

**South Dakota Water Research Institute
Annual Technical Report
FY 2006**

Introduction

South Dakota's Water Resources Research Institutes program is administered through the College of Agricultural and Biological Sciences at South Dakota State University (SDSU). Dr. Van Kelley has been the Director since August 1, 2000. Dr. Kelley is also the head of the Agricultural and Biological Sciences Engineering Department. The annual base grant from the United States Geological Survey (USGS) and a legislative appropriation of \$92,335 form the core of the SDWRRRI budget. The core budget is supplemented by research grants from a variety of funding agencies as well as private organizations interested in specific water issues.

The mission of the South Dakota Water Resources Institute is to address the current and future water needs of people, agriculture, and industry through research, education, and service. This report is a summary of activities conducted during Fiscal Year 2006 to accomplish this important mission.

Research Program

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 2006, 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. The Advisory Committee reviews grant applications and recommends projects for funding that address research priorities, have a good chance of success, and increase our scientific knowledge. Manure management and its impact on water quality, drinking water quality, and conservation of irrigation water were emphasized in fiscal year 2006.

Support was also provided to a project to determine the influence of manure placement on crop yields and the transport and fate of nutrients and antibiotics in manure. As the livestock industry grows and develops in South Dakota, manure management and its impact on water quality will continue to be a priority for research.

With growth in the South Dakota economy, increasing demands have been placed on water supplies. Irrigation is a major use of water in South Dakota and wise use of irrigation water is important if other water needs like ethanol production are to be met in the future. In FY2006, research was supported to develop methods to conserve irrigation water by using an automated irrigation management system. This technology is expected not only to conserve water but also reduce pumping costs, increase crop production, and minimize leaching of nitrates into groundwater supplies.

Some areas of South Dakota have elevated levels of arsenic, cadmium, and lead in drinking water supplies. Removal of these metals especially by small rural water system operators is a challenge. A research project to improve the efficiency of limestone-based materials for metal removal from drinking water was supported in FY2006. This is part of the effort to develop low-cost remediation technology that can be used to help small or rural water supply systems meet regulations.

Nutrient and sediment loads from animal feeding operations (AFOs) can negatively impact the quality of surface waters and groundwaters. A research project to evaluate the technical and financial feasibility of vegetated treatment areas (VTAs) as a non-basin alternative for reducing nutrient and sediment loads from AFOs having less than 1,000 animal units was supported. Five AFOs in different areas of South Dakota were established.

Two projects from previous years were continued in 2006 to allow principal investigators to collect additional data and to meet the project's objectives. These included:

1. Establishing the relationship between soil test phosphorus and runoff phosphorus for South Dakota soils and
2. Evaluating phosphorus loss on a watershed scale.

The Influence of Manure Placement on Crop Yields and the Transport and Fate of Nutrient and Antibiotics

Basic Information

Title:	The Influence of Manure Placement on Crop Yields and the Transport and Fate of Nutrient and Antibiotics
Project Number:	2005SD29B
Start Date:	3/1/2005
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Agriculture, Water Quality, Solute Transport
Descriptors:	
Principal Investigators:	Sharon Clay, C. Gregg Carlson, David E. Clay

Publication

1. Reiman, M. 2006. The impact of deep manure injection on water infiltration, nutrient distribution, and corn yield. M.S. Thesis, SDSU Brookings, SD.
2. Lehnert, K., V. Brözel, S. Gibson, and S. Clay. 2006. Antibacterials in manure influence soil microbial activity. Poster for NC Amer. Microbiology Society Meeting. Brookings, SD. October, 2006.
3. Hoese, A., S. Gibson, V. Brozel, R. Thaler, and S. Clay. 2006. The influence of antimicrobial chemicals on soil and herbicide degrading bacteria. ASA meetings, November. Indianapolis, IN
4. Lehnert, K., S. A. Clay, S. Gibson and V. Brozel. 2007. Detecting shifts in soil microbial community structure and function post landspread of manure or biosolids containing antimicrobial chemicals. ASA meetings, November, New Orleans, LA (submitted)
5. Graduate student seminars. 2005, 2006, and 2007. Ms. Lehnert, Mr. Reiman, and Mr. Hoese presented seminars for faculty and students in Biology and Plant Science Departments as part of their ongoing graduate training.
6. Carlson, C.G. D.E. Clay, and C. Reese. 2007. Deep manure injection. North and South Dakota Watershed Manager Training. Feb 12, 2007. Aberdeen, SD.
7. Clay, D.E., C.G. Carlson, and S.A. Clay. 2007. Precision deep manure applications. SD EPA319 task force planning meeting. March 20, 2007, Pierre SD.
8. Kleinjan, J., C.G. Carlson, and D.E. Clay. 2006. Precision deep manure application (poster) Brookings field day. June 2006. Brookings SD.
9. Reicks, G, C.G. Carlson, and D.E. Clay. 2006. The Impact of Deep Manure Injection on Nutrient Distribution and Corn Yield. SE. Farm field days. September 6, 2006.
10. Reese, C. L., D. E. Clay, D. Beck, J. Kleinjan, C. G. Carlson and S. Clay. Lessons learned from implementing management zones and participatory research in production fields. Eighth International Conference on Precision Agriculture. 23 26 July 2006. Marriott Hotel, Minneapolis, Minnesota.

Completion Report for FY06 USGS 104b Project

Title: The influence of manure placement on crop yields and the transport and fate of nutrient and antibiotics.

Principal investigators: S.A. Clay, SDSU, Brookings, SD
D.E. Clay, SDSU, Brookings, SD
C.G. Carlson, SDSU, Brookings, SD

Introduction

Wind and water soil erosion are processes that transports P, N, microorganisms, and antibiotics contained within manure from agricultural fields to surface waters and drainage networks. Erosion reduces land productivity and contaminants may impair water quality for planned uses. Erosion and runoff are likely to occur whenever there is excess water on a slope that cannot be absorbed or trapped in soil. In addition, the antimicrobial chemicals tylosin (Tyl) and chlortetracycline (CTC) are used as growth promoters in animal production and can be excreted as the parent compound. Landspreading manure can move these chemicals into the soil. To meet water quality goals, techniques that reduce the potential for off-site transport of microorganisms, nutrients, and antibiotics contained within the manure while simultaneously increasing yields and reducing erosion are needed. Previous experience indicated that for SD producers to voluntarily adopt a best management practice (BMP), the practice must generate revenue, fit into their operation, pay for the costs associated with adopting the BMP, make sense in their operation, and the operator must be committed to make the management practice work. Revenue can be generated by two general approaches, direct payment or increased profitability.

This project was integrated into an EPA 319 funded project and a special EPA project so that infiltration and runoff of N, P, and antibiotics could be monitored as well as some of the effects on native soil microorganisms. The South Dakota Precision Farming Consortium works to develop management tools that reduce the adverse impacts of agriculture on the environment, improve water quality, and maintain land productivity. Consortium membership includes: scientists; producers; consultants; and USDA-NRCS, USDA-ARS, and government agency personnel. The consortium has held annual planning and informational meetings where priorities for the upcoming year are identified, review of research occurs, develops training materials such as the "Site Specific Management Guidelines" (available at <http://www.ppi-far.org/ssmg>), sponsors workshops, helps producers conduct on-farm-research, and assists in the development of public education segments that can be aired on Today's Ag. The research conducted in this proposal was the direct outcome of a producer/scientist focus group held in January 2002.

The goals of the overall 2-year projects were to determine the impact of precision manure management/placement on the fate and transport of water, carbon, organisms, and antibiotics contained within manure to non-target areas. The hypothesis of this project is that by integrating soil and other landscape information manure can be

managed such that adverse effects are minimized and profitability is increased. Fields selected for implementation have the following characteristics: (i) evidence of substantial erosion; (ii) glacial till parent materials; and (iii) have been identified as high risk by TMDL and water monitoring studies. This project 1) field tested management approaches that were designed to simultaneously increase productivity and reduce the impact manure on the surface and ground water quality and 2) conducted laboratory studies to observe the impact of manure on soil process including microbial activity. Specific experiments within this overall project investigated 1) the effect of deep manure placement on infiltration, nutrient availability to the crop, and runoff potential of manure and manure contaminants; 2) the effect of antimicrobials alone on isolated soil microbes; 3) the effect antimicrobials on the activity of specific isolated herbicide degraders; and 4) the effect of antimicrobials on 'normal' herbicide degradative soil processes.

Research Objectives

This project was a multi-faceted project that bridged several projects to examine the environmental fate of manure, the impact of manure and its contaminants on soil microbial activity, and test an application technique that would minimize the negative aspects of manure application and maximize its nutrient crop value as a source of N and P and as a soil amendment.

Specific objectives included:

1. To determine the influence of precision manure placement and landscape position on tylosin and chlortetracycline transport and fate.
2. To determine the influence of precision manure placement and landscape position on water budgets and nutrient (C, N, and P) cycling.
3. To determine the influence of manure placement and landscape position on crop yields, runoff, and P transport.
4. Train undergraduate and graduate students in water resources.
5. To share research findings with the general public and the scientific community.

The management practice tested was precision deep manure placement. It was hypothesized that deep manure placement in highly eroded glacial till soils would increase water infiltration, help build a deep soil profile, and reduce surface transport of P, N, microorganisms, and antibiotics from fields to non-target areas.

Methodology

Field research was initiated at two South Dakota sites in 2004. Yields, water infiltration, P, and N transformations were measured for the two years following manure injection. Treatments were deep manure injection (45cm), shallow manure injection (15 cm), and conventional fertilizer-based management. At each site, treatments were replicated three times. Soil samples to a depth of 90 cm were collected and analyzed for Bray P, ammonium-N, and nitrate-N. Apparent saturated hydraulic conductivity and crop grain yields were measured. In the fall of 2004, several replicated deep manure placement studies in 2 producer's fields were initiated. Funding for this project was provided by EPA-319. The goals of the EPA 319 funded project were to field test the impact of deep manure placement on P transport and yields in producer's fields. This project expanded the scope of this project to include the impact of precision deep manure placement on water budgets and the transport and fate of antibiotics, carbon, N, and organisms contained within the manure.

Figure 1. Manure applicator with shanks 15 to 18” deep for application.



Double ring infiltration (Figure 2) was done at 3 sites and sprinkler infiltration (Figure 3) was conducted at two sites and infiltration rates measured. Infiltration rates using the double ring techniques was significantly greater (36 to 139%) in deep or 6” injection treatments vs surface applied or typical farm management areas. One area was tested in early summer and September and the magnitudes of infiltration differences for the treatments were measured. similar at each time indicating a fairly long term affect. Sprinkler infiltration was statistically greater at one site and numerically greater at another with deep manure injection.

In another related study, swine were fed with rations that contained no antibiotic, or tylosin or chlortetracycline (CTC) at labeled rates. Manure and manure from treated swine were placed on the soil surface of a silty clay loam soil. A microsprinkler system was used to water treated areas for about 45 min 1-d after application to determine runoff/run-in of manure and chemicals. Runoff was collected in about 500 ml increments from the area and each runoff increment was analyzed for antimicrobial concentration. The area was allowed to dry for several days and soil samples were taken in about 15 cm increments to a depth of about 45 cm with soil extracted to determine the concentration of antimicrobials in each soil increment.



Figure 2. Double ring infiltrometer to measure infiltration rates after manure application.



Figure 3. Microsprinkler system used to examine infiltration and antibiotic runoff from soil after manure application.

In addition to field studies, laboratory studies were conducted. In one study, we examined the susceptibility of microbes plated from soil (10 strains) and swine manure (5

strains) to tylosin and CTC. In another the soil microbial diversity and community shifts were examined using several techniques including most probable number (MPN) and denaturing gradient gel electrophoresis (DGGE) of the V3 region of the 16S rRNA gene pool at 0, 7, 28, and 42 days after treatment (DAT) of manure with or without antibiotic present and the herbicide, 2,4-dichlorophenoxyacetic acid (2,4-D). The degradation of 2,4-D and atrazine were also examined using pure known degrading cultures of microbes that were used alone or with CTC or tylosin.

Principal findings and significance

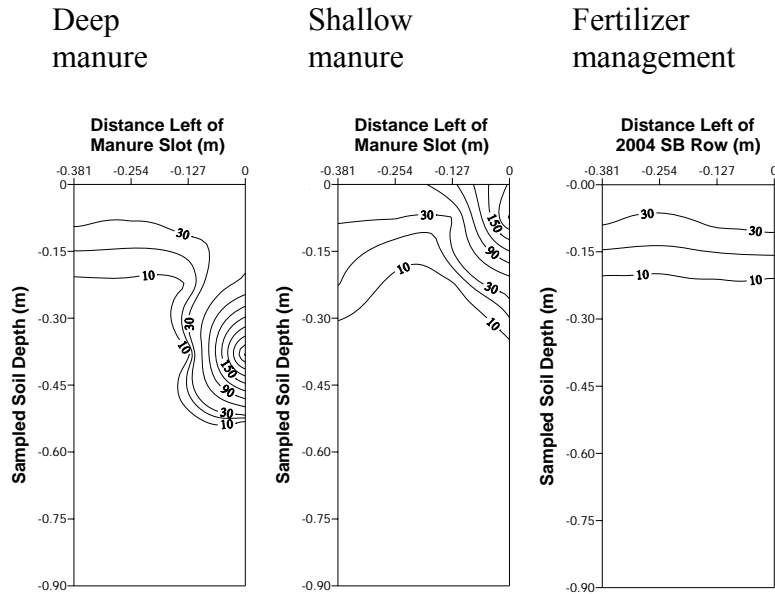
Replicated field studies were managed by collaborating farmers. Students (both graduate and undergraduate) assisted and conducted independent field, laboratory, simulation studies, and were trained in sampling techniques and laboratory procedures. Students obtained hands-on experience in water quality research and gained an understanding in land and resource stewardship when addressing environmental issues. Fact sheets, workshops, seminars, posters, and scientific papers are continuing to be prepared by undergraduate and graduate students with the assistance of the project coordinator and faculty members.

Manure application rates based on N requirements can result in P build up in soil (Figure 4). With increasing N fertilizer costs, the ammonia in the manure is more important than ever. Adopting techniques designed to reduce ammonia volatilization losses may reduce the total amount of manure required to meet the plants N requirement. Deep manure injected increased apparent saturated hydraulic conductivity. However, this increase was short lived, and after two years, apparent hydraulic saturated hydraulic conductivity in deep manure and conventionally managed treatments were almost identical. For the two years after manure injection, deep manure treatments contained more inorganic N than shallow manure treatments (Figures 5 and 6). These results were attributed to deep injection reducing organic N mineralization rates, nitrification rates, and N losses. Deep manure injection increased corn (*Zea mays*) yields if N limited growth. Results from this study suggest that deep placement of manure should be considered as a technique to reduce N losses from manure, which in turn can reduce N fertilizer requirements and amount of manure required to meet the crops N requirement.

When differences occurred among treatments, corn and soybean yield were greater in areas when manure was deep injected into the soil, compared to surface application of manure and conventional management with inorganic fertilizers (Table 1). This response may have been due to higher N levels retained in soil or greater water infiltration rates.

Figure 4. The influence of manure placement at Flandreau on the distribution of Bray-P between the corn rows 7 and 12 months after application. (Reiman, 2006)

7 months after application



12 months after application

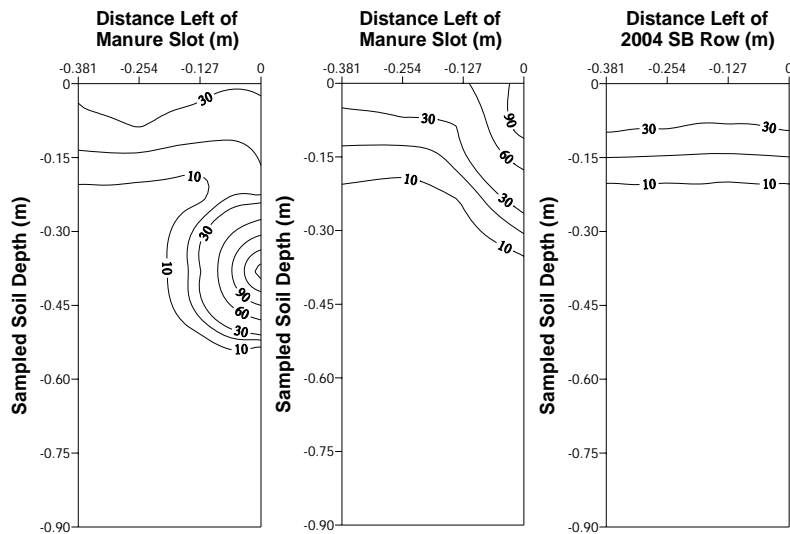
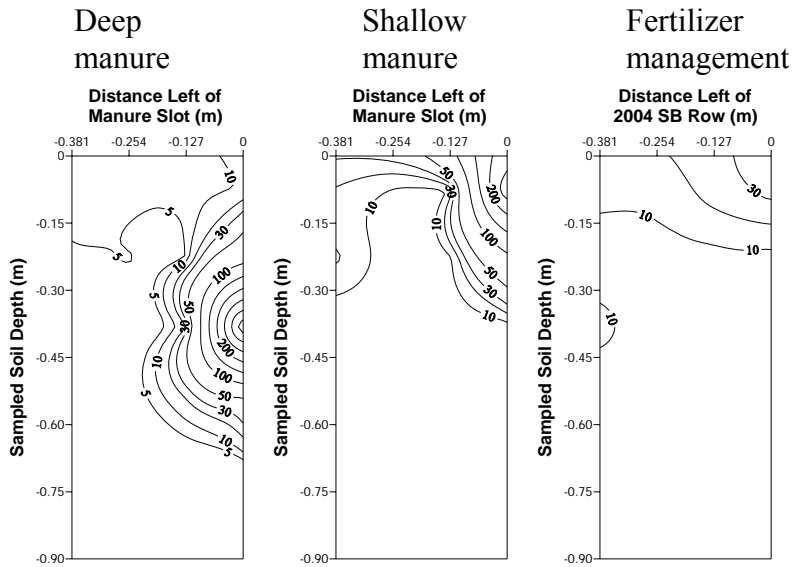


Figure 5. The influence of manure placement at Flandreau on the ammonia concentration in the zone between the corn rows 7 and 12 months after application. (Reiman,2006)

7 months after application



12 months after application

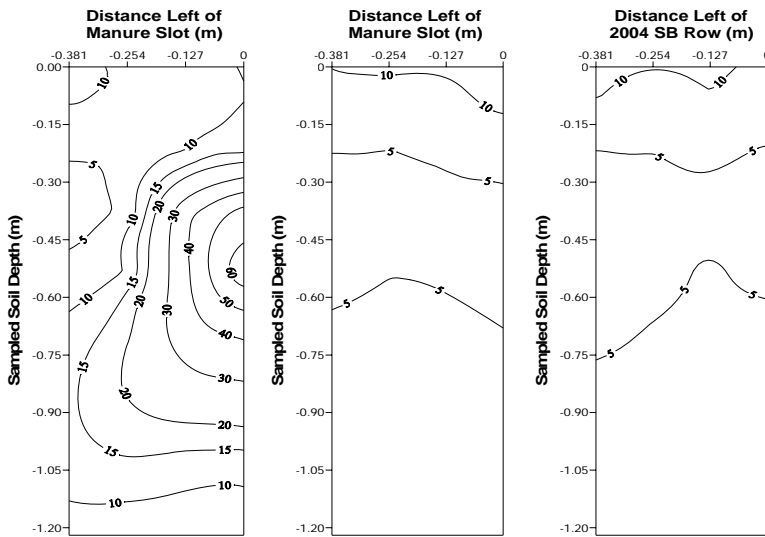
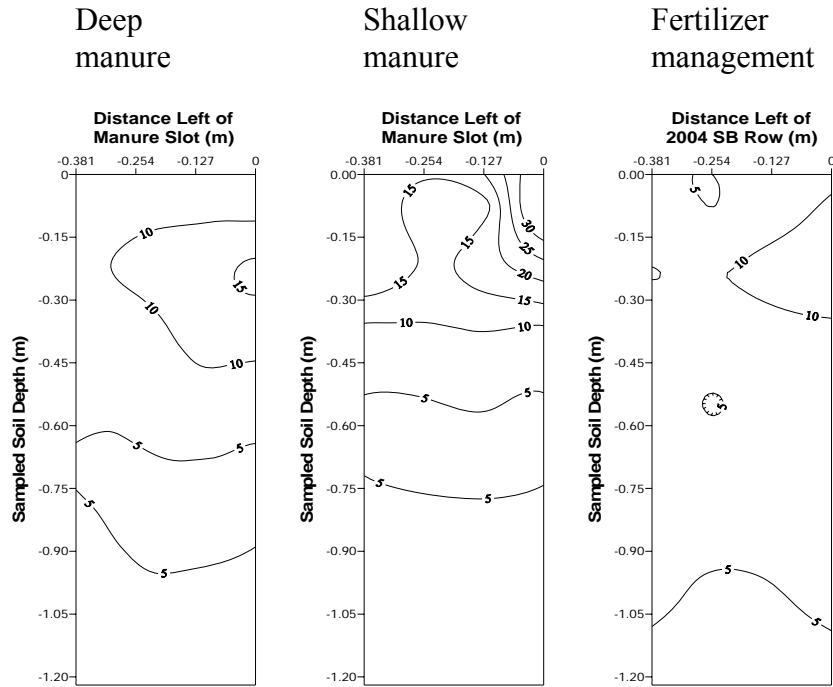


Figure 6. The influence of manure placement at Flandreau on nitrate-N (ppm) concentration in the area between the corn rows 7 and 12 months after application. (Reiman, 2006)

7 months after application



12 months after application

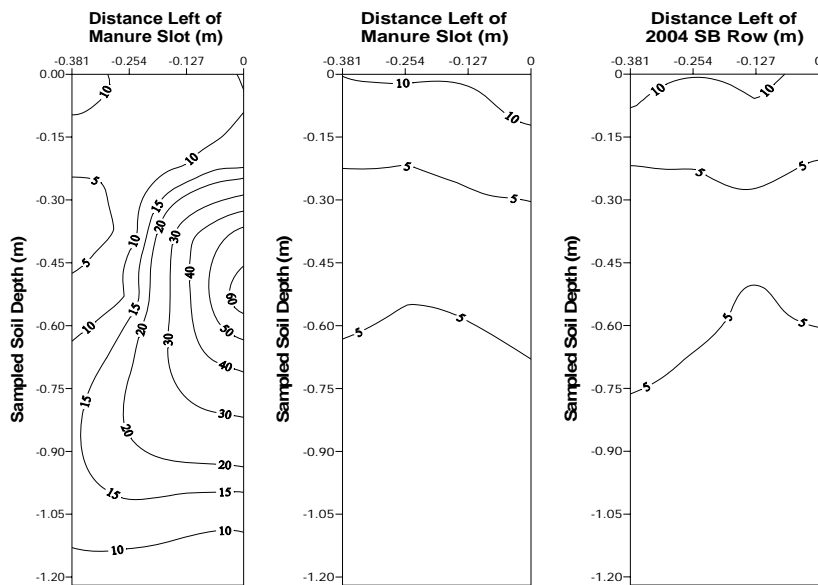


Table 1. Influence of manure on Flandreau and Volga corn and soybean yields in 2005 and 2006. (Reiman, 2006)

Treatment	Flandreau		Volga	
	Corn 2005	Corn 2006	Corn 2005	Soybean 2006
			kg/ha	
DI	13,500	12,000	9,200	4,090
SA			8,890	4,040
SI	13,100	11,500	9,140	3,960
CM	12,700	11,300	9,010	3,760
P	0.078	0.022	0.09	0.12
LSD _(0.10)	530	440	188	

†DI = 38 cm manure injection; SA = surface manure application; CM = conventional management with inorganic fertilizers, SI = 15 cm manure injection.

In areas treated with surface manure applications, runoff was much greater than in untreated areas due to sealing of the soil surface. The amount of CTC in manure was 118 mg per treatment whereas the amount of tylosin in the same amount of manure addition was 0.11 mg. CTC was present in runoff water and ranged from 0.9 to 3.5% of the applied amount and the amount was 1.8 to 4.2 mg (Table 2 and Figure 7). The total amount of tylosin in runoff was much lower ranging from 18 to 27 µg but the percentage of tylosin was much greater ranging from 9 to 12% of the amount applied (Table 3 and Figure 8).

Table 2. Runoff amounts and chlortetracycline (CTC) content in runoff after manure application in 2005. The amount of manure applied to the microinfiltration sprinkler area contained a total of 118 mg chlortetracycline. (authors unpublished data)

Location	Water Applied	Water Recovered	CTC runoff	
	(L)	(%)	(mg)	(%)
Brkg1	4.26	95.0	1.80	1.55
Brkg16	5.45	89.7	4.20	3.54
Aurora	5.54	93.9	1.00	0.86

CTC Runoff

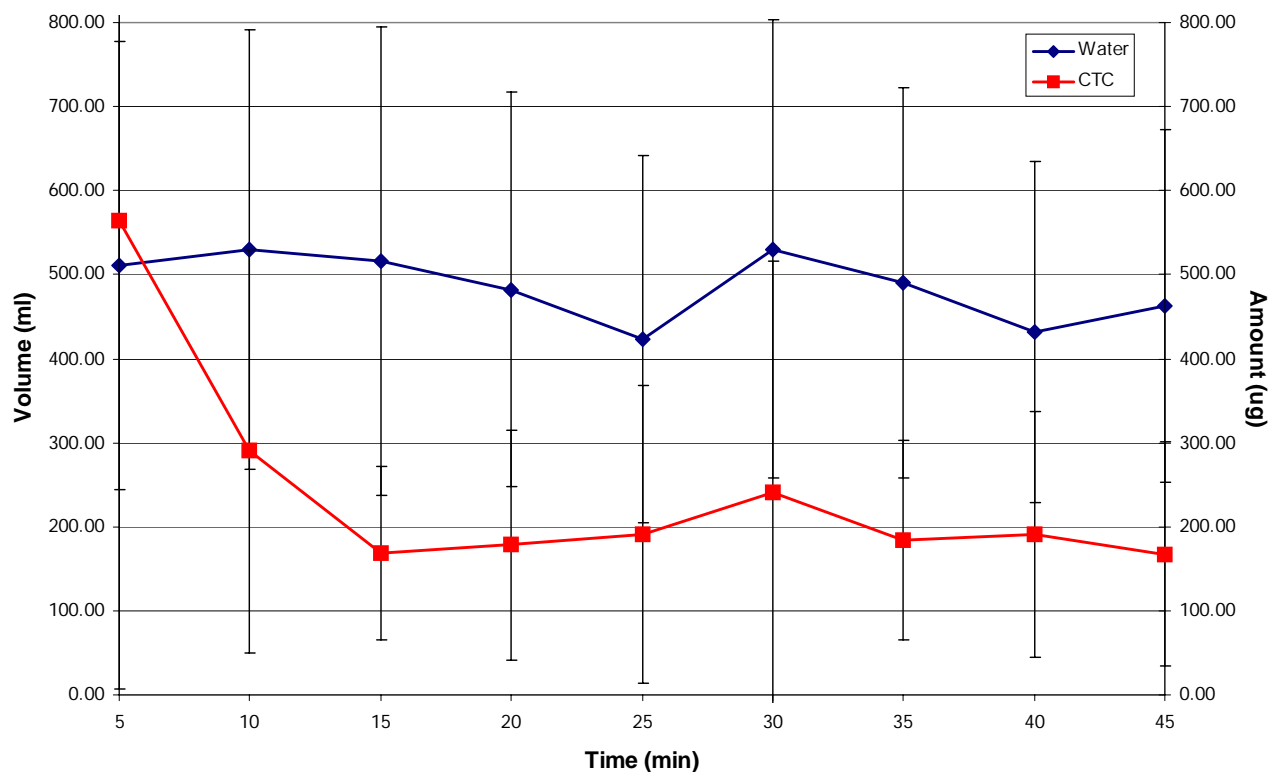


Figure 7. Runoff volume and CTC amount in runoff after manure application and sprinkler infiltration. (authors unpublished data)

Location	Water Applied	Water Recovered	Tylosin runoff	
	(L)	(%)	(µg)	(%)
Brkg1	5.73	92.9	27.80	12.07
Brkg16	4.23	89.7	19.20	8.40
Aurora	5.73	88.3	20.60	8.98

Table 3. Runoff amounts and tylosin content in runoff after manure application in 2005. The amount of manure applied to the microinfiltration sprinkler area contained a total of 0.11 mg tylosin. (authors unpublished data)

Tylosin Runoff

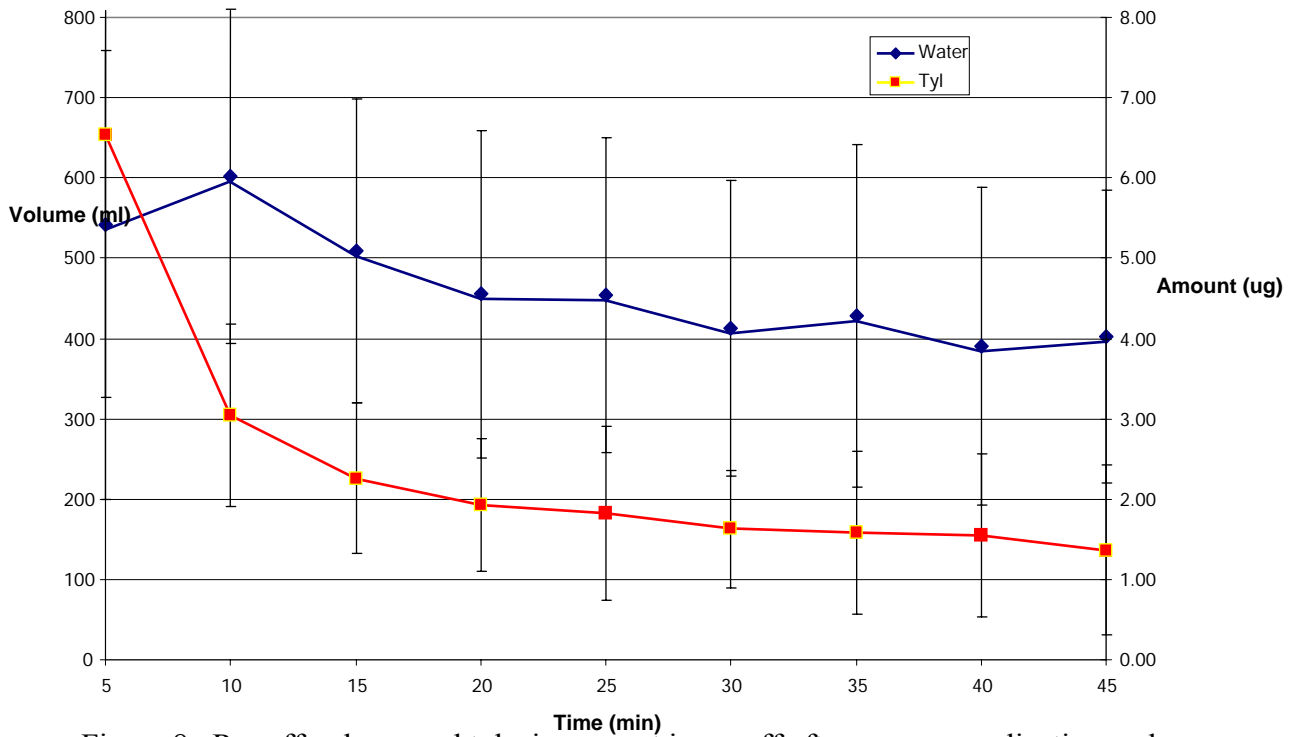


Figure 8. Runoff volume and tylosin amount in runoff after manure application and sprinkler infiltration. (authors unpublished data)

In 2006, this same study was repeated. Swine were fed at the same antibiotic concentration, and slurry was collected and a similar amount of slurry was applied. However, the concentration of antibiotic was much lower in 2006 than 2005. The amount of CTC present in slurry was only about 14 mg applied and tylosin, while it was detectable in the slurry it was low enough so that quantification was not possible. The results were that runoff from either set of antibiotic plots at all locations had no detectable antibiotic levels, even though the amount of water applied were similar between years. Another difference between the two years of application was that the initial water content of soil prior to manure application was about 20% in 2005 but as low as 10% in 2006 due to dry conditions. This may have allowed for more antibiotic to sorb to the dry soil. When soil samples were taken to examine the depth of infiltration, the amount of antibiotic in either treatment was not detectable at any depth in either year.

Growth of soil microbes could be inhibited by very low amounts of CTC (<5 ppb) but not tylosin (Figures 9 and 10). Microbial growth from strains purified from swine manure were not affected by CTC up to 50 ppb.

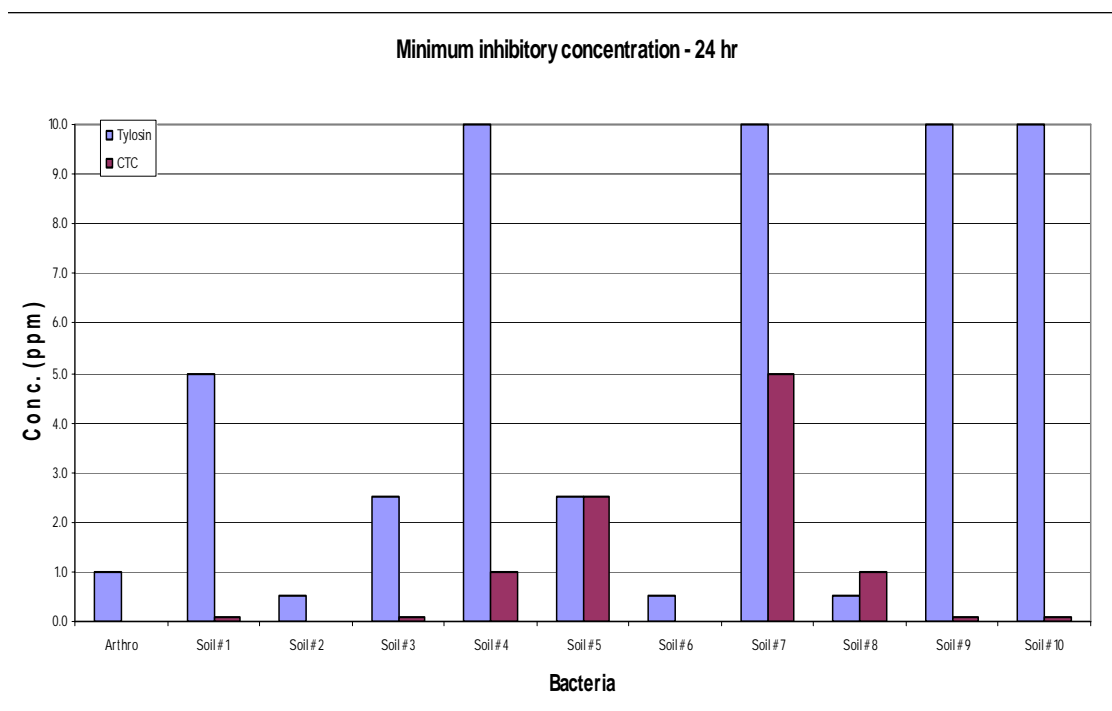
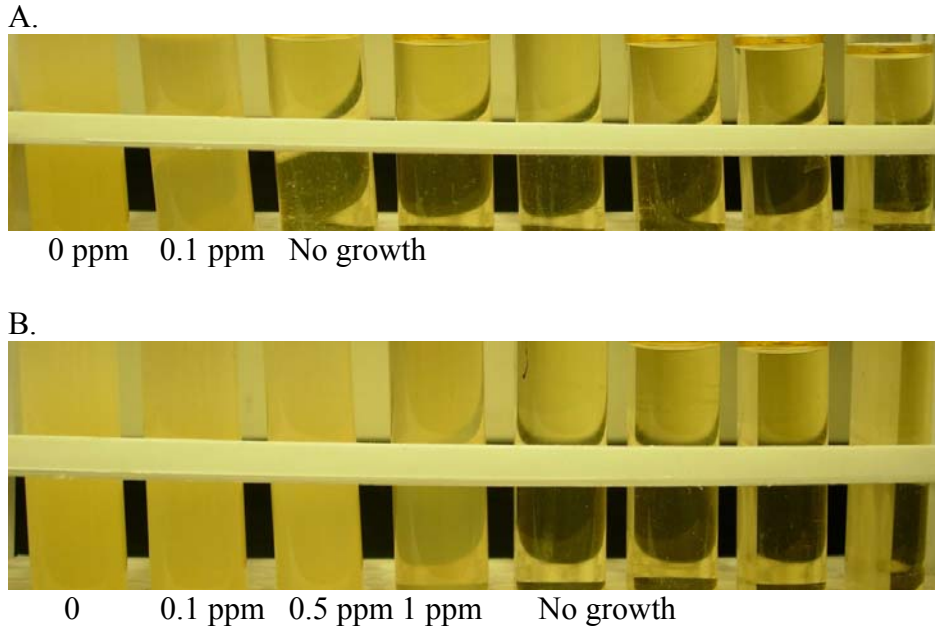


Figure 9. Minimum inhibitory concentrations of tylosin and chlortetracycline (CTC) after 24 hours of growth to 10 strains of bacteria, most of which were isolated from soil. Most isolated soil bacteria were very sensitive to CTC with concentrations of <5ppb inhibiting growth. Strains were not as sensitive to tylosin. (authors unpublished data)

When using microbial strains that were specific herbicide degraders, atrazine was fully degraded after 24 h in the control and tylosin cultures and after 72 h in the chlortetracycline culture. About 88% of the 2,4-D in control treatments was mineralized by the 2,4-D degraders 96 h after treatment, whereas tylosin slowed the initial degradation with only 4% mineralized by 10 days after treatment (DAT). However by 14 DAT, recovery occurred and the amount mineralized in the tylosin treatment was similar to the control. Chlortetracycline substantially decreased the activity of *S. herbicidovorans* with only 12% of the added 2,4-D mineralized 14 DAT. Manure decreased microbial mineralization of atrazine compared to soil. When manure contained chlortetracycline (when soil was treated with manure from swine feeding trials), the amount of atrazine mineralized was significantly less (Figure 11). Soil amended with biosolid or biosolid that contained tetracycline had amounts of atrazine mineralization that were similar to soil alone.

Figure 10. Example of sensitive and nonsensitive microbes to CTC. In example A, no growth of bacteria occurred after 24 hr in tubes that contained more than 0.1 ppm CTC. In example B, growth of bacteria could be seen in concentrations up to 1 ppm CTC. (authors unpublished data)



Colony forming units (CFU) of heterotrophic microorganisms culturable under aerobic conditions on R2A agar plates were 10-fold higher 7DAT in soil treated with manure containing CTC compared with all other treatments but it is unclear if the increase in CFU was due to native soil or manure organisms. The density of 2,4-D degrading microorganisms using the MPN method indicate a nearly 20 fold increase in number of 2,4-D degraders after adding 2,4-D to soil samples compared to soil samples without the application. The addition of manure with or without antibiotics did not influence the numbers of 2,4-D degrading organisms. DGGE analysis allowed for representation of all microorganisms present, culturable or not. Significant shifts in the 16S rRNA gene pool occurred within and among the different treatments over time.

Atrazine Mineralization Study

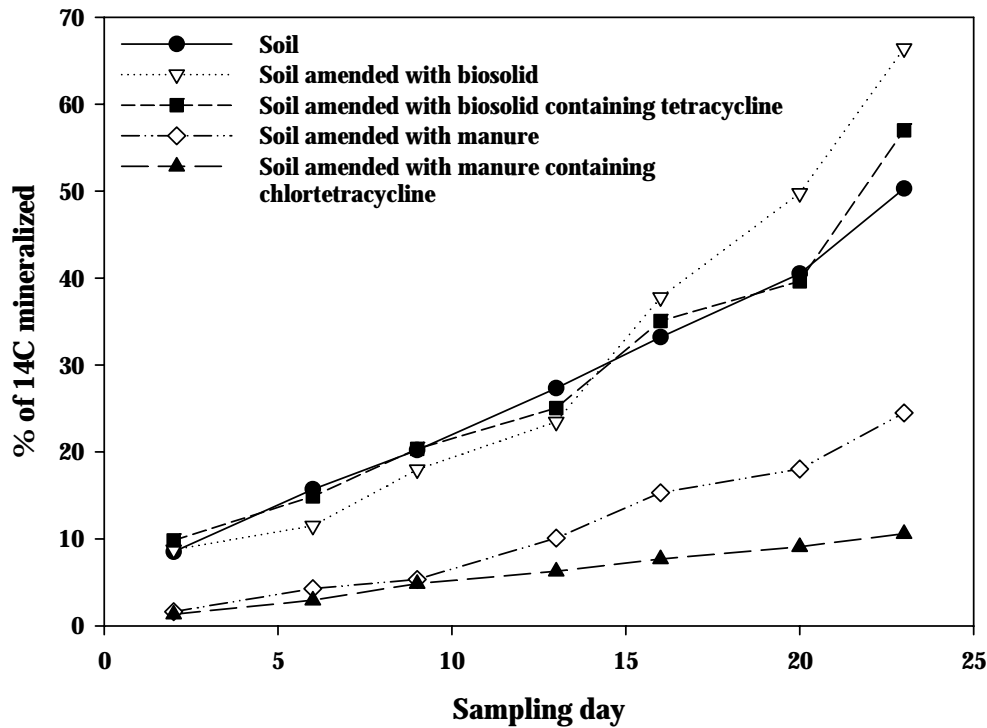


Figure 11. Atrazine mineralization in soil amended with soil, biosolid, and manure either alone or treated with antibiotics (tetracycline or chlortetracycline). (authors unpublished data)

These data suggest that deep application of manure in appropriate soils (i.e. in areas where large rocks would not interfere with application or other areas where deep tillage could be done) would 1) help conserve nutrients, especially N, 2) will not negatively affect corn or soybean yield, and 3) may be a method to reduce the effects of antimicrobial and nutrient movement in runoff waters to nontarget areas. Just adding manure affected microbial mineralization of atrazine, but less so than in the manure contained chlortetracycline. Placing manure off the soil surface may also reduce impacts on the normal biological processes of surface soil. The use of antimicrobials in some stages of swine development is often mandatory from pork processors. Choice of antimicrobial compound may also be of importance to minimize the disruption of normal soil processes after landspreading manure. For example, tylosin was found to have less inhibitory effect on native soil microbes and soil processes (i.e. herbicide mineralization) than an antibiotic such as chlortetracycline.

Publications, citations, and information transfer.

Completed

Reiman, M. 2006. The impact of deep manure injection on water infiltration, nutrient distribution, and corn yield. M.S. Thesis, SDSU Brookings, SD.

Lehnert, K., V. Brözel, S. Gibson, and S. Clay. 2006. Antibacterials in manure influence soil microbial activity. Poster for NC Amer. Microbiology Society Meeting. Brookings, SD. October, 2006.

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Graduate student seminars. 2005, 2006, and 2007. Ms. Lehnert, Mr. Reiman, and Mr. Hoese presented seminars for faculty and students in Biology and Plant Science Departments as part of their ongoing graduate training.

Carlson, C.G. D.E. Clay, and C. Reese. 2007. Deep manure injection. North and South Dakota Watershed Manager Training. Feb 12, 2007. Aberdeen, SD.

Clay, D.E., C.G. Carlson, and S.A. Clay. 2007. Precision deep manure applications. SD EPA319 task force planning meeting. March 20, 2007, Pierre SD.

Kleinjan, J., C.G. Carlson, and D.E. Clay. 2006. Precision deep manure application (poster) Brookings field day. June 2006. Brookings SD.

Kleinjan, J., C.G. Carlson, and D.E. Clay. 2005. Precision deep manure application (poster) Brookings field day. June 2005. Brookings SD.

Reicks, G, C.G. Carlson, and D.E. Clay. 2006. The Impact of Deep Manure Injection on Nutrient Distribution and Corn Yield. SE. Farm field days. September 6, 2006.

Reese, C. L., D. E. Clay, D. Beck, J. Kleinjan, C. G. Carlson and S. Clay. Lessons learned from implementing management zones and participatory research in production fields. Eighth International Conference on Precision Agriculture. 23 – 26 July 2006. Marriott Hotel, Minneapolis, Minnesota.

Reese, C., L., D. E. Clay, S. A. Clay, C. G. Carlson and J. Kleinjan. 2005. South Dakota State Report. Upper Midwest Aerospace Consortium Annual Meeting. 3-5 February 2005. Grand Forks, ND.

Clay, D.E., S.A. Clay, C.G. Carlson. 2005. Is precision farming a BMP. National 406 water quality meeting. San Diego California, February 7-10, 2005

Carlson, C. G. and D. E. Clay, 2005. Precision Manure Management, East Central conference on integrating emerging technology into agriculture, 26 January, Sioux Falls.

Carlson, C. G. and D. E. Clay, 2005, South East Field Days. Deep tillage update, 1 September, Beresford

Carlson, C.G. 2005. Precision manure management for improved profitability. East central conference on integrating emerging technologies into agriculture. Sioux Fall SD, January 26, 2005

Clay, S.A. 2005. Manure effects on factors other than nutrients. East central conference on integrating emerging technologies into agriculture. Sioux Fall SD, January 26, 2005

Carlson, C.G. 2005. Precision deep fertilizer placement. SD Professional Soil Scientists. Huron, SD March 10, 2005

Web-page development

A web-site that highlights research activities has been developed. The site is available at <http://plantsci.sdstate.edu/precisionfarm/index.aspx>. This site contains a virtual tour of the manure Flandreau deep manure research experiment.

Symposiums

A day long symposium on integrating emerging technologies into production systems was held in Sioux Fall, SD on January 26, 2005 and in Aberdeen SD on March 8, 2005. At these meetings approximately 100 and 250 producers attended the Sioux Falls and Aberdeen meetings, respectively. The Sioux Fall meeting discussed manure management and ethanol production from corn. A discussion of deep manure management was presented at the Aberdeen meeting.

In preparation

Clay, D.E., C.G. Carlson, and M. Reiman. 2008. Deep manure impact on soil nutrient concentrations and corn yields. A draft has been prepared. This paper is ready for internal review which will be followed up with submittal to the Journal of Environ. Qual.

Hoese, A. 2007 (in progress). Tylosin and chlortetracycline, soil runoff and impact on soil microbes. M.S. Thesis. SDSU, Brookings.

SDSU Research Farm Field Days. Brookings and Beresford, SD. June, September 2007. Information presented by: Graig Reicks.

Student support:

Graduate student involvement (3): Mark Reiman, Aaron Hoese, Kelly Lehnert

Undergraduate or high school student involvement (7): Dan Clay, Mitch Olson, Steve Biersbach, Kelsey Wick, Elissa Olson, Neal Bainbridge, Jesse Hall

Notable Awards and Achievements

Lehnert, K. 2006. Monitoring soil diversity after tylosin and chlortetracycline laden manure treatments. First Place. SDSU Sigma Xi Graduate Student Proposal Contest

Reiman, M. 2005. The impact of deep manure injection on water infiltration, nutrient distribution, and corn yield. Second Place. SDSU Sigma Xi Graduate Student Proposal Contest

Based on some of the research with manure and antibiotics, an NSF grant that is a joint effort between SDSU and SDSMT was funded in 2006 to investigate the fate of antibiotics in manure and its effects on manure prior to land application.

Water Conservation Using Automated Irrigation Water Management for Center Pivots

Basic Information

Title:	Water Conservation Using Automated Irrigation Water Management for Center Pivots
Project Number:	2005SD35B
Start Date:	3/1/2005
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	First
Research Category:	Not Applicable
Focus Category:	Irrigation, Water Use, Agriculture
Descriptors:	
Principal Investigators:	Hal D. Werner, Todd P. Trooien

Publication

1. Oswald, Jared, 2006, Automated Water Management for Center Pivot Irrigation Systems, MS Engineering Thesis, Agricultural and Biosystems Engineering Department, College of Engineering, South Dakota State University, Brookings, SD, 97 pages.
2. Werner, Hal, Todd Trooien, and Jared Oswald, 2006, Irrigation Water Management Using Automated Center Pivots, Eastern South Dakota Water Conference, WRI, South Dakota State University, Brookings, SD.

Progress Report

State Water Resources Institute Program (SWRIP) March 2006 to February 2007

Title: Water Conservation Using Automated Irrigation Water Management for Center Pivots

Investigators: Dr. Hal Werner and Dr. Todd Trooien

Introduction:

This project is a continuation project begun in 2005 with the goal to develop an automated irrigation management system for center pivot irrigation that will perform scientific irrigation scheduling. The expected outcome is that farmers will save water and energy, improve production and protect the environment. The first objective of the research to develop an irrigation scheduling model was completed during the initial year. Due to hardware problems and weather conditions, the system was not field tested in 2005. Plans were to attempt field testing again in 2006 but once again weather delayed field testing. The continuation project included a second objective to develop training software based on the simulation model.

Project Information:

Specific objectives of this continued research are to:

- Test the center pivot automation (CPA) system under field conditions to determine the effectiveness of the irrigation scheduling and the water conservation benefits.
- Develop a software package based on the automated irrigation management system that can be used as a training tool to assist farmers in scientific irrigation scheduling.

The irrigation scheduling model was developed using the ASCE Penman ET equation. Crop coefficients were adapted for corn, soybeans and potatoes. Initially about 4000 simulations were completed. The simulation model has been adapted to alfalfa/grass. The model has also been adapted to simulate part circle center pivots and multiple crops within the same center pivot coverage. Figure 1 shows the output screen for the simulator.

Limited irrigation water can impact the producer's water management. Results of the simulations for corn are being used to determine the impact of various inputs on crop yield. Future work will analyze how best to use limited irrigation water with center pivot irrigation systems.

A major limitation of any irrigation scheduling practice is obtaining soil moisture readings that can be used to index and validate the soil water balances. A number of methods for measuring soil moisture are available that are suited to automation. The accepted standard of measuring soil moisture using neutron scattering is not adapted to automation. A laboratory study of four different soil moisture instruments was begun. An undergraduate student developed and built the test apparatus, then conducted preliminary testing before the student was lost to graduation. Figure 2 shows the laboratory test setup for the soil moisture sensors. Figure 3 shows the installation of Watermark® sensors and radio equipment in the field.

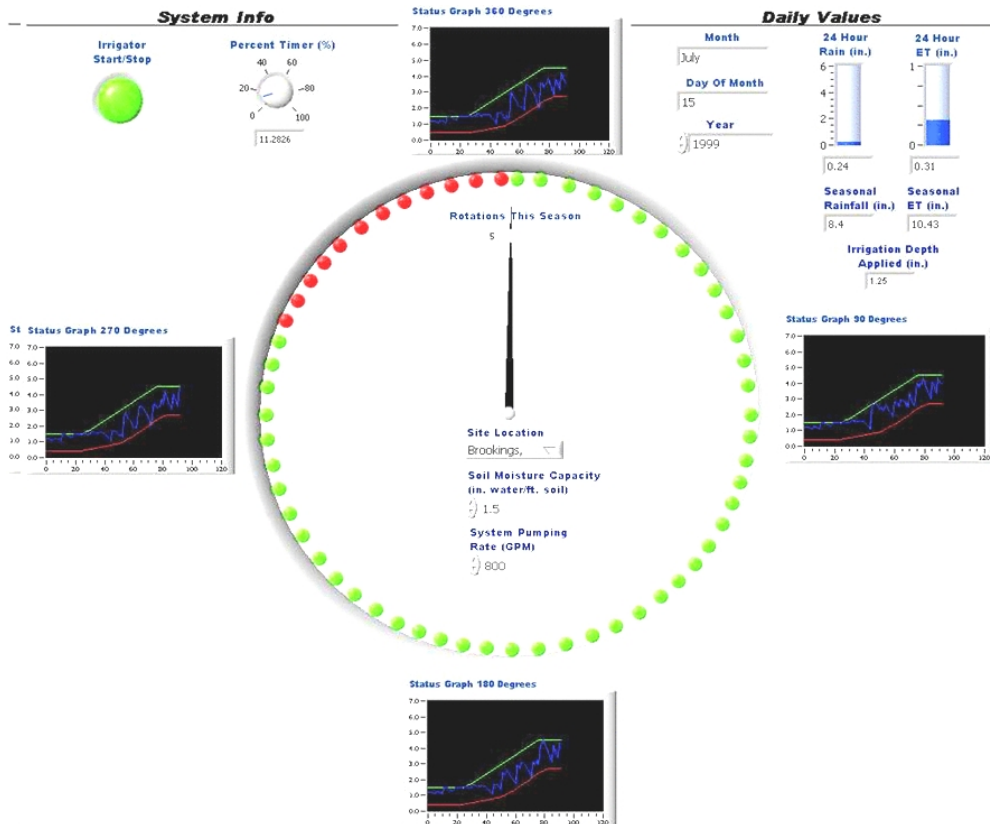


Figure 1 Simulator output screen.

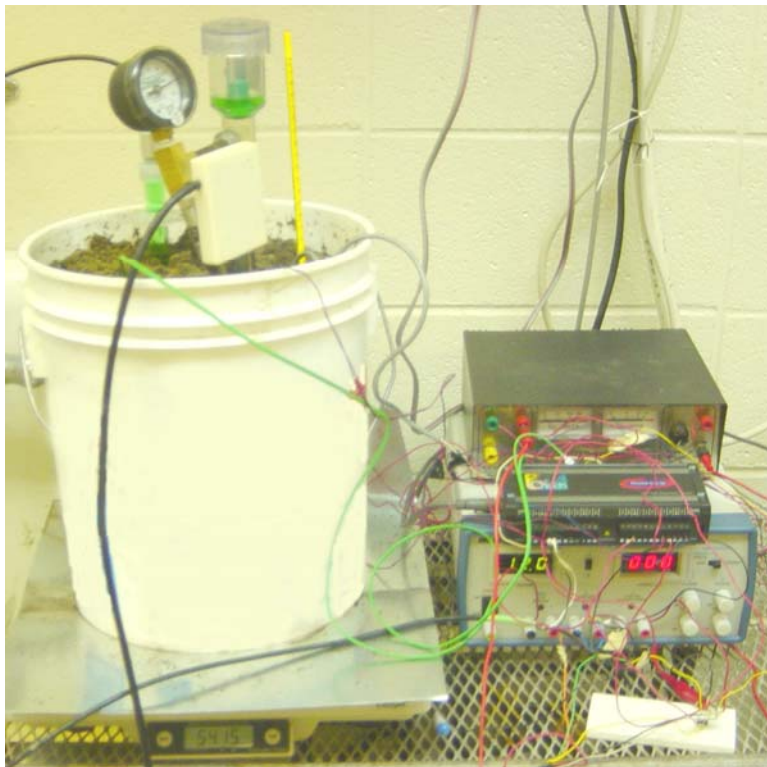


Figure 2 Laboratory setup for soil moisture sensors.



Figure 3 Field testing of Watermark sensor.

The second objective of the continuation project was to develop training software to assist producers with the concepts of irrigation water management. Two undergraduate students began development of the software but were not able to complete the project due to leaving for other commitments. Replacement students have not become available. Figure 4 is a screen shot of the prototype training software.

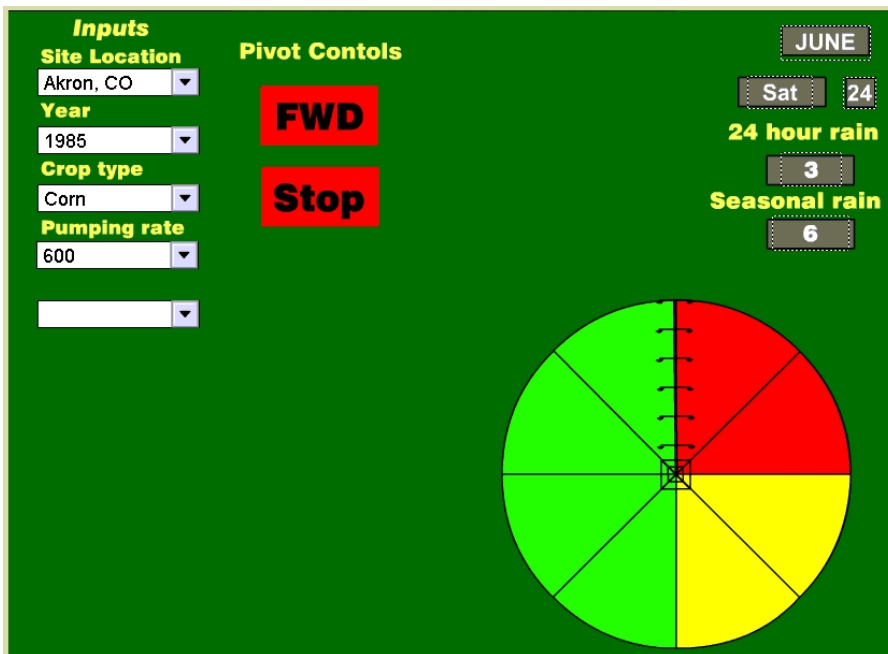


Figure 4 Screen shot of prototype training software.

Fixed-Bed Adsorption Column Studies and Engineering Scale-Up Design of a Limestone-Based Metals Removal Technology for Small Water Supply Systems

Basic Information

Title:	Fixed-Bed Adsorption Column Studies and Engineering Scale-Up Design of a Limestone-Based Metals Removal Technology for Small Water Supply Systems
Project Number:	2005SD37B
Start Date:	3/1/2005
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	First
Research Category:	Not Applicable
Focus Category:	Toxic Substances, Treatment, Water Supply
Descriptors:	
Principal Investigators:	Arden D Davis, David J. Dixon

Publication

1. Davis, A.D., Webb, C.J., Dixon, D.J., Sorensen, J.L., and Dawadi, S., 2007, Arsenic removal from drinking water by limestone-based material: *Mining Engineering*, v. 59, no. 2, p. 71-74.
2. Webb, C.J., Davis, A.D., Dixon, D.J., Sorensen, J.L., Berryman, G., and Williamson, T.E., Arsenic remediation of drinking water using limestone: characterization of limestone and dolomite: Submitted for publication, *Environmental Science and Technology*.
3. Sorensen, J.L., Davis, A.D., Dixon, D.J., and Hocking, C.M., 2007, Further testing of limestone-based material for arsenic removal from small water systems: Presented at 20077 Western South Dakota Hydrology Conference, April 19, 2007, Rapid City, South Dakota.
4. Davis, A.D., Dixon, D.J., and Sorensen, J.L., 2006, Fixed-bed adsorption column studies and engineering scale-up design of a limestone-based metals removal technology: Eastern South Dakota Water Conference, Brookings, South Dakota, November, 2006.
5. Sorensen, J.L., Davis, A.D., Dixon, D.J., and Webb, C.J., 2006, Development of an agglomeration process to increase the efficiency of limestone-based material for removing metals from drinking water: Presented at 18th Annual South Dakota Ground-Water Quality Conference, March, 2006, Pierre, South Dakota.
6. Sorensen, J.L., Davis, A.D., Dixon, D.J., and Webb, C.J., Controlling factors on arsenic removal from water by limestone-based material: Presented at Western South Dakota Hydrology Conference, April, 2006, Rapid City, South Dakota.
7. Webb, C.J., Campbell, C., Davis, A.D., Dawadi, S., Dixon, D.J., and Sorensen, J.L., 2006, Arsenic remediation of drinking water using limestone-based material: American Chemical Society, Division of Environmental Chemistry, Symposium on Current Status of Research on Arsenic Remediation, 231st National Meeting, March 26-30, Atlanta, Georgia.
8. Davis, A.D., Webb, C.J., Dixon, D.J., Sorensen, J.L., and Dawadi, S., 2006, Arsenic removal from drinking water by limestone-based material: Preprint 06-034, Society for Mining, Metallurgy, and Exploration, Littleton, Colorado, 3 p.
9. Process and apparatus to reduce the amounts of arsenic in water: Dr. Cathleen J. Webb, Dr. Arden D. Davis, and Dr. David J. Dixon; U.S. Patent Application Serial No. 10/861,586; patent pending. Continuation-in-part filed in 2005.

Progress Report

State Water Resources Institute Program (SWRIP) March 2006 to February 2007

Part I.

Title: Fixed-Bed Adsorption Column Studies and Engineering Scale-Up Design of a Limestone-Based Metals Removal Technology for Small Water Supply Systems

Investigators: Dr. Arden D. Davis, S.D. School of Mines and Technology
Dr. David J. Dixon, S.D. School of Mines and Technology

This project quantified and compared the effectiveness of both unprocessed limestone chips and manufactured limestone-based granules to remove arsenic from naturally occurring arsenic-contaminated ground water. Keystone, South Dakota, City Well No. 4 was used as the water source. By running column studies with three columns in series, the researchers extended the amount of adsorbent used to treat the water, in comparison to previous column studies that have used only one column at a time. This extended the length of the mass transfer zone established as the adsorbent media reacts with arsenic in the water. The length of the mass transfer zone is directly affected by contact time with the adsorbent. Longer contact time results in a shorter mass transfer zone and results in more complete utilization of the adsorbent.

A breakthrough curve was plotted for each column in each study. Breakthrough in this study occurred when the arsenic concentration went from undetectable to 10 ppb, the new drinking water standard. Exhaustion of a column, the point at which the media must either be replaced or regenerated, occurred when the influent and effluent concentrations of the metal in question were equal. Empty bed contact time (EBCT) for each column study also was calculated. The EBCT was used to represent the length of time a stream of water was in contact with the adsorbent media. This is related to the system's kinetics.

The principal investigators requested a one-year extension on the project because of unexpected difficulties that delayed column work with Keystone water. Column studies have been completed. Results from the column studies using Keystone well water are being used to design a scaled-up pilot project for future application at Keystone City Well No. 4. Pilot project operating variables include: adsorbent type, column diameter, water flow rate, adsorbent bed depth, weight of adsorbent in column(s), contact time, influent and effluent impurity concentrations (ions present other than arsenic), and desired effluent impurity concentrations. More than one design method will be applied for comparison purposes. In addition, column testing of the limestone-based granules as a treatment method for cadmium removal will help quantify cadmium removal capacity of the adsorbent in a fixed-bed adsorption column.

Benefits of this research include a low-cost treatment technology that will reduce select metals to below drinking water standards. This project will bring installation of a

pilot arsenic treatment technology at the Keystone, South Dakota City Well No. 4 site one step closer to reality.

The objectives of this work were to:

- 1) Determine breakthrough and exhaustion of three columns run in series using crushed limestone of 1-2 mm in size as the treatment media and Keystone city well water as the arsenic source. Empty bed contact time was determined.
- 2) Determine breakthrough and exhaustion of three columns run in series using manufactured limestone-based granules 1-2 mm in size as the treatment media and Keystone city well water as the arsenic source.
- 3) Scale-up the results of column studies in Objectives 1 and 2 using engineering design methods. Design plans are being developed to evaluate the potential for a future onsite field pilot study at Keystone, South Dakota City Well No. 4.
- 4) Determine breakthrough and exhaustion of a column run using manufactured limestone-based granules 1-2 mm in size as the treatment media and an influent cadmium water solution above the drinking water standard of 5 ppb. Results are being used to calculate adsorption capacity of the limestone-based media using a fixed bed treatment method.

Methods and Accomplishments

Tasks achieved during this research were: 1) a review of related published literature was completed, 2) a summary of the properties of arsenic, carbonates, adsorption theory, and agglomeration processes was completed to provide technical background for the research, 3) the properties of other innovative arsenic technologies in comparison to limestone-based arsenic removal were summarized, 4) batch tests were completed for seven manufactured granule formulas using solutions of 100 and 500 ppb initial arsenic concentration, 5) batch tests were completed for the seven granule formulas using Keystone well water, 6) three columns in series were run using 0.5 – 1.0 mm Minnekahta Limestone, 7) a column test of 0.5 – 1.0 mm Minnekahta Limestone and granulated ferric hydroxide was run, and 8) engineering scale-up was begun by using the results from the column test with three columns in series to evaluate the potential for an onsite pilot study at the Keystone well.

Arsenic is a persistent, bio-accumulative toxin. The maximum contaminant level for arsenic, formerly 50 parts per billion (ppb), was lowered to 10 ppb in 2006 because of links to cancer. Lowering of the standard will cause economic pressures for rural communities with high levels of arsenic in their drinking water supplies. Current removal technologies are expensive and their implementation will cause economic pressures for rural communities. The American Water Works Association has estimated the cost of decreasing the arsenic standard to 10 ppb in South Dakota at \$8.25 million, and has estimated a cost of \$550 million per year to meet the new standard nationally (Frost et al., 2002).

Cadmium is a persistent and bio-accumulative toxic metal. Long-term exposure has the potential to cause kidney, liver, bone, and blood damage. The maximum contaminant level for cadmium is set at 5 ppb because of health concerns and links to

cancer. Cadmium in the environment is the result of both natural and anthropogenic sources. Anthropogenic sources are the greater environmental threat, and include industrial activities such as smelting operations, urban and industrial wastes, and fertilizer production and application. About one percent of cadmium ingestion is via drinking water; most cadmium intake is related to the food supply. On average, carbonate rocks contain about 48 ppb cadmium, while shales and igneous rocks contain about 200 ppb cadmium (Hem, 1978)

Materials used for testing arsenic removal (numerous limestone rock types and reagent grade calcium and magnesium carbonates) were characterized by surface area measurements, particle size analysis, and X-ray diffraction analysis (to determine material composition). Research has shown that as the particle size is reduced, the efficiency and capacity of arsenic removal are improved significantly.

The proposed mechanism for the removal of arsenic by limestone is the adsorption/precipitation of hydrated calcium arsenates, $\text{Ca}_3(\text{AsO}_4)_2 \cdot x\text{H}_2\text{O}$, or hydrated magnesium arsenates, $\text{Mg}_3(\text{AsO}_4)_2 \cdot x\text{H}_2\text{O}$, onto the heterogeneous surface of the limestone. The solubility product of calcium arsenate, $\text{Ca}_3(\text{AsO}_4)_2$, is 6.8×10^{-19} and the solubility product of magnesium arsenate, $\text{Mg}_3(\text{AsO}_4)_2$, is 2.0×10^{-20} . The removal of arsenic, and the subsequent stability of the waste product, is facilitated by the alkaline surface pH of the limestone (pH 9-10). Calcium-rich arsenic compounds have been observed with scanning electron microscopy when samples were prepared with about 1,000 to 8,000 ppm arsenic.

Minnekahta Limestone from the Pete Lien and Sons Quarry in Rapid City, South Dakota, was used as the limestone source for this research. Based on X-ray diffraction analysis, Minnekahta Limestone is composed of about 95 percent calcite, 4 percent quartz, and 1 percent microcline.

Water from Keystone Well No. 4 was obtained during spring, 2006, in five-gallon buckets that were sealed and transported to the laboratory at South Dakota School of Mines and Technology for testing. An analysis of a sample of the water is shown in Table 1.

Parameter	KEY-2, Sampled 11/12/04
Physical Properties	
Electrical Conductivity	461 umhos/cm
Hardness	116 mg/L
Total Dissolved Solids	252 mg/L
Total Suspended Solids	<5.00 mg/L
Turbidity	1.5 NTU
pH	8.06
Non-Metallics	
Acidity	<10.0 mg/L
Alkalinity	217 mg/L
Bicarbonate	264 mg/L
Carbonate	0.00 mg/L
Chloride	4.50 mg/L
Sulfate	23.8 mg/L
Metals – Total	
Aluminum	0.043 mg/L
Arsenic	0.053 mg/L
Cadmium	<0.001 mg/L
Chromium	0.001 mg/L
Copper	<0.005 mg/L
Iron	0.043 mg/L
Lead	<0.001 mg/L
Lithium	0.058 mg/L
Manganese	0.047 mg/L
Nickel	0.008 mg/L
Selenium	<0.005 mg/L
Silicon	5.33 mg/L
Strontium	2.69 mg/L
Vanadium	<0.001 mg/L
Zinc	<0.050 mg/L
Metals – Dissolved	
Aluminum	<0.010 mg/L
Arsenic	0.050 mg/L
Cadmium	<0.001 mg/L
Calcium	23.6 mg/L
Chromium	<0.001 mg/L
Copper	<0.005 mg/L
Iron	<0.050 mg/L
Lead	<0.001 mg/L
Lithium	0.058 mg/L
Magnesium	13.8 mg/L
Manganese	0.047 mg/L
Nickel	0.008 mg/L
Selenium	<0.005 mg/L
Silicon	5.21 mg/L
Sodium	62.5 mg/L
Strontium	1.33 mg/L
Vanadium	<0.001 mg/L
Zinc	<0.050 mg/L

Table 1. Water analysis from Keystone City Well No. 4, Keystone, South Dakota.

The columns were constructed of PVC pipe of varying diameters and lengths, depending on the column design. Columns were constructed using plumbing materials available in most hardware stores. PVC pipe was used as the column bed. PVC female adapters were cemented to each end of the length of PVC pipe. Threaded PVC plugs were used to seal each end of the column. A 3/8-inch threaded hole was drilled at the center of each plug and 3/8-inch nylon barb adapters were cemented into each hole. Wire mesh (mesh size 0.175 mm), slip joint washers, and drain strainers were used to hold the packed material in the column bed. Vinyl tubing and shut-off valves were used at the inlet and outlet of the column to control flow through the column. Metal pipe hangers were used to mount the column to a vertically-hanging plywood board attached to a table. Figure 1 shows a typical column set up.

For this research 12 inch by 1.5 inch columns were used. Flow was eight bed volumes per hour (2.9 L/hr or 48 mL/minute). Column effluent samples were collected regularly during a column run. The pH and conductivity of the collected samples were measured and effluent samples were filtered through a 0.45 μm pore size membrane filter. Collected samples were acidified using concentrated nitric acid and analyzed by MidContinent Testing Laboratories in Rapid City, South Dakota for total arsenic concentration.

Influent metals solutions were mixed to varying concentrations, depending on the experiment and the metal being examined. Metals solutions are pH balanced to a pH of 8 ± 2 prior to use. The influent solution was pumped into the column from the bottom up and a constant flow rate out of the column is set using valves at the flow outlet at the top of the column. Samples of effluent were collected regularly and the pH and conductivity of the effluent are measured. Samples were filtered with a 0.45 μm filter and then were analyzed by MidContinent Testing for metals concentrations. Figure 1 shows a typical column set up for two columns. Later experiments used three columns in series.



Figure 1. Photo of column experiments being run.

A column test of 0.5-1.0 mm sized Minnekahta Limestone in three columns in series using Keystone well water was performed for this research. Each column was 1.5 inches in diameter by 12 inches long. The columns were run from the bottom up, with hose connecting each column to the next. All three columns were sampled regularly in unison. An unfiltered water sample from the last column in series was collected after about 2 hours of running the column for comprehensive water quality analysis. A column

test of 0.5-1.0 mm sized Minnekahta Limestone and Granular Ferric Hydroxide (GFH) was also run using Keystone well water. The column was 1.5 inches in diameter by 12 inches long. The column was run from the bottom up. Of the total mass of material added to the column, about 0.5 percent consisted of GFH mixed in with the limestone during packing as thin layers.

After testing, limestone particles were examined. Scanning electron micrograph (SEM) images of the surfaces of limestone granules were taken to visually characterize the granule surfaces. Figure 2 shows the surface of a limestone particle. X-ray fluorescence indicated that these crystals are composed of calcium carbonate. This type of crystallization was not observed on all the particles and was not widespread.

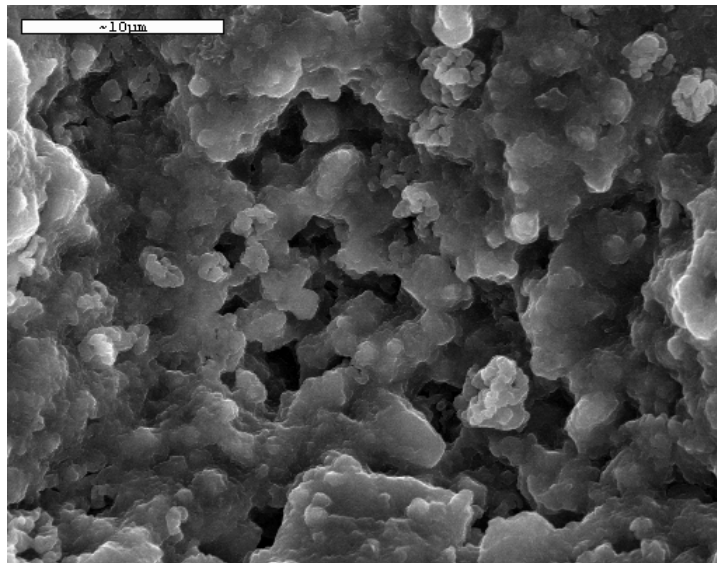
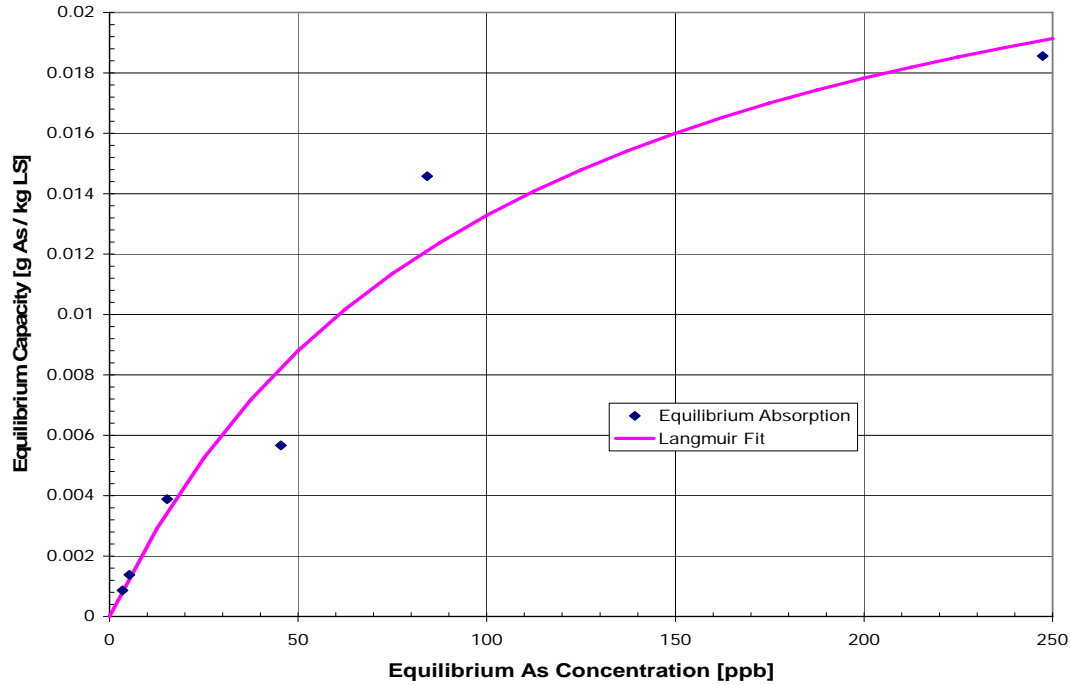


Figure 2. Limestone granule with 10 percent Portland cement binder, taken at 3,500x magnification.

Results of arsenic removal with Minnekahta Limestone showed that the Langmuir isotherm appears to fit the trend of equilibrium adsorption (Figure 3).



Arsenic (V) Adsorption on Minnekahata Limestone (< 0.5 mm) at ~25 °C.

Figure 3. Langmuir isotherm fitted to arsenic-removal data from experiments.

Experiments with cadmium solutions in the range of parts per billion removed all cadmium in solution. Solution concentrations were increased to part per million levels in order to reach effluent cadmium concentrations greater than 10 ppb. Because cadmium removal was greater than 99 percent, an adsorption isotherm could not be developed.

Adsorption capacities showed that cadmium uptake increased dramatically for increasing cadmium concentrations. In Figure 4, initial cadmium concentration values (5, 20, and 50 ppm) are plotted versus adsorption capacity. At an initial concentration of 5 ppm, adsorption capacity is 4.4 $\mu\text{mol/g}$ while at an initial concentration of 50 ppm, adsorption capacity increases to 44.4 $\mu\text{mol/g}$. The data presented in Figure 4 fit the trend line well (R^2 value > 0.9) and it follows that this figure could be useful in predicting limestone cadmium capacities for experiments under similar conditions at other cadmium concentrations in the range of about 0 to 60 ppm. From these results it is clear that the capacity for limestone to remove cadmium is much greater than the capacity for arsenic removal.

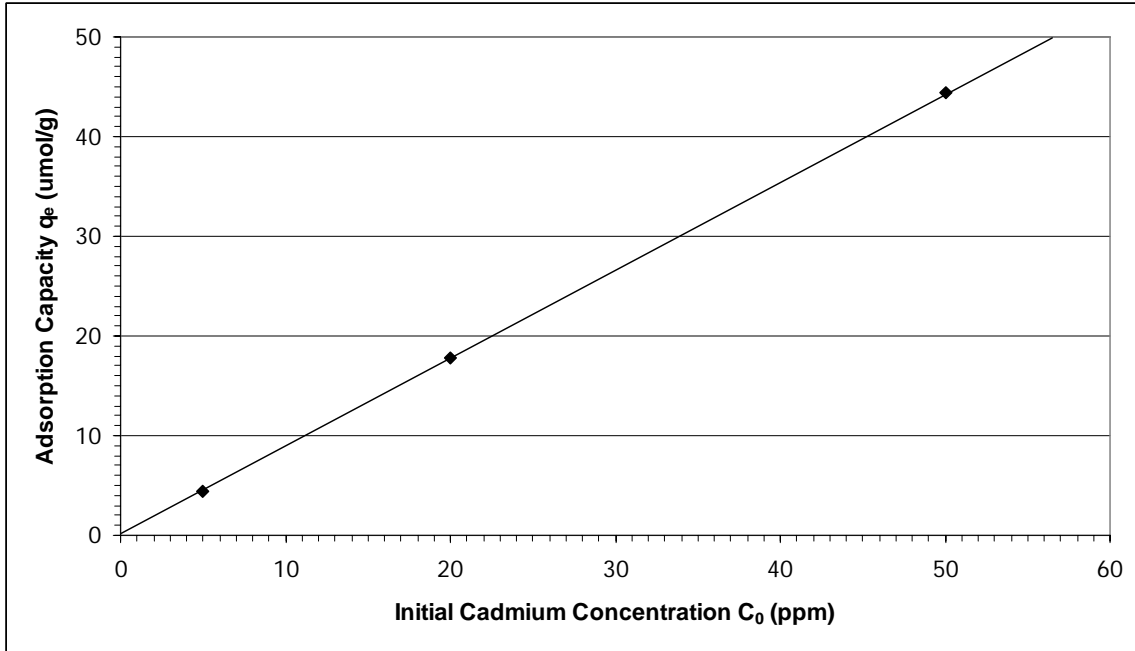


Figure 4. Cadmium adsorption capacity of limestone for initial cadmium concentrations of 5, 20, and 50 ppm. Initial pH 8.0 ± 0.2 pH units, room temperature.

Results of other ongoing work will be presented after completion of the research during the project extension. This will include results of other column experiments and engineering scale-up studies for Keystone City Well No. 4 (shown below on Figure 5).



Figure 5. Keystone City Well No. 4.

Part II.

Information Transfer Program: A field demonstration project was set up for arsenic removal using ground water at a well in Keystone, South Dakota. Well water was used on-site, and water samples also were transported to a laboratory at South Dakota School of Mines and Technology for arsenic-removal tests.

Publications and presentations from the work are listed below.

Student Support: A Ph.D. student, Jenifer L. Sorensen, was funded as a graduate research assistant. Ms. Sorensen defended her Ph.D. dissertation during spring semester, 2006. Her dissertation was based in part on this research work. This research also supported a Master of Science student, Crystal M. Hocking, as a graduate research assistant.

Microbial Indices of Soils and Water Associated with Vegetated Treatment Areas (VTAs) from Five Animal Feeding Operations (AFOs) in South Dakota

Basic Information

Title:	Microbial Indices of Soils and Water Associated with Vegetated Treatment Areas (VTAs) from Five Animal Feeding Operations (AFOs) in South Dakota
Project Number:	2006SD74B
Start Date:	3/1/2006
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Surface Water, Acid Deposition
Descriptors:	
Principal Investigators:	Bruce Bleakley, Todd P. Trooien

Publication

1. Bleakley, B.H. 2007. Microbial indices of soil and water. South Dakota Water Resources Institute Water News. January 2007, volume 3, number 1.

Microbial indices of soils and water associated with vegetated treatment areas (VTAs) from five animal feeding operations (AFOs) in South Dakota

Introduction:

Nutrient and sediment loads from animal feeding operations (AFOs) can reduce the quality of surface waters and groundwaters. Basin technologies can help alleviate some of these problems, but they can be costly, and cause odor problems. The potential for development and implementation of alternative non-basin technologies interests a variety of stakeholder groups. An EPA funded grant, "Evaluating the Performance of Vegetated Treatment Areas," (Dr. Todd Trooien, P.I.), seeks to evaluate the technical and financial feasibility of vegetated treatment areas (VTAs) as a non-basin alternative for reducing nutrient and sediment loads from AFOs having less than 1,000 animal units. For this EPA grant, each of five AFOs in different areas of South Dakota have had or will have VTAs established. Performance of each VTA is being measured by sampling inflows and outflows from vegetated areas. The samples are being analyzed for nutrients (N and P), salts, sediment, and numbers of fecal coliform bacteria. Data from these measurements will allow calculation of water and salt balances, loss or gain of nutrients, removal of sediment, and fecal coliform numbers. Data will be entered in a basin model to simulate basin performance, that will be compared to measured VTA performance. Samples have been obtained from 2005 to 2007. For the EPA project, only numbers of fecal coliform bacteria are being measured. Other aspects of the microbiology of the inflow and outflow areas associated with the VTAs are not addressed, and are the focus of this 104b proposal.

Information Transfer Program:

Some of the information presented here was also presented at a stakeholders meeting tied to the Ag United meeting for the Vegetative Treatments Systems project (sponsored by EPA via DENR) held on December 7, 2006 at the Sioux Falls Ramkota Inn.

Data from this project will continue to be presented at such stakeholder meetings; and at field days at one or more of the VTA sites of the study.

Problem:

Nutrient and sediment loads from animal feeding operations (AFOs) can negatively impact the quality of surface waters and groundwaters. One accepted way to reduce nutrient and sediment loads from AFOs is by use of basin technologies, which are effective but can be costly, and lead to air quality problems due to unpleasant odors. The potential for development and implementation of alternative non-basin technologies interests a variety of groups, including the South Dakota Cattlemen's Association, South Dakota Farm Bureau, South Dakota Association of Conservation Districts, South Dakota State University, South Dakota Department of Agriculture, Natural Resources

Conservation Service, South Dakota DENR, and cattle producers. The Iowa Cattlemen's Association (ICA) is also interested.

An EPA funded grant, "Evaluating the Performance of Vegetated Treatment Areas," (Dr. Todd Trooien, P.I.), has been underway since 2005 to the present. Its goal is evaluation of the technical and financial feasibility of vegetated treatment areas (VTAs) as a non-basin alternative for reducing nutrient and sediment loads from AFOs having less than 1,000 animal units. Each of five AFOs in different areas of South Dakota have had or will have VTAs established. Performance of each VTA will be measured by sampling inflows and outflows from vegetated areas. The samples are being analyzed for nutrients (N and P), salts, sediment, and numbers of fecal coliform bacteria. Data from these measurements will allow calculation of water and salt balances, loss or gain of nutrients, removal of sediment, and fecal coliform numbers. Data will be entered in a basin model to simulate basin performance, that will be compared to measured VTA performance.

For the EPA project, counts of *E. coli* before and after each VTA are the only measure being taken of bacterial effects on water quality in pre- and post-VTA areas. Other microbial measures affecting water quality would also be valuable, such as detecting presence or absence of toxigenic *E. coli*, such as *E. coli* O157:H7; and total fecal coliforms (including both non-toxigenic *E. coli* and other genera that are found in feces) in pre- and post-VTA areas at each site, to better assess whether water quality in post VTA areas is better (has lower numbers of these bacteria) than in pre-VTA areas. Also, since microbial activity can influence physical and chemical parameters of soil and water, such as whether aerobic or anaerobic processes are occurring, other measures of microbial activity would be valuable for both pre-VTA and post-VTA areas at each site, to further assess water quality in these areas. The 104b project described here is providing a more detailed and broader understanding of some microbiological issues relating to this waste management system.

Research Objectives:

For the EPA project described above, counts of *E. coli* before and after each VTA are the only measure being taken of bacterial effects on water quality in pre- and post-VTA areas. Other microbial measures affecting water quality would also be valuable, such as detecting presence or absence of toxigenic *E. coli*, such as *E. coli* O157:H7; and total fecal coliforms (including both non-toxigenic *E. coli* and other genera that are found in feces) in pre- and post-VTA areas at each site, to better assess whether water quality in post VTA areas is better (has lower numbers of these bacteria) than in pre-VTA areas. Also, since microbial activity can influence physical and chemical parameters of soil and water, such as whether aerobic or anaerobic processes are occurring, other measures of microbial activity would be valuable for both pre-VTA and post-VTA areas at each site, to further assess water quality in these areas.

Differences in the microbiology of soils in the inflow and outflow areas associated with VTAs is being assayed by measuring the following microbial indices: (a) Soil respiration; (b) oxidation/reduction potential; (c) heterotrophic microbial activity; (d) soil bacterial diversity; (e) numbers of total culturable fecal coliforms (including non-pathogenic *E. coli* but including other culturable fecal coliforms as well); and (f) numbers of culturable pathogenic *E. coli* O157:H7. Data for these microbial indices will be added

to the data sets from the EPA project, to get a better idea of the number and activity of microbes in soils associated with inflow and outflow areas.

Methodology:

Soil respiration is being measured in the field with a portable soil respirometer. Both plant root respiration and microbial respiration can contribute to the values obtained (Alef, 1995a; Beck, 1996). Oxidation/reduction potential of wet soils will be assayed in the field with a portable meter fitted with an oxidation/reduction electrode (Zausig, 1995). Heterotrophic microbial activity is being evaluated by assaying ability of soil samples to hydrolyze fluorescein diacetate (Alef, 1995b). Soil bacterial diversity will be assayed in two ways: (1) by use of Biolog EcoPlates that assay the ability of a soil microbial community to utilize different carbon sources (Insam and Goberna, 2004) ; and (2) by molecular methods, using polymerase chain reaction (PCR) and denaturing gradient gel electrophoresis (DGGE) (Hastings, 1999; Baker and Harayama, 2004). We are evaluating the numbers of specific fecal coliforms and/or potential pathogens of humans and animals in both inflow and outflow water by use of several agar media that are selective and differential for specific bacterial types. Water samples from the Howard site have been analyzed by counting coliforms on mfc agar, then picking these colonies over onto Chromagar plates that are more specific in identifying colonies of *E. coli*. A serologic test was used to determine if water samples contained *E. coli* O157:H7.

Principal Findings:

- i) Assessing the redox state of the soil and/or water in inflow versus outflow areas: Because of dry conditions throughout the state for most of 2006 including at the Howard site, redox potential has not yet been measured at Howard or elsewhere, but will be when moist soil conditions allow.

The hypothesis being tested is that redox values will be more negative in areas having largest amounts of organic load from the AFOs; where microbial respiration will have depleted oxygen gas concentration and led to anaerobiosis.

- ii) Assessing the activity of microorganisms in soil and/or water in inflow versus outflow areas by use of a portable soil respiration monitor (for drier soils only): Carbon dioxide measurements were made at the Howard site in pre VTA and post VTA areas from late summer to fall of 2006. Preliminary analysis of respiration data suggests that there were not significant differences in CO₂ production between pre VTA and post VTA areas on the dates sampled, possibly because the respiration of grass roots was so dominant and equivalent in both areas. It is clear from data obtained to date that soil temperature is a major determinant of soil respiration, more so than moisture. Soil temperatures around 21° C gave respiration values (g CO₂/m²/hour) ranging from 2 to 6; while soil temperatures around 8° C gave values that were three to eight times lower.

We are testing the hypothesis that respiration will be higher in inflow areas compared to outflow areas, due to greater organic matter load stimulating microbial respiration in the inflow areas than in the outflow areas.

- iii) Assessing the heterotrophic activity of microorganisms in soil and/or water in inflow versus outflow areas by use of a spectrophotometric assay of fluorescein diacetate (FDA) hydrolysis in inflow vs. outflow soil and/or water: Soil samples from pre VTA and post VTA areas of

the Howard site collected from late summer to fall of 2006 have been analyzed for FDA activity, but data have not yet been statistically analyzed. We hypothesize that FDA hydrolysis will be greater in inflow areas than outflow areas, since higher amounts of organic matter in inflow areas should stimulate more microbial activity than in outflow areas.

- iv) Assessing soil bacterial diversity in inflow versus outflow soil and water by means of denaturing gradient gel electrophoresis (DGGE) to compare number of gel bands obtained from samples from inflow versus outflow soil and water, employing 16S ribosomal DNA primers and polymerase chain reaction (PCR) methodology: This is a molecular method that will be able to assess both the culturable and non-culturable bacteria in soil samples. Soil samples from pre VTA and post VTA areas of the Howard site will be analyzed using DGGE. We hypothesize that bacterial diversity will be greater in inflow versus outflow areas, due to greater amounts and types of organic matter available in the inflow areas; and to more likely frequent periodic aerobic/anaerobic transitions in the inflow areas, versus the outflow areas.
- v) Assessing soil bacterial diversity in inflow versus outflow soil and water by means of carbon source utilization profiles of soil microbial communities in the inflow and outflow areas using Biolog EcoPlates: Soil samples from pre VTA and post VTA areas of the Howard site have been analyzed using Biolog plates, but have not yet been statistically analyzed. We hypothesize that bacterial diversity will be greater in inflow versus outflow areas, due to greater amounts and types of organic matter available in the inflow areas; and to more likely frequent periodic aerobic/anaerobic transitions in the inflow areas, versus the outflow areas.
- vi) Evaluating the numbers of specific fecal coliforms and/or potential pathogens of humans and animals in both inflow and outflow soil and water by use of several agar media that are selective and differential for specific bacterial types: Water samples from the Howard site have been analyzed by counting coliforms on mfc agar, with numbers ranging from 10^4 to 10^5 CFU coliforms/ml in the pre-VTA and post-VTA samples. Picking these colonies over onto Chromagar plates has shown that most (in excess of 50%) but not all of the initial isolated colonies were *E. coli* in the pre-VTA and post-VTA areas. In water samples from the river in the area behind the post-VTA area, fecal coliforms were found in lower numbers (10^2 CFU coliforms/ml), with from 20% to 70% of these verified as *E. coli*. We have detected presence of *E. coli* O157:H7 in pre-VTA and post-VTA water samples, but not in river samples situated after the post-VTA area. This indicates that the VTA is effectively removing *E. coli* strains of the greatest health concern before they reach the river.

Significance:

Management issues that could be impacted by results of the study include management of undesirable odors affiliated with the AFOs; extent of anaerobic versus aerobic microbial processes in inflow versus outflow areas; ability of the VTAs to filter out specific pathogenic bacteria such as *Escherichia coli* O157:H7 ; amount of CO₂ gas produced from soil in pre-VTA versus post-VTA areas; and overall heterotrophic microbial activity and microbial community diversity in soil and water in pre-VTA versus post-VTA areas as a measure of the ability of the VTA in removing organic compounds from the AFO inflow. Results could influence future management decisions for AFOs making use of VTAs; and afford information to better understand how to manage microbial populations in the soils affiliated with the VTAs to achieve desirable air and water quality in these areas.

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Development of an Optimal Macroinvertebrate Bioassessment Index for Prairie Lakes in Northeastern South Dakota

Basic Information

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Development of an Optimal Macroinvertebrate Bioassessment Index for Prairie Lakes in Northeastern South Dakota

INTRODUCTION

Monitoring biological communities can provide a good estimate of ecosystem integrity (i.e. chemical, physical, and biological integrity) in aquatic environments (Plafkin 1989). Biological communities are sensitive to stressors (i.e. domestic waste, agricultural runoff, and sedimentation) that pollute water bodies (Lewis 2001). Biological monitoring can be performed on algae, fish, and benthic macroinvertebrate communities. There are advantages of using benthic macroinvertebrates in biological monitoring. Macroinvertebrates are ubiquitous in aquatic systems throughout the world and they are good indicators of localized conditions due to limited migration ability. Benthic macroinvertebrates respond to short-term environmental disturbances and degraded conditions can be detected through taxa identification (Plafkin 1989). Long-term effects of stress can be seen through changes in community structure (Barbour et al 1999). Another advantage of biological monitoring is its relatively low cost when compared chemical and toxicity tests (Ohio EPA 1987, Karr 1993).

Metrics are measurable components of biological systems used to describe communities. They show predictable change in value along a gradient of human disturbance (Gronke 2004). Metric categories include community composition, richness, feeding, habit and tolerance measurements. A multimetric index approach to bioassessment encompasses all these types of descriptors in biological communities. Multimetric indexes quantify the biological effects of a broad array of human activities because they are sensitive to water quality, habitat structure, flow regime, energy source and biotic interactions (Karr and Chu 1999). Metrics are ranked based on discriminatory power and coefficient of variation. Metrics that are most sensitive to anthropogenic disturbances are combined to form an index of biotic integrity (IBI). An IBI scores sites based on impact of disturbance compared to a reference site. Reference sites will have highest IBI scores while more polluted water bodies should have a lower score.

Study Sites

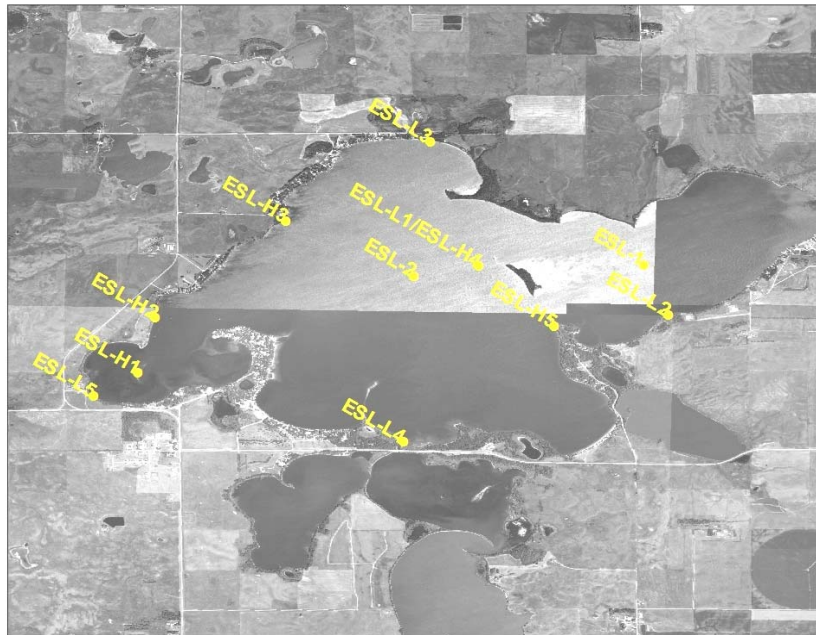
Three different lakes were selected based on previous knowledge of water quality conditions. Enemy Swim Lake was used as a reference site because of its favorable water quality condition. Clear Lake and Lake Minnewasta were thought to progressively decrease in water quality condition. All the lakes were located in the Northern Glaciated Plains (NGP) ecoregion of northeastern South Dakota. Beneficial uses for all three lakes include:

- (4) warm water permanent fish life propagation
- (7) immersion recreation
- (8) limited contact recreation
- (9) wildlife propagation and stock watering

Enemy Swim Lake

Enemy Swim Lake is located in Day County, South Dakota (Figure 1). It is a large (3.35 sq. mi.) and deep lake (26 ft. max.). It has a large immediate watershed (20.47 sq. mi.) with about ninety-five percent of the runoff entering the lake through an eastern tributary (State Lakes Preservation Committee 1977). The majority of the watershed (73%) consists of pasture and less intensive land use practices. In 1996-1998, only twelve percent of the watershed was utilized as cropland (Skadsen 2005). Fisheries personnel describe Enemy Swim “as one of a few South Dakota lakes having a complex basin with highly variable substrates including rock, boulders, gravel, cobble, sand, and silt.” Enemy Swim Lake’s Carlson’s Trophic State Index (TSI) labels the lake as mesotrophic, containing moderate amounts of nutrients.

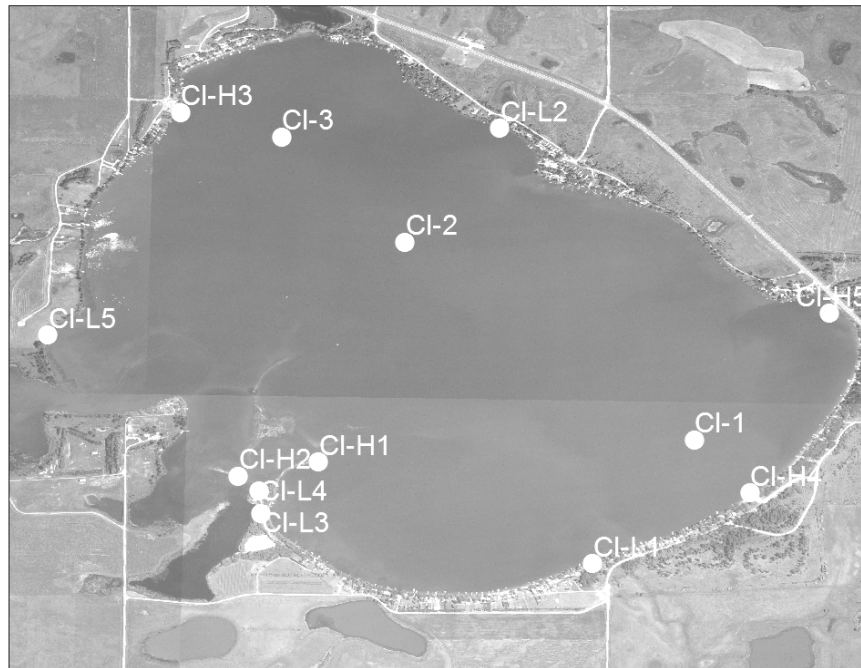
Figure 1: Site Map of Enemy Swim Lake, Day County, SD (1-3=basin/water quality sites, H1-5=Hester-Dendy sites, L1-5=sweep-net sites)



Clear Lake

Clear Lake is located in Marshall County, South Dakota (Figure 2). It has an area of 1.71 sq. mi. and a maximum depth 20 ft. Clear Lake has a small immediate watershed (4.05 sq. mi.) making sediment input less significant (State Lakes Preservation Committee 1977). It has been labeled a eutrophic lake based on its TSI value which ranged from 47-63 when sampled by the SD Department of Environmental and Natural Resources in 1989-1993 (Stewart and Stueven 1994).

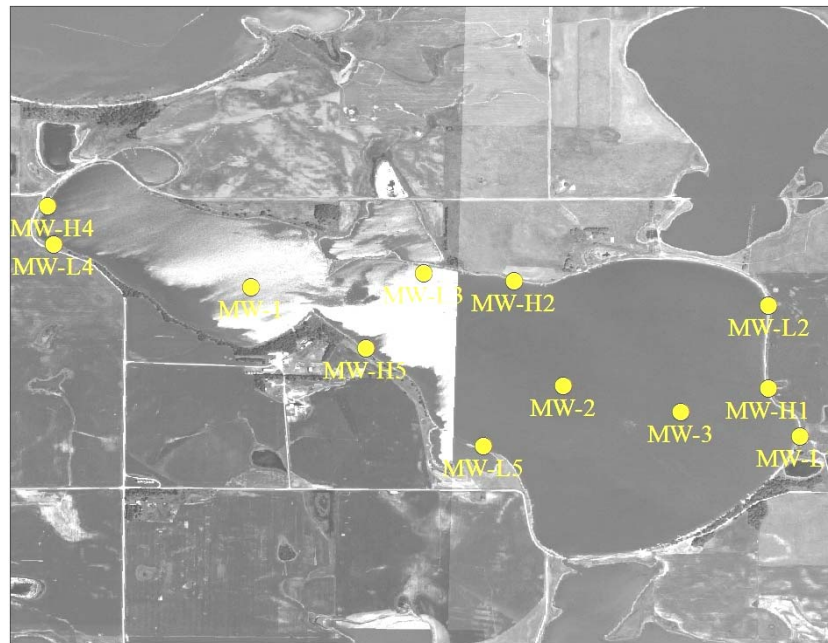
Figure 2: Site map of Clear Lake, Marshall County, South Dakota (1-3=basin/water quality sites, H1-5=Hester-Dendy sites, L1-5=sweep-net sites)



Lake Minnewasta

Lake Minnewasta is located in Day County, South Dakota (Figure 3). It is the smallest lake (0.95 sq. mi.) and the most shallow (14 ft. max.) of the study. Lake Minnewasta has an immediate watershed is 1.12 sq. mi. with 15% under cultivation in 1977. Current TSI values for Lake Minnewasta classify it as hyper-eutrophic, containing an excess amount of nutrients.

Figure 3: Site map of Lake Minnewasta, Day County, South Dakota (1-3=basin/water quality sites, H1-5=Hester-Dendy sites, L1-5=sweep-net sites).



Previous Work

This study was based on the work done by A. Gronke (2004). Gronke developed an index of biotic integrity for prairie pothole lakes in eastern South Dakota. The study examined the phytoplankton, macrophyte and macroinvertebrate communities of seven lakes. Sixty-four candidate invertebrate metrics were tested to find an optimized set for an IBI. Gronke (2004) sampled basin and littoral invertebrate habitats. A total of 86 invertebrate taxa were identified during the study. Reference sites from this study contained greater total taxa richness compared to study sites. Reference sites also had significantly higher percentage of intolerant taxa than study sites. A total of 10 optimized littoral invertebrate metrics were identified (Table 1). Gronke (2004) concluded that macroinvertebrate communities of other prairie pothole lakes need to be inventoried and the validity of metric sets must be tested further.

Table 1: Top 10 optimized littoral invertebrate metrics for prairie pothole lakes in Eastern South Dakota (Gronke 2004).

	Metric	Group
1	Hilenhoff's biotic index	Tolerance
2	Evenness	Richness
3	Percent dominant taxa	Composition
4	Percent collector gatherers	Feeding
5	Shannon-Wiener Index	Richness
6	Percent swimmers	Habit
7	Percent predators	Feeding
8	Tolerant taxa	Tolerance
9	Total taxa	Richness
10	Percent Hemiptera	Composition

Braskamp (2002) selected fourteen lakes in eastern South Dakota and characterized littoral invertebrate community structure, habitat and shoreline condition. A total of 179 macroinvertebrate taxa were identified during this study. Braskamp (2002) found differences in the invertebrate communities of two ecoregions, Northern Glaciated Plains (NGP) and the Northwestern Glaciated Plains (NWGP). There were also correlations identified between the invertebrate community and environmental conditions. This demonstrated the importance of optimizing metrics for specific ecoregions. Optimized invertebrate metrics for lake littoral zones are crucial to lake management (Braskamp 2002).

German (2005) surveyed the macrophyte and macroinvertebrate communities of Enemy Swim Lake and nearby Pickerel Lake. The study identified a more diverse community than what was expected based on previous studies on South Dakota lakes (German 2005). Enemy Swim Lake exhibited characteristics of lakes that are mesotrophic to early eutrophic in 2005. German (2005) stated that a shift to a slight eutrophic condition may be apparent in Enemy Swim Lake during recent years.

In 2001, a watershed improvement project was started on Enemy Swim Lake. During this project 1,444 acres of cropland in the watershed were converted to grassland using the Conservation Reserve Program. Cattle stream crossings, pasture renovation and cattle watering systems were also used to reduce sediment and nutrient loads to the lake. Activities from this improvement project resulted in a thirty-seven percent reduction of in-lake phosphorus concentrations. TSI values shifted from a eutrophic to a mesotrophic state and an increase in water clarity was seen through Secchi disk transparency readings (Skadsen 2005).

OBJECTIVES

This project was designed to gather baseline invertebrate data for Enemy Swim Lake, Clear Lake and Lake Minnewasta. Invertebrate research has not been performed on the latter two lakes. The current trophic state of the three lakes was determined and the macroinvertebrate communities were described. Another goal of this project was to

proceed in developing a multimetric macroinvertebrate index for South Dakota prairie lakes. This will be done by testing metrics identified by Gronke (2004) on Enemy Swim Lake, Clear Lake and Lake Minnewasta.

METHODS

Water Quality

Water quality conditions of the three lakes were monitored during May, June, July, August and September. Samples were collected within six days of mid-month for the following parameters:

1. Total phosphorus
2. Total dissolved phosphorus
3. Organic nitrogen
4. Ammonia
5. Nitrate + nitrite
6. Suspended solids
7. pH
8. Air and water temperature
9. Dissolved oxygen
10. Secchi depth
11. Chlorophyll a (surface samples only)
12. Fecal coliform bacteria (surface samples only)



Undergraduate Student Ross Vander Vorste with Hester-Dendy Sampler used for invertebrate collection.

Water samples were collected with a Van-Dorn type water sampler from three mid-lake sites at surface and near bottom depths. Composite surface and bottom samples were made using equal water quantities from the three in-lake sites. Physical parameters were measured using methods and equipment similar to German (1997). Samples were sent to the South Dakota State University Water Quality Laboratory for chemical analysis.

Macroinvertebrate Collection

Three different sampling methods were used to collect macroinvertebrates. An Eckman dredge was used to collect basin invertebrates at three locations in each lake (Gronke 2004). Site locations corresponded to the sites used to collect water samples. Samples were sieved (250 μ m) to wash away fine sediment and placed to coolers. Littoral invertebrates were collected at five sites in each lake using a three-minute sweep-net technique (Braskamp 2002). Modified Hester-Dendy multi-plate samplers were anchored at five littoral sites in each lake and allowed to colonize for approximately 30 days (Britton and Greeson 1987). Littoral invertebrate samples were rinsed into coolers to preserve living invertebrates.

Invertebrate specimens were picked from samples as soon as possible after collection to avoid preliminary preservation with 70% alcohol. The majority of samples were volumetrically subsampled to downsize the amount of specimens needed to be picked and identified. All samples were visually examined for large and rare invertebrate taxa. Invertebrate specimens were picked, sorted into vials and preserved with 70% alcohol or a 10% Formalin solution. Specimens were identified to family or genus if

possible (Table 2). Habit guilds, feeding groups and tolerance values were obtained from Hilsenhoff (1987, 1988, 1998), DeShon (1995), Merrit and Cummins (1996) and Barbour et al. (1999).

Table 2: Literature sources used to identify invertebrate specimens.

Assemblage	Order	Sources
Invertebrate		
	Chironomidae	Wiederholm (1983), Mason (1973) Merrit and Cummins (1996)
	Tricoptera	Wiggins (1996), Merrit and Cummins (1996)
	Corixidae	
	Coleoptera	Merrit and Cummins (1996) Hilsenhoff (1975)
	Molluska	Pennack (1978)
	Hyrachnida	
	Others	Sawyer (1972), Thorp and Covich (2001)

RESULTS

Water Quality

Laboratory analysis of water quality samples collected in 2006 at Enemy Swim Lake , Clear Lake, and Lake Minnewasta are presented in Tables 3, 4, and 5, respectively.

Table 3.

Enemy Swim Lake							
Sample Location	Sample Date	Ammonia Nitrogen mg/L (ppm)	Nitrate Nitrogen mg/L (ppm)	Total Dissolved Phosphorus mg/L (ppm)	Total Phosphorus mg/L (ppm)	Total Kjeldahl Nitrogen (TKN) mg/L (ppm)	Total Suspended Solids mg/L (ppm)
SURFACE	5/16/2006	0.116	0.06	0.006	0.016	0.72	3.5
BOTTOM	5/16/2006	0.076	0.06	0.008	0.016	0.649	3
SURFACE	6/17/2006	0.047	0.04	0.061	0.026	0.729	4.33
BOTTOM	6/17/2006	0.061	0.04	0.009	0.026	1.1	4.75
SURFACE	7/17/2006	0.104	0.07	0.013	0.023	0.776	5.25
BOTTOM	7/17/2006	0.154	0.05	0.018	0.022	0.838	5.25
SURFACE	8/17/2006	0.199	0.05	0.012	0.027	0.998	4
BOTTOM	8/17/2006	0.164	0.04	0.011	0.028	1.2	5.25
SURFACE	9/20/2006	0.073	0.05	0.014	0.024	1.18	5.25
BOTTOM	9/20/2006	0.101	0.04	0.013	0.029	0.844	6.88

Table 4.

Clear Lake							
Sample Location	Sample Date	Ammonia Nitrogen mg/L (ppm)	Nitrate Nitrogen mg/L (ppm)	Total Dissolved Phosphorus mg/L (ppm)	Total Phosphorus mg/L (ppm)	Total Kjeldahl Nitrogen (TKN) mg/L (ppm)	Total Suspended Solids mg/L (ppm)
SURFACE	5/16/2006	0.17	0.06	0.027	0.039	1.31	1.75
BOTTOM	5/16/2006	0.138	0.07	0.018	0.037	0.868	1.75
SURFACE	6/15/2006	0.104	0.03	0.017	0.041	1.03	3.25
BOTTOM	6/15/2006	0.044	0.02	0.02	0.037	1.05	2.5
SURFACE	7/17/2006	0.063	0.06	0.026	0.054	1.03	3.75
BOTTOM	7/17/2006	0.127	0.08	0.043	0.046	0.948	4.25
SURFACE	8/17/2006	0.152	0.04	0.036	0.053	1.04	4.5
BOTTOM	8/17/2006	0.143	0.03	0.034	0.056	1.02	4
SURFACE	9/19/2006	0.115	0.03	0.024	0.055	0.927	4.75
BOTTOM	9/19/2006	0.076	0.04	0.022	0.057	0.971	5.5

Table 5.

Lake Minnewasta							
Sample Location	Sample Date	Ammonia Nitrogen mg/L (ppm)	Nitrate Nitrogen mg/L (ppm)	Total Dissolved Phosphorus mg/L (ppm)	Total Phosphorus mg/L (ppm)	Total Kjeldahl Nitrogen (TKN) mg/L (ppm)	Total Suspended Solids mg/L (ppm)
SURFACE	5/16/2006	0.173	0.06	0.042	0.097	1.77	10.2
BOTTOM	5/16/2006	0.138	0.05	0.043	0.106	1.87	11.4
SURFACE	6/15/2006	0.14	0.11	0.17	0.209	2.07	14
BOTTOM	6/15/2006	0.122	0.11	0.179	0.21	2.06	14.5
SURFACE	7/17/2006	0.243	0.07	0.15	0.266	2.95	17.7
BOTTOM	7/17/2006	0.198	0.06	0.15	0.236	2.72	18.2
SURFACE	8/17/2006	0.161	0.16	0.222	0.29	2.46	14.3
BOTTOM	8/17/2006	0.168	0.14	0.214	0.266	2.23	17.7
SURFACE	9/19/2006	0.186	0.15	0.219	0.295	2.44	28
BOTTOM	9/19/2006	0.18	0.14	0.223	0.296	2.52	32

Trophic status of the three lakes ranged from mesotrophic to hyper-eutrophic. (Figure 4, Figure 5) Enemy Swim Lake had the lowest TSI value (50.24) with Clear Lake (59.68) and Lake Minnewasta (82.92) falling below in water quality standards based on Phosphorus TSI values.

Biological

Overall species diversity was highest in Enemy Swim Lake with 23 families found. Clear Lake and Lake Minnewasta followed with 22 and 14 families respectively (Table 1). A Modified ASPT Index was used to rank the lakes based on invertebrate community's tolerance to pollution (Figure 4). Enemy Swim (5.17) had the highest ranking thus having more pollution intolerant species. Clear Lake (4.73) and Lake Minnewasta (4.50) contained invertebrate communities with more tolerant species. The Ephemeroptera and Trichoptera (ET) Index was used to compare lakes. Enemy Swim Lake, 5 families, had the highest ET diversity while Clear Lake, 3 families, and Lake Minnewasta, 1 family, fell below (Figure 5)..

Figure 4.

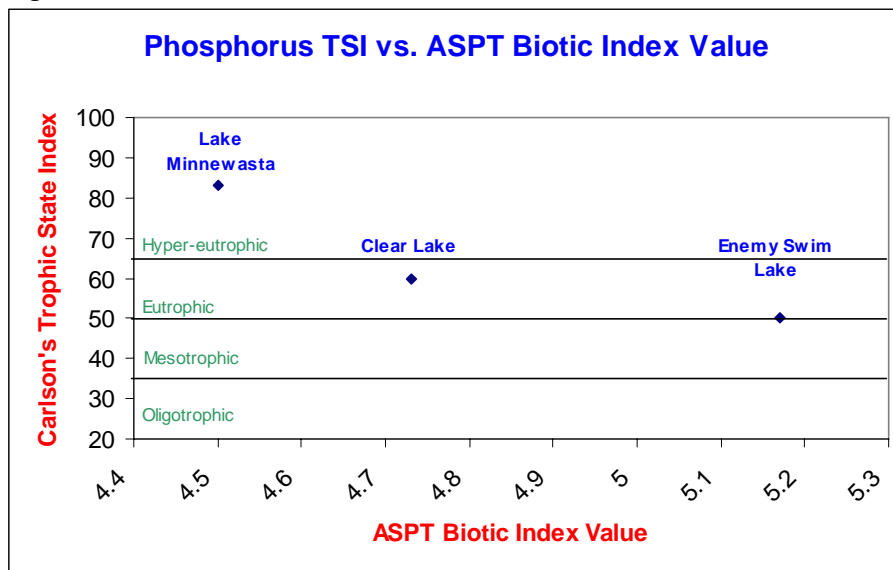


Figure 5.

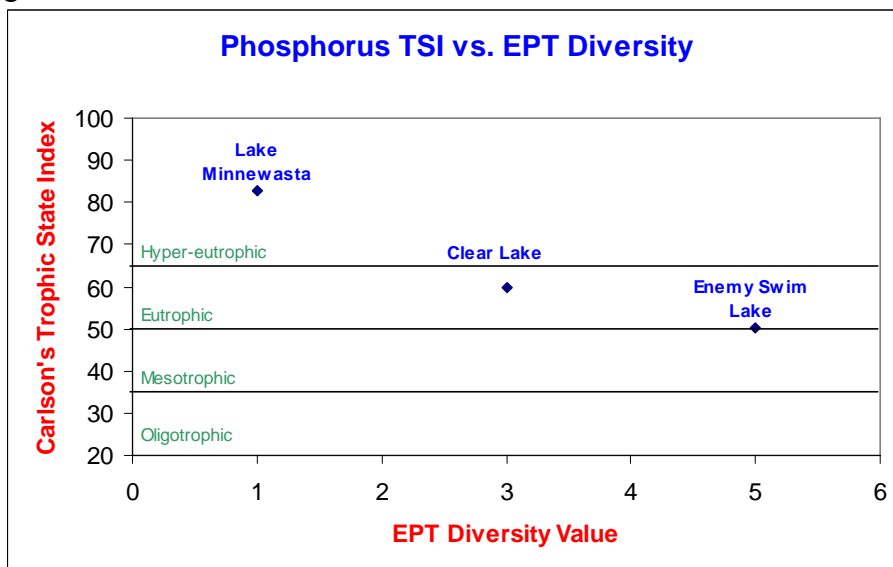
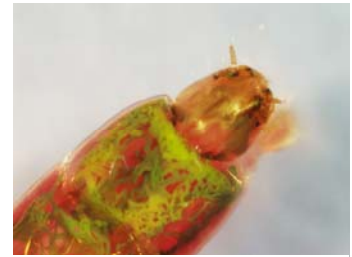


Table 6. Family List for Enemy Swim Lake (E), Clear Lake (C), Lake Minnewasta (M)

MAJOR GROUP	MINOR GROUP	FAMILY	LAKE
Annelida	Oligocheata	Tubificidae	E,C,M
	Hirudinoidea	Glossiphoniidae	E,C,M
Crustacean	Amphipoda	Gammaridae	E,C,M
		Talitridae	E,C,M
	Decapoda	Cambarinae	C
Insecta	Diptera	Chironomidae	E,C,M
		Ceratopogonidae	E,C,M
		Phychodidae	E
		Tipulidae	C
		Phoridae	C
	Hemiptera	Corixidae	E,C,M
	Trichoptera	Polycentropodidae	E,C,M
		Leptoceridae	E,C
		Helicopsychidae	E
		Limnephilidae	E
		Phryganeidae	E
	Hydroptilidae		C
Ephemeroptera	Ephemeridae	E,C	
	Caenidae	E,C,M	
Coleoptera	Haliplidae		E,C,M
			E
	Curculionidae		E
			C
Dytiscidae		C	
Coleoptera	Hydrophilidae		M
Odonata	Coenagrionidae		E,C,M
Mollusca	Bivalvia	Sphaeriidae	E,C
	Gastropoda	Hydrobiidae	E,C
		Physidae	E,C,M
		Planorbidae	E,C,M
		Valvatidae	E



Chironomus sp.
"Bloodworm"



Chironomus sp.
"Adult Bloodworm"



Mystacides sp.
"Caddisfly"

SUMMARY

Statistical and metric analysis showed that Enemy Swim Lake was placed in a mesotrophic status during the sampling period. It was also found to contain the least pollution tolerant families and the highest ET family diversity. Clear Lake was found to be in the eutrophic status based on Phosphorus TSI values. Clear Lake fell in between Enemy Swim Lake and Lake Minnewasta in the ASPT Index and ET Diversity values. Lake Minnewasta was found to be hyper-eutrophic and also had the most pollution tolerant invertebrate communities and the least ET Diversity. This relationship corresponds with Gronke 2004 in which reference littoral sites had significantly higher percentages of intolerant species. Further taxonomic identification and water chemistry analysis should further show a relationship between water quality and invertebrate communities.

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Information Transfer Program

Information dissemination is an important part of the South Dakota Water Resources Institute (SD WRI) program. Information dissemination activities include a web site, project reports, fact sheets, water analysis interpretations, workshops, conferences, presentations, and water festivals. Emphasis is also placed on publication of scientific papers. Institute staff also participate in state, federal, and local committees and organizations. Feedback to these agencies is often given in the form of presentations at state meetings, local zoning boards, and informational meetings for non-point source and research projects.

SD WRI also encourages faculty, staff, and students to participate in science related activities. These activities range from giving talks, presentations, workshops, and demonstrations to K-12 students as well as area producers.

SD WRI staff also routinely responded to questions from the general public, other state agencies, livestock producers, and County Extension Agents. 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, manure runoff, and irrigation drainage.

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2005SD52B
Start Date:	3/1/2005
End Date:	2/29/2008
Funding Source:	104B
Congressional District:	First
Research Category:	Social Sciences
Focus Category:	Education, Acid Deposition, None
Descriptors:	
Principal Investigators:	Van C Kelley, David R. German, Jennifer L. Pickard

Publication

FY2006 Information Transfer Program
South Dakota Water Resources Institute

PUBLIC OUTREACH

Public outreach is an important part of the South Dakota Water Resources Institute's Information Transfer Program. Information Transfer takes many forms. The South Dakota Water Resources Institute *Water News* newsletter is in its third year of publication. This is an effective format to disseminate information about activities in which the Institute participates, funds, and promotes. The newsletter is published quarterly via e-mail, as well as a link on the SD WRI homepage (<http://wri.sdstate.edu>) in PDF format allowing for viewing of past and present issues. Water-related research including updates on present projects, notification of requests for proposals, state-wide water conditions, conferences, as well as information on youth activities are highlights in each issue. SD WRI's web site has been redesigned to improve user access to the updated links which include publications to help diagnose and treat many water quality problems. The site allows the public to keep in touch with 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 Web. The "Research Projects" section of the SD WRI Web is updated with past and present research projects, highlighting the Institute's commitment to improving water quality.

SD WRI made the region's drought situation a priority in its outreach/information transfer efforts by posting information for farmers and ranchers on this subject on the Institute's web page (<http://wri.sdstate.edu/drought.htm>). The SDSU Agricultural Communications Department also developed a press release and special web page dealing specifically with the drought. This web page referred producers who had questions about their water quality to the SD WRI web page.

An extensive library of information has been developed and continues to be updated on-line. Information regarding analytical services available at the Oscar E. Olson Biochemistry Labs Water Quality Laboratory and information that may be used to address drinking water problems is available on-line.

Another important component of the Institute's Information Transfer Program is the Water Quality Laboratory (WQL). The lab was consolidated with the Oscar E. Olson Biochemistry Labs in 2004. The WQL continues to provide important testing services to water users across the state. Water Resources Institute 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. New topics for publication including fecal coliform and tastes, colors, and odors in water have been researched. These publications facilitate public awareness and promote education.

The drought in western South Dakota which continued to a lesser degree in 2006 has demonstrated the importance of the services offered by the Water Quality Laboratory.

The inherent quality of surface waters in western South Dakota is commonly low, leading to chronic livestock production problems. However, drought has intensified this problem for livestock producers in these semi-arid rangelands. Many dugouts and ponds degraded to the point of causing cases of livestock illness and, in some instances, deaths. Lab services provided by the WQL and interpretation of results by WRI staff is important to livestock producers as they try to manage risks associated with water shortages and poor water quality. Although water quality problems in western South Dakota are common, some isolated cases of livestock illness and deaths due to poor surface water quality have occurred in eastern South Dakota as well.

SD WRI staff also routinely responded to water resource questions unrelated to laboratory analysis from the general public, other state agencies, livestock producers, and County Extension Agents. 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, and irrigation drainage. WRI continues to provide soil and water compatibility recommendations for irrigation permits to the SD Division of Water Rights.

SD WRI staff assisted in implementing the first annual Eastern South Dakota Water Conference held on November 1-2, 2006 to provide a forum for water professionals to interact and share ideas. The Eastern South Dakota Water Conference was started to serve as a mechanism to educate participants on water resource issues in South Dakota.

The goal of the conference was to focus on sustainability and economic development. Presentations were planned to bring together technical and real world views from a variety of constituencies across the region. Senator Tim Johnson, Representative Stephanie Herseth-Sandlin, and Mark Anderson, director of the U.S. Geological Survey in South Dakota delivered keynote addresses on the importance of water resources. A state and regional panel included Secretary John Cooper of the South Dakota Department of Game Fish and Parks; Secretary Larry Gabriel of the South Dakota Department of Agriculture; Kevin Smith of the Sioux Falls Department of Public Works; and Dave Templeton of the South Dakota Department of Environment and Natural Resources.

Concurrent sessions throughout the conference offered information important to wide array of stakeholders including engineers, industry, public officials, agricultural producers, and conservation groups. Sessions focused on watershed management/non-point source pollution, and land use and remote sensing, water use/management, surface water quality, sustainable infrastructure, and watershed assessment.

Sponsors were the South Dakota Water Resource Institute in SDSU's College of Agriculture and Biological Sciences, the Water and Environmental Engineering Research Center in SDSU's College of Engineering, the East Dakota Water Development District in Brookings, and the U.S. Geological Survey. The conference is planned to be an annual event.

To find more information and view abstracts from the 2006 conference, go online to <http://wri.sdstate.edu/esdwc>.

AGENCY INTERACTION

The SD WRI Information Transfer program includes interaction with local, state, and federal agencies/entities in the discussion 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 Non-Point Source (NPS) Task Force. The NPS Task Force coordinates, recommends, and funds research and information projects in this high priority area. Participation on the NPS Task Force allows SD WRI input on non-point source projects funded through the state and has provided support for research in several key areas such as phosphorus in soil 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.

Another example of this interaction to solve water quality problems is a program started by the Cooperative Extension Service (CES) to help livestock producers identify unsuitable water sources. The CES provides many of its Extension Educators with hand-held conductivity meters for use in the field. If samples are shown to be marginal by field testing, they are sent to the Water Quality Lab for further analysis. Often, high sulfates limit the use of waters that have elevated conductivity.

Another important interaction is with the South Dakota Department of Environmental and Natural Resources (DENR). Completion of Total Maximum Daily Load (TMDL) studies on South Dakota lakes has been a priority for DENR over the past several years. SD WRI is providing technical assistance to local sponsors working with DENR to complete the TMDL water quality assessments on several publicly owned lakes that do not have an established lakeside community.

Several other local and state agencies conduct cooperative research with SD WRI or contribute funding for research. Feedback to these agencies is often given in the form of presentations at state meetings, local zoning boards, and 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 sites including Spearfish, Rapid City, Pierre, Huron, Vermillion, Brookings and Sioux Falls. Since their inception, Water Festivals in South Dakota have impacted approximately 90,000 Fourth Graders state wide. The Big Sioux Water Festival, held locally in Brookings, has recorded attendance of over 16,600 kids, 2,150 adults and 3,450 workers since 1993. SD WRI staff members continued to support and participate in Water Festivals throughout the state in FY2006. SD WRI also supported water quality education in local schools

including classroom presentations and assisting local educators with field trips. Institute staff also conducted sessions on aquatic invertebrates and their use as water quality indicators for the “Lakes are Cool” field trip in conjunction with the Enemy Swim Lake 319 project in Day County and at the Sportfishing Day held in Aberdeen annually.

ADULT EDUCATION

David German (SDWRI) and Dennis Skadsen (Day Conservation District) presented a lake water quality workshop at Enemy Swim Lake made possible with funds through an EPA 319 grant.

The idea behind the workshop stemmed from the fact that most water quality events like Water Festivals are usually targeted towards children. That is why German decided to teach a lake water quality class to adults.

Another reason for doing the workshop was the idea of “teaching the teachers.” Helping adults learn about water quality and providing them with useful information encourages them to teach others in their home community how their behaviors affect the lake. A PowerPoint presentation was available for participants to take home to help encourage them to share what they learned at the workshop. Several other hands-on activities were developed that helped workshop participants share their new-found knowledge of lakes. These activities included “The Lake Game” and demonstrations of lake stratification, photosynthesis and aquatic plants, as well as biomagnification using “mercury cookies.” A Clear Lake resident in Marshall County a participant who has already shared his new-found knowledge during the Clear Lake Association’s Annual Meeting.

The group also made their own Secchi discs to monitor the transparency of the lakes they live on. This allows participants to monitor the water quality of a lake and provides an avenue for individuals to take an active part in monitoring their lake.

PUBLICATIONS

Distribution of research findings to the public, policy makers and sponsors of non-point source pollution control projects is another important component of the SD WRI Information Transfer program. This is needed so that the lessons learned through research and implementation projects are not lost as the next generation of projects develops. SD WRI is committed to making this material readily available to persons within South Dakota as well as in other states. A library is maintained at SD WRI to make these materials readily available. Abstracts of research projects funded by the institute have been placed on the WRI web site along with photos and summaries showing progress on these projects will be published on the site as they become available.

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	11	0	0	0	11
Masters	6	0	0	0	6
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	19	0	0	0	19

Notable Awards and Achievements

Lehnert, K. 2006. Monitoring soil diversity after tylosin and chlortetracycline laden manure treatments. First Place. SDSU Sigma Xi Graduate Student Proposal Contest

Reiman, M. 2005. The impact of deep manure injection on water infiltration, nutrient distribution, and corn yield. Second Place. SDSU Sigma Xi Graduate Student Proposal Contest

Based on some of the research with manure and antibiotics, an NSF grant that is a joint effort between SDSU and SDSMT was funded in 2006 to investigate the fate of antibiotics in manure and its effects on manure prior to land application.

Publications from Prior Projects

None