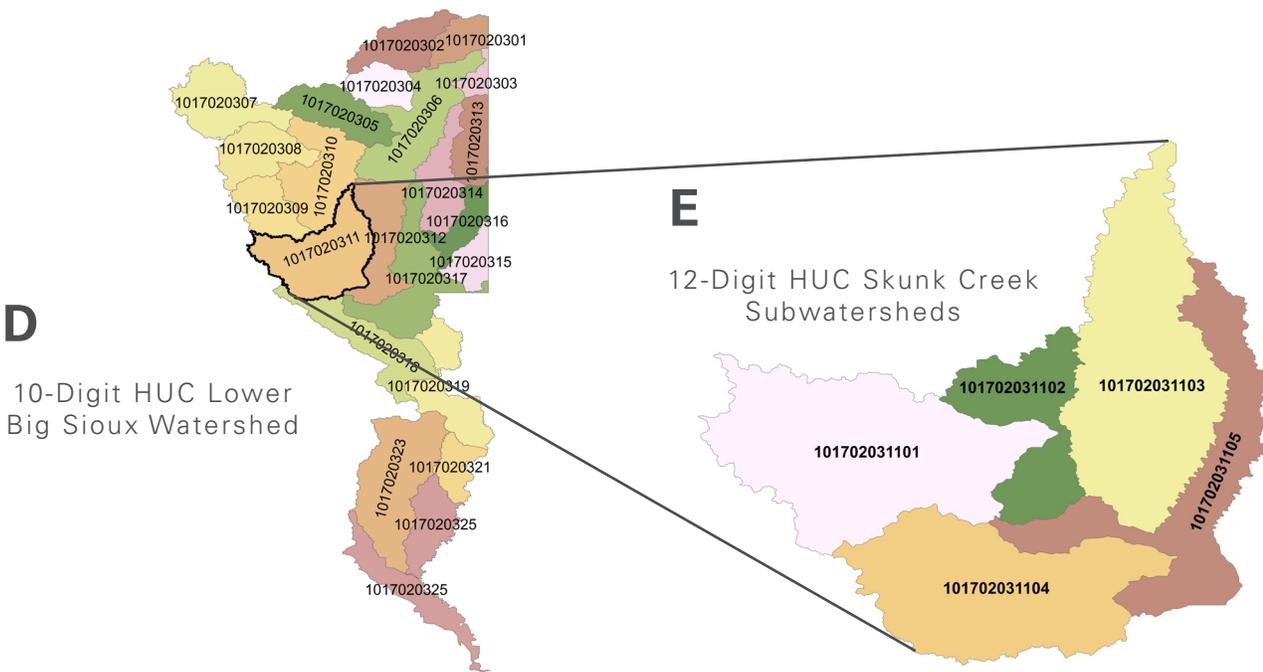
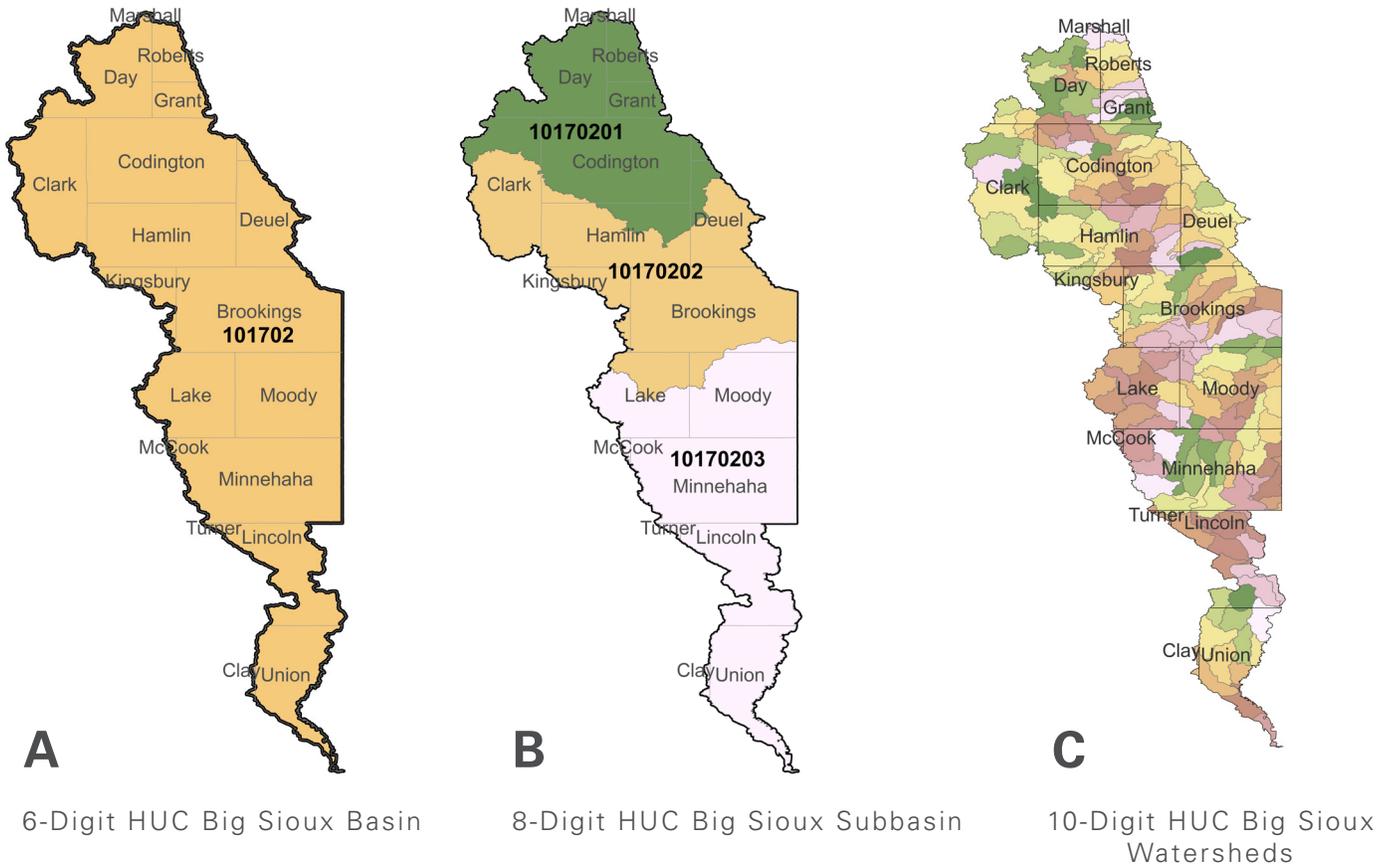


Figure 3: Hydrological Unit Codes (HUC) for the Big Sioux Watershed, SD from 6 to 12 digits (top) and an example of 10 and 12 digit HUC for the Lower Big Sioux Watershed and Skunk Creek Subwatershed (bottom).

1.2 Identify stakeholders and resource personnel

Successful watershed management needs local involvement and support. Participation from stakeholders representing a watershed's population and interests is essential. Direct stakeholders live or own property within a watershed and influence water quality and quantity, while indirect stakeholders live outside the watershed boundaries but may use its water or have a legislative mandate, such as state water quality protection.

Technical expertise may be conveyed to stakeholders and decision makers by consulting with individuals or groups with specific expertise including scientists, engineers, policy experts and attorneys.

Who are stakeholders in my watershed?

Although every watershed is unique, examples of stakeholders include:

Typical Direct Stakeholders

- Landowners (permanent and absentee)
- Homeowners
- Local businesses
- Agricultural producers
- Industries

Typical Indirect Stakeholders

- City and county officials
- State or federal officials
- Water and wastewater utilities
- Civic groups
- Mass Media

2. Data Collection

2.1 Relevant information to collect

Without background information about the watershed of sufficient substance, discussions will be based on emotions and anecdotal evidence, and the watershed management process will be impeded. The informa-

tion that is relevant to collect varies between watersheds, but the following information is normally useful (Reimold, 1998).

- Sizes, locations, and designated uses of all water bodies of interest
- Demographic data and growth projections
- Economic conditions, such as income and employment
- Impairments rendering the water unfit for its intended uses
- Pollution sources and estimates of their loadings
- Water attributes: physical, biological, chemical
- Groundwater quality and sources affecting it
- Fish and wildlife surveys
- Maps: topographic, hydrologic, land use and cover (including wetlands and riparian areas) and changes in land use
- Detailed soil surveys
- Threatened and endangered species and their habitat
- List of relevant local stakeholders

A substantial amount of information about South Dakota watersheds is available from state and federal agencies, including

- United States Army Corps of Engineers
- United States Environmental Protection Agency
- United States Geological Survey
- United States Fish and Wildlife Service
- United States Department of Agriculture Natural Resources Conservation Service
- South Dakota Department of Environment and Natural Resources
- South Dakota Department of Game, Fish, and Parks
- Water Development Districts
- Municipal utilities and rural water systems
- Tribal water resource authorities

Sources of information are listed in the resources section at the end of this document.

In case pertinent information about the watershed is not available, it must be generated, for example through monitoring or surveying programs. Establishing routine monitoring that follows standard procedures for sampling and analysis is crucial to developing meaningful information to be used in watershed management. SD DENR (2005) outlines suggested procedures to follow, including pre-sampling considerations, sample collection and analysis, instrument calibration and quality assurance. Having an outside entity not directly involved in the watershed management plan development undertake the monitoring typically lends additional credibility to the monitoring data.

2.2 Estimation of pollution load

When developing a watershed management plan, it is necessary to identify the source(s) of possible pollutants and establish what the current conditions are. This may be achieved by analyzing available information and historical monitoring data, or new data may need to be collected. Pollutants may stem from natural sources or from human activities. The total pollutant load is broken down using the formula:

$$\text{Total Pollutant Load} = \text{Total Point Source Load} + \text{Total Nonpoint Source Load}$$

Point Sources of Pollution

Point source pollution is the term used to identify those contaminants that enter the watershed at an easily defined location, for example, through an outlet pipe. Examples of point sources include:

- Wastewater treatment plant discharges
- Industrial waste discharges
- Stormwater collection systems discharge
- Concentrated Animal Feeding Operations (CAFO)

State and federal environmental agencies monitor and regulate point source pollution based on established water quality and quantity water standards.

Nonpoint Source Pollution

Nonpoint source pollution comes from numerous and widely scattered sources not discharging from a

clearly defined point. The pollutant load from any single location may represent a small and seemingly insignificant contribution. However, the collective impact of all these loads may have substantial impact on the water quality in the watershed. Since these pollutants sources are not coming from a defined point, they are difficult to monitor and treat effectively.

Examples of nonpoint source pollutants common to South Dakota include:

- Bacteria and nutrients from livestock, pet wastes and faulty septic systems
- Excess fertilizers and pesticides from agricultural lands and residential areas through surface and subsurface runoff
- Sediment from improperly managed construction sites, crop and forest lands, gardens and eroding stream banks
- Oil, grease, and toxic chemicals from urban, industrial, and agricultural runoff and energy production
- Acid drainage from abandoned mines
- Atmospheric deposition (the transfer of pollutants from the air to the earth's surface)

In most cases, the types of activities that can lead to nonpoint source pollution are not specifically regulated. Nonpoint source pollution may be controlled through the design, construction and maintenance of best management practices (BMPs). Putting BMPs into place is a voluntary action, but is often supported through cost-share programs.

3. Assessment and Targeting

3.1 Water quality standards

South Dakota Codified Law 34A-2-1 outlines the public policy for protecting and conserving the quality of the waters of the state. Surface water quality standards are laid out in Administrative Rules of South Dakota (ARSD). ARSD 74:51:01 defines eleven general categories for the designated, beneficial use of regulated lakes and streams in the state:

1. Domestic water supply waters;

2. Coldwater permanent fish life propagation waters;
3. Coldwater marginal fish life propagation waters;
4. Warmwater permanent fish life propagation waters;
5. Warmwater semipermanent fish life propagation waters;
6. Warmwater marginal fish life propagation waters;
7. Immersion recreation waters;
8. Limited contact recreation waters;
9. Fish and wildlife propagation, recreation, and stock watering waters;
10. Irrigation waters; and
11. Commerce and industry waters.

A stream or lake may have more than one designated use. Each designated use is associated with a set of water quality standards. The standards specify thresholds for water quality impairments that are used to identify instances where the water quality may be inadequate for its designated use. The surface water quality standards are designed to:

- Establish numerical and narrative goals for water quality; and
- Provide a basis for the South Dakota Department of Environment and Natural Resources (SD DENR) to develop reasonable methods for reaching these goals.

3.2 Identifying Impaired Waters

Federal and state agencies conduct and oversee water quality monitoring and normally make the results publicly available. Every two years (in even numbered years) the SD DENR conducts a statewide surface water quality assessment. The outcome of the assessment is published in the report “Integrated Report for Surface Water Quality Assessment” (SD DENR, 2012) which is available for download from the SD DENR website at no cost. The report lists the impaired water bodies where the water quality does not meet the standards for its designated uses (known as the 303(d)

list) and identifies Total Maximum Daily Load (TMDL) programs for streams and lakes not meeting state standards for particular impairments (see box).

What are the Surface Water Quality Assessment and the 303(d) list?

The Surface Water Quality Assessment addresses the quality of South Dakota’s waters and is conducted by the SD DENR. The 303(d) list identifies water bodies not meeting designated use standards. These reports satisfy federal Clean Water Act requirements for Sections 305(b) (water quality reports) and 303(d) (lists). The US Environmental Protection Agency (EPA) must approve the list before it is considered final.

What is a TMDL?

A Total Maximum Daily Load (TMDL) estimates the maximum amount of a pollutant that a water body can receive and still meet water quality standards. A “budget for pollution,” the TMDL uses a scientific model to:

- determine the maximum amount of a pollutant at which a stream or lake can attain and maintain its designated use standards; and
- assign this load amount to point and nonpoint sources in the watershed.

An implementation plan puts the TMDL into action by outlining voluntary and regulatory steps necessary to reduce pollutant loads.

Is my watershed part of a TMDL?

To determine whether you are in a watershed that has a TMDL established, 1) find your watershed using SD DENR (2012) or one of the websites provided at the end of this document, 2) review the information on whether the current 303(d) list includes your watershed and its associated water quality parameter.

Do I contribute to a TMDL in my area?

All activities, whether agricultural, industrial, municipal or recreational, contribute to the water quality of your watershed. For example, applying excess fertilizer in an untimely manner to a lawn or garden may contribute to the TMDL. However, depending on the nature of the pollutants involved, some activities may contribute more than others.

How is a TMDL designation removed?

A plan to manage your watershed's TMDL must be developed and effectively implemented before your watershed can be removed from the 303(d) list of impaired water bodies.

modeling results with considerations for the social acceptability of suggested water quality solutions. Also, models only predict changes based on available data and assumptions. Actual water quality monitoring is necessary to determine the impact of implementation of best management practices and other changes in management practices in the watershed.

4. Strategy Development

By providing input and helping to set goals and to assign priorities to them, direct and indirect stakeholders play a key role in identifying strategies and in designing watershed management plans. Plan development should also involve interest groups, experts (such as private- or public-sector engineers and scientists) and policy makers (such as local, regional, state and federal planning personnel). Seeking input from a wide range of individuals increases the likelihood of producing a feasible and successful management plan.

Management plans that outline specific goals produce the best results for stakeholders. For example, instead of specifying a goal to "improve water quality," it is better to specify "reduce watershed phosphorus loading by 25 percent". Also, it is useful to model (see box on Water Quality Models) the effects of BMP implementation. If set up properly, water quality models will help predict impacts of different scenarios relating to increases or decreases in loadings for a particular stream or lake to determine whether or not implementation of a corrective water quality measure has the desired impact on water quality.

What are Water Quality Models?

Water quality models use mathematics to simulate natural watershed processes. As input, such models need information about topography, land use, climate, soils and current and historical management of the watershed. Water quality models allow managers, engineers and planners to develop and evaluate "what-if" scenarios. They can assist stakeholders in evaluating the effect on the watershed of management strategies and land use changes. But a model's usefulness can be limited by the size of the watershed (scale) and by the amount and quality of data available (such as stream flow and water quality parameters). Successful outcomes of a modeling effort rely on combining the

5. Implementation

5.1 Implement goals and strategies

Stakeholders and decision makers commonly customize the 'tools' that exist for implementing watershed management plans. These tools include 1) permits, 2) best management practices (BMPs) and 3) educational programs.

Permits

Regulatory permits are used most often to control point sources of pollution. Such permits are issued by government agencies and specify discharge levels for pollutants. Point sources may not exceed these permitted levels. Point source contributors might address water quality issues by modifying permits to change certain pollutants' allowed discharge quantities. However, putting such permit changes into practice may require plant expansion and/or new processes that will increase treatment costs for a facility's users or consumers. A watershed management strategy that uses permits as its sole tool will be effective only if point sources are the dominant contributors to water quality problems.

What is the major permitting program in place?

As authorized by the Clean Water Act, the permit program of the National Pollutant Discharge Elimination System (NPDES) controls water quality by regulating point source pollution, including discharges into United States waters by concentrated animal feeding operations (CAFOs), combined sewer overflows (CSOs), pretreatment (wastewater treatment) plants, sanitary sewer overflows (SSOs) and stormwater (construction activities, industrial activities, and municipal stormwater sewers). In South Dakota, these permit programs are administered and enforced by the SD DENR.

Best Management Practices (BMPs)

BMPs are the preferred approach to managing non-point source pollution. Although BMPs are often voluntary, some regulatory agencies require their inclusion in watershed management plans. A watershed management strategy that uses BMPs as its sole tool will be effective only if nonpoint sources are the dominant contributors to water quality problems and if a sufficient number of landowners are willing to participate in voluntary programs. Water quality improvements cannot be expected from projects that rely solely on voluntary efforts if landowners do not participate.

Examples of Best Management Practices

Changes in land use or management such as

- Vegetated buffer strips along lakes and streams
- Grassed waterways
- Nutrient management
- Conservation tillage
- Use of wetlands
- Sedimentation basins
- Septic system maintenance
- Stream bank stabilization

Educational Programs

Education is a key component to a successful watershed management plan. Education programs help alert stakeholders regarding watershed problems and help involve them in decision making. Educational programs also draw the attention of both agency employees and stakeholders to the need for a proper strategic balance between permits and BMPs. Such balance leads to management plans that address pollution from both point and nonpoint sources. Outreach programs can also raise the level of awareness about the importance of watershed water quality issues among those who may not consider themselves to be direct, or even indirect, stakeholders.

What types of Educational Programs can be useful?

- Publications
- Field days
- Demonstration projects
- Tours
- Focus groups
- Media coverage
- Newsletters
- Surveys

5. 2 Measure plan progress

The progress of a watershed management plan needs to be measured to assess whether it is successful. For example, if a plan's goal is to reduce lake phosphorus concentrations by 25 percent, ongoing monitoring should assess concentration trends over time compared to the base or beginning condition. Such monitoring will help determine whether plan strategies (permits, BMPs, education) are achieving desired outcomes.

REPEATING THE CYCLE

The watershed management approach can be used to decide when and what actions are needed either to correct water quality or quantity problems (reactive mode) or to prevent such problems (proactive) from occurring. Measuring and assessing the success of a watershed management plan is an ongoing process. Because watersheds and watershed management tools are dynamic, the steps outlined in Figure 1 must be repeated continually to ensure that the goals set up in the plan are reached. Also, ongoing monitoring may show that a given action may not have had the anticipated effect and adjustments to the plan are needed to attain the goals. It is important to continue to have stakeholder participation throughout the process and to make sound decisions to meet the plan goals

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South Dakota Department of Environment and Natural Resources [<http://denr.sd.gov/>]

South Dakota Water Resources Institute, South Dakota State University, [<http://www.sdstate.edu/abe/wri/index.cfm>]

US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)

Geospatial Data Gateway [<http://datagateway.nrcs.usda.gov/>]

US Environmental Protection Agency Resources

Clean Water Act [<http://www.epa.gov/lawsregs/laws/cwa.html>]

National Pollutant Discharge Elimination System (NPDES) [<http://cfpub2.epa.gov/npdes/>]

Water Quality Assessment and TMDL Information [<http://www.epa.gov/waters/ir/>]

Conservation Technology Information Center, Purdue University

Know Your Watershed [<http://www.ctic.purdue.edu>]

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USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	6	0	0	0	6
Masters	2	0	0	0	2
Ph.D.	0	0	0	1	1
Post-Doc.	0	0	0	0	0
Total	8	0	0	1	9

Notable Awards and Achievements

The Assistant Director of the SD WRI, Kevin Dalsted was a co-editor of the iGrow Wheat Production Management Manual along with Dr.'s David Clay and C. Gregg Carlson (35 chapters)- <http://igrow.org/product/igrow-wheat-best-management-practices-for-wheat-production/>. Dalsted was also a co-author with Dr. Chang on the Precision Wheat Management chapter in this publication. This compendium received a national award from the American Society of Agronomy: Certificate of Excellence, Educational Materials Awards Program, publications over 16 pages.

Publications from Prior Years