USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Assessment of Non-Point Source Pollution Projects in South Dakota: A Case Study of Pickerel Lake

Focus categories: Non-point pollution, surface water, water quality

Key Words: Watershed management, lakes, water quality, Geographic Information System, non-point source pollution

Duration: March 1, 2000 to February 29, 2001

FY 2000 Federal Funds:	$18,897		
Non-federal funds allocated:	$20,499 (Total)	$10,100 Direct	$10,399 Indirect

Principal investigator's name and category:

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Congressional District: First

Statement of the critical regional or state water problems

Lakes are an important surface water resource in South Dakota. Many lakes are used as water supplies for human and livestock use. They also support boating, fishing, swimming and other recreational activities. Non-point source pollution, largely from agricultural watersheds, threatens the loss of these beneficial uses in many lakes. Reduction of non-point source pollution and improved watershed management is a high priority in South Dakota. A Non-Point Source Task Force was formed in the state to address non-point source pollution through the EPA's 319 Program, in conjunction with local project sponsors. The task force is responsible for prioritizing lakes and rivers and recommending specific projects to decrease non-point source pollution of these resources.

Many South Dakota lakes suffer from algal blooms that occur all summer on an annual basis. Algal blooms and associated weed growth often limit recreational use of these lakes. Public concern about declining water quality in lakes led to a lake restoration program in the state. The major focus of the lake restoration program was on lakes that had been severely degraded. Lake restoration projects often involve dredging to remove sediments, which is usually cost prohibitive for large lakes. Therefore, once the damage has been done, larger lakes may suffer permanent loss of some beneficial uses.

Prior to 1990, there was no lake protection program in South Dakota, even though preventing the decline of a lake is far easier to accomplish and much less expensive than restoration. Because of generally better water quality, less attention was paid to lakes that had not degraded to the point where restoration was needed. A lake protection program was needed to prevent the decline of these lakes. In June, 1990, a Lake Protection Committee was formed by the Non-Point Source Task Force. It was the consensus of the committee that management of these lakes was hampered by a lack of data. A priority list could not be generated because little was known about many of these lakes. A seed grant through the USGS 104 Program was used to begin collecting water quality data on 20 lakes that met the criteria as candidates for lake protection in 1991. The seed grant led to additional research on the 20 lakes through the EPA 319 Program. Pickerel Lake was included in the lake protection study.

The South Dakota Department of Water and Natural Resources (SD DWNR) reported that Pickerel Lake was in danger of losing some beneficial uses due to declining water quality (SD DWNR 1985). In-lake sampling indicated Pickerel Lake was becoming eutrophic, as evidenced by concentrations of total phosphorus and organic nitrogen. Dangerous nutrient loadings from the watershed were also reported (SD DWNR 1985). The most troublesome finding of the Water Quality Area Report was that in-lake water quality appeared to be declining and that the lake was in danger of switching from phosphorus limitation to nitrogen limitation. If that occurred, one would expect to see an increase in nitrogen fixing blue green algae, which tend to be very undesirable for recreation and as a food base for the fishery. Other problems were indicated by in-lake water quality data collected through the USGS 104 Program in 1991. Weak thermal stratification and an anoxic hypolimnion were observed in 1991 (German, 1997). An anoxic hypolimnion increases the release of phosphorus from the sediment, which can lead to a downward spiral of increased eutrophication, decreased oxygen, and increasing sediment release of phosphorus.

Due to these concerns, Pickerel Lake became the first lake protection project recommended for funding to the US EPA by the Non-Point Source Task Force. A lake protection project sponsored by the Day Conservation District started in 1992. The project was completed in 1996 (Skadsen and German, 1996). Several other lake protection projects have since been funded and are currently in various stages of completion. There have been no efforts made to determine the effectiveness of these projects. Have measurable water quality improvements occurred in the targeted lakes? Have farmers continued to use management practices designed to improve water quality after cost share incentives ended? Did the lake protection project have a lasting affect on land use in the watershed? This proposal is designed to provide quantitative answers to these questions using Pickerel Lake as a case study. The first year of study has been completed. This proposal is intended to complete the second and final year of study.

Statement of results and benefits, and/or information expected to be gained and how they will be used

This study will provide a means of comparing in-lake water quality before, during and after the Pickerel Lake Protection project to determine if measurable water quality changes have occurred. Evidence of water quality improvement or maintenance of current water quality could be used to support similar efforts underway or planned for other lakes that have been designated for lake protection projects. A more thorough understanding of a lake's response to watershed treatment will improve our ability to manage these lakes.

This study will provide better insight into farmer's attitudes and degree of acceptance of lake protection projects. It will also provide a measure of whether watershed treatment measures remain in place after financial incentives have ended. This information will be used by future non-point source projects to improve farmer acceptance and increase the permanence of watershed treatment measures.

A Geographic Information System (GIS) will be used to compare pre-project, post-project, and current watershed conditions. The GIS will be evaluated as a tool for watershed assessment and post-project evaluation. GIS methods and procedures developed for the Pickerel Lake watershed would be available for use on other non-point source projects.

A graduate student in Geography will produce a thesis based on the use of GIS as a watershed evaluation or assessment tool. The graduate student will receive a twelve month assistantship to combine water monitoring and GIS to develop pollutant values for various areas of the watershed, and use a watershed model to predict future water quality and loadings if land use in the watershed changes.

Nature, scope and objectives of the research:

This proposal is intended to fund the first year of what is intended to be a two year study.

Lake Description

Pickerel Lake is a deep, natural lake located in northeastern Day County about fifteen miles north of the town of Waubay, South Dakota. The lake covers approximately 955 acres to an average depth of 22 feet, and a maximum depth of 43 feet. The lake bottom is predominately rubble with scattered areas of sand and gravel. Silt and organic clay are found in the bays and deeper areas of the lake. Haworth (1972) reported that the north bay of the lake contains 24 feet of sediment, which has accumulated over the 12,000 years since the lake was formed. The lake is deep enough to thermally stratify during the summer months (Day Conservation District, 1991).

The State of South Dakota has assigned the following beneficial uses to Pickerel Lake:

- Warm water permanent fish life propagation

- Limited contact recreation

- Immersion recreation; and

- Wildlife propagation and stock watering

Watershed Description

The Pickerel Lake Watershed is situated in the Coteau des Prairie, a hilly plateau of glacial moraine. The climate is continental with cold, dry winters and short springs marked by rapid weather changes. The mean annual temperature is about 44^{o} F. Average annual precipitation and lake evaporation amount to 22 and 32 inches, respectively. Most cultivated soils are subject to erosion. Control of erosion is the main concern of conservation (Day Conservation District, 1991).

Land use in the 15,015 acre watershed is predominately agriculture. Approximately 62% of the area is grassland, 30% cropland, 7% water and wetlands, and 1% forest lands, farmsteads, and/or lake cottages. Small grains are the main crops grown in the watershed. The major portion of the watershed is privately owned, although several areas adjacent to the lake are administered by the U.S. Bureau of Indian Affairs and the Sisseton-Wahpeton Sioux Tribe. Approximately 55% of the shoreline has been developed and includes 330 homes, cabins, and mobile homes. Other developments include three resorts, two restaurants, a YMCA camp, a Bible camp, and two State recreational areas (Day Conservation District, 1991).

The watershed consists of two major drainages and three minor drainages. Chekepa Creek enters the lake from the east and drains the largest area in the watershed. Dry Creek drains the next largest area and enters Pickerel Lake from the north. The remaining watershed area includes direct runoff areas along the shoreline and three minor drainages (Day Conservation District, 1991).

Water Quality Impairments

A detailed study of Pickerel Lake was conducted from 1979 to 1984 by SD DWNR. The purpose of this study was to determine the lake's water quality, and to identify water quality problems and the possible causes of those problems (SD DWNR, 1985). The study indicated that the lake was eutrophic with high concentrations of organic nitrogen and total phosphorus. Nutrient loading to the lake was considered "dangerous" and exceeded the loading levels proposed by Vollenweider (1968). Total phosphorus concentrations also appeared to increase over the course of the study (Day Conservation District, 1991).

Total nitrogen:total phosphorus ratios indicated nutrient co-limitation with ratios near to what could be considered as nitrogen limitation. This could favor the growth of more

noxious blue-green algae. (Day Conservation District, 1991). These problems appeared to be due to runoff from agricultural lands in the watershed, feedlots, faulty septic systems, and lakeshore erosion. Dense weed beds in near shore areas were also impairing the beneficial uses of the lake.

Lake Protection Project

The Day Conservation District received a $95,740 EPA 319 grant to begin a lake protection project in 1992. The Day County ASC Committee submitted a request for Water Quality Incentive Project (WQIP) funds to assist the Pickerel Lake Protection Project in reducing non-point source pollution from agricultural land. In 1991, there were 2,921 acres of cropland, and 14,455 acres of grassland (excluding CRP acres) in the Pickerel Lake Watershed. The goal of this project activity was to treat the 2,000 most critical acres of cropland that were contributing sediments and nutrients via soil erosion, and treat 4,000 acres of grassland. The Project received $51,000 from WQIP to be used as financial incentives to secure the cooperation of watershed landowners and operators in implementing best management practices (BMP's) on cropland, and constructing animal waste management systems on feedlots located within the Pickerel Lake Watershed. The South Dakota Coordinated Soil and Water Conservation Fund grant provided an additional $30,500 to be used as an incentive for implementation of BMP's, and $10,000 to pay for technical assistance in conservation planning (Skadsen & German 1996).

Landowner/operators were required to implement WQIP Practice Components to receive incentive payments. The following WQIP practices were implemented:

> **#328 Conservation Cropping Sequence** - Growing crops by using a combination of needed cultural and management measures. Cropping systems include rotations that contain certain grasses and legumes, as well as rotations in which the desired benefits are achieved without using these crops.
> **#329 Conservation Tillage** - A form of non-inversion tillage that keeps protective amounts of residue mulch on the surface throughout the year.
> **#411 Grasses and Legumes in Rotation** - Establishing grasses and legumes or a mixture of them and maintaining the stand for a definitive number of years as part of a conservation cropping sequence (Skadsen and German, 1996).

Best management practices were implemented by nine landowner/operators in 1,463 acres of cropland in the Pickerel Lake Watershed. An additional 88 acres of cropland were planted to grass or alfalfa. Fifty three percent of the 2,921 acres of cropland present in 1992 received some type of BMP treatment during the Protection Project (Skadsen & German 1996).

Resource and conservation agencies offer a number of other programs aimed at reducing soil erosion and other forms of non-point source pollution. Although not a part of the 319 Workplan, these conservation programs supplemented the activities of the Pickerel Lake Protection Project. They included the Conservation Reserve Program (CRP), the Great Plains Conservation Program, and the U.S. Fish & Wildlife Service programs. In 1996, there were 2,154 acres (64 contracts) of CRP in the Pickerel Lake Watershed, and 766 acres in the Great Plains Conservation Program. Major land use changes affected by release or enrollment of CRP in the Pickerel Lake Watershed could affect water quality in Pickerel Lake. Several landowner/operators participated in the U.S. Fish & Wildlife Services "Partners in Wildlife" program. Two landowners have implemented rotational grazing systems on 1,592 acres of pasture land in the Pickerel Lake Watershed. One agreement protected a critical riparian area located near the south end of Pickerel Lake. Sixty-four wetlands totaling 110 acres were restored under the Partners program in the Pickerel Lake Watershed (Skadsen and German, 1996).

Skadsen and German (1996) stated that it is unclear at this time whether these operators will continue conservation practices implemented during the project without incentive payments. They recommend that "State and Federal Resource Agencies should track future land use practices after projects such as this are concluded to determine if any long term benefits are derived". A key objective would be to determine if best management practices are continued by landowners and operators after incentive payments are terminated (Skadsen and German, 1996).

Water quality data collected by the SDSU Water Resources Institute from 1991 to 1995 indicated an improvement for some parameters. The lake appeared to shift from a eutrophic toward a mesotrophic state during the lake protection project. These improvements may have resulted from land use changes or could be a natural fluctuation. Further in-lake monitoring is needed to determine if improvements in water quality have been maintained or continue to improve (Skadsen and German, 1996).

Project Objectives

1) Evaluate current water quality and trophic state of Pickerel Lake to determine if changes have occurred following the Pickerel Lake project.

2) Use GIS to compare current watershed conditions with those present during the implementation phase. Interview landowners, and update the GIS land use layer to determine if cost-shared practices have been maintained by cooperating farmers.

3) Demonstrate the use of GIS as a watershed assessment and post-project evaluation tool.

Methods, procedures, and facilities:

Water Quality Monitoring

In-lake water quality samples will be collected with a Van Dorn-type water sampler from three mid lake stations on Pickerel lake using a boat. A composite surface sample for the lake will result from mixing equal amounts of water from each site. A composite near bottom sample will be formed by mixing water collected near the bottom from each of the three sites in each lake. Parameters to be analyzed on lake

samples include:

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)

EPA-approved methods will be used for all analyses. Samples will include QA-QC on at least 10% of the samples collected. In addition to the above parameters, the algal community of each lake will be described. Composite samples will be collected within six days of mid-month in June, July, August, September and October.

Equipment used for sampling will consist of the following:

1. Winkler Kit for dissolved oxygen
2. D.O. meter with 50 ft. cord
3. Secchi disk

4. Filtration equipment

5. Coolers and sample bottles

6. pH meter and buffers

7. Van Dorn sampler

Runoff samples and flow measurements will be collected by both grab sampling and the use of automatic samplers at a watershed for each land use (cropland, CRP, pasture, and hayland) in the watershed. Runoff water quality will be used to select appropriate runoff coefficients for use in the GIS analysis of the watershed. Parameters to be analyzed on runoff samples include:

1. Total phosphorus

2. Total dissolved phosphorus

3. Organic nitrogen

4. Ammonia

5. Nitrate + nitrite

6. Suspended solids

During the first year of the study, water quality monitoring of Pickerel Lake was conducted according to the same methods used during the 1991-1995 lake protection study. A second year of monitoring will be conducted under this proposal.

GIS Studies

A Geographic Information System (GIS) is a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems. The GIS has the specific purpose of permitting spatial operations on environmental and related data. A GIS can link different data sets together to solve complex relationships which are difficult to otherwise comprehend. A GIS can do many operations because it uses geography, or space, as the common key between the data sets. Information is then linked together if it relates to the same space as does another set of information.

A GIS is proposed as an efficient means of creating, storing, displaying, editing and analyzing the various maps and databases necessary for the research. The 1:24,000-scale USGS 7.5-minute quadrangle maps will serve as the base mapping series for the project. Several layers of digital data already exist for both the Pickerel and Enemy Swim

Watershed areas. The existing layers include soils, roads, public land survey system (PLSS), county boundaries, lakes, streams, wetlands (from the National Wetland Inventory) and quadrangle boundaries. Layers of data that need to be developed or completed are the watershed boundary, township boundaries (optional), ownership and land use. The GIS software proposed for the project is PC ARC/INFO and ArcView.

The graduate student will use ArcInfo to conduct GIS analysis. Information for GIS layers will be obtained in a digital format where possible. Other available data will be digitized as necessary. Information will be gathered from existing sources as well as field surveys.

The tasks envisioned for the project are:

Task 1: Use the PLSS layer and the ARC/INFO NODEPOINT and UNGENERATE commands to create registration tic marks at each section corner. This will make it possible to register other layers of data whose features are delineated on section-sized maps or images to the base map available from the Consolidated Farm Services Agency (CFSA).

Task 2: Digitize the watershed and subwatershed boundaries which have been delineated on 1:24,000-scale quadrangle maps.

Task 3: Clip the watershed from the roads, PLSS, county boundary, lakes, streams, and quad boundary layers.

Task 4: Convert the soils data from DLG to ARC/INFO format for the Pickerel Lake watershed. Clip the watershed from each county's coverage and append the two clipped data sets to create a soils coverage for the entire watershed. Use the soils attribute data to create slope and erodibility map for the watershed.

Task 5: Download the National Wetlands Inventory (NWI) data from its Internet site, clip the watershed from each quadrangle, and append the clipped data sets to create a NWI coverage for the entire watershed.

Task 6: Derive the township layer from the PLSS layer.

Task 7: Download the 1:250,000-scale USGS Digital Evaluation Model (DEM) data from the Internet, or use other sources if digital elevation data as available. Clip the watershed from the digital elevation data.

Task 8: Using aerial photos and field data, develop the land use layers for the Pickerel Lake watershed to represent pre-implementation, post-implementation, and current land use. In the attribute table, create fields to represent different classes of land use and management.

Task 9: Analyze changes in land use by comparing these land use layers.

Task 10: Create a layer showing general land ownership, (e.g., private, tribal, state, county and federal) and specific operators so management practices can be related to operator.

Task 11: Prepare maps that combine various layers such as CRP acreages, hydrology and cultural features.

Task 12: Drape layers such as land use and ownership over the DEM to produce 3-D visualizations of the layer.

Task 13: Use various spatial modeling and analysis techniques to investigate the relationship between land use and water quality. Analysis variables may include cropland acreage, soil factors, land use, CRP acreage, crop types, land management practices (e.g. minimum tillage), distance from cropland to lakes (straight line and via drainage), precipitation/runoff, water quality analysis results, and runoff coefficients.

Task 14: Use the GIS model to predict how conversion of CRP to cropland or other potential watershed changes may affect in-lake water quality.

During the first year of this study, the graduate student has:

· Evaluated Arc/Info versus ArcView software for best suitability to accomplish the project goals.

· Completed course work in the modeling, and spatial applications of ArcView, and basic cartographic and land use land cover philosophies. He also developed a thesis proposal and plan which is under review for application to the South Dakota State University Graduate School.

· Conducted a literature search on the use of GIS as a watershed management tool.

· Selected representative small watersheds and installed monitoring sites for each land use practice. Four monitoring stations were established in the watershed representing four major land uses. Dry conditions existed following establishment of the sites and no samples were collected. Runoff samples will be collected in spring 2000.

Through acquisition of existing data and work conducted by the graduate student, Tasks 1, 2, 3, and 5 were completed, and tasks 4, 7 and 8 were partially completed.

Related Research

Currently there are no studies being conducted in South Dakota to evaluate the long term effectiveness of non-point source pollution projects. Monitoring is usually conducted

during the project to track water quality trends but that monitoring typically ends upon project completion. A study is currently underway at Purdue University by Jane R. Frankenberger, Project Leader, to develop GIS as a tool for watershed analysis. The goal of the Purdue study is to improve methods of quantifying hydrologic processes including surface runoff, subsurface drainage, and leaching to ground water in urban and agricultural watersheds. Frankenberger et. al demonstrated the use of GIS in watershed management (Frankenberger et al 1996) and runoff risk assessment (Frankenberger et.al 1995). Steenhuis et al (1995) developed equations to evaluate watershed runoff. The graduate will conduct a thorough literature review as a part of his masters thesis and will incorporate the latest information into a GIS system to meet the need for watershed assessment and project evaluation in South Dakota.

This project will be used to provide training to one M.S. graduate student in geography working with the GIS part of the project, as well as two undergraduate students to assist with data entry.

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