Dickinson Soil and Water Conservation District

Dickinson County Clean Water Alliance

The Iowa Great Lakes Watershed Management

Photo 1.1: East Okoboji Sunset (David Thoreson, Blue Water Studios)

Water Quality Management Plan for the Iowa Great Lakes Watershed

> "The Marshlands that once sprawled over the prairie from the Illinois to the Athabasca are shrinking northward. Man cannot live by marsh alone; therefore, he must needs live marshless. Progress cannot abide that farmland and marshland, wild and tame, exist in mutual toleration and harmony". (Leopold, 1949, p. 162)

By: John H. Wills

Welcome

This document is intended to aid watershed planning groups in creating a watershed management plan to improve water quality. Planning serves as a road map for turning today's problems into tomorrow's solutions. Water quality improvement is a big task, and trying to tackle it all at once can be daunting. This Management Plan encourages a phased approach to implementation to ensure incremental progress is made within the framework of big picture goals for the watershed.

This Management Plan provides a starting place for the planning process. It does not contain an exhaustive list of management alternatives but rather a starting place. The table of contents provides an outline for what is covered in the document. Additionally, examples (hypothetical and/or from past plans) are cited for illustrative purposes.

The more time and effort invested in watershed planning, the greater the chance of success. The planning process consists of fact-finding, analysis and interpretation of information and trends concerning the local political, social, environmental and economic aspects of the watershed. The planning process takes into consideration viable alternatives and their cost effectiveness to create recommendations to meet present and future needs in a comprehensive plan. Planning is a continuous process where progress and goals need to be revisited and revised at least every five years.

The following are symbols for contact resources and agencies used throughout the template.

Federal Agencies:

State Agencies:

Local Agencies

Table 1.1 List of Acronyms/Abbreviations

Term	Acronym/Abbreviation
Agricultural Environmental Management Plans	AEM
Best Management Practice	BMP
Colony Forming Unit	CFU
Chain Of Custody	COC
Cooperative Lakes Area Monitoring Project	CLAMP
Clean Water Alliance	CWA
County Conservation Board	CCB
Data Quality Objective	DQO
Department of Natural Resources	DNR
Dickinson County Conservation Board	DCCB
Dissolved Oxygen	DO
East Okoboji Beach	EOB
Environmental Protection Agency	EPA
Geographic Information System	GIS
Iowa Lakes Community College	ILCC
Iowa Department of Natural Resources	IDNR
Iowa Great Lakes Watershed	IGLW
Iowa Lakeside Laboratory	ILL
Iowa Watershed Improvement Review Board	WIRB
IOWATER Program	IOWATER
Nephelometric Turbidity Unit	NTU
Nitrate Nitrogen	NO_3-N
Natural Resources Conservation Services	NRCS
Quality Assurance Coordinator	QAC
Quality Assurance Manual	QAM
Quality Assurance/Quality Control	QA/QC
Quality Assurance Project Plan	QAPP
Resource Conservation and Development	RCD
Relative Percent Difference	RPD
Relative Standard Deviation	RSD
Standard Operating Procedure	SOP
Standard Methods	SM
Soil and Water Conservation District	SWCD
STORage and RETrieval	STORET
Total Maximum Daily Load	TMDL
Total Phosphorus	TP
Total Suspended Solids	TSS
United States Department of Agriculture	USDA
University of Iowa Hygienic Laboratory	UHL

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1 COMMUNITY BASED PLANNING

"If the water is not clean the cash registers won't ring."
Ace Cory

The Iowa Great Lakes Watershed has a rich history of community based planning to protect the Lakes within the watershed. The first group in the state which was organized with the idea of protecting a water body was formed over 100 years ago on West Okoboji Lake and is known as the Okoboji Protective Association. In recent history, the Clean Water Alliance marks the modern day era of community based planning for the Iowa Great Lakes with the idea of protecting these lakes. The Clean Water Alliance (CWA) was formed in the late 1980's when the Dickinson Soil and Water Conservation District, the Iowa Natural Heritage Foundation, and the Iowa Department of Natural Resources, among other groups, found there was a need to begin developing a local organization with interest in protecting the surface water in the Iowa Great Lakes.

The Clean Water Alliance has strong roots in the county and coordinates, educates, and communicates for the member organizations of the Alliance. To date there are over 70 members of the Clean Water Alliance with diverse and sometimes opposite backgrounds with one exception, protecting the Iowa Great Lakes. The Clean Water Alliance has met steadily on a quarterly basis, throughout the year, since its inception in the 80's providing educational opportunities, communicational insight, and coordination ability to the local population.

The CWA has been a strong voice in such community planning efforts as the Highway 71 reconstruction project, the Dickinson County Management Plan, the Source Water Protection Team, the Resource Protection and Enhancement Program, and many other smaller initiatives. More importantly the CWA has conducted 2 major initiatives in the 25 plus years of its existence for providing planning and protection of the Iowa Great Lakes.

The first such planning initiative was the Clean Water Alliance Long Range Plan. The initiative was held in 2002 and was the first major attempt at developing a plan specifically for the protection of the Iowa Great Lakes. Part of that plan included a

THE IOWA GREAT LAKES SWAT SOURCE WATER ACTION TEAM (SWAT)

The Source Water Assessment was completed in 1999. In 2002, the Region 7 U.S. EPA invited its four-state region (IA, KS, MO, and NE) to self -nominate potential communities that had completed their Source Water Assessments to participate in a pilot project. The pilot project was to be used to help communities move from assessment to a community-supported plan to protect their source water. Once completed, these communities will become a mentor community to help other communities learn about community-created Source Water Planning.

The IGL community was selected, and a partnership was created between U.S. EPA and the Public Water Supply of Milford. The local environmental cooperative, the Clean Water Alliance, was engaged to help organize the effort through its membership. A public meeting was held where over 70 citizens attended. However, a year into the effort the Clean Water Alliance removed itself as the lead organization.

In the summer of 2003, the Public water suppliers, Milford, Wahpeton, Spirit Lake and Central Water, and the U.S. EPA continued the work on plan development. In September 2004, the public water supply directors recruited twelve local citizens with a diverse background to serve on the SWAT and help with the effort. Seven resource agencies also participated.

WATERSHED PARTNERS:

Clean Water Alliance (CWA):
The CWA coordinates the efforts of governmental agencies, non-profit and private organizations through the help of a branch of the Dickinson County Soil and Water Conservation District (DSWCD). Its slogan is, “united to keep our lakes alive.” The CWA is an uncommon federation of 61 groups working in harmony to protect the water resources of the area. The Dickinson County SWCD and the Iowa Natural Heritage Foundation, the area lake protective associations and the Iowa DNR, formed the CWA in 1990. It continues to coordinate activities for water quality. The mission of the Dickinson Clean Water Alliance is ***to coordinate, educate, and communicate for the improvement and protection of the water resources affecting Dickinson County, Iowa***.

Water Quality Commission (WQC):
The WQC was established in 2001 to provide a steady funding source, using local money as a match to state and federal revenues for water quality projects for lakes in Dickinson County. This one-of-a-kind organization in the state is comprised of 18 commissioners who represent the county and its ten municipalities. Among the many objectives of the WQC are to bring a minimum of $3 in federal, state and private matching funds for every 1 dollar the local communities contribute to improve water quality. In the first year of operation in 2001, the WQC had a pool of $100,000 to grant to water quality projects to improve lakes in Dickinson County. In each subsequent year, the WQC has administered $200,000 in water quality projects. The 28-E agreement that created the WQC is in effect until 2009, and automatically renews for a two-year period thereafter.

Lake Protective Associations cover all the major lakes in the county with similar missions to protect and enhance water quality for the lake in which they were formed. The oldest of these is the Okoboji Protective Association, which celebrated its 100th anniversary in the summer of 2005. The most popular protective associations in Dickinson County are the Okoboji Protective Association, East Lake Okoboji Improvement Corporation, Spirit Lake Protective Association, Three Lakes Protective Association, and the Silver Lake Park Improvement Corporation. Together these associations have a membership of over 1,200 members.

The Iowa Great Lakes Water Safety Council (WSC) is unique among the non-profit public service organizations because it concerns itself with both water safety and clean water issues. In its short history, the WSC played a large role, for instance, in the passage of a state law raising boat registration fees, providing funds for water safety, and the prevention of invasive species projects.

Iowa Lakeside Laboratory (ILL) is a year-round environmental education facility with over 40 buildings on a 143-acre campus on West Lake Okoboji. Classes held at the lab serve numerous students from various universities throughout the Midwest. University of Iowa botany professor, Thomas MacBride, founded ILL in 1908. He wanted to establish an onsite scientific research facility in the lakes area, which he said supported the most diverse environmental habitats in Iowa.

The Iowa DNR Northwest Regional Headquarters houses the Spirit Lake Fish Hatchery, and is the only warm water hatchery in the state. This hatchery is noted for its walleye, northern pike, and muskellunge production, which help to sustain healthy game fish populations in the lakes, streams, and reservoirs of Iowa. The DNR regional headquarters also has offices dedicated to the management of fisheries and wildlife resources in NW Iowa and the research of Iowa’s natural lakes.

The partners and members of the Clean Water Alliance are as follows:

Local Businesses
Beck Engineering Inc.
Nonprofit Associations
Center Lake Protective Association
Conservation Foundation of Dickinson County
Ducks Unlimited
Dickinson County Pheasants Forever
East Okoboji Improvement Corp.
Friends of Iowa Lakeside Lab
Iowa Environmental Council
Inter-Lake Association
Iowa Great Lakes Association
IGL Water Safety Council
Iowa Natural Heritage Foundation
Okoboji Protective Association
Osceola County Pheasants Forever
Silver Lake Park Improvement Association
Spirit Lake Protective Association
Three Lakes Protective Association
Okoboji Foundation
Local Governments and Commissions
Active Okoboji
Central Water
Character Counts in Dickinson County
City of Arnolds Park
City of Lake Park
City of Milford
City of Okoboji
City of Orleans
City of Spirit Lake
City of Superior
City of Terril
City of Wahpeton
City of West Okoboji
Dickinson County
Dickinson County Board of Supervisors
Dickinson County Water Quality Commission
Iowa Great Lakes Chamber of Commerce
Iowa Great Lakes Sanitary District
Milford Utilities
Okoboji Tourism
Spirit Lake Utilities
County Boards and Districts
Dickinson Co. Conservation Board
Dickinson County Farm Bureau
Dickinson County Soil & Water Conservation District
Jackson (MN) Co. Soil & Water Conservation District
Jackson (MN) Co. Planning & Environmental Services
Osceola County Soil and Water Conservation District
State Agencies
Iowa Dept. of Land Stewardship, Division of Soil Conservation
Iowa Department of Natural Resources
Iowa Lakeside Laboratory
Iowa Rural Water Association
Iowa State University Extension Service
Minnesota Department of Natural Resources
Federal Agencies
Environmental Protection Agency
Farm Service Agency
Natural Resources Conservation Service
Iowa Great Lakes RC&D
U.S. Fish & Wildlife Service
U.S. Geological Service

Table 1.2 Clean Water Alliance Members

- Native biological diversity is encouraged
- Infiltration practices are promoted
- Impaired waters are protected and improved
- High quality waters are improved

The area continues to urbanize with construction of larger summer homes and condominiums and the associated recreational and service facilities, such as golf courses, strip malls, and restaurants. The long-range strategic plan developed by the Alliance has identified four main watershed goals for the Great Lakes area:
The Alliance recognizes that a successful watershed approach to protecting and enhancing the water quality in the Great Lakes region requires clearly identifying needs and goals, selection of management alternatives based on good science, and a genuine stakeholder partnership. The Alliance promotes a voluntary conservation program driven by landowners, lake and park users, and public and private organizations that will reduce or prevent negative impacts to water, land, and economic resources within Dickinson County.

"Never doubt that a small group of thoughtful committed citizens can change the world. Indeed, it is the only thing that ever has." -Margaret Mead

The process outlined in the following figure (figure 1.1) is one that demonstrates the Adaptive Management Cycle. The cycle is one of great importance in achieving local buy-in. One of the key aspects of an Adaptive Management Plan is to generate alternatives that are recognized and used by the population. Hammond states the key to "generating a good set of alternatives isn't all that difficult, but it takes time and thought" (Hammond, Keeney, & Raiffa, 1999, p. 48). The process identified in figure 1.1 was used in the formation of the Clean Water Alliance and played a significant role in the development of the atmosphere that has come to be accepted as the Clean Water Alliance. As the figure shows, the Alliance is constantly adjusting to meet new challenges and to improve its methods.

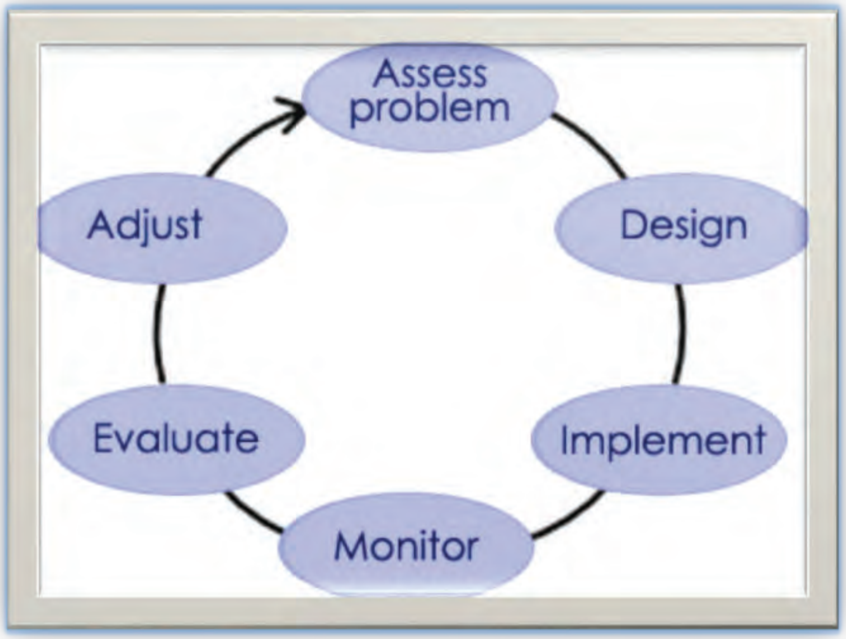


Figure 1.1. The Cycle of Adaptive Management

Throughout the following dialogue a discussion of alternatives and thoughts on developing an acceptable watershed management plan that can then be implemented in the Iowa Great Lakes Watershed will occur. It is important to note that throughout the process the cycle did not happen in a nice neat pattern, but rather "bounced around" in an irregular basis and at times was a chaotic event. The important thing to remember is that trust and knowledge was gained, as the cycle is went through and continues through its motions. It has been proven many times that Adaptive Management will gain the trust and knowledge that is necessary, where many other approaches will fail. Figure 1.2 shows how leaders should focus their efforts in order to gain that trust.

Adaptive Management is an approach that brings all stakeholders together and allows an equal voice in how to solve a problem. In government, many times, the old approach of telling all involved how something is going to happen does not develop trust or give knowledge to those stakeholders. Many times, it fosters mistrust and a lack of "buy-in".

There is a capacity for trust that must be considered. Figure 1.2 shows the capacity for trust and how it is a cyclical approach to building cohesion and agreement in a organization. In any endeavor, there is a level of trust that is present. That level is the capacity for trust. Many factors gauge how much trust is present or what that capacity is. Those factors include length of time being together, openness, truthfulness, acknowledgement of skills, and being consistent, among others.

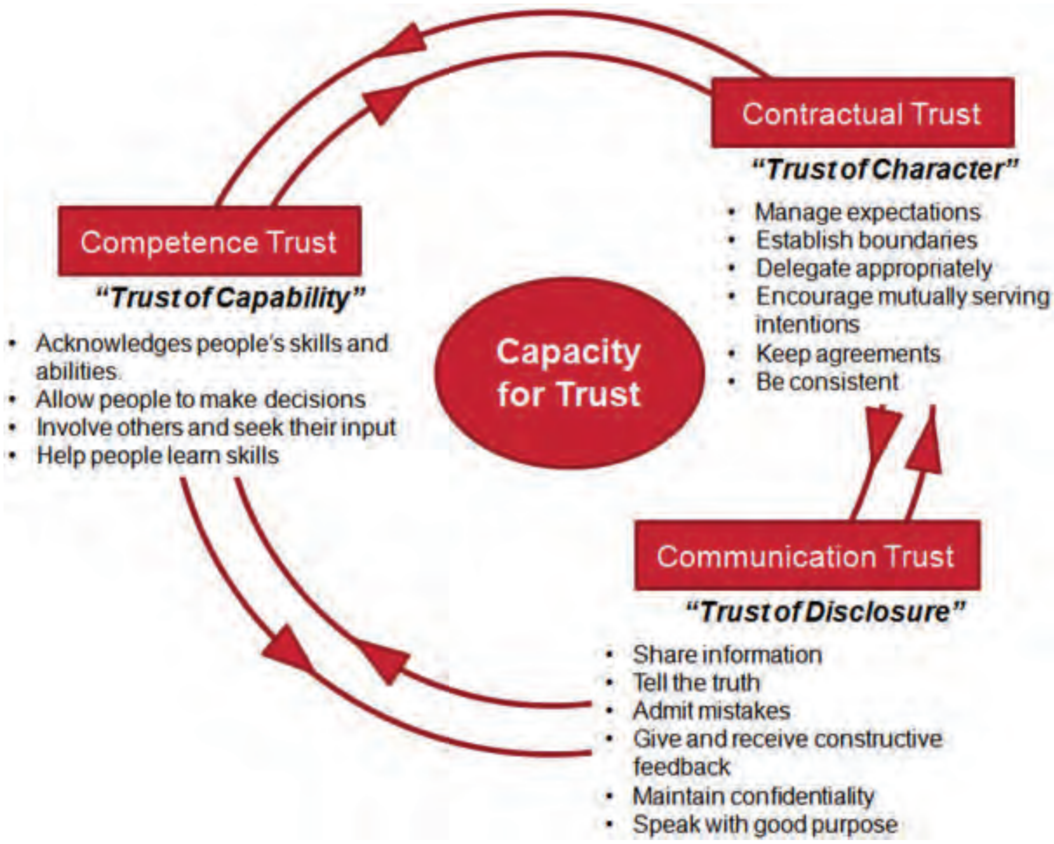


Figure 1.2 Capacity for Trust (Ambler, 2008)

> "There is great power in being in place, in knowing the watershed we belong to, in knowing the processes that have shaped the geography" Terry Tempest Williams (EPA, 2001).

Watershed management in the Iowa Great Lakes is nothing new. Watershed work in the Iowa Great Lakes has been active since the late 1980's. The Dickinson Soil and Water Conservation District, Iowa Natural Heritage Foundation, Okoboji Protective Association, Iowa DNR, and Iowa State Extension began the Clean Water Alliance and the conservation movement in Dickinson County as an effort to protect and improve the water quality of our Lakes. Many studies have been completed in the Iowa Great Lakes making the process of identifying a specific management plan an easy one to attempt.

The groups involved in improving, protecting, and preserving the water quality of the Iowa Great Lakes are a loose knit group. Many of the member groups have their own reason for wanting the Iowa Great Lakes protected. The Clean Water Alliance has many constituents and often one group does not agree totally with a specific measure. The Clean Water Alliance has developed into an information sharing and political machine, but very seldom will take a firm stance on any controversial issue. The Dickinson Soil and Water Conservation District and the Clean Water Alliance have developed a Watershed Management Process that fits its existence and ideals while at the same time doing positive things to protect our lakes.

WATERSHED MANAGEMENT PROCESS

The Clean Water Alliance adopted a watershed management process for the following reasons:
(1) to strike a balance between serving both the natural environment and economic system needs;
(2) to empower Clean Water Alliance members to take independent initiative that fits within an agreed upon framework; and
(3) to assure that individual actions under the strategic plan address well-defined goals and reinforce the actions of others.

Clean Water Alliance Watershed Management Process:

The watershed management process for the Dickinson Clean Water Alliance is to develop approaches for maintaining and improving water quality that:

- Address broad ecosystems;
- Consider the ambiguity from conflicting values of stakeholders;
- Consider the uncertainty from the failure of any one program to be definitive;
- Clearly define the goals and strategies that will be employed; and
- Balance technical and economic criteria with local, regional and national values.

Public Policy and Public Involvement

The Clean Water Alliance adopts the following policies and practices:

- To have goals that are embraced by leaders at all levels of government, business and the community;
- Ensure that diverse participants are brought into the process early, have generous opportunity to participate, and are afforded a productive long-term role;
- Maintain continual public and institutional education programs; and to
- Create icons or symbols as part of the education process.

Proper Balance of Science and Policy

The Clean Water Alliance adopts the following policies and practices:

- To understand the functioning and critical control points of our ecosystems;
- Maintain state-of-the-art research efforts;
- Make policy decisions based on the best science available;
- Monitor and reassess policy decisions; and to
- Demonstrate expertise.

PROGRAM DEVELOPMENT

Guiding Principles for Successful Programs

The Clean Water Alliance recognizes that successful programs have:

- Clearly expressed and understood needs;
- Clearly expressed goals;
- Good research;
- An open climate for discussion of issues; and
- Genuine partnership among stakeholders.

Critical Elements of a Successful Program

The Clean Water Alliance recognizes that successful programs require the following:

- Having trust in the leadership and process;
- Discovering leaders;
- Defining roles of responsibility;
- Recognizing changing roles;
- Understanding the lack of clarity effects / benefits;
- Defining the problem correctly;
- Being persistent;
- Solving one problem at a time;
- Having good data from good science;
- Including measures of success; and
- Urgency always helps.

Watershed Ethic

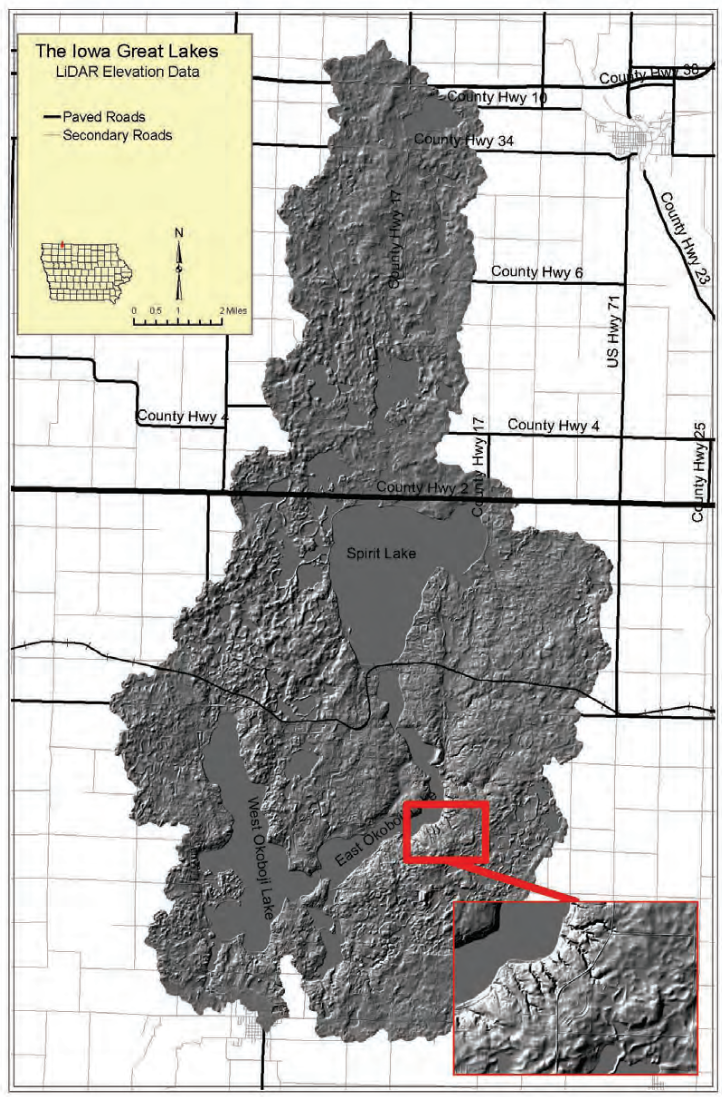
The Clean Water Alliance adopted a watershed ethic for the following reasons: (1) to provide a guiding philosophy for planning and programming; (2) because sound watershed management is instilled by extensive and prolonged education; and (3) to create and reinforce a way of life in our watershed.

Clean Water Alliance Watershed Ethic

The watershed ethic for the Dickinson Clean Water Alliance is ***Environmental Sustainability***, that is, that current economic or recreational activity within the watershed leaves an undiminished and unimpaired stock of environmental goods for future generations.

The Clean Water Alliance supports:

Sustainable agricultural practices
Sustainable urban practices
Sustainable recreational practices



2 2050 VISION STATEMENT

In the Year 2050, we envision an Iowa Great Lakes Watershed where quality of life and economic vitality continue to be fostered by stewardship and sustainable use of the watersheds natural resources.   Land uses, and development are balanced with conservation and water quality is improved and maintained for future generations.

“Our Task...is not to fix the blame for the past, but to fix the course for the future”.   John F. Kennedy

3 PUBLIC OUTREACH

The Iowa Great Lakes Communication Plan has been developed in 2004 in connection with community visioning that occurred . This plan is organized around the four priority topics:

1) Save the Waves!

2) Stink or Swim!

3) It's a Shore Thing!

4) Make a Splash!

"One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well and does not want to be told otherwise". Leopold, A. (1949).

Each priority topics each have goals listed with action items that can be used to reach those goals. Each priority topic along with the action items are listed below:

Save the Waves
Goal: Boaters inspect and clean their boats and trailers to keep Aquatic Invasive Species (AIS) out of the IGL.
Action Items:
- Establish and maintain an AM band radio station
- Run an Information campaign on radio, television, and newspaper
- Provide posters, maps, and other print material that has AIS information

Stink or Swim
Goal: Reduce nutrients and other pollutants that are used in the watershed which cause problems such as algae growth and fish kills.
Action Items:
Change habits regarding fertilizer:
- Use no-phosphorus lawn fertilizer on urban lawns and apply only as much fertilizer on farm fields as is needed. *(may include where to buy lake-friendly fertilizer)*
- Use no more fertilizer than you need (soil test, application rate) and only apply as much fertilizer as is needed.
- Don't use quick-release fertilizers
- Clean off sidewalks after applying fertilizer

Learning to value/employ infiltration in landscaping:
- Use rain gardens, natural landscaping, wetlands, and prairie on slopes, etc to increase infiltration
- Don't run gutters into lakes
- Don't clip banks or remove glacial deposits on your shoreline
- Choose a gravel rather than an asphalt driveway
- Restore the lakeshores natural vegetation to allow less wave action on the shoreline and more infiltration of water moving toward the lake.

Other:
- Don't dump trash, oil, leaves, etc in storm sewers

Conservation is a state of harmony between men and land. — Aldo Leopold

It's a Shore Thing

Goal: Landowners can take specific, simple actions that can slow run-off and keep contaminants out of run-off.

Action Items:

- Shoreline vegetation can soak up nutrients and prevent the shoreline from eroding
- Rain Gardens and other LID practices slow water from reaching the lake and filter nutrients and pollutants from that water
- Farming BMP's can reduce runoff and prevent farm nutrients and chemicals from reaching the lakes.

Make a Splash (with cash)

Goal: The business community understands the importance of the Clean Water Alliance communication efforts and contributes cash to conduct an information and education campaign yearly.

In addition to the above goals and action items the a core technical advisory committee with key professionals will be maintained. This committee will provide much needed technical advice to provide direction based on the most up to date science available. A public relations person or firm who can bring the "watershed ethic" message to residents and visitors of the watershed will be hired.

Target Audiences

Stakeholders in this plan are varied and come from all lifestyles. The bottom line for each stakeholder is that they have a stake in what happens with Silver Lake. There are five groups of Stakeholders that have been identified. Those five groups are federal, State, local government, Non-governmental Organizations, and private citizens.

Federal Stakeholders:

U.S. EPA, Region, 7 Non-point Source Region Headquarters (Section 319 Non-point Source Pollution Program)

U.S. Fish and Wildlife Service, Desoto Bend Wildlife Area (Private Lands Biologist)

USDA, Natural Resource Conservation Service, Dickinson County, District Conservationist (Wetlands Restoration Program, Wildlife Habitat Incentive Program, Environmental Quality Incentives Program)

State Stakeholders:

Iowa Department of Natural Resources, bureaus of Fisheries, Wildlife, and Water Resources (Private Lands Wildlife Biologist)

Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation, Field Services Bureau. (Resource Enhancement and Protection Funds, Watershed Protection Funds, Iowa Financial Incentives Program, Watershed Improvement Review Board)

Iowa Department of Economic Development

Local Government Stakeholders:

City of Orleans, Spirit Lake, Okoboji, Arnolds Park, Milford, West Okoboji, and Wahpeton

Dickinson Soil and Water Conservation District, Commissioners (Local Grants)

Jackson (MN) Soil and Water Conservation District, Commissioners (Local Grants)

Dickinson County, Supervisors

Jackson County Commissioner

Spirit Lake School District (Future Farmers of America)

Okoboji School District (Future Farmers of America)

Iowa Great Lakes Sanitary Sewer District

Public Utilities, Alliant Energy

Dickinson County Conservation Board

Non-governmental Organizations:

Dickinson County Clean Water Alliance, John H. Wills, Coordinator (Coordination and local funding)

Iowa Natural Heritage Foundation, Mark Ackelson, Chairman (Easement funds)

The Nature Conservancy, Bob Moats, Private Lands Biologist (Habitat Restoration Program)
Pheasants Forever, John Linquist, Regional Representative (Build A Wildlife Area)
Ducks Unlimited, Dr. John Synhorst (Wetland Restoration Assistance)
Dickinson County Water Quality Commission, Brad Jones, Chairman (Water Quality Grants)
Private Citizens:
Property owners (urban and agricultural)
Fishermen
Hunters
Investors
Farmers
Developers
Boaters
Swimmers
Marinas
Resort owners
Bankers
Chamber of Commerce
Golf Courses/clubs

Importance of Water Quality

According to the Center for Agriculture and Rural Development water quality is more important than either proximity or local park facilities in determining where households recreate. Figure 3.1 shows the results of a question that asked respondents to allocate 100 importance points to a number of factors they might consider when choosing a lake for recreation. The average point allocation is shown. Respondents indicated that water quality was the single most important factor they consider when choosing a lake for recreation, with proximity of the lake and park facilities also being relatively important. In contrast, activities near the lake or town are not particularly important in their choice of a lake site.

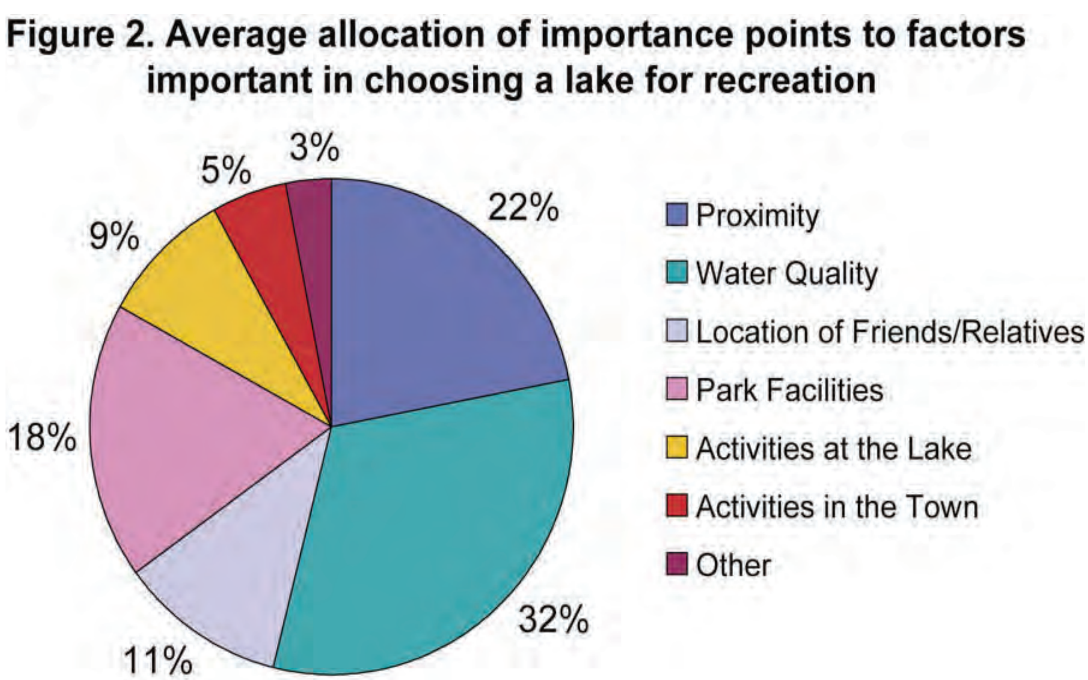


Figure 3.1 Importance in choosing a lake for recreation (Center for Agricultural and Rural Development. 2008)

4 WATERSHED ANATOMY

The primary impairment of the Iowa Great Lakes is excessive sediment, which brings with it excessive phosphorous. Each lake, in the chain of lakes, has its own individual problems or impairments, however, the root of these problems is sediment. The critical part of the impairment is that phosphorous grows excess algae and causes bad odors, possible health concerns, and aesthetic settings that most people do not like.

The Issue:
The State of Iowa has developed TMDL's for portions of the Iowa Great Lakes and provided them to the local stakeholders. An Assessment has been complete for the Iowa Great Lakes which highlights, in detail, the problems and challenges that face the Iowa Great Lakes.

Photo 4.1 Watershed location. *Image Credit:* (District, 2008, p. 14)

Facts About The Issue:
Location

The Iowa Great Lakes Watershed is an area of about 88,167 acres (140 square miles) located in northwest Iowa and southwest Minnesota. Approximately 76 percent of the watershed lies within Dickinson County, Iowa and the remainder within Jackson County, Minnesota. (Dickinson Soil and Water Conservation District, 2008). The Iowa Great Lakes are a group of lakes in NW Iowa that are regularly visited by over 1 million people from the region each year.

4.1 WATERSHED MAP

We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect. — Aldo Leopold

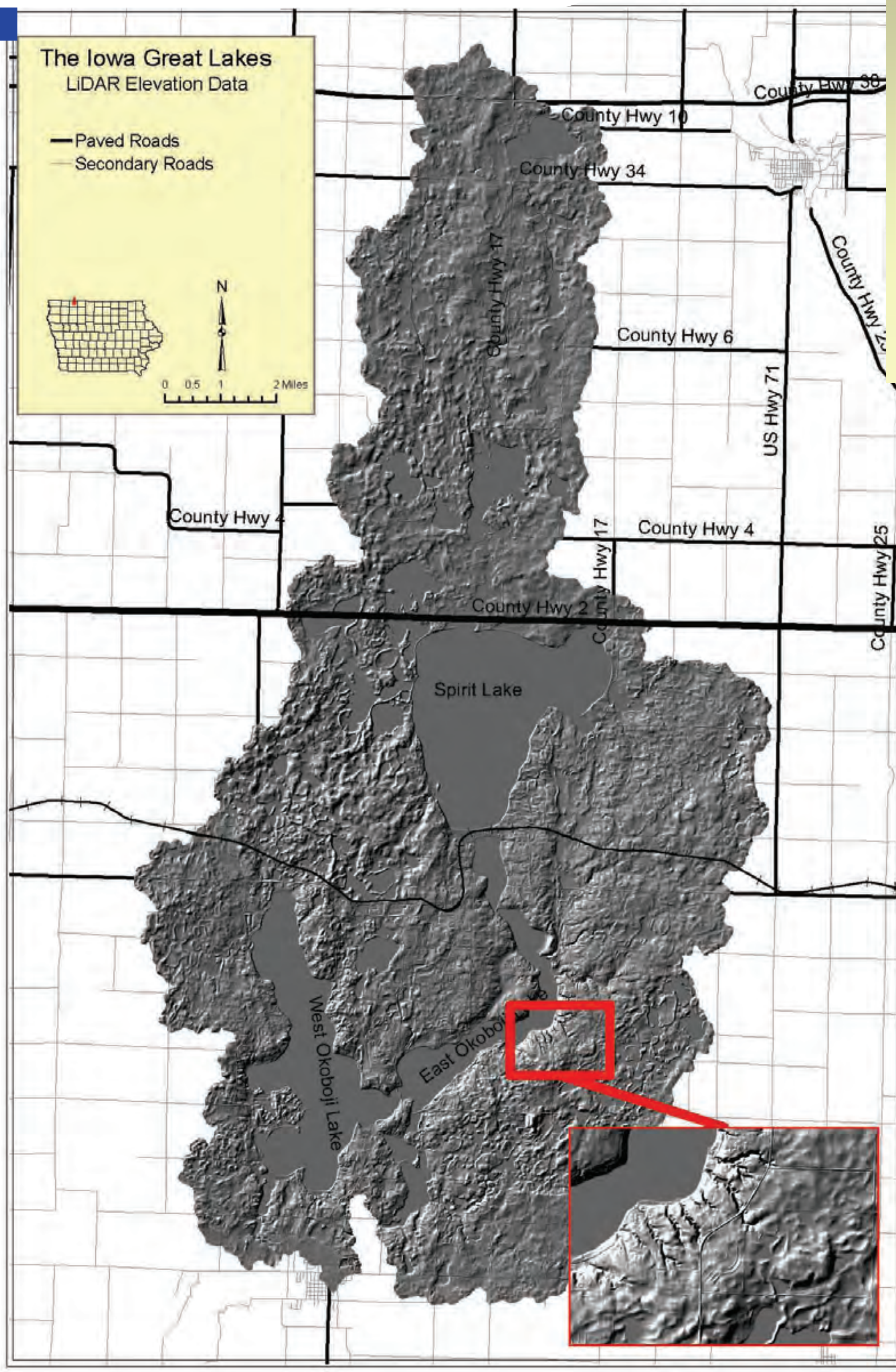


Figure 4.1 Watershed Map with Boundaries

4.2 LOCATION NARRATIVE AND HISTORY

Special points of interest:

- **Water quality issues emerge as the strongest environmental concern for state residents**
- **State residents believe that all Iowa residents have a personal responsibility to protect the state's natural resources**
- **Of the issues, pollution of rivers, lakes, and streams" is second only to "a lack of affordable health care for state residents.**

The Iowa Great Lakes watershed is an area of about 88,167 acres (140 square miles) located in northwest Iowa and southwest Minnesota. Approximately 76 percent of the watershed lies within Dickinson County, Iowa and the remainder within Jackson County, Minnesota. The Iowa Great Lakes are major recreational lakes for Iowa residents and visitors from adjacent states. Agricultural runoff containing sediment, fertilizers, pesticides, herbicides and feedlot waste negatively affect water quality. Urbanization contributes pollution from stormwater run-off and as well as a number of private sewage disposal systems within the watershed area that are improperly installed.

The largest lake within the Iowa portion of the watershed is Big Spirit Lake (5,684 acres), the longest is East Okoboji (approximately 5 miles) and the deepest is West Okoboji (136 feet deep). The watershed also includes several smaller Minnesota lakes, in addition to Little Spirit Lake, Upper Gar Lake, Minnewashta Lake and Lower Gar Lake in Iowa.

The lakes are interconnected and water flows from Spirit Lake and West Okoboji into East Okoboji Lake, and then through Upper Gar, Minnewashta, and Lower Gar into Milford Creek. Milford Creek flows into the Little Sioux River and is the only surface outlet from the Iowa Great Lakes. Little Spirit Lake, Upper Gar Lake, Lower Gar Lake and Milford Creek are listed in Iowa's 1998 impaired waters list. In addition, Little Spirit Lake and Milford Creek are listed in Iowa's 2004 list of impaired waters list. Total Maximum Daily Loads (TMDL) is written for Little Spirit Lake, Upper, and Lower Gar Lakes. It is also proposed that Emerson Bay on West Okoboji Lake will be added to the DNR's impaired waters list.

The center of the watershed lies at the intersection of the principal north-south route through both counties (U.S. Highway 71) and the principal east-west route through Dickinson County (Iowa Highway 9). The two routes meet in the City of Spirit Lake. Dickinson County cities and towns within the watershed include Arnolds Park, Lake Park, Milford, Okoboji, Orleans, Spirit Lake, Superior, Terrill, Wahpeton and West Okoboji.

The Great Lakes Trail system connects communities in the Iowa Great Lakes Region, including Spirit Lake, Okoboji, Arnolds Park and Milford. Residents and visitors use the multi-use trail extensively for nature viewing, hiking, biking and cross-country skiing. Snowmobiling is allowed on some segments of the trail. The Great Lakes Trail currently loops around most of Spirit Lake and there are plans to expand it around the entire lake. There are 60 miles of connecting biking routes, including the Kenue Park Trail, Arnolds Park City Trail and Spirit Lake City trail. In the spring of 2009, the trail will extend to the Minnesota state border, Mini-Wakan State Park, and connect with the trail system in Jackson County, Minnesota.

The lakes within the Minnesota portion of the watershed include Clear Lake, Rush Lake, Pearl Lake, Loon Lake, Chandler Lake, Grover's Lake, and Little Spirit Lake. Little Spirit Lake is listed in Minnesota's 2004 impaired waters list. Loon Lake has been assessed as "not supporting" recreational or fishing uses.

Interstate 90 passes through Jackson County approximately ten miles north of the Iowa border. The major cities within Jackson County and the watershed include Alpha, Heron Lake, Jackson, Lakefield, Okabena and Wilders. In addition, there are several townships with significant populations.

Geography
The Iowa Great Lakes was formed in the last major ice age to have reached this region. The Iowa Great Lakes were dug out as the Des Moines Lobe of the Wisconsin Glacier receded. Silt, loam, and clay sediments have accumulated on the bottom of some parts of the lake. Enriched with nutrients, the sediment increases turbity when it becomes re-suspended in the water column. This re-suspension can occur because of wind action, power boating, and bottom feeding fish (Ikenberry C. , 2009, p. 15). The Iowa Great Lakes range in depth but West Okoboji reaches a maximum depth of 136 feet at its deepest.

Demographics
As of the census of 2000, in Dickinson County, Iowa there were 16,424 people, 7,103 households and 4,759 families residing in the county. The median income for a household in the county was $39,020 and the median income for a family was $47,739. The per capita income for the county was $21,929; 6 percent of the population and 4 percent of families were below the poverty line including, 6 percent of those under the age of 18 and 7 percent of those age 65 and older.

As of the census of 2000, in Jackson County, Minnesota there were 11,268 people, 4,556 households and 3,116 families residing in the county. The median income for a household in the county was $36,746, and the median income for a family was $43,426. The per capita income for the county was $17,499. About 5 percent of families and 9 percent of the population were below the poverty line, including 11 percent of those under age 18 and 8 percent of age 65 or over. (US Census Bureau, 2000)

Economics
"The U.S. Economy is a market economy. The heart of a market economy is the multitude of supply and demand markets" (Eggert, 1943). As water quality declines so will the number of visitors to that water body. According to the Iowa Department of Economic Development, each group of travelers in Iowa spends an average of 252 dollars per day. Any change for the positive or the negative to the lakes water quality will affect the economy of the area.

Photo 4.1 Courtesy David Thoreson, Blue Water Studio

4.3 PHYSICAL CHARACTERISTICS

Land Use

The total Great Lakes watershed area encompasses 88,167 acres. Within the watershed, land is used for a number of purposes including row crop, urban, golf courses, and other uses. For the most part, land use has not changed a great deal in the years of the survey except land has been taken out of production of row crops in favor of urban development.

2003 Land use	Acres	%
Row Crop	43,710	49.5
Water (Lakes)	15,381	17.4
Grassland, Grassed Waterways	11,104	12.5
Urban/Residential	5,597	6.3
Hay/Pasture	2,943	3.4
Wetlands	2,422	2.8
Roadways	2,202	2.5
Trees and Tree Plantings	1,808	2.0
Farmsteads	1,712	1.9
Golf Courses	772	.9
Streams or Waterways	256	.3
Salvage yard, Landfill, Quarry	199	.2
Animal Feeding Operations	61	.1

2006 Land use	Acres	%
Row Crop	42,663	47.6
Water (Lakes)	15,392	17.2
Grassland, Grassed Waterways	13,095	14.6
Urban/Residential	5,999	6.7
Hay/Pasture	2,564	2.9
Wetlands	2,538	2.8
Roadways	2,262	2.5
Trees and Tree Plantings	2,220	2.5
Farmsteads	1,658	1.8
Golf Courses	766	.8
Streams or Waterways	243	.3
Salvage yard, Landfill, Quarry	199	.2
Animal Feeding Operations	73	.1

Table 4.1: Land use data for the years 2003 & 2006 as verified by NRCS field office personnel.

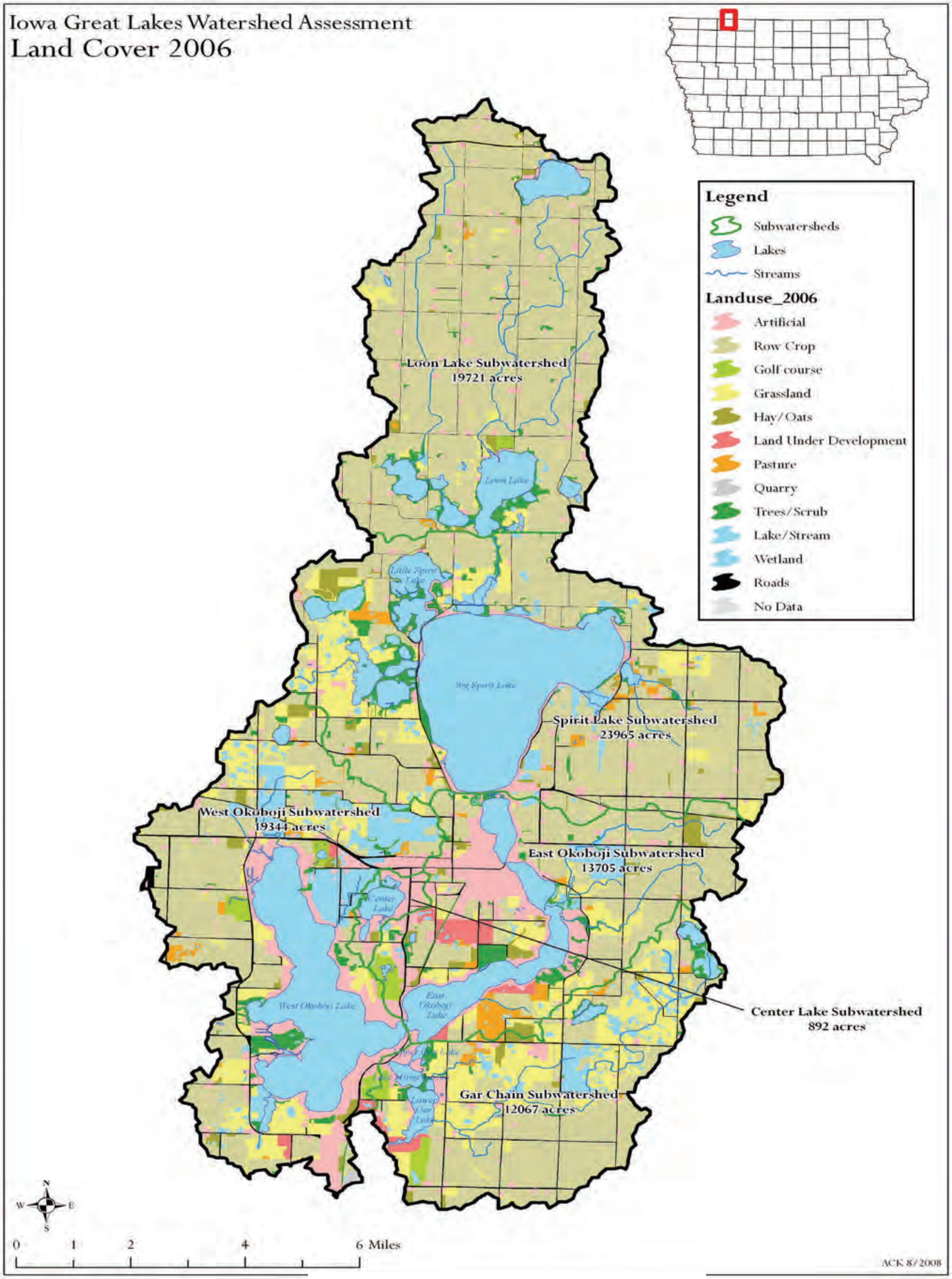


Figure 4.2 Land Use for the Iowa Great Lakes

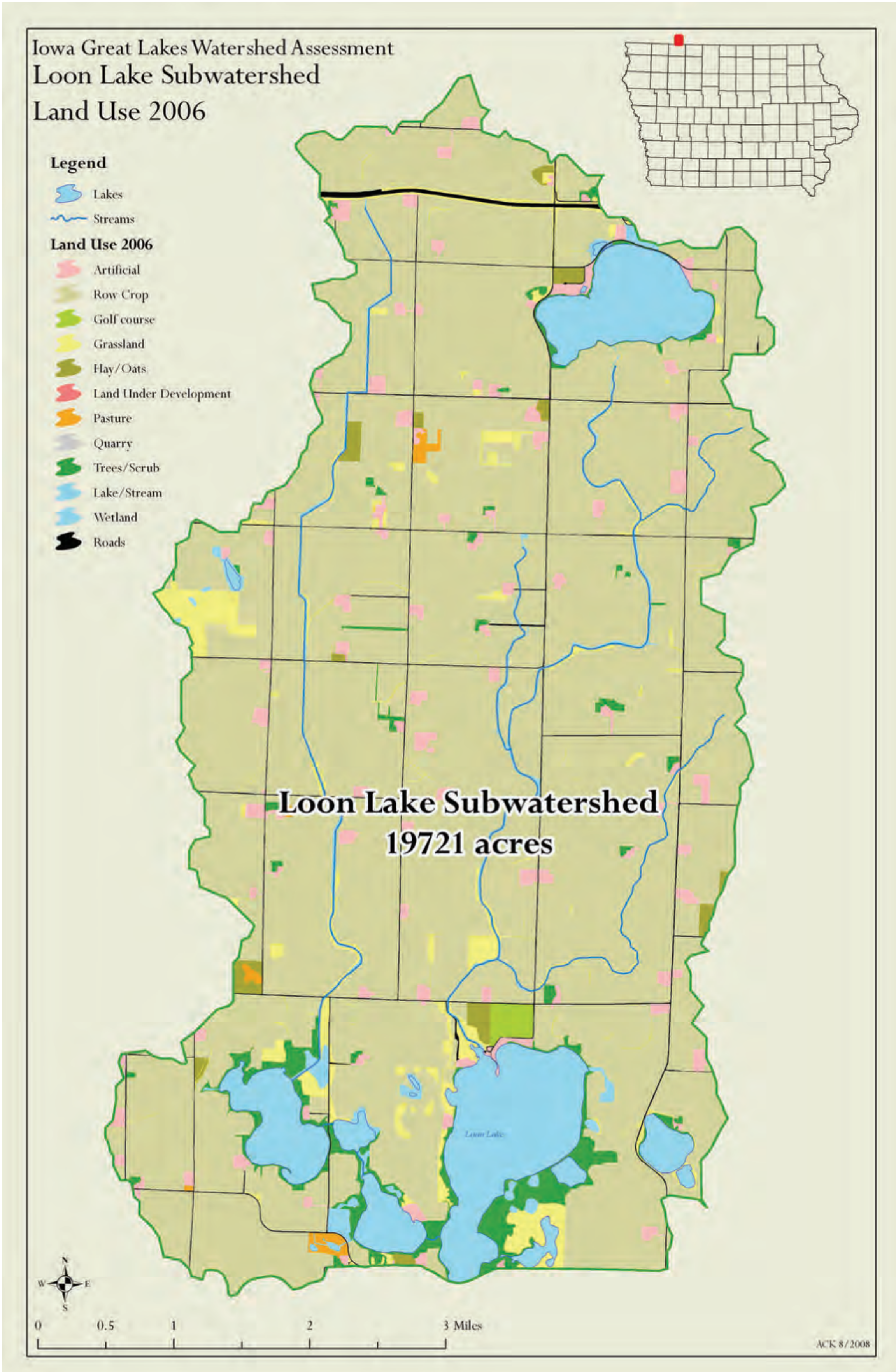


Figure 4.3 Land Use for the Loon Lake (Minnesota) portion

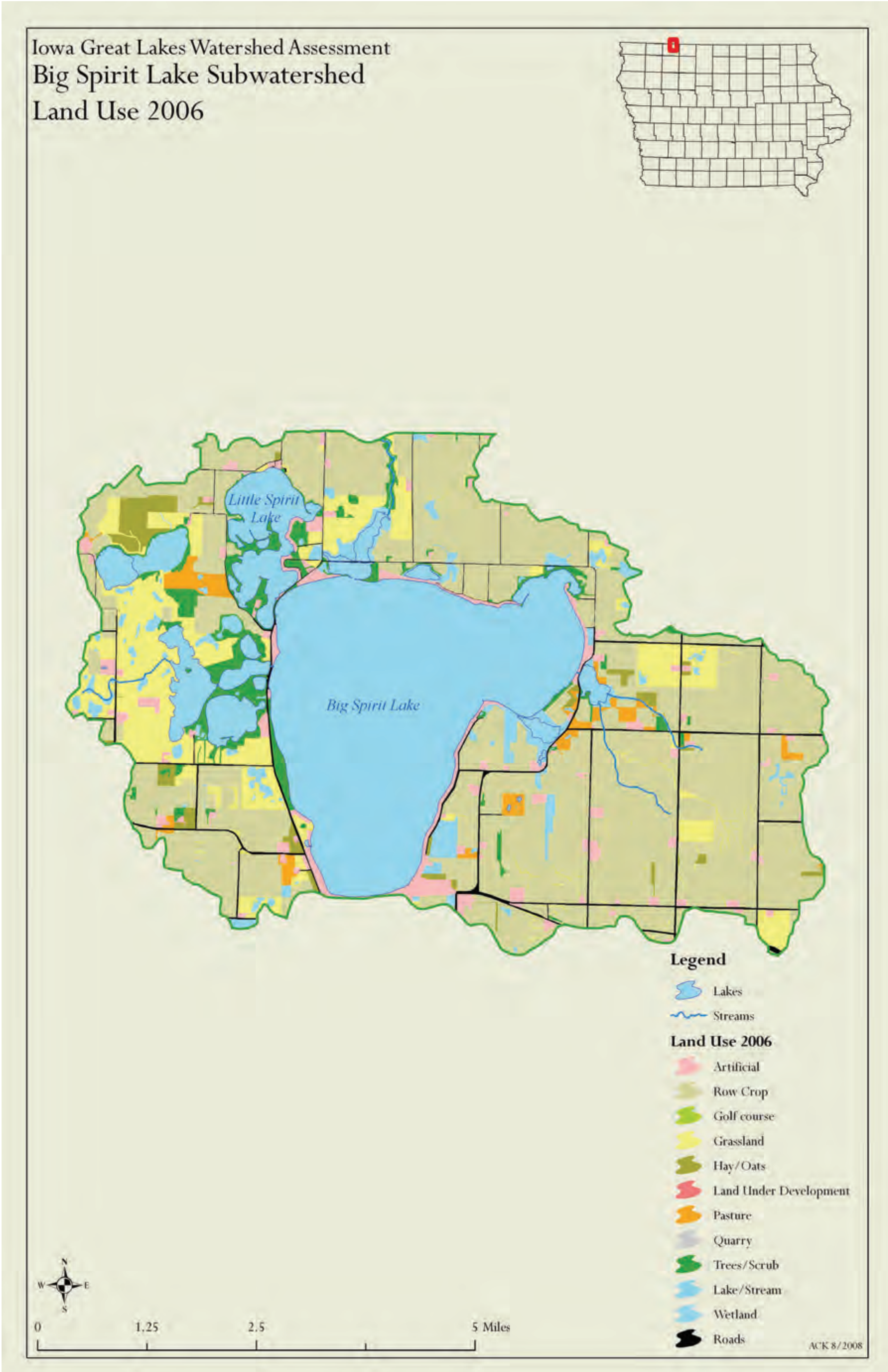


Figure 4.4 Land Use for the Big Spirit Lake Watershed

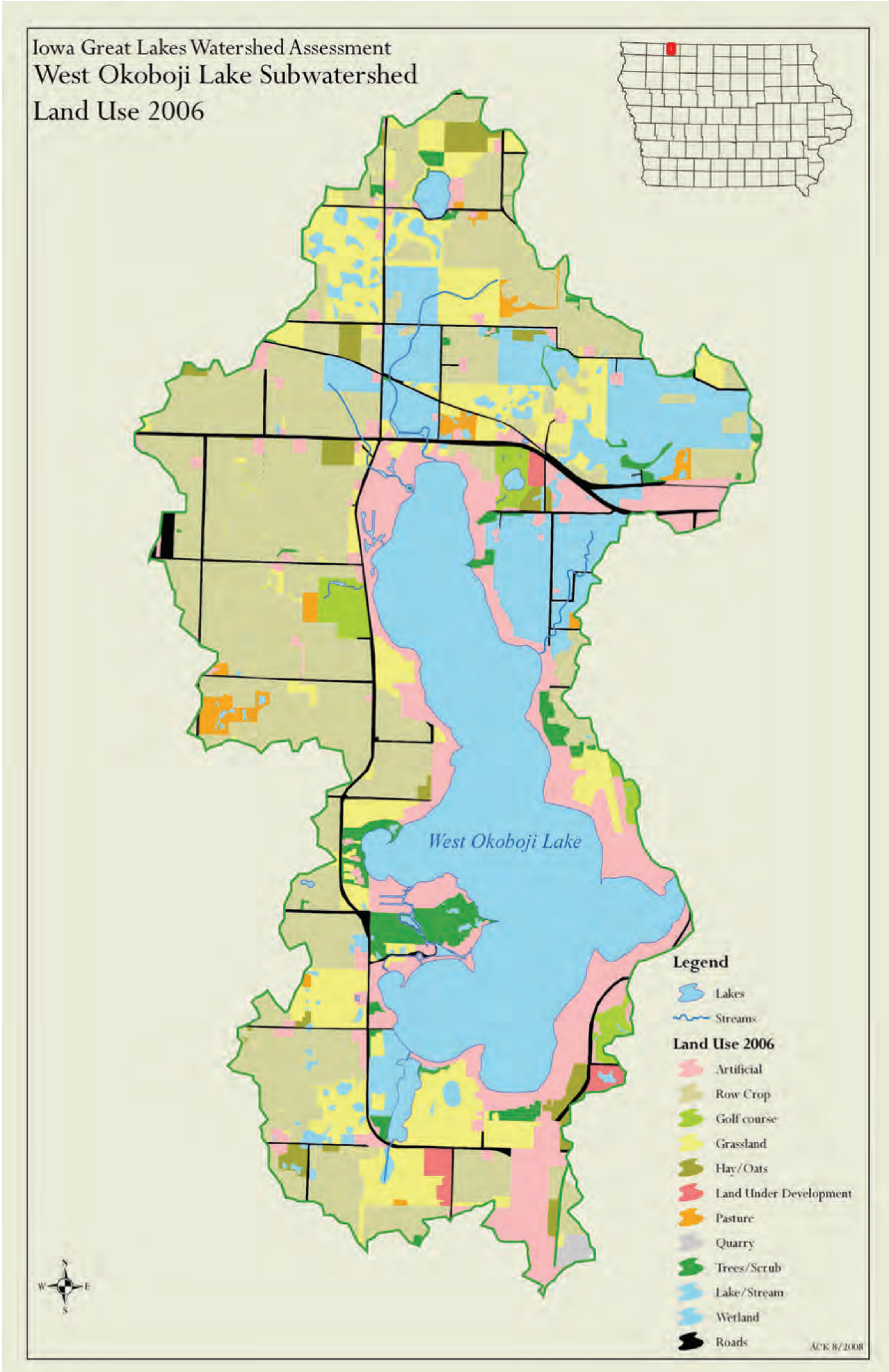


Figure 4.5 Land Use for the West Okoboji Lake Watershed

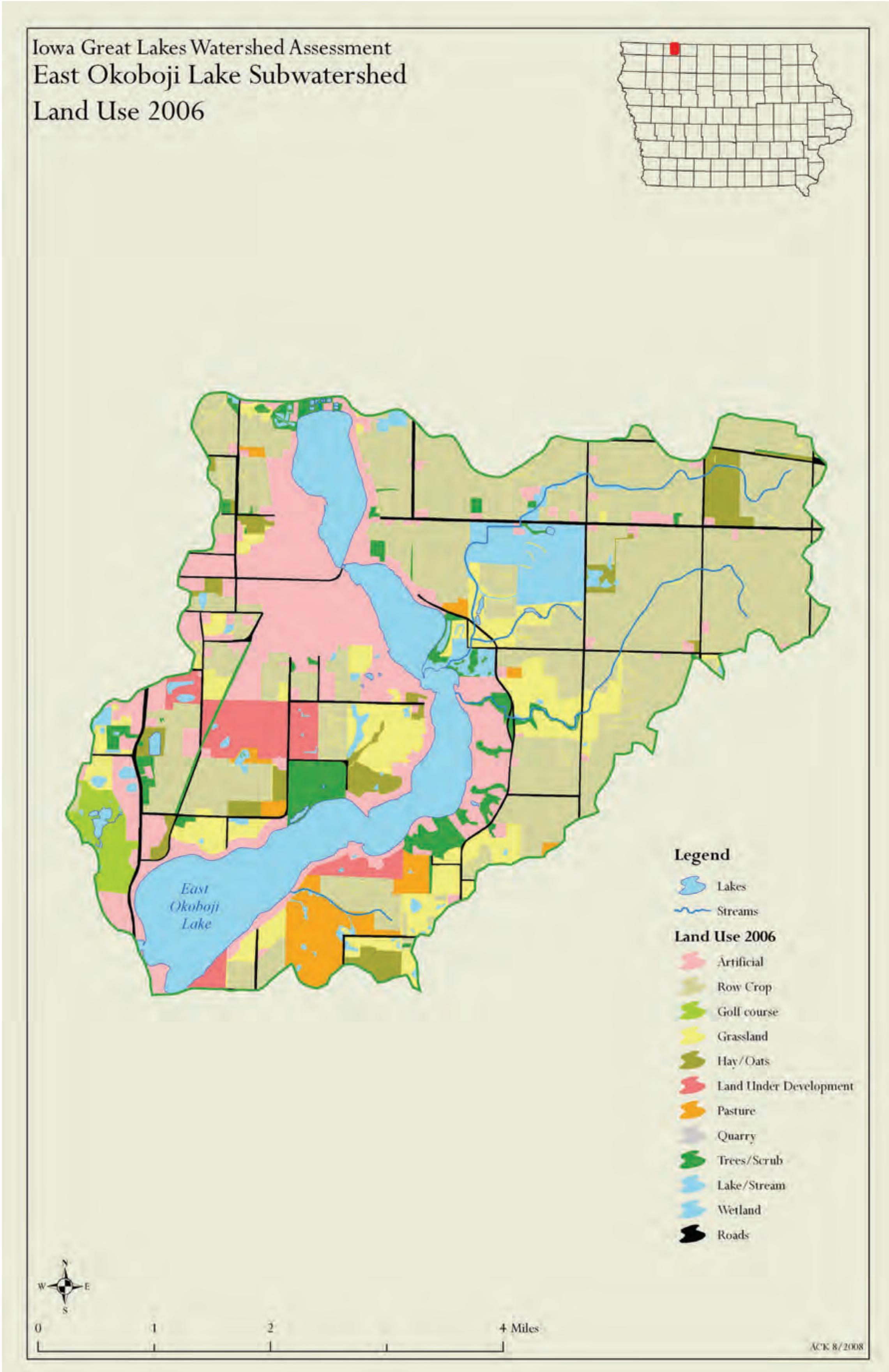


Figure 4.6 Land Use for the East Okoboji Lake Watershed

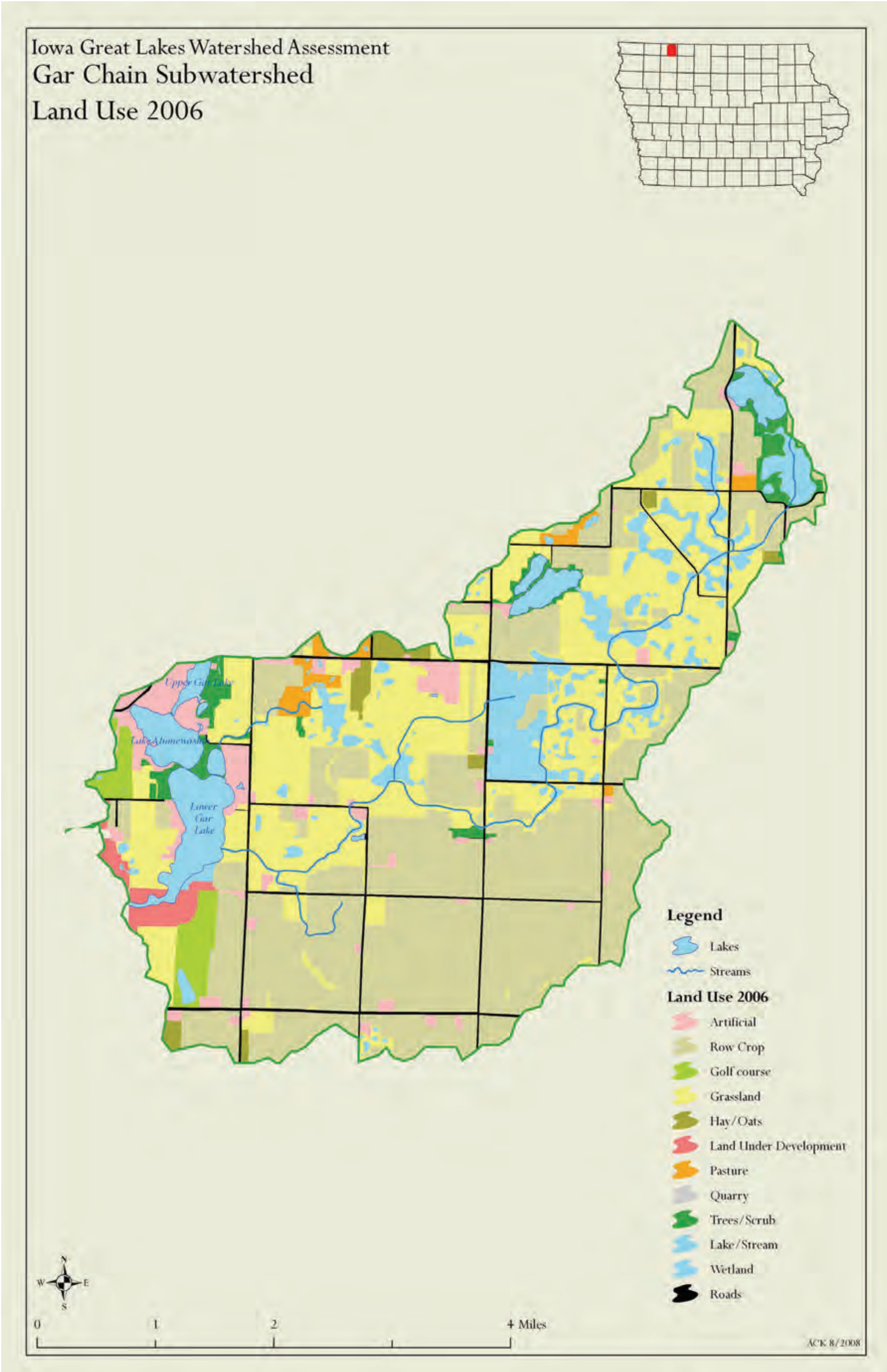


Figure 4.7 Land Use for the Gar Chain Watershed

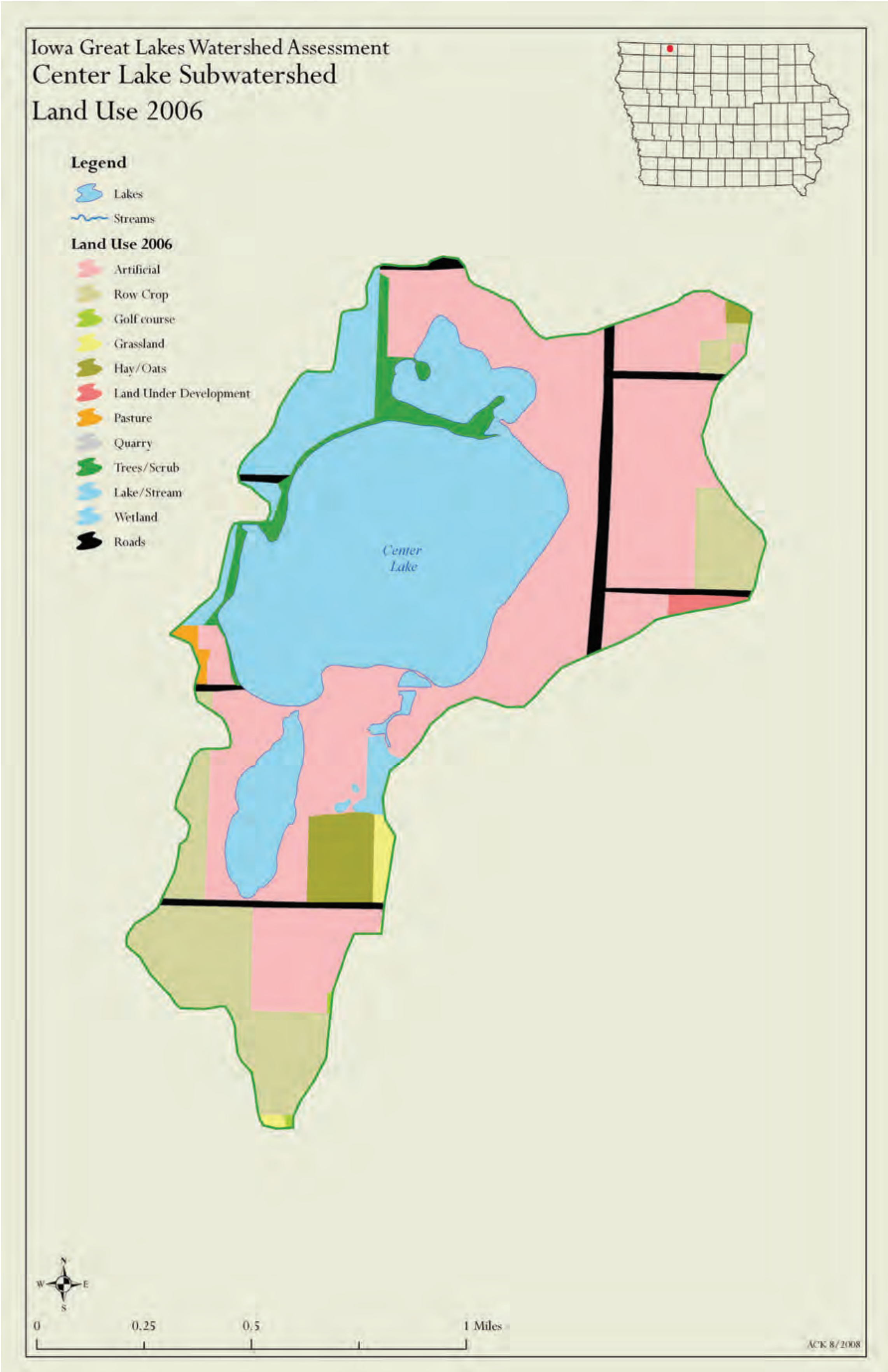


Figure 4.8 Land Use for the Center Lake Watershed

Concentrated urban development in the Iowa Great Lakes region and rural areas in the remainder of the county characterize Dickinson County land use. There is increasing density of development and redevelopment on lakefront property. The county is also experiencing substantial growth along major transportation routes, and in unincorporated portions of Dickinson County and cities near the lakes.

In addition to the parks and recreational facilities within the county, one of the state's largest publicly owned land tracts is located just east of East Okoboji Lake. The Spring Run Complex is a public wildlife and recreation area that encompasses 3,577 acres. The area is the primary watershed for Lower Gar Lake. The Iowa Department of Natural Resources owns and operates 38 public areas, including Spring Run, encompassing 19,911 acres within Dickinson County.

The county encompasses 243,904 acres, of which 203,000 acres (83 percent) are farmland. According to the 2002 Census of Agriculture, there are 492 farms in Dickinson County. The average farm size is 413 acres, compared to the state average of 350. Agricultural trends indicate the county is moving toward larger farm corporations and fewer family farms. As urbanization continues, more agricultural lands are taken out of production. (US Census Bureau, 2000)

According to the Dickinson County Land Use Development Plan Summary, the County's land use objectives are to "establish a pattern of land uses that will maximize the safety and welfare of the residents, while considering the protection, preservation, and mitigation of sensitive environmental areas and critical natural habitats." (Dickinson County Comprehensive Planning and Development Plan, 2006)

In Jackson County, significant lakeshore development has occurred around Clear Lake, Loon Lake and Little Spirit Lake. In 1993, Jackson County adopted new shoreline regulations regarding vegetation removal, soil erosion, upgrading of sewage systems, the operation of feedlots, and established a shoreline classification on rivers and streams. There has been some local conflict over establishing acceptable water levels for Clear Lake and Loon Lake.

Land use in Jackson County is expected to remain predominantly agriculture. The county encompasses 458,880 acres, of which 398,068 acres (95 percent) is cropland and pasture. The remainder is urban and recreational development, or wildlife habitat. There is a trend towards larger and more intensive farming in both livestock and grains. Much of the livestock expansion is total confinement operations with storage of manure in concrete pits. Jackson County reviews feedlot permits for location from water bodies and recharge areas, slope, and sites to be used for manure disposal, in order to avoid contamination of surface and ground water. (US Census Bureau, 2000)

Climate

The climate of the Great Lakes region is classified as humid-continental. Seasonal temperatures range from highs of 110 degrees Fahrenheit to lows of -40 F, while daily variations may be as much as 50 F. The area receives 28 inches of precipitation per year while the US average is 37 inches. Snowfall averages around 33 inches in Dickinson County. The average US city gets 25 inches of snow per year. The number of days with any measurable precipitation is 84.

On average, there are 208 sunny days per year in Dickinson County, IA. The July high is around 84 degrees. The January low is four. Our comfort index, which is based on humidity during the hot months, is a 45 out of 100, where higher is more comfortable. The US average on the comfort index is 44. (Sperlings Best Places, 2008)

Two-thirds of the precipitation falls between May and September. Summer precipitation ranges from severe storms to occasional drought. High summer temperatures produce evaporation levels typical of the prairies.

The average frost-free season is approximately 150 days, with a maximum growing season of 225 days from March 29 to November 9. The climate is dry enough to have aided the development of the prairie soils and humid enough to support a highly productive agricultural economy.

Geology

A geological drama occurred 14,000 years ago when the Des Moines lobe of the Wisconsin glacier retreated across the upper Midwest - created a glacial phenomenon that sculpted the earth with unimaginable power and beauty, fashioning the landscape now known as the Iowa Great Lakes Region. With more lakes, wetlands, public land and state parks than any county in Iowa, Dickinson County is arguably the most environmentally diverse in the state.

The geological resources (lakes) of the area are a reason the IGL region has developed as a tourist and recreational area. The geologic history of the area has affected the surface contours of the land; the formation of soil types; location of minerals; groundwater; lake basins; and stream channels. During the ice ages, massive glaciers moved across the region, carrying with them boulders, gravel, sand and clay and organic remains. As the glaciers melted, millions of tons of debris were deposited (glacial drift). The glacial drift forms a 200 to 300-foot cover over the region's bedrock.

The glacial drift in the Iowa Great Lakes area was deposited in the Wisconsin Age of the Pleistocene Epoch. The Wisconsin glacier was the last of at least three major ice sheets to cover the area. The Des Moines lobe of the Wisconsin glacier, which originated in the Keewatin District west of Hudson Bay in Canada, pushed down into north-central Iowa across an area 70 to 80 miles wide. As the glaciers receded, the glaciers occasionally left large blocks of ice, which melted and formed basins for future lakes. The rugged bottom of West Okoboji Lake suggests it may have been formed in this manner.

Water from the melting glaciers also cut new drainage patterns in the deposits below the ice. Outwashes of sand and gravel were carried by streams that drained glacial melt and deposited it in the valleys, which the glaciers had formed. The Milford Gravel Flat and Spirit Lake appear to have been formed by a buildup of glacial outwash.

Underlying the glacial drift are shale's and sandstone created in the Cretaceous Age. The shale varies in thickness and is several hundred feet thick just north of the northern boundary of the watershed. The sandstones vary in thickness but generally do not exceed the thickness of the shale.

Below the Cretaceous units, data regarding the age of the soil is limited. However, it appears that Ordovician and Cambrian Age sediment underlie the Cretaceous units in the southeastern half of the watershed. A few miles north of the northern watershed boundary there also exists a buried northwest-southeast trending quartzite ridge of Pre-Cambrian Age.

Soils

Heavier textured glacial soils occur within the Great Lakes watershed. The soils are not as erosive as the predominantly lighter textured loess soils found 50 miles to the southwest, but the soils do erode–especially during periods of abnormal rainfall or excessively high winds. Water erosion takes a toll on the steeper lands that are being row-cropped. The flatter land is more subject to wind erosion when it is left over winter without a cover of crop residue.

There are four major soil associations within the watershed. The major and minor soils are listed in order of importance below. Two associations may contain the same soils, but in a different pattern.

Wadena - Estherville
The Wadena – Estherville association consists of soils that are medium to moderately coarse textured, gently sloping (2 to 5 percent). The association developed from glacial outwash is shallow to deep gravel and is calcareous in nature. The soils are prone to drought when sand and gravel are within 15 to 30 inches of the surface. Minimum tillage is an excellent conservation practice to use here, since it retains moisture in the surface soil and slows wind erosion.

Webster - Clarion – Nicollet
These soils occur in a small portion of the watershed; one area is at the northern tip and one at the southern edge. The area is typified by level to gently undulating (0-5 percent slopes) medium and moderately fine textured soils that are developed from glacial till. There may be pond spots and high lime areas.

This has low potential as a sediment producing area because of its gentle slopes. Simple conservation practices such as contouring, strip cropping and minimum tillage are all that maybe needed to keep erosion in check. Occasionally, terraces maybe recommended on steeper slopes.

Clarion – Nicollet - Webster
This association is characterized by gently undulating to gently rolling (2 to 9 percent) slopes. The soils are developed from glacial till and are medium and moderately fine textured. This area is used extensively as farmland. Some steeper slopes and wet areas are in permanent pasture. Conservation measures would include contouring, contour stripping, stubble mulching, and minimum tillage with modified terraces on steeper slopes.

Clarion - Storden – Okoboji
The Clarion soils occupy the greater portion of this association. They are dark brown, loamy, well-drained soils occupying an upland position on gently undulating to steep slopes. The Storden soils occur on the steeper slopes and knobs, usually above the Clarion soils on the landscape. Most of the larger permanent pastures are in the areas of predominately Storden soils, since they are not as well suited to faming operations, as is Clarion. The Okoboji soils are dark, deep and poorly drained. They occupy potholes or small depressions within the association and ordinarily require artificial drainage to be productive farmland.

Conservation measures on this association, principally Clarion and Storden, consist of mulch tillage and terraces. Terracing is usually difficult because of short, irregular slopes. The steeper the slopes the higher the importance is of being converted to permanent pasture. (Dickinson County Soil Survey, 1974)

Topography
The topography of the watershed can be characterized as gently rolling. Lakes and marshlands lie within the hollows of the terrain. Runoff from precipitation drains into the lakes, evaporates, or percolates into the soil where it recharges the groundwater. Water draining into the lakes and streams carry contaminants from the land, which affect the water quality of the lakes.

The watershed area of the Iowa Great Lakes can be divided into five major sub-watersheds, which define the drainage areas for each of the three major lakes plus an extensive area that drains into Lower Gar Lake from the east. Each of the major sub-watersheds is made up of smaller watersheds. Although most of the runoff from the watersheds reaches the lakes due to natural drainage, some runoff is diverted to the lakes by man-made features or modifications of the natural system. Examples are constructed storm sewer outlets, tile lines and drainage ditches throughout the watershed.

Physical Characteristics
Dickinson County is home to 20 natural lakes covering more than 16,000 acres, all of which are public use resources. Although most of the lakeshore acres on these lakes are held in private ownership, there are ten

lakeside state parks. The lakes are noted fisheries for game species such as walleyes, northern pike, large-mouth and smallmouth bass, yellow perch, crappies and bluegills. Large numbers of anglers from throughout the Midwest travel to Dickinson County each year to sample the fishing. Walleye Weekend, for example, held annually on the walleye opener in early May, attracts thousands of anglers.

In addition to the natural lakes, Dickinson County has more than 15,000 acres of public land managed by the Department of Natural Resources or about 15 percent of the total land area in the county. These areas consist of shallow natural lakes, natural or restored prairie wetlands, prairie grass uplands, woodlands and meadows. Enjoyed by hunters, anglers, bird watchers, kayakers, canoeists and nature lovers, these public acres add to the environmental allure of the area. About half of the land in Dickinson County remains agricultural cropland, 12% grassland and about 2% woodland. Work continues throughout the lakes watersheds to restore wetlands and other buffers to reduce runoff pollution.

Surface Water

Surface waters consist of tributaries, rivers and lakes that make up the Little Sioux River drainage basin; the Little Sioux River and several tributary streams flow year-round. Most creeks are intermittent and carry water only in periods of heavy rainfall or spring thaw. Runoff corresponds to the annual precipitation rate. The large lakes, small lakes and wetlands make up a unique lake district. The lakes provide municipal drinking water supplies for communities within both Dickinson and Jackson counties.

Dickinson County-Spirit Lake

Spirit Lake is located about one mile north of the center of the City of Spirit Lake, and is the largest of Iowa's natural lakes. The lake encompasses 5,684 acres, and is approximately six miles long and three miles wide. Shoreline length is 15.25 miles and average depth is 17 feet, with a maximum recorded of 24 feet. The northern edge of Spirit Lake borders the Minnesota state line and the majority of its watershed lies in Minnesota. There are three state parks—Templar Park, Marble Beach and Minnewashta—and 8 public areas—Trickles, Hales, Anglers, Orleans (two), Orleans Beach, Pump House and Grade—with lake access bordering the shoreline. Forty species of fish, including 13 species of sport fish sought after by fishing enthusiasts, are located within Big Spirit Lake.

Little Spirit Lake

Little Spirit Lake lies on the Iowa-Minnesota border, with approximately 40 percent of the lake located in Iowa. The lake is 618 surface acres in size with an average depth of six feet and a maximum of 10 feet. Since Little Spirit Lake is a border lake, anglers must comply with Minnesota bag limits and fishing seasons as well as Iowa's fishing regulations. The lake is on both state's impaired waters lists and has an aeration system. There is one public access in both Iowa and Minnesota.

Center Lake

Center Lake is located between the northern halves of West and East Okoboji Lakes, within the City of Spirit Lake. The lake encompasses 272 surface acres with an average depth of 14 feet and a maximum of 17 feet. The entire northeastern shoreline is developed, but public access to the lake remains good, with approximately 25 percent of its 4.7-mile shoreline in timber and wetlands.

This watershed may be protected by using conservation and land retirement programs in the agricultural part of the watershed. In the urban portion, using low impact development practices will protect the lake from urban runoff. Center Lake also has the highest ratio of urban area to agricultural land for its watershed.

West Okoboji

West Okoboji Lake is located southwest of the city of Okoboji and northwest of the city of Arnolds Park. West Lake is the largest of the six interconnected lakes in the Iowa Great Lakes chain, reaching over 3,847 surface acres with an average depth of 38 feet and maximum depth of 138 feet. The lake has 19.8 miles of shoreline. The natural drainage area, or watershed, around the lake encompasses about 13,668 acres.

Public access is provided at Emerson Bay, Triboji, Givens Point, Pillsbury Point, Gull Point, and Pikes Point. West Okoboji Lake was formed as glaciers retreated north. More than 47 species of fish are found in the lake, including 11 species of popular sport fish.

East Okoboji
The City of Okoboji is located on the Western shores of East Lake Okoboji. The lake includes 1,835 surface acres with an average depth of 10 feet and a maximum of 22 feet. Only 6 percent of the 16.8 miles of shoreline is publicly owned; 85 percent of the shoreline is developed. Eleanor Bedell State Park offers access to fishing, camping, picnicking and playground facilities. Additionally, North Park, Iowa DNR Fish Hatchery, East Okoboji Beach, Claire Wilson Park and Hattie Elston Park are public parks in the watershed. The lake's watershed encompasses 12,212 acres.

Upper Gar Lake
Upper Gar Lake connects the south bay of East Okoboji Lake to Minnewashta Lake. Upper Gar covers 37 surface acres and is the smallest of the Iowa Great Lakes chain. The lake is essentially a shallow channel connecting two larger bodies of water. The average depth of Upper Gar Lake is only 3.5 feet; it has the smallest watershed with, one boat ramp, and warrants 5-miles per hour speed limit on the lake.

Minnewashta Lake
Minnewashta Lake is the second in a string of the small-interconnected lakes south of East Okoboji Lake. The lake is located within the city of Arnolds Park. The lake is 126 surface acres in size with 2.3 miles of shoreline. Average depth of the lake is 10 feet with a maximum of 16.5 feet. Most anglers fishing Minnewashta are in search of bass and pan fish populations. It is also a small watershed with one boat ramp and two state parks.

Lower Gar Lake
Lower Gar Lake is the southernmost lake in the Iowa Great Lakes chain, but has the largest watershed percentage. The lake is shallow and discharges into Milford Creek at the southwest corner of the lake. Lower Gar encompasses 273 surface acres, but the average depth is only 3.6 feet. There are four public areas on the lake. A dam on the lake holds back water to enable a higher water level.

Minnesota Lakes
Clear Lake
Clear Lake is located 3 miles west of the City of Jackson, Minnesota and is noted as one of the reference lakes for this region. This 451-acre lake has a relatively small watershed of under 1200 acres. Clear Lake has a maximum depth of approximately 10 feet and a 6-helixor aeration unit was installed in 1976. The OHW for Clear Lake is 1503.5 feet and the highest recorded lake level was 1504.3 in July of 1993. The lake is managed for walleye, which are stocked. The lake also has a healthy supply of perch, crappie, and bullhead. Clear Lake has a public access on the north and south side of the lake as well as some county parkland on the west side. Clear Lake is proposed to be on the 2008 MPCA, TMDL list for total phosphorous. (Jackson County Planning and Environmental Services. November 28, 2007)

Loon Lake
Loon Lake is located just one mile north of Big Spirit Lake. This 725-acre lake has a watershed of nearly 20,000 acres or a watershed ratio of 27:1. Loon Lake has a maximum depth of approximately 7 feet and a 9-helixor aeration unit was installed in 1982. The majority of the water drains into Loon Lake by way of either the drainage ditch on the north side or the creek which comes from Pearl Lake into Loon Lake on the west side of the lake. The OHW for Loon Lake is 1406.8 feet. The highest water level was in June of 1993.

Loon Lake is managed for walleye and secondarily for perch and northern pike. Loon Lake has a county park on the east and west side of the lake as well as a large USFWS property on its east side. A residential development, as well as a golf course is located on the north side of the lake. Loon Lake is proposed to be on the 2008 MPCA, TMDL list for total phosphorous. (Jackson County Planning and Environmental Services. November 28, 2007)

Pearl Lake

Located adjacent to the west shore of Loon Lake; this 155 acre lake has a watershed of approximately 7000 acres. Pearl Lake has a maximum depth of approximately 6 feet and a 3-helixor aeration unit was installed in 1987. Pearl Lake does not have an established OHW at this time. The lake is presently managed for northern pike as a primary species while walleye, yellow perch, and black crappie are managed secondarily. Pearl Lake has a county park on its east and west side with very little residential development around the lake. (Jackson County Planning and Environmental Services. November 28, 2007)

Rush Lake

Rush Lake is located immediately to the west of Pearl Lake and serves as a filter for much of the water that enters Pearl and Loon Lake from the west. This 293 acre lake is very shallow with a maximum depth of approximately 3'. There is very little development around this lake and the only public access is from the Federal Waterfowl Production Area on the east side of the lake. Rush Lake does not have an established OHW at this time. A 1988 survey indicated populations of perch, northern pike, buffalo, bullhead, carp and suckers were all present in the lake. (Jackson County Planning and Environmental Services. November 28, 2007)

Groundwater Resources

The Dakota sandstone and the Ordovician and Cambrian Age sandstones are the most important of the deep flow systems. The well source in the watershed is mainly from the Dakota sandstone aquifer. The wells in the region average 130-500 feet in depth. The gradient of the groundwater is generally south but local high water levels are found throughout the area following land surface contours. Ground water highs are found below the hills east and west of West Okoboji Lake and east of East Okoboji Lake. Topographic high areas are recharge areas and low-lying marshes and wetlands are discharge areas.

The flow system having direct bearing on the lakes and streams of the area is the shallow system found in the glacial drift. The gradient of the ground water in the drift generally is to the south, but local ground water highs are found throughout the area. The piezometric levels generally follow topographic highs and lows, and ground water highs are found below the hills east and west of West Okoboji Lake and east of East Okoboji Lake. The topographic high areas are recharge areas and the low-lying swamps and lakes are discharge areas. In the areas adjacent to the Little Sioux River, the contour configuration indicates that the river is receiving ground water discharge. The lakes are also receiving base flow from ground water.

The quality of ground water varies throughout the area depending upon location and well depth penetration. The Dakota sandstone and Ordovician and Cambrian Age sandstones typically contain highly mineralized waters. Dissolved solids are found in concentrations exceeding 1000 parts per million (ppm). The water is also very hard with concentrations of more than 700 ppm of total hardness. High sulfates are characteristic of the Dakota sandstone.

Water Use-Dickinson County

Water in Dickinson County is primarily used for public and private water supplies. Public water supplies provide 900 million gallons per year to Dickinson County residents and visitors. Other water usage consists of private use, and farms that accounts for 62 million gallons per year. Irrigation and mining combined account for 83 million gallons per year.

Visitors to the region increase the summer population within the county from approximately 16,424 to more than 100,000 people. The tourist population presents challenges to dealing with public wastewater systems, and raised concerns as early as the 1930s about a need to maintain a pollution-free environment. Currently, the Iowa Great Lakes Sanitary District consists of 95 miles of sanitary sewers, 63 pump stations, and 1 central wastewater treatment facility. The sanitary district has expanded to include more than 23,450 acres, 11,550 acres of which are water.

The primary threats to the water quality of the Iowa Great Lakes are sedimentation, excess nutrients, human and livestock waste, stormwater contaminants and loss of natural wetlands. The most common nutrient problem in Iowa lakes is excess phosphorous. Limiting phosphorous limits algal growth slowing eutrophication and consequent water quality impairments. The hyper-eutrophic condition of the Iowa Great Lakes makes total phosphorous the target pollutant for determining the total maximum pollutant load to the lakes of the watershed

Agricultural runoff contributes contaminants such as sediment, commercial fertilizers, pesticide, herbicides and feedlot effluent.   Increased urban development has presented stormwater quality and quantity problems. Urban stormwater runoff carries contaminants such as sediment, excess nutrients, pesticides and herbicides, heavy metals, and road salt. There is increasing pressure on drinking water supplies by the growing permanent population base and an expanding summer seasonal population. Good water quality is vital to the region's economy and quality of life for those who visit or live within the area. Potential spills of hazardous waste and invasion of aquatic Invasive species are also a concern.

Factors which influence phosphorous inputs to the lakes of the watershed vary with each lake, with each season, and with the amount of precipitation and size of storms for a given period. Water quality in Iowa Great Lakes is influenced only by nonpoint sources and internal recycling of pollutants from bottom sediments. Nonpoint source categories identified in this plan include inflow from other lakes combined with internal recycle, atmospheric deposition and watershed loads in the immediate watershed. There are no point source discharges in the watershed.

Photo 4.3 Courtesy David Thoreson, Blue Water Studio

5 POLLUTANTS AND CAUSES

Surface water in Dickinson County is the single most important reason for the county's current economic prosperity and tourism industry. Dickinson County water resources are an important source of drinking water, recreation, wildlife habitat, and aesthetic enjoyment for residents and visitors. Because of the importance of surface water to the county and its residents, there are many individuals, groups and organizations currently working to educate residents and businesses in the area about protecting water quality.

Dickinson County encompasses some of Iowa's most unique natural resources and environmentally sensitive areas. One of Iowa's largest publicly owned tracts of land is located just to the east of East Okoboji Lake, Minnewashta Lake, and Upper and Lower Gar Lakes. The Spring Run Complex is a public wildlife and recreation area of more than 1,600 acres and serves as the primary watershed for the lakes listed above.

Photo 5.1: Body of water at the Iowa Great Lakes. Courtesy of the Dickinson County 2006 Comprehensive Land Use Plan.

The prairie potholes and marshes adjacent to the lakes are ground water recharge areas, and serve as a natural filtration system for the Iowa Great Lakes (IGL) by filtering and capturing contaminants carried in stormwater runoff, and infiltrating runoff from surrounding developed land. In the past, wetlands have been drained in favor of agriculture and urban developments, but it has more recently been recognized that wetlands are an integral part of a complex ecological system. In addition to the parks and recreation activities within Dickinson County, the wildlife and natural areas provide wildlife habitat and opportunities for walking, hiking, and bird watching.

The primary threats to the water quality of the Iowa Great Lakes are sedimentation, excess nutrients, human and livestock waste, stormwater contaminants and loss of natural wetlands. Agricultural runoff contributes contaminants such as sediment, commercial fertilizers, pesticide, herbicides and feedlot effluent. Potential spills of hazardous waste and invasion of aquatic Invasive species are also a concern.

Increased urban development has presented stormwater quality and quantity problems. Urban stormwater runoff carries contaminants such as sediment, excess nutrients, pesticides and herbicides, heavy metals, and road salt. There is increasing pressure on drinking water supplies by the growing permanent population base and an expanding summer seasonal population. Good water quality is vital to the region's economy and quality of life for those who visit or live within the area.

5.1 DESIGNATED USE

The Iowa Water Quality Standards (IAC, 1996) list the designated uses for the Iowa Great Lakes as:

Class "A". Primary Contact Recreation. Waters in which recreational or other uses may result in prolonged and direct contact with the water with the risk of ingesting water such as swimming, water skiing, and canoeing.

Class "B (LW)". Aquatic Life. Water in which a significant and viable aquatic community is maintained year round. Class B waters are to be protected for wildlife, fish, aquatic and semi-aquatic life, and secondary contact uses.

Class "HQ". High Quality Water. Waters with exceptionally better quality than the minimum expected and with exceptional recreational and ecological importance. Special protection is warranted to maintain the unusual, unique, or outstanding physical, chemical, or biological characteristics which these waters possess.

Iowa does not have numeric standards for turbidity. The portions of the Iowa Great Lakes "partially supported" assessment for aquatic life uses was made by IDNR Fisheries staff based on information collected in 1992 and 1993. This 1994 evaluation was carried over to the 1996 and 1998 305(b) assessments. The partially supporting assessment caused the lake to be placed on the 1998 impaired waters list. The hyper-eutrophic lake conditions of lakes such as Lower Gar, Little Spirit Lake, and Center Lake is the direct cause of the turbidity impairment. Severe algal blooms and loss of clarity have caused a condition incompatible with an aquatic community "normally associated with lake-like conditions". Severe algal blooms and loss of clarity have caused a condition incompatible with an aquatic community "normally associated with lake-like conditions".

Photo 5.2 Gull Point Boats, Courtesy David Thoreson, Blue Water Studio

5.2 WATER QUALITY DATA

> ***A thing is right when it tends to preserve the integrity, stability , and beauty of the biotic community. It is wrong when it tends otherwise. — Aldo Leopold***

WATER QUALITY STUDIES

An overview of water and nutrient budget information for the IGL obtained during three publicly funded water quality investigations is presented in the following paragraphs. The information is intended to provide a summary of the purpose and scope of the projects, and a general discussion of the results and findings. Content is credited to the appropriate authors.

"A Management Plan for Water Quality of Iowa Great Lakes"

Background

In 1970, three IGL lake associations began a comprehensive study of water quality in the lakes and their watersheds. The lake associations and primary businesses and industries in the area contributed financing. Many local volunteers agreed to contribute services to the program.

The Dickinson County Board of Supervisors subsequently received a federal grant from the Water Quality Office of the Environmental Protection Agency in 1971, and hired Hickok and Associates to coordinate the activities of the many agencies involved in the study and evaluate the data being collected. The Board of Supervisors also appointed a seven-person committee to administer the program, which included representatives from the Okoboji Protective Association, East Okoboji Lakes Improvement Corporation, Spirit Lake Protective Association, Dickinson County Extension Service, Dickinson County Regional Planning Commission, Dickinson County Soil Conservation District, and Jackson Planning Commission.

The study was conducted from March 1, 1971 to December 31, 1972 in order to evaluate long-term trends, identify sources of pollution, and provides the basis for developing an overall pollution abatement and water quality improvement plan. Potential issues included urban drainage, agricultural runoff, land use, sanitary sewage, and institutional and financial difficulties. For a complete review of data collection, data analysis, and results and findings see *Management Plan for Water Quality in Iowa Great Lakes*, submitted by Hickok and Associates to the Dickinson Board of Supervisors, February 1974. (Hickok and Associates, 1974)

Hydrologic Budget

Available hydrologic data in the IGL watershed were adequate only for an approximate, generalized hydrologic budget determination. Long-term precipitation records were available from the Iowa Lakeside Lab Station on West Okoboji Lake. Lake level records for Spirit Lake and Lower Gar Lake were initiated in 1971. However, approximate flows were determined for these areas by extrapolating from lake stage records and existing stream flows.

Hydrologic budget year calculations were related to the IGL region water year, which begins on October 1 and ends on September 30. This was done to recognize the effect snow and frost have on the precipitation - runoff relationship. For the IGL area, a water year starting about December 1 would more nearly approach the desired objective of reducing carry-over of substantial quantities of stored water from one water year to the next. A water year coinciding with the calendar year was chosen for this study for ease of understanding and with due recognition that runoff observed in the spring may occasionally contain precipitation that occurred during the previous year and was stored in the form of snow during the winter.

Hydrologic Budget Summary
Based on the 1971 stream flow measurements and corresponding lake level stages, a stage discharge correlation was established. In general, a rise in the lake level and eventual overflow at the outlet of the respective basins correlated with greater than average precipitation. However, the correlation is not a direct ratio since temperature, precipitation rates, intensities and antecedent moisture conditions play an important role in determining distribution of water in the hydrologic cycle.

Nutrient Budgets
A sampling program was established to estimate the annual inputs of phosphorous and nitrogen into the IGL. Beginning March 1, 1971, tributary streams were sampled about once a week if there was measurable flow. Orthophosphate phosphorous, nitrate nitrogen nitrite nitrogen, and ammonia nitrogen levels were determined. Beginning in September of 1971, total phosphorous concentration was also analyzed. This entire report is based on concentration of total phosphorous or TP. Volume of flow was estimated by determining the average width and depth of each stream to find the cross-sectional area. The average velocity was estimated by timing a small float over a measured distance, and the two values were multiplied together to obtain flow in cubic meters per second.

The analysis covered by this report is separated into two periods: March 1, 1971 to February 29, 1972, and March 1, 1972 to December 31, 1972. Since spring runoff usually does not start until after March 1, and most of the annual runoff occurs before December, these two periods are good approximations of the annual nutrient inputs for the calendar years 1971 and 1972. Total phosphorous, nitrate-N, and ammonia-N concentrations in mg/l were determined for 750 stream samples.

The total of each of the nutrients delivered by each of the streams was calculated by multiplying the concentration of the nutrient by the volume of flow. This was repeated for the next sampling date, and the average value for the two dates was multiplied by the number of days between samples. Since flows were in cubic meters per second, the result was multiplied by the number of seconds in a day. This was done for each of the two years, and the increments were then totaled to arrive at an annual input of TP, nitrate-N, and ammonia-N.

In the watersheds of each lake, the metered streams covered only a portion of the total watershed area. In order to estimate inputs from the non-metered area, the total input from the metered areas was multiplied by the area of the un-metered portion and divided by the area of the metered portion. The sum of the metered and unmetered watershed inputs represented the total annual input of the respective lakes. Since USGS had not released the flow data for the stream that flows from Loon Lake to Spirit Lake, it was not possible to complete the 1972 calculations for that lake. For the same reason, it was not possible to calculate the loss from Spirit Lake into East Okoboji Lake, nor the loss from Lower Gar Lake into Milford Creek.

Rural septic tanks, feedlot runoff, soil erosion, and soil nutrient leachates were contributors to the results and analysis of the monitoring studies of the metered watersheds. The exact quantities contributed by each of these factors was not determined because it was beyond the project scope, however, correlation analysis of the results with the various parameters was conducted. Total phosphorous in urban stormwater runoff from developed areas were determined from the results of monitoring stormwater runoff during several storms at several points in the system (Table 1). Urban inputs were analyzed separately and as a component of the other sources (Tables 2, 3, 4 and 5).

Since Upper Gar and Lake Minnewashta are connected to East Okoboji and have no tributary streams flowing into them, they were combined with East Okoboji Lake. Lower Gar is connected to this system but is being treated separately using only inputs from its own watershed. In general, the inputs of TP and ammonia-N were greatest in 1971, which was also a year of high stream flows. The nitrate-N concentrations were about the same for both years.

The nutrient budget includes groundwater contributions, stormwater contributions, and rainfall contributions. Groundwater input is based on an estimated inflow of three inches per year over the lake surface with a TP concentration of 0.02 mg/l. Between August of 1971 and October of 1972, analyses were made of 17 rainwater samples. They had the following average concentrations: 0.05 mg/l TP, 0.29 mg/l nitrate-N, and 0.56 mg/l ammonia-N.

Photo 5.3 West Okoboji. Courtesy David Thoreson, Blue Water Studio

Lake	Total Phosphorous (kg)
Big Spirit Lake	249
West Okoboji Lake	1,058
East Okoboji Lake, Lake Minnewashta, Upper Gar Lake	826
Lower Gar Lake	28

Table 5.1. Estimated TP Input from Urban Stormwater Runoff

Source	Total Phosphorous (kg)		Nitrate-N (kg)		Ammonia-N (kg)	
	1972	1971	1971	1972	1971	1972
Metered Watersheds	2,781	1,804	31,564	24,188	9.777	2,370
Un-metered Watersheds	1,534	995	17,406	13,338	5,392	1,307
Subtotal	4,315	2,799	48,970	37,523	15,169	3,677
*Other Sources	1,142	1,116	3,263	3,113	6,953	6,662
Total	5,457	3,915	52,233	40,636	22,122	10,339

Table 5.2 Nutrient Inputs to East Okoboji Lake, Upper Gar Lake, and Lake Minnewashta
*Includes urban runoff, groundwater and nutrients from precipitation.

Source	Total Phosphorous (kg)		Nitrate-N (kg)		Ammonia-N (kg)	
	1972	1971	1971	1972	1971	1972
Metered Watersheds	630	680	6,140	9,349	1,072	1,948
Un-metered Watersheds	100	108	976	1,486	329	310
Subtotal	730	788	7,116	10,835	5,401	2,258
*Other Sources	74	70	416	395	579	537
Total	804	858	7,532	11,230	5,980	2,785

Table 5.3 Nutrient Inputs to Lower Gar Lake
*Includes urban runoff, groundwater and nutrients from precipitation.

Source	Total Phosphorous (kg)		Nitrate-N (kg)		Ammonia-N (kg)	
	1971	1972	1971	1972	1971	1972
Metered Watersheds	1,472	736	22,555	23,609	3,052	1,569
Un-metered Watersheds	1,709	854	26,183	27,407	3,543	1,821
Loon Lake Outlet	2,011		15,206		13,525	
Subtotal	5,192		48,738		20,120	
*Other Sources	1,153	1,079	8,027	7,599	9,992	9,166
Total	6,345		56,765		30,112	

Table 5.4 Nutrient Inputs to Big Spirit Lake
*Includes urban runoff, groundwater and nutrients from precipitation

Source	Total Phosphorous (kg)		Nitrate-N (kg)		Ammonia-N (kg)	
	1972	1971	1971	1972	1971	1972
Metered Watersheds	1,441	497	14,716	13,324	3,743	1,452
Un-metered Watersheds	566	195	5,782	5,235	1,471	570
Subtotal	2,007	692	20,498	18,559	5,214	2,022
*Other Sources	1,700	1,648	6,235	5,931	11,210	10,609
Total	3,707	2,340	26,733	24,490	16,428	12,631

Table 5.5 Nutrient Inputs to West Okoboji Lake.
*Includes urban runoff, groundwater and nutrients from precipitation.

Critical Nutrients

The hypothesis that the annual input of plant nutrients is a major factor in determining the standing summer crop of plankton algae in the IGL was tested. The summer standing crop for each lake in each year was estimated as the average chlorophyll a value for samples taken June through September. The nutrient input was taken as the total amount of TP and inorganic nitrogen entering the lakes divided by the volume of the respective lakes to yield a potential concentration.

The period for each year extended from March 1 through July 31 on the assumption that nutrients entering after that time would not contribute to summer bloom. In 1971 about 95%, and in 1972 about 68% of the measured flow of the tributary streams occurred in the above period. These percentages were applied to annual inputs of TP and nitrogen for each year to arrive at the nutrient incomes for those periods (Table 7).

Several things were noted. First, the order of the lakes with respect to summer chlorophyll a concentrations is the same as the order of the potential concentrations of TP and inorganic nitrogen (Table 6). Second, the concentrations of both the plant pigments and nutrients were higher in 1971 than 1972. There was a highly significant correlation between the concentrations of chlorophyll a and the potential concentration of TP. A similar calculation using inorganic nitrogen also produced a highly significant relationship. The ratio of nitrogen to TP in the inputs to the lakes ranges from 13.3:1 to 25.3:1, which is similar to the ratio in which these elements are found in planktonic algae (about 15:1).

Lake	**Chlorophyll a** mg/m^3	**Potential TP** mg/l	**Potential Inorganic N** mg/l
1971			
West Okoboji Lake	5.70	0.010	0.133
Spirit Lake	57.89	0.046	0.616
East Okoboji Lake	169.84	0.184	2.73
Upper Gar Lake	135.06	0.184	2.73
Lake Minnewashta	160.86	0.184	2.73
Lower Gar Lake	338.54	0.439	7.51
1972			
West Okoboji Lake	3.42	0.003	0.076
Spirit Lake	9.44	*	*
East Okoboji Lake	107.50	0.085	1.25
Upper Gar Lake	93.31	0.085	1.25
Lake Minnewashta	74.85	0.085	1.25
Lower Gar Lake	123.41	0.339	5.63

Table 5.6 Average summer concentrations of chlorophyll a for the IGL. Potential concentrations of TP and inorganic N calculated from total amounts added up to July 31, divided by the volumes of the respective lakes. *Flow records not available at time of analysis

Total phosphorous is considered the critical element in the IGL systems. It appears that there is a linear relationship between TP inputs and algal levels so that a halving of the TP input to a given lake might be expected to reduce the algal population by one-half. There is, of course, a lower limit to this relationship for if all inputs were removed, there would still be phosphorous recycled from the sediments. This appears, however, to be a small amount.

Watershed Factors Associated with Nutrient Inputs

It was noted in the study that there were differences in the nutrient concentrations between streams. A statistical procedure was conducted to determine if the differences were due to differences in land use practices in the respective watersheds. In setting up the analyses, it was assumed that the amount of a particular nutrient would be proportional to the size of that watershed. It was further assumed that the quantity of each nutrient delivered per unit area in kilograms per hectare (kg/ha) could be expressed in a linear relationship. A positive value would indicate an increase in nutrient loss from that land use, and a negative value would indicate a decrease in nutrient loss.

Land use categories included row crops, pasture, urban uses, marshlands, and animal units. For TP, the only watershed factor that could be correlated with differences between streams was the number of animal units per hectare. A highly significant relationship indicated that animal units were associated with the major fraction of TP inputs.

The results for nitrate-N concentrations were less clear-cut. There was a significant negative correlation for the percent of watersheds in marshlands and a positive correlation for animal units. However, when the two factors were combined in a multiple regression analysis, no significant correlation was found for animal units. An earlier analysis of 1971 data produced a significant relationship between nitrate-N and percent of watersheds in row crops and a negative relationship with percentage of watersheds in marshland. No significant relationship was found between ammonia-N and any of the watershed land uses.

The only consistent, strong relationship was between animal units and TP. Animals and row crops may have had some role in the delivery of inorganic nitrogen to streams, but the evidence was not conclusive.

Relationship Between Livestock and Phosphorous Inputs

In this analysis, emphasis was placed on the 15 largest sub watersheds with areas greater than 100 hectares. These watersheds had flowing streams for longer periods and were considered to yield the most reliable data on flows and nutrient concentrations. The periodic measurements of flow and phosphorous concentrations were integrated over time to yield annual outputs of phosphorous for each watershed. These were divided by the respective watershed areas to yield the annual outputs in kilograms per hectare. Average concentrations for each stream were determined by dividing the annual output of phosphorous by the annual output of water.

The land use in each watershed was inventoried. The categories included the percentages of each watershed in row crops, pasture, woodlands, marshes and urban uses. The livestock numbers in each watershed was determined. The USEPA guidelines were utilized to convert the numbers into animal units (one animal unit = one beef animal). The animal units were divided by the areas of the watersheds to establish animal units per hectare. The number of animals in feedlots and in pastures, and whether or not runoff drained to a stream or tile intake also was determined.

The years 1971 and 1972 differed in several respects. Due largely to a heavy snow pack there was exceptionally high runoff in 1971, which resulted in an annual runoff in 1971 that was 50% higher than that recorded in 1972. The concentration of TP in the 1971 runoff was also higher than in 1972, so that a result was a higher output of TP from the watersheds in 1971. Each of the six lakes in the system had higher levels of plankton algae in the summer of 1971.

If correlations between TP inputs or concentration and animal units represent a cause and effect relationship rather than an experimental artifact, then it is not surprising that the strongest relationship was found in 1971 when the runoff was greatest. Under these conditions, animal waste would be most efficiently transported to the streams. Other studies in Iowa rivers have shown that under conditions of high flow there is a significant rise in biological oxygen demand that can be attributed to animal wastes. Sewage effluents on the other hand tend to become more dilute under higher flows.

Summary

In comparing the years 1971 and 1972 it was found that 1971 had the largest surface runoff, the highest phosphorous concentration in the streams, and the greatest input of phosphorous to the lakes and highest levels of summer algal blooms in the lakes. Of all the variables tested only the number of animal units in a watershed showed any significant correlation with the amount of phosphorous delivered by that watershed. The highest correlation was found with the numbers of animals in a feedlot that drained into streams or tiles. The study proposed that livestock are a significant source of phosphorous to the IGL.

Findings

Briefly stated, the following elements were recommended by Hickok and Associates for adoption and implementation to ensure that the water quality of the IGL is preserved and protected as one of the most important natural resources in the State of Iowa:

Formation of a regional inter-governmental agency with broad power to implement a water quality management plan.

Construction of feedlot and barn lot runoff collection facilities. The waste collected should be disposed of on the land according to specific guidelines.

Management of livestock so they are not allowed in a stream, watercourse or drainage path within 1,000 feet of a lake. For our purposes, the first 1,000 from a lake is considered shoreline. Include the addition of low berms to prevent direct runoff from pasture to the drainage ways are recommended for areas outside the 1,000-foot area.

Construction of required erosion control structures, terraces, and waterways.

5) Preparation of a municipal plan for each municipality for management and transportation of surface water resulting from urban development. Each municipality should identify in their land development plan guides and drainage plans the swamps and marshes to be preserved in their natural states. Direct surface drainage to the IGL and other public waters should be avoided. Where runoff from urban or suburban lands are contributing the pollution of the waters, a suitable system of catch basins, filters and settling ponds shall be cleaned and maintained by the local municipalities.

Adoption of stormwater policies and guidelines pertaining to the development of municipal and private drainage systems, including specific additions to existing facilities.

Adoption of zoning ordinances that require minimum setbacks from the lakes, stormwater management, and adequate septic system or sanitary sewer availability as a prerequisite for development.

Sanitary sewer service provided to all developed areas as soon as possible.

Development of a coordinated land and water management program to assist with retention of open space lands and wildlife habitat, marshes, wetlands, and drainage ways within the watershed.

Data from Minnesota

Loon Lake and Clear Lake Results

2003-2007

37 tests

Turbidity: 3-8 NTU

Loon Lake	32.30
Clear Lake	19.27

Fecal: 200 f.c/100 mg/L		
	Loon Lake	150.30
	Clear Lake	28.11
Phosphorous: .06-.15 mg/L		
	Loon Lake	0.36
	Clear Lake	0.08
Nitrogen – TKL: 1.3-2.7 mg/L		
	Loon Lake	2.28
	Clear Lake	2.25
34 tests		
Chlorophyll: 30-80 mg/cubic m		
	Loon Lake	78.84
	Clear Lake	42.49
Secchi:		
	Loon Lake	1.84
	Clear Lake	1.83

Table 5.7: Loon Lake and Clear Lake Minnesota Sampling results
Courtesy of Ardis Hotzler, GIS Specialist, Jackson County Planning & Environmental Services

"Cooperative Lakes Area Monitoring Project"
Background
The Cooperative Lakes Area Monitoring Project (CLAMP) began in 1999 as a partnership between Iowa Lakeside Laboratory and Friends of Lakeside Laboratory to take advantage of a rich tradition of volunteer involvement in the Iowa Great Lakes region. A group of volunteers was organized and trained to monitor water quality on 10 lakes in northwest Iowa. CLAMP focuses on monitoring nutrient levels (nitrogen and phosphorous) as well as chlorophyll *a* (an index of algal abundance) and Secchi depth (an index of water clarity). By monitoring these parameters, CLAMP volunteers provide an integrated measure of each lake's water quality.

Since its inception in 1999, over 100 volunteers have participated in CLAMP. These volunteers have taken over 3500 samples on nine lakes in Dickinson County: Big Spirit Lake, Center Lake, East Okoboji Lake, Little Spirit Lake, Lower Gar Lake, Lake Minnewashta, Silver Lake, Upper Gar Lake, and West Okoboji Lake. By volunteering their time, CLAMP volunteers are providing a long-term data set that will be useful in protecting these prized resources. CLAMP volunteers also provide information on the variation in water quality within a lake by sampling multiple sites on each lake. At the same time, volunteers have an opportunity to learn more about water quality issues and the ecology of their lakes. (Limnology Laboratory, 2007)

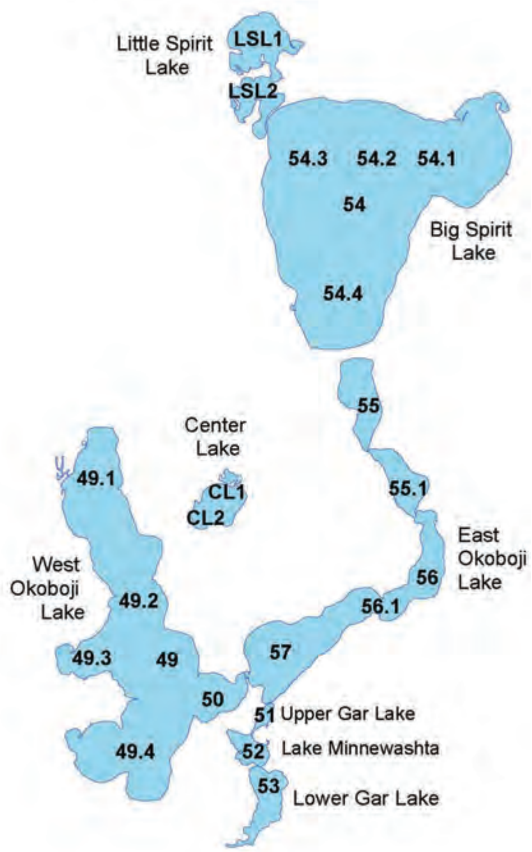


Figure 5.1: CLAMP Lakes and Sampling Locations. (Limnology Laboratory, 2007)

Water Quality in the Iowa Great Lakes

Water quality varies greatly among the lakes in the Iowa Great Lakes region. Activities in the watershed dictate the quality of water reaching the lake. The size and depth of the lake also influence the water quality. Large lakes with large volumes of water can dilute nutrients from the watershed. Shallow lakes are susceptible to mixing and disturbance of the bottom sediments which allow nutrients to be released to the water column, while deep lakes don't experience as much mixing and stirring of the bottom sediments.

Lake	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)		Nitrate (mg/L)	Chlorophyll *a* (µg/L)
Big Spirit Lake	1.5	0.06	1.13	0.07	20
East Okoboji Lake	1	0.13	1.33	0.11	26
West Okoboji Lake	3.7	0.02	0.83	0.06	5
Upper Gar Lake	0.7	0.13	1.59	0.12	43
Lake Minnewashta	0.9	0.12	1.75	0.14	40
Lower Gar Lake	0.4	0.15	2.01	0.19	41
Little Spirit Lake	0.4	0.29	3.03	0.24	83
Center Lake	0.9	0.15	2.54	0.18	78
Silver Lake	0.7	0.16	2.81	0.62	39
All Natural Lakes*	0.5	0.11	1.81	0.31	34

Table 5.8: Median Values sites at the deepest location CLAMP data (1999-2006)

All natural lakes monitored by the ambient lake monitoring program.

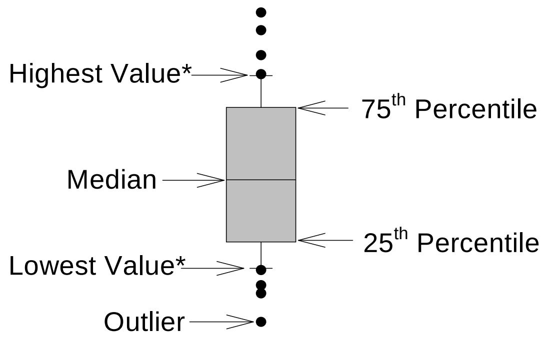


Figure 5.2: Reading a box plot. The median is the middle value in a group of numbers arranged in increasing order. If the median line is not in the center of the box, then the data are skewed. The length of the box represents the spread of the data (the larger the box, the greater the spread). An outlier is an unusual case.

Highest Value* Lowest Value* Median Outlier 75th Percentile 25th Percentile

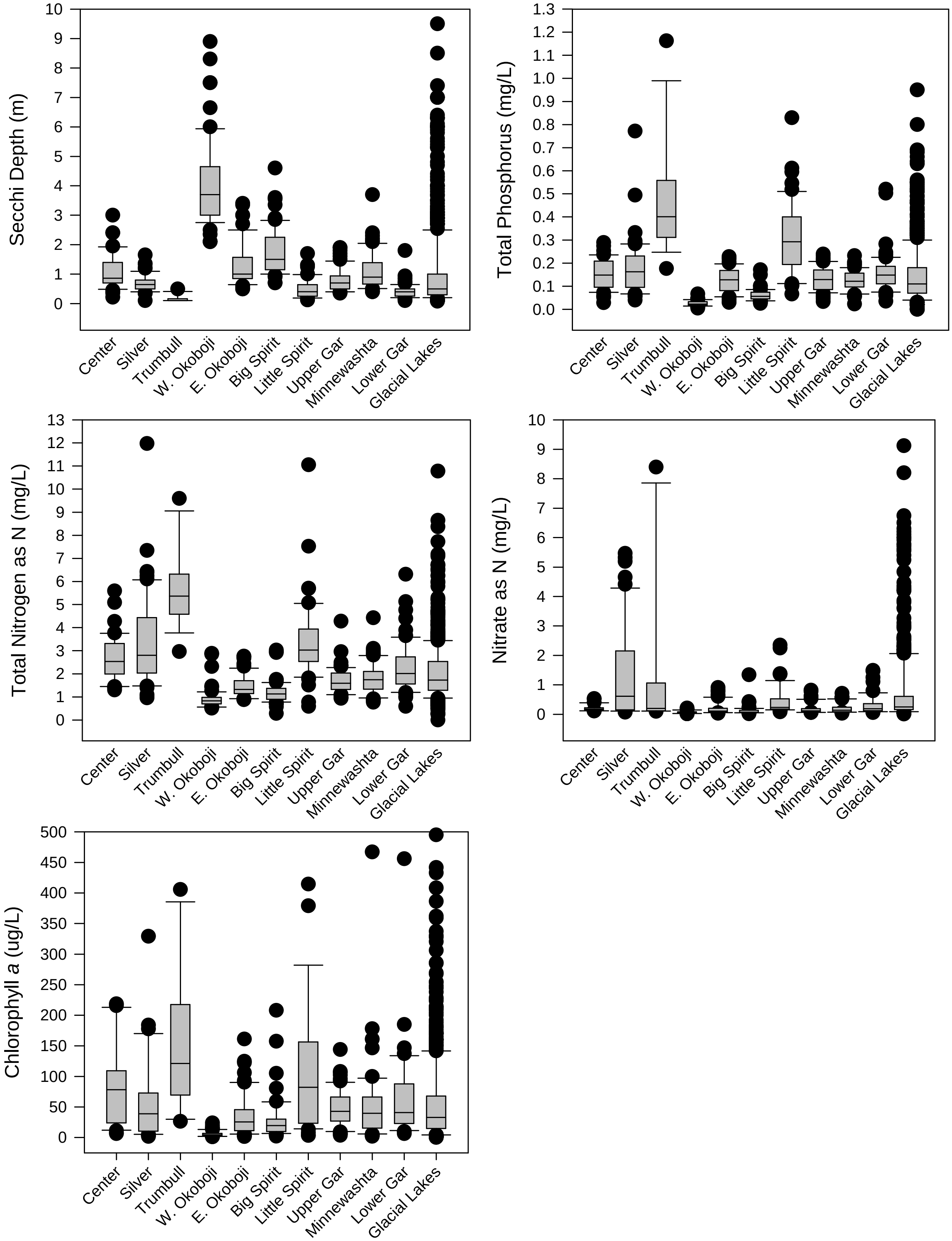


Figure 5.3 CLAMP data 1999-2006. (Limnology Laboratory, 2007)

Big Spirit Lake
Secchi depth ranged from 0.7 m on 8/25/2005 to 4.6 m on 6/8/2001, with the deepest Secchi depths occurring in spring, when algal productivity is the lowest, and the shallowest in late summer, when algal productivity is greatest. Overall, the median Secchi depth in Big Spirit was deeper than all other CLAMP lakes with the exception of West Okoboji and deeper than the median of all monitored, glacial lakes in Iowa (Figure 3.2).

Total phosphorous and total nitrogen concentrations were low in Big Spirit compared to other CLAMP lakes. With the exception of West Okoboji, Big Spirit had the lowest median total phosphorous (0.06 milligrams per liter [mg/L]) and total nitrogen (1.1 mg/L) as well as a lower median concentration than all monitored, glacial lakes (Figure 3.2). Total phosphorous ranged from 0.025 mg/L to 0.171 mg/L. Total nitrogen ranged from 0.28 mg/L to 3.03 mg/L.

Chlorophyll *a* concentrations ranged from 2 micrograms per liter (µg/L) (6/8/01) to 208 µg/L (8/22/04). The median chlorophyll *a* concentration was less than all other CLAMP lakes with the exception of West Okoboji and less than the median for all monitored, glacial lakes (Figure 3.2).

East Okoboji Lake
Secchi depth ranged from 0.5 m to 3.4 m in East Okoboji Lake, with the deepest Secchi depths occurring in the spring, and the shallowest in late summer. Overall, Secchi depths in East Okoboji were in the middle of the range when compared to other CLAMP lakes and were deeper than the median for all monitored, glacial lakes in Iowa (Figure 3.2).
Total phosphorous and total nitrogen concentrations in East Okoboji were in the middle of the range when compared to other CLAMP lakes. East Okoboji had the fifth highest median total phosphorous concentration (0.13 mg/L) and the seventh highest median total nitrogen (1.3 mg/L) out of 10 lakes. East Okoboji had slightly higher median total phosphorous and slightly lower median total nitrogen compared to all monitored, glacial lakes (Figure 3.2).

Chlorophyll *a* concentrations ranged from one µg/L (6/8/2005) to 161 µg/L (9/16/2004). East Okoboji had the third lowest median chlorophyll *a* concentration behind West Okoboji and Big Spirit and a lower concentration than all monitored, glacial lakes (Figure 3.2).

West Okoboji Lake
Secchi depth ranged from 2.1 m to 8.3 m, with the deepest Secchi depths occurring in the spring, and the shallowest in late summer. Overall, Secchi depths in West Okoboji were deeper than all other CLAMP lakes and all monitored, glacial lakes in Iowa (Figure 3.2).

Total phosphorous ranged from 0.01 mg/L to 0.07 mg/L. Total nitrogen ranged from 0.6 mg/L to 2.9 mg/L. Both total phosphorous and total nitrogen concentrations were lowest when compared to other CLAMP lakes and all monitored, glacial lakes in Iowa (Figure 3.2).

Chlorophyll *a* concentrations ranged from one µg/L to 24 µg/L. The median chlorophyll *a* concentration in West Okoboji Lake was less than all other CLAMP lakes and all monitored, glacial lakes.

Upper Gar Lake
Secchi Depth ranged from 0.4 m to 1.9 m with the deepest Secchi depths occurring in the spring, and the shallowest in late summer. Overall Secchi depths in Upper Gar were shallower than many other CLAMP lakes and slightly deeper than the median for all monitored, glacial lakes (Figure 3.2).

Total phosphorous concentrations ranged from 0.03 mg/L to 0.3 mg/L. The median total phosphorous concentration (0.13 mg/L) was similar to Lower Gar, Minnewashta, and East Okoboji and slightly higher than the median for all monitored, glacial lakes. Total nitrogen concentrations ranged from 1.0 mg/L to 4.3 mg/L. Total nitrogen concentrations in Upper Gar were similar to other CLAMP lakes and similar to all monitored, glacial lakes (Figure 3.2).

Chlorophyll *a* concentrations ranged from four μg/L to 144 μg/L. Chlorophyll *a* concentrations in Upper Gar were similar to other CLAMP lakes and the median of all monitored, glacial lakes (Figure 3.2).

Lake Minnewashta

Secchi depth ranged from 0.4 m (8/12/2002) to 2.4 m (6/8/2005) with the deepest Secchi depths occurring in the spring, and the shallowest in late summer. Overall, Secchi depths in Minnewashta were in the middle of the range of CLAMP lakes and deeper then the median for all monitored, glacial lakes (Figure 3.2).

Total phosphorous ranged from 0.02 mg/L to 0.23 mg/L with the highest concentrations occurring in the late summer and the lowest occurring in spring. Total phosphorous concentrations in Minnewashta were similar to Upper Gar, Lower Gar and East Okoboji and were slightly higher than the median for all monitored, glacial lakes. Total nitrogen ranged from 0.8 mg/L to 3.1 mg/L and was similar to Upper Gar and Lower Gar as well as the median for all monitored, glacial lakes (Figure 3.2).

Chlorophyll *a* concentrations ranged from three μg/L on 5/20/2000 to 467 μg/L on 6/28/2004. The median chlorophyll *a* concentration was in the middle of the range for CLAMP lakes and was slightly higher when compared to all monitored, glacial lakes (Figure 3.2).

Lower Gar Lake

Secchi depth ranged from 0.1 m to 1.8 m with a median value of 0.4 m. Overall, Secchi depths in Lower Gar were shallower than other CLAMP lakes with the exception of Trumbull and Little Spirit and near the median for all monitored, glacial lakes in Iowa (Figure 3.2).

Total phosphorous concentrations ranged from 0.04 mg/L to 0.50 mg/L with a median of 0.15 mg/L. With the exception of Trumbull and Little Spirit, Lower Gar had the highest median total phosphorous among CLAMP lakes and was higher than the median for all monitored, glacial lakes. Lower Gar's median total nitrogen concentration (2.0 mg/L) was also higher than all monitored, glacial lakes and higher than many other CLAMP lakes (Figure 3.2).

Chlorophyll *a* concentrations ranged from 7μg/L (6/3/2006) to 456 μg/L (6/28/2004). Lower Gar's median chlorophyll *a* concentration was similar to Upper Gar and Minnewashta and was the median for all monitored, glacial lakes (Figure 3.2). Only Center, Trumbull, and Little Spirit had higher median chlorophyll *a* concentrations.

Little Spirit Lake

Secchi Depth ranged from 0.1 m to 1.7 m, with the deepest Secchi depths occurring in the spring, and the shallowest in late summer. Overall, Secchi depths in Little Spirit were shallower than other CLAMP lakes and near the median for all monitored, glacial lakes in Iowa (Figure 3.2).

Total phosphorous and total nitrogen concentrations were high in Little Spirit compared to other CLAMP lakes. With the exception of Trumbull, Little Spirit had the highest median total phosphorous (0.29 milligrams per liter (mg/L)) and total nitrogen (3.1 mg/L) as well as a higher median concentration compared to all monitored, glacial lakes (Figure 3).

Chlorophyll *a* concentrations ranged from 3 μg/L (6/5/2002) to 4217 μg/L (8/2/2005). Chlorophyll *a* concentrations varied greatly in Little Spirit between 1999 and 2006. The median chlorophyll *a* concentration for Little Spirit was greater than other CLAMP lakes with the exception of Trumbull, and was greater when compared to all monitored, glacial lakes (Figure 3.2).

Center Lake
Secchi depth ranged from 0.2 m on 7/11/2002 to 3.0 m on 6/15/2003, with the deepest Secchi depths occurring in the spring, and the shallowest in late summer. Overall, Secchi depths in Center Lake were in the middle of the range of other CLAMP lakes and slightly deeper than the median for all monitored, glacial lakes (Figure 3.2).

Total phosphorous and total nitrogen concentrations were slightly higher than other CLAMP lakes as well as being higher than the median value for all monitored, glacial lakes. Center Lake had median total phosphorous of 0.15 mg/L and median total nitrogen of 2.54 mg/L. Only Trumbull, Little Spirit and Silver Lake had greater median total phosphorous and total nitrogen values (Figure 3.2).

Chlorophyll *a* concentrations ranged from six µg/L (9/4/2006) to 218 µg/L (8/5/2001). The median chlorophyll *a* concentration (78µg/L) was greater than all other CLAMP lakes with the exception of Trumbull and Little Spirit and greater then the median for all monitored, glacial lakes (Figure 3.2).

Silver Lake
Secchi depth ranged from 0.1 m to 1.7 m, with the deepest Secchi depths occurring in the spring, and the shallowest in late summer. Overall, Secchi depths in Silver Lake were shallower than most other CLAMP lakes and similar to the median for all monitored, glacial lakes in Iowa (Figure 3.2).

Total phosphorous concentrations ranged form 0.03 mg/L to 0.3 mg/L. The median total phosphorous concentration for Silver Lake was higher than all other CLAMP lakes with the exception of Trumbull and Little Spirit and higher than the median for all monitored, glacial lakes. Total nitrogen concentrations in Silver Lake were also higher than most other CLAMP lakes and the median for all monitored, glacial lakes (Figure 3.2).

Chlorophyll *a* concentrations ranged from 3 µg/L to 753 µg/L. The median chlorophyll *a* concentration for Silver Lake was similar to Upper Gar, Minnewashta, and Lower Gar as well as the median for all monitored, glacial lakes (Figure 3.2).

Trophic State
The large amount of water quality data collected by CLAMP can be difficult to evaluate. In order to analyze all of the data collected it is helpful to use a trophic state index (TSI). A TSI condenses large amounts of water quality data into a single, numerical index. Different values of the index are assigned to different concentrations or values of water quality parameters.

The most widely used and accepted TSI, called the Carlson TSI, was developed by Bob Carlson (1977). Carlson's TSI is a set of mathematical equations created from relationships between summertime total phosphorous, chlorophyll *a*, and Secchi disk transparency for numerous lakes. Using this method a TSI score can be generated by just one of the three measurements. Carlson TSI values range from 0 to 100. Each increase of 10 TSI points (10, 20, 30, etc.) represents a doubling in algal biomass. Data for one parameter can also be used to predict the value of another.

The Carlson TSI is divided into four main lake productivity categories: *oligotrophic* (least productive), *mesotrophic* (moderately productive), *eutrophic* (very productive), and *hypereutrophic* (extremely productive). The productivity of a lake can therefore be assessed with ease using the TSI score for one or more parameters. Mesotrophic lakes, for example, generally have a good balance between water quality and algae/fish production. Eutrophic lakes have less desirable water quality and an overabundance of algae or fish. Hypereutrophic lakes have poor water quality and experience frequent algal blooms and hypolimnetic anoxia.

Carlson's TSI can be used to classify the CLAMP lakes. West Okoboji and Big Spirit have the lowest TSI scores indicating they are the least productive (Figure 3.3). Little Spirit Lake and Silver Lake have the highest

TSI scores indicating they are the most productive (Figure 3.3). Most lakes are in the *eutrophic* category based on Carlson's TSI (Figure 3.3). West Okoboji generally is in the *mesotrophic* category. Little Spirit Lake and Center Lake are generally in the *hypereutrophic* category.

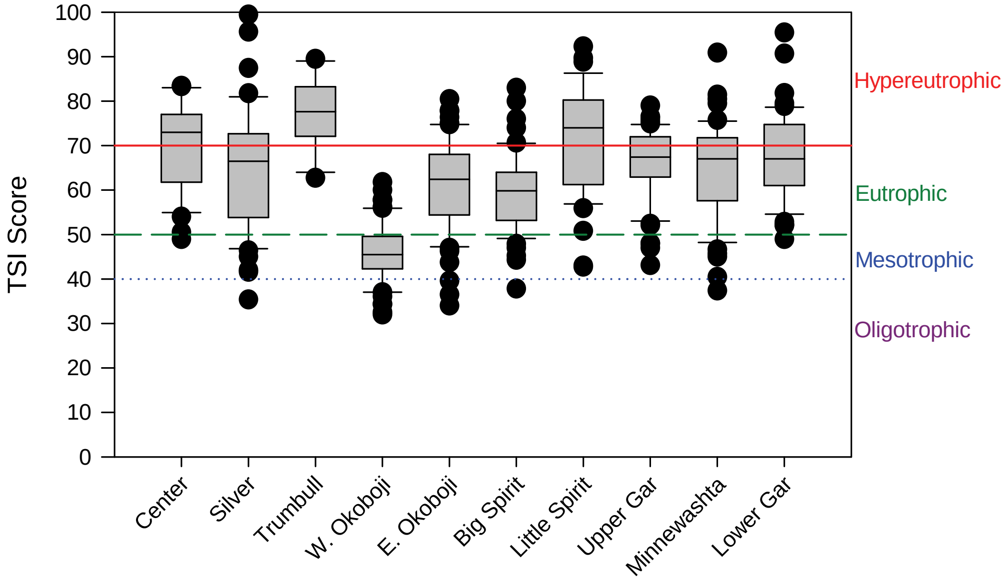


Figure 5.4 Chlorophyll *a* trophic state value (TSI) by lake: 1999-2006 CLAMP data. (Limnology Laboratory, 2007)

Trends

Seasonal

The data can also be used to learn about seasonal trends in water quality. The data show that nitrate concentrations are highest in the spring and early summer months before declining in the summer. This time coincides with spring applications of fertilizers as well as high amounts of rain. Nitrate is a water-soluble compound and thus is transported easily by runoff from spring rains. The data also show that water clarity is greatest in the spring before water temperatures increase and algal populations increase. Figure 3.4 shows that Secchi depths are generally deepest in June and shallowest in August and September for the lakes.

Spatial

The CLAMP program monitors multiple sites on many of the lakes, which is useful in understanding how water quality varies in different areas of the lakes. East Okoboji has the deepest Secchi depths at Site 57, which is in the deepest part of the lake, and the shallowest Secchi depths at Sites 55 and 55.1, which are at the shallow end of the lake (Figure 3.3). In Big Spirit Lake, Secchi depths are deepest at Site 54 and shallowest at Site 54.1, which is in a shallow area of the lake (Figure 3.4).

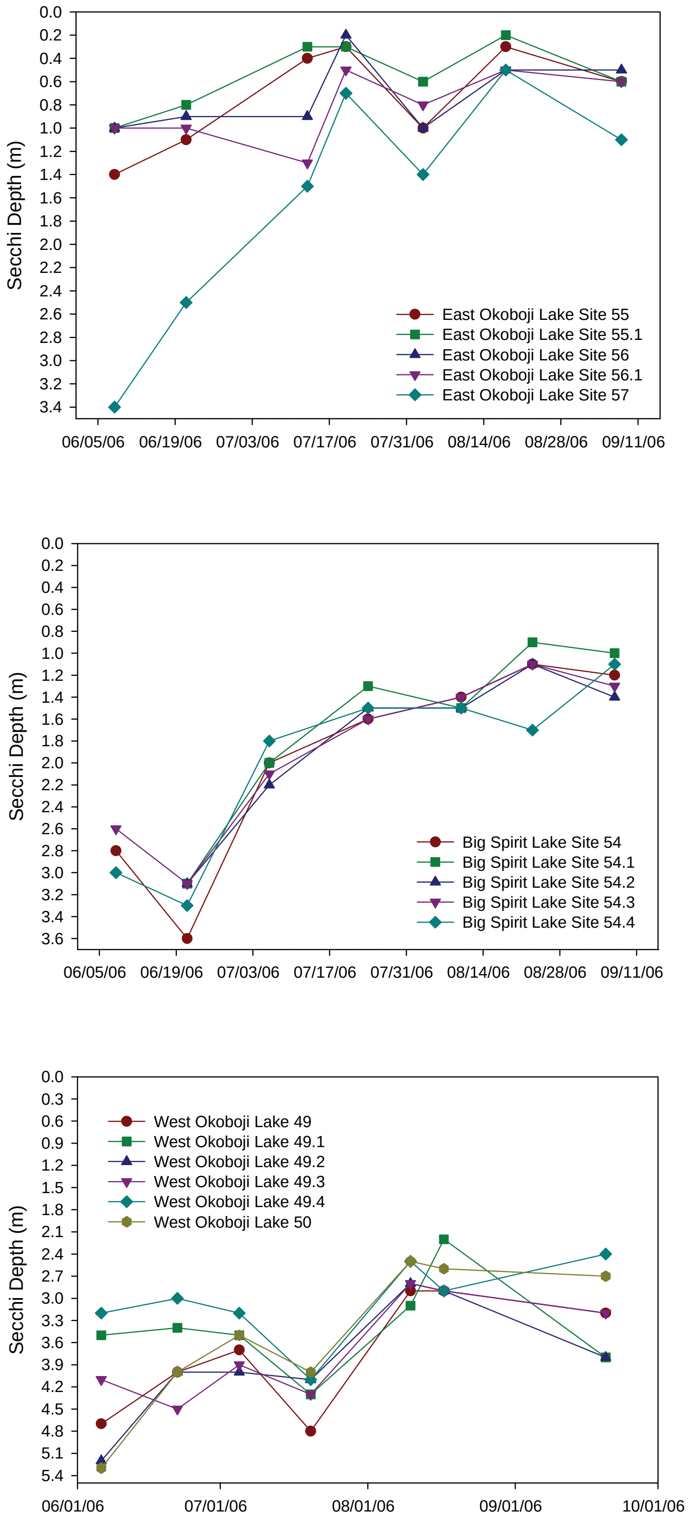


Figure 5.5 Variation in Secchi depth among sites for East Okoboji, Big Spirit, and West Okoboji in 2006. (Limnology Laboratory, 2007)

Long-term

CLAMP data has now been collected for 7 years on many of the lakes. This can show how these lakes have changed during that time. While it is a relatively short period, the data can be used to track any major changes in water clarity or nutrient levels. Over time, this data can be used to evaluate the effectiveness of lake restoration programs, track how changes in watersheds affect lake water quality, and provide a long-term reliable data set to show how the lakes are changing over time.

CLAMP data can also be combined with data from previous lake assessments to track how the lakes have changed. A survey of Iowa's lakes by Roger Bachmann in the 1970's provides historical data to help determine long-term trends. Figure 3.5 is an example of the trend line for West Okoboji Lake. In general, East Okoboji, West Okoboji, Big Spirit, and Lower Gar have small decreasing Secchi depth trends, based on visual assessment, while Secchi depths in Upper Gar and Minnewashta have not changed over time.

"Ambient Lake Monitoring Program"
The Iowa Department of Natural Resource's ambient lake monitoring program began in 2000. One hundred thirty-one lakes located throughout the state are monitored between 3 and 5 times during the summer by Iowa State University (2000-2007) and University of Iowa Hygienic Laboratory (2005-2007). Big Spirit, Little Spirit, East Okoboji, West Okoboji, Lower Gar, Upper Gar, Minnewashta, Center, and Silver Lake are all monitored as part of this program. Through the ambient lake-monitoring program, the lakes are monitored for a number of physical, chemical, and biological parameters. Physical parameters include temperature, dissolved oxygen, specific conductivity, pH, Secchi depth, turbidity, total suspended solids, total fixed suspended solids, and total volatile suspended solids. Chemical parameters include total nitrogen, nitrate + nitrite, ammonia, total phosphorous, soluble reactive phosphorous, silica, alkalinity, total organic carbon, and total dissolved solids. Biological parameters include chlorophyll *a*, phytoplankton biomass and composition, and zooplankton biomass and composition. The ambient monitoring program characterizes current water quality in the monitored lakes and tracks the trends in lake water quality.

The ambient lake monitoring program differs from the CLAMP program in that professionals collect the samples. The ambient program however only samples the lakes three to five times throughout the summer, while the CLAMP program is able to sample the lakes more frequently. The ambient program also only samples one location on the lake (deep spot) so that the data from each lake can be compared to other lakes in the state. The CLAMP program samples multiple locations on each lake, which allows for a more complete spatial characterization of the lakes.

The ambient program tests for more parameters than are feasible through the CLAMP program. This allows for a greater understanding of the characteristics of each of the lakes. The CLAMP program includes Secchi depth, total phosphorous, total nitrogen, nitrate plus nitrite nitrogen, and chlorophyll *a*, which are all explained above. The additional parameters monitored by the ambient lake monitoring program are explained below. Table 2 contains the median values (2000-2006) for some of the parameters measured by the ambient lake monitoring program. (Downing, 2008)

Physical Parameters
Temperature and Dissolved Oxygen (DO) profiles are measured at the sampling location. A probe is lowered in the water column and a reading is taken at regular intervals to determine if the lake is thermally stratified. Thermal stratification occurs when surface waters warm and the density difference between the cooler, deeper water and the warm surface water prevents mixing. One potential consequence of thermal stratification is anoxia (or low oxygen conditions) in the hypolimnion (the deep cold-water area) due to respiration. Hypolimnetic anoxia can lead to release of phosphorous from the sediment, which can lead to algae blooms. The extent of thermal stratification depends on several factors including depth, wind fetch, wind exposure, and spring temperatures. West Okoboji is the only lake in the Iowa Great Lakes that stratifies regularly. The other lakes are too shallow and are susceptible to mixing by the windy conditions in that area of the state.

Turbidity is a reduction in clarity that results from the presence of suspended particles. Turbidity usually consists of inorganic particles, such as sediment, and organic particles, such as algae. In general, the lakes in the

Iowa Great Lakes region have lower turbidities than other natural lakes in the state with the exception of Little Spirit, Lower Gar, Upper Gar and Silver.

Total Suspended Solids (TSS) includes all suspended particles in water that will not pass through a filter. Big Spirit (6 mg/L) and West Okoboji (2.3 mg/L) have low concentrations of TSS when compared to other natural lakes. Lower Gar (21.1 mg/L) and Silver (17.1 mg/L) have the highest TSS concentrations of the Iowa Great Lakes.

Total Fixed Suspended Solids (TFSS) is a measure of the inorganic fraction (sediment) of suspended solids. Big Spirit, Center, East Okoboji, Minnewashta and West Okoboji all have relatively low median TFSS concentrations (below the 25th percentile for all monitored, natural lakes).

Total Volatile Suspended Solids (TVSS) is a measure of the organic fraction of suspended solids. Big Spirit, East Okoboji, Minnewashta, Upper Gar and West Okoboji all have relatively low median TVSS concentrations (below the 25th percentile for all monitored, natural lakes).

Total Organic Carbon (TOC) is the sum of all organic carbon from decaying organic material, bacterial growth, metabolic activities of living organisms, and chemicals. (Humic acid, fulvic acid, amines, and urea are types of natural organic matter. Detergents, pesticides, fertilizers, herbicides, industrial chemicals, and chlorinated organics are examples of synthetic sources of organic carbon.) TOC can be used as a measure of organic contamination. Little Spirit (18.5 mg/L) and Center (14.6 mg/L) have relatively high levels of TOC (above the 75th percentile for all monitored, natural lakes). All other lakes in the Iowa Great Lakes with the exception of Silver fall below the 25th percentile for all monitored natural lakes.

Specific Conductivity is a measure of the ability of a solution to electrical flow. Specific conductivity is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution. The higher the specific conductivity, the higher the amount of dissolved ions in the water. Silver (629 μS/cm) and Center (571 μS/cm) have the highest median specific conductance among the Iowa Great Lakes, which was above the 75th percentile for all monitored, natural lakes. Big Spirit (480 μS/cm) and West Okoboji (466 μS/cm) had the lowest median specific conductance among the Iowa Great Lakes.

Chemical Parameters

Soluble Reactive Phosphorous (SRP) is the form of phosphorous used by algae and therefore constitutes the fraction of total phosphorous that is available to be used by algae. In phosphorous-limited situations, this form should be low to undetectable, as is the case in Big Spirit (0.003 mg/L) and West Okoboji (0.003 mg/L). As SRP increases, it implies that phosphorous is either not needed by algae or it is being supplied at a rate that is faster than the rate of biologic uptake. Little Spirit (0.09 mg/L), Silver (0.04 mg/L) and East Okoboji (0.04 mg/L) have relatively high SRP levels when compared to other monitored, natural lakes in Iowa (greater than the 75th percentile).

Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen and ammonia in water. High concentrations of TKN in a water body are generally from organic pollution, such as sewage or manure discharges. Little Spirit (2.6 mg/L) and Center (2.0 mg/L) have TKN concentrations above the median for other monitored, natural lakes in Iowa (1.7 mg/L).

Ammonia is a soluble form of nitrogen that is found in water. Ammonia can be toxic to fish and invertebrate populations when at high levels. Ammonia is commonly used as an agricultural fertilizer. Little Spirit, Minnewashta, Center, and Lower Gar have the highest median ammonia concentrations, while Big Spirit and West Okoboji have the lowest (Table 3.9).

Biological Parameters
Phytoplankton wet mass and composition are measured to get a better understanding of the biological dynamics of each lake. Phytoplankton or algae are the photosynthetic organisms that form the base of the food chain in lakes. The median phytoplankton wet mass ranged from 9.1 mg/L in West Okoboji to 36.0 mg/L in Upper Gar. All lakes in the Iowa Great Lakes had a lower median concentration than the median for all monitored, natural lakes in Iowa (39.7 mg/L). Most phytoplankton samples were dominated by Cyanobacteria, which often dominate summer plankton in productive lakes.

Zooplankton wet mass and composition are measured to get a better understanding of the biological dynamics of each lake. Zooplankton is the microscopic and macroscopic animals that float, drift, or swim weakly in the water column. Zooplankton is the primary consumers of algae and many fish rely on them as a food source. The median zooplankton wet mass ranged from 94.1 mg/L in West Okoboji to 288.5 mg/L in Lower Gar. Zooplankton samples were composed mainly of cladocerans, copepods, protozoa and rotifers.

Lake Name	Secchi Depth (m)	Total Phosphorous (mg/L)	Soluble Reactive Phosphorous (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Ammonia (mg/L)	Nitrate +Nitrite (mg/L)	Chlorophyll *a* (ug/L)	Dissolved Oxygen (mg/L)
Big Spirit	2.0	0.046	0.003	1.0	0.044	0.205	11	8.8
Center	1.0	0.107	0.032	2.0	0.149	0.255	25	9.4
East Okoboji	1.2	0.082	0.041	1.2	0.070	0.243	15	8.6
Minnewashta	1.3	0.081	0.036	1.3	0.160	0.211	14	8.5
Little Spirit	0.6	0.220	0.090	2.6	0.167	0.429	38	8.7
Lower Gar	0.5	0.100	0.023	1.4	0.136	0.379	28	8.5
Upper Gar	1	0.867	0.027	1.3	0.090	0.194	27	8.7
West Okoboji	5.8	0.021	0.003	0.8	0.051	0.166	3	9.4
Silver	0.6	0.114	0.043	1.4	0.111	2.183	14	8.7

Lake Name	Turbidity (NTU)	Total Suspended Solids (mg/L)	Total Organic Carbon (mg/L)	Total Fixed Suspended Solids (mg/L)	Total Volatile Suspended Solids (mg/L)	pH	Alkalinity (mg/L)	Specific Conductivity (uS/cm)
Big Spirit	7.3	6	8.5	3	4.0	8.7	172.5	480
Center	17.1	10.2	14.6	4.3	6.0	8.8	170.0	571
East Okoboji	11.3	7.5	8.6	3.0	3.4	8.6	199.5	508
Minnewashta	16.7	8.4	8.5	4.3	4.6	8.5	190.0	505
Little Spirit	36	18	18.5	9	8.5	8.9	200.0	489
Lower Gar	30.7	21.1	8.0	12.9	8.1	8.5	200.0	514
Upper Gar	21	13.1	8.1	7.7	5.2	8.6	193.8	501
West Okoboji	1.5	2.3	7.5	1.5	1.6	8.5	192.0	466
Silver	33.9	17.1	9.4	11.4	6.1	8.4	151	629

Lake Name	Phytoplankton Wet Mass (mg/L)	Zooplankton Wet Mass (mg/L)	Carlson Trophic State Index (Secchi)	Carlson Trophic State Index (Total Phosphorous)	Carlson Trophic State Index (Chlorophyll)
Big Spirit	23.0	121.9	50	60	54
Center	20.3	206.1	61	72	62
East Okoboji	15.1	101.5	57	68	57
Minnewashta	9.9	182.7	56	67	57
Little Spirit	24.5	274.7	69	82	66
Lower Gar	28.0	288.5	71	71	63
Upper Gar	36.0	170.1	60	68	63
West Okoboji	9.1	94.1	35	48	41
Silver	21.1	169.5	68	72	56

Table 5.9: Median values for ambient lake monitoring program data (2000-2006). (Downing, 2008)

“Quantification of Nutrient Inputs into the Iowa Great Lakes”

Background

This study examined water and nutrient budgets for West Okoboji Lake, East Okoboji Lake, and Lower Gar Lake. The three lakes, along with Upper Gar Lake and Minnewashta Lake, form a series of interconnected lakes within the IGL system. The only surface outflow from these lakes is over a low-head dam at the south end of Lower Gar Lake. The purpose of the study was to better understand and quantify how water and nutrients move into, among, and out of the lake system. For a complete review of data collection, data analysis, and results see *Quantification of Nutrient Inputs into the Iowa Great Lakes*, submitted by Stenback, Crumpton, and van der Valk to the U.S. Environmental Protection Agency, December 2005. (Quantification of Nutrient Inputs into the Iowa Great Lakes, 2005)

In order to develop water and nutrient budgets, three additional types of monitoring were initiated to fill data gaps, including 1) inputs of nutrients in wet and dry depositions, 2) collection of lake and inflowing surface water samples for nutrient analyses, and 3) evaporation rates.

A thirteen-year numerical water budget model based on local daily rainfall data, watershed input from the nearby Ocheyedan River water yield and lake to watershed area, lake-to-lake water flow, and local pan evaporation data was developed for the period of January 1, 1992 to December 31, 2004. For each lake, total phosphorous (TP) and total nitrogen (TN) budgets were estimated each year from 1999-2004, using measured lake concentration data, modeled watershed inputs estimated from inflowing stream data, and wet/dry depositions.

The flow of nutrients into, among, and out of the lake system was estimated using the water budget model and nutrient concentration data. For each lake’s nutrient budget, lakebed sediment was treated as a nutrient source or sink to maintain water column nutrient concentrations after accounting for all other inputs and outputs.

Spirit Lake, which was not a direct focus of this study, was modeled separately to obtain an estimate of lake discharge into East Okoboji Lake. The lake water budget model was developed as a component of a separate study to look at phosphorous cycling in portions of the lake system. Existing water monitoring programs provided much of the data needed to develop the water and nutrient budgets. Data on water and nutrient yields from different kinds of watersheds were used to estimate water and nutrient loads from each lake’s watershed. In order to complete mass balance budgets for the lakes, additional monitoring was conducted to obtain inputs of nutrients in wet and dry deposition, nutrients in lake water and inflowing surface water samples, and evaporation rates.

Model Input and Data Sources

Watershed inputs to each lake include:

Watershed input was modeled as the product of watershed area and water yield based on data from the Ocheyedan River near Spencer, IA (USGS Station 06605000).

Rainfall directly to the lake surface using rain data Milford, IA (NOAA NNDC Climate Online Data Online, Station 135493).

Spirit Lake model outflow was used as a water input into East Okoboji.

Watershed exports to each lake include:

1. Evaporation from the lake surface, based on the product of a pan evaporation coefficient and pan evaporation data obtained online from University of Minnesota, Southwest Research and Outreach Center, Lamberton, MN (Station 23669). Lamberton is 50 miles north of the Iowa Great Lakes area. Pan evaporation

data was also collected at the Lakeside Laboratory in 2003 and 2004. The Lakeside Laboratory data were significantly less variable ($p<0.0001$) than the Lamberton data and had a significantly lower mean than the Lamberton data (about 23% lower, $p<0.0001$) for the 180 days when both stations had measurements. The Lamberton data were used because they have a more complete record for the time of the study. The difference in average values between Lakeside and Lamberton data is compensated for by the application of the pan evaporation coefficient in the numerical model.

2. Discharge from the lake outflow structure to Milford Creek and or into adjacent lakes.

Groundwater inputs to and exports from the lake system are assumed to be negligible. Five stream monitoring sites were chosen for streambed stability and approximately U-shaped channels (see figure 3.6 on page 52). American Sigma 900 Max auto-samplers equipped with depth/velocity probes were used at each site to record average depth and water velocity at five-minute intervals. Stream cross-section profiles were completed at each probe location and an area versus stream water depth relationship was developed corresponding to one millimeter depth interval changes. Five-minute stream discharges were calculated as the product of the average velocity and the area associated with the average stream depth over each five-minute period. Daily stream discharges were calculated by summing the five-minute discharges for a 24-hour period.

Evaporation and rainfall was identical for each day and each lake in the model. Rainfall and evaporation were applied directly to the lake surface area so that rainfall and evaporation affected change in the lake surface elevation identically for each lake. Because of this, rainfall and evaporation generally have no effect on modeled water movement between the lakes. One exception to this occurs if rainfall inputs raises lake surface elevation enough to cause discharge over the Lower Gar spillway at a sufficiently high rate to stop any upstream flow that might be occurring, and start downstream flow. The major effect of rain for the purpose of nutrient balance is as a source of nutrients, while the effect of evaporation is to concentrate nutrients already in the lake.

East Okoboji Lake

During relatively wet years, lake-to-lake flow accounts for more than 60 or 70 percent of the East Okoboji water budget. The quantity of water delivered to East Okoboji from both rain and watershed input are generally similar. Water input from West Okoboji to East Okoboji was always less (except in the 1993-flood year) than surface water input to East Okoboji from its watershed, and in relatively dry years, net flow was into West Okoboji from East Okoboji. Water input from Spirit Lake to East Okoboji may exceed surface water input during wet years, but during relatively dry years, Spirit Lake provides little or no flow to East Okoboji.

Water output to Upper Gar exceeds water input to East Okoboji from its watershed during wet years, but during the very dry years (2000, 2002, and 2003); Upper Gar was a net source of water to East Okoboji. While flow through East Okoboji varied considerably from year to year, and in some years more water flows into the lake than out of it, the outflow to Upper Gar indicates that sufficient water flows in and out of East Okoboji to completely replace the lake water every few years, except during extended dry periods such as 2002 and 2004. During the 1993 flood year, sufficient water flowed through East Okoboji to replace its volume nearly eight times.

Upper Gar Lake

During wet years, lake-to-lake flow accounts for more than 60 or 70 percent of the Lower Gar water budget. During 1992-2004, surface water flow from the watershed into Lower Gar exceeded the lake volume each year of the study. However, during three dry years (2000, 2002, and 2003), there was little or no outflow and net flow was upstream out of Lower Gar into Minnewashta.

During the dry years, watershed input and lake-to-lake flow dominated the water budget. With the exception of the dry years and 1998, sufficient water flowed in and out of Lower Gar to replace the entire lake volume more than ten times each year. During the 1993 flood year, approximately 200 lake volumes flowed out of Lower Gar to Milford Creek.

Water Budget Summary
While small lake elevation differences produce alternating flow direction between lakes, there is a net long-term flow of water from the upper to lower Iowa Great Lakes, with significant annual variability between wet and dry years. During wet periods, water flows from West Okoboji to East Okoboji and downstream through the lower lakes and out the overflow structure below Lower Gar Lake.

During relatively dry years, outflow from the upstream lakes may cease for periods lasting months to more than a year. During the dry periods, the water level in Lower Gar, which has a large watershed to lake ratio, rises at a greater rate than the upstream lakes. This causes reversed or up-lake flow.
Therefore, during dry periods nutrients from the smaller, shallower and more nutrient-rich Lower Gar, Minnewashta, and Upper Gar Lakes may flow up lake into East Okoboji Lake. In addition, during the dry periods East Okoboji Lake may exchange water with West Okoboji Lake. West Okoboji Lake is the largest, deepest and least nutrient enriched of the Iowa Great Lakes chain. Because East Okoboji has greater TP and TN concentrations, it can be a significant source of nutrients to West Okoboji during periods of up lake water flow.

During wet periods when a lake volume is overturned multiple times, particularly for Lower Gar and occasionally East Okoboji, the nutrient load of primary concern is that of the last lake volume because all of the preceding volumes have flowed through and out of the lake. Understanding water inputs and outputs is a first step towards understanding how nutrients that are dissolved or suspended in the water column move into, within, and out of the lake system.

2004 Nutrient Budget Model
Mass balance nutrient budgets were developed for TP and TN for 2004. The nutrient budget inputs to the lake water column include direct rain and atmospheric deposition, inflowing stream water, flux from the sediment, and input from adjacent lakes. Nutrients may be exported from a lake along with water flowing between lakes or discharged to Milford Creek from Lower Gar. Nutrients may be stored within the lake in lakebed sediments, elevated aqueous concentration or associated with suspended solids. Nutrient flux from the water column to lakebed sediment is considered an export from the lake water column even though the nutrients are stored within the lake system.

Mass balance models were constructed for nutrients using a daily time step for 2004. Initial conditions include the lake water volume determined from the water budget model and a lake water column nutrient mass determined from an initial lake nutrient concentration and water volume. The model assumes that once nutrients enter a lake, they are completely mixed within the lake. The mass of nutrients entering and exiting are determined at each daily time step and the resulting model lake nutrient concentration is determined.

When all non-sediment related nutrient inputs and outputs are accounted for, the model lake nutrient concentration is compared to the measured lake nutrient concentration. If the model lake concentration is greater than the measured lake concentration, nutrients are forced into the sediment to make up the difference. If the model lake concentration is less than the measured lake concentration, nutrients are taken from the sediment to make up the difference. Since daily measured lake nutrient concentrations are not available, a linear interpolation generated by ModelMaker was used to estimate a daily concentration value between each measured value.

Water samples were collected from inflowing streams from April 6 to October 4 during 2004 and analyzed for TP and TN. Stream discharge at these locations was measured daily, although occasional equipment failures occurred resulting in several data gaps. The data were evaluated using ModelMaker to estimate flow-weighted average (FWA) concentrations; however, because the data encompass less than a full year and the FWA concentrations are dependent on the particular flow events during this period of record, they may not be appropriate for use outside of this particular period. These data were utilized to estimate concentrations in inflowing water from surface runoff to the lakes.

The TP concentration data showed some tendency to increase with increasing discharge, although there is considerable scatter in the data. Differences in mean TP concentration and variation among sites at low discharge are minimal and concentrations at all sites show a similar tendency to increase with increasing discharge as would be expected for phosphorous concentrations associated with water carrying suspended particulate matter. Accordingly, the linear relationship between increasing total phosphorous concentration with increasing discharge was used to estimate a phosphorous concentration associated with discharge estimated from the product of the Ocheyedan water yield and the sub watershed area for watersheds within the main watershed for each of the lakes in this study.

There is a non-linear relationship between FWA TN concentration and percentage of the watershed area in row crop. The FWA TN concentrations were determined as the total TN mass load divided by the total water volume for the five sub watershed sites over the approximately six-month data collection period from early April to early October of 2004. The non-linear relationship between FWA TN and percent cropland was used to generate daily TN concentrations for surface water input in the nutrient budget models.

Watersheds were delineated using a D8 directional flow algorithm described by O'Callaghan & Mark (1984). One arc second elevation data was obtained from the USGS National Elevation Dataset (USGS). Percent row crop was derived by zonal statistics of each watershed based on a 2003 land cover dataset. Land cover information was obtained from the USDA National Agricultural Statistics Service.

An Aerochem Metrics Inc. Automatic Sensing Wet/Dry Precipitation Collector was used to collect wet-dry samples to estimate TP and TN inputs from both rainwater and dry deposition. Rainwater samples were collected during August to October 2003 and all of 2004. Lake TP and TN concentrations were available from the ongoing lake water quality-monitoring program, Cooperative Lakes Area Monitoring Program (CLAMP), a partnership between the local community and Iowa Lakeside Laboratory. The CLAMP data were used to estimate lake water nutrient concentrations for the nutrient budget. Initial lake (January 1, 2004) concentrations were determined by linear interpolation between the concentration determined for the last sampling event in 2003 and the first event in 2004. Final December 31, 2004 lake concentrations were set equal to the initial concentration.

West Okoboji Lake 2004 TP and TN Budgets

The model indicates that net TP inputs to West Okoboji for 2004 total 3.3 metric tons (t) with 22% from rain, 25% from dry deposition, 41% from surface runoff, and 12% from East Okoboji. The net input from East Okoboji is interesting because the net water movement during 2004 was primarily from East Okoboji to West Okoboji. This occurred because water flow was primarily from East Okoboji to West Okoboji during the early part 2004, while late in the year water generally moved downstream from west to east.

Because the TP concentration is greater in East Okoboji than in West Okoboji, the net flux of TP was from east to west even though the net flux of water was from west to east. Approximately 2.8 t TP was stored in the lake sediment (about 86% of the net TP input) and 0.5 t was stored in the water column (about 14% of the net TP input).

The model results indicate that net TN inputs to West Okoboji for 2004 total 35.5 t with 22% from rain, 14% from dry deposition, 59% from surface runoff, and 4% from East Okoboji. About 29 t TN (83% of the input TN) was deposited to the lakebed sediment and approximately 6 t TN was stored in the water column (about 17% of the net TN input).

East Okoboji Lake 2004 TP and TN Budgets

The model results indicate that net TP inputs to East Okoboji for 2004 total 21 t with 16% from rain, 18% from dry deposition, and 65% from watershed runoff. Spirit Lake did not overtop its outflow structure during 2004 so no TP phosphorous was contributed from that potential source. About 0.4 t TP (19% of the input TP) was output from East Okoboji to West Okoboji and 0.7 t TP (34%) of the net TP input was output to Lower Gar during 2004. Approximately 0.3 t TP (15% of the net TP input) was deposited to the lake sediment and 0.7 t TP (33% of the net TP input) was stored in the water column.

The model results indicate that net TN inputs to East Okoboji for 2004 total 38.5 t with 10% from rain, 6% from dry deposition, and 84% from surface runoff. About 2.8 t (7% of the input of TN) was output to West Okoboji and 5.5 t (14% of the input TN) was output to Upper Gar Lake. About 24 t of TN (63% of the input TN) was deposited to the lakebed sediment and approximately 6.1 t of TN was stored in the water column (about 16% of the net TN input).

Lower Gar Lake 2004 TP and TN Budget

The model results indicate that net TP inputs to Lower Gar for 2004 total 2.9 t with 2% from rain, 2% from dry deposition, 52% from surface runoff, 4% from Minnewashta Lake, and 41% released from the lakebed sediment to the water column. About 2.8 t TP (97% of the input TP) was output to Milford Creek and approximately 0.8 t TP (about 3% of the net TP input) was stored in the water column.

The model results indicate that net TN inputs to Lower Gar for 2004 total 42 t with 1% from rain, 1% from dry deposition, 52% from surface runoff, and 46% from lakebed sediment. About 33 t (79% of the input TN) was output to Milford Creek and 8 t of TN (18% of the input TN) was exported to Minnewashta Lake. Approximately 1 t of TN (about 3% of the net TN input) was stored in the water column.

2004 TP Budgets on a Mass per Lake Area and Mass per Lake Volume Basis

Because the lake areas and volumes vary, expressing the TP nutrient budget in terms of mass per lake area and mass per lake volume provides a different perspective on TP source load to the lakes and on between lake comparisons. The rain and dry deposition inputs are the same for each lake when evaluated on a per lake area basis.

However, on a per lake volume basis, the rain and dry deposition inputs are lowest for West Okoboji and highest for Lower Gar, which is the opposite of the order of actual mass input to these lakes. While the actual watershed input mass is similar for each lake, the per lake area watershed input is lowest for West Okoboji and highest for Lower Gar, and because of the relative lake depths, this effect is even more pronounced on a per lake volume basis.

1999 to 2004 Six-Year Annual Nutrient Budget Model

A temporal assessment of the nutrient budget was developed using CLAMP lake concentration data available from 1999 to 2004. Lake samples were collected on seven to ten days each year in each lake from 1999 to 2004. Spirit Lake did not contribute to the 2004 nutrient budget because there was no outflow from Spirit Lake that year. However, Spirit Lake did contribute water and nutrients to East Okoboji during 1999 and 2001. Adequate lake concentration data is not available for the years between 1992 and 1999 so the lake budget model could not be extended to years prior to 1999. Wet deposition for the six-year nutrient budget is based on 2004 wet/dry average TP and TN rain concentrations applied to daily ran data as described in the water budget model. The average 2004 dry deposition rate was used for the six-year modeling period. The TP and TN watershed inputs were based on the 2004 sampling data, the relative proportions of water inputs to each lake (watershed runoff, precipitation, and lake-to-lake flow) described for the thirteen-year water budget model, and TP estimated as a function of discharge coupled with estimated surface runoff from Ocheyedan water yield (R^2=0.379). Otherwise, watershed and from adjacent lake nutrient budgets were modeled as previously described. The resulting nutrient budgets are given in Tables 3.10-3.14.

Lake	Inputs					Outputs		Storage	Total Mass In Lake
	Rain	Dry Dep.	Watershed	Adjacent Lakes	Sediment Flux	Adjacent Lakes or Milford Creek	Sediment Flux	Stored in the Water Column*	Nutrient Mass in Lake Water Column at End of 2004
West Okoboji	0.047	0.052	0.086	0.026			0.18	0.030	0.35
East Okoboji	0.047	0.052	0.19			0.055 (WOL) 0.096 (UGL)	0.042	0.092	0.64
Lower Gar†	0.047	0.052	1.5	0.41	0.95	2.9 (Milford Cr.)		0.084	0.20

* End of 2004 minus beginning of 2004 mass of TP in the lake water column.

† One outlier TP concentration of 0.52 mg/L collected on August 2, 2004 was set to 0.2 mg/L to better match temporally adjacent measurements.

Table 5.10: Lake TP nutrient flux model budget summary for 2004 in mass per lake area

Lake	Inputs					Outputs		Storage	Total Mass In Lake
	Rain	Dry Dep.	Watershed	Adjacent Lakes	Sediment Flux	Adjacent Lakes or Milford Creek	Sediment Flux	Stored in the Water Column*	Nutrient Mass in Lake Water Column at End of 2004
West Okoboji	0.0041	0.0046	0.0075	0.0023			0.016	0.0026	0.031
East Okoboji	0.015	0.017	0.059			0.017 (WOL) 0.030 (UGL)	0.013	0.029	0.20
Lower Gar†	0.043	0.048	1.4	0.38	0.88	2.6 (Milford Cr.)		0.077	0.19

* End of 2004 minus beginning of 2004 mass of TP in the lake water column.

† One outlier TP concentration of 0.52 mg/L collected on August 2, 2004 was set to 0.2 mg/L to better match temporally adjacent measurements.

Table 5.11: Lake TP nutrient flux model budget summary for 2004 in mass per full lake volume (g/m3).

	Inputs					Outputs		Annual Water Column Storage*	Nutrient Mass In Lake Water Column at End of Year
Nutrient	Rain	Dry Dep.	Watershed	Adjacent Lake (EOL)	Sediment to Lake Flux	Adjacent Lake (EOL)	Lake to Sediment Flux		
TP									
1999	0.5 (20)	0.8 (35)	1.0 (45)			0.1 (5)	1.2 (53)	1.0 (43)	5.9
2000	0.5 (30)	0.8 (47)	0.2 (12)	0.2 (11)			0.2 (10)	1.6 (90)	7.5
2001	0.6 (15)	0.8 (22)	2.2 (60)	0.1 (3)			4.1 (111)	-0.4 (-11)	7.1
2002	0.5 (26)	0.8 (44)	0.3 (18)	0.2 (12)			3.8 (205)	-1.9 (-105)	5.1
2003	0.4 (20)	0.8 (41)	0.4 (22)	0.3 (17)			2.2 (108)	-0.2 (-8)	5.0
2004	0.7 (22)	0.8 (25)	1.3 (41)	0.4 (12)			2.8 (86)	0.5 (14)	5.5
TN									
1999	5 (8)	5 (8)	17 (28)		34 (55)	6 (10)		55 (90)	213
2000	6 (32)	5 (28)	4 (21)	3 (19)			83 (463)	-65 (-363)	148
2001	6 (14)	5 (12)	31 (73)	0.5 (1)			57 (134)	-14 (-34)	133
2002	5 (15)	5 (14)	6 (17)	3 (9)	16 (46)			36 (100)	169
2003	4 (19)	5 (22)	8 (35)	6 (25)			24 (107)	-2 (-7)	167
2004	8 (22)	5 (14)	21 (59)	2 (4)			29 (83)	6 (17)	174

* End of year minus beginning of year mass of TP in the lake water column.

Table 5.12: Model lake nutrient budget summary for West Okoboji Lake (metric tons, (% of Total Inputs)

Nutrient	Inputs							Outputs			Annual Water Column Storage*	Nutrient Mass In Lake Water Column at End of Year
	Rain	Dry Dep.	Watershed	Adjacent Lake (WOL)	Spirit Lake	Adjacent Lake (UGL)	Sediment to Lake Flux	Adjacent Lake (WOL)	Adjacent Lake (UGL)	Lake to Sediment Flux		
TP												
1999	0.22 (10)	0.39 (17)	1.0 (45)	0.11 (5)	0.48 (21)		0.08 (3)		1.7 (75)		0.58 (25)	2.96
2000	0.25 (21)	0.39 (32)	0.21 (17)			0.36 (30)		0.19 (16)		0.69 (57)	0.33 (28)	3.29
2001	0.27 (8)	0.39 (11)	2.42 (71)		0.33 (10)			0.12 (4)	1.7 (48)	2.7 (78)	-1.02 (-30)	2.27
2002	0.23 (13)	0.39 (22)	0.32 (18)			0.26 (15)	0.58 (33)	0.22 (12)			1.56 (88)	3.83
2003	0.19 (15)	0.39 (31)	0.44 (36)			0.22 (18)		0.34 (28)		0.67 (54)	0.23 (19)	4.06
2004	0.3 (16)	0.4 (18)	1.4 (65)					0.4 (19)	0.7 (34)	0.3 (15)	0.7 (33)	4.75
TN												
1999	2.4 (5)	2.4 (5)	27 (53)	6.2 (12)	11 (22)		1.5 (3)		49 (98)		1.0 (2)	49
2000	2.7 (16)	2.4 (14)	5.8 (35)			5.8 (35)		3.4 (20)		21 (125)	-7.5 (-45)	41
2001	2.9 (5)	2.4 (4)	48 (80)		6.8 (11)			0.5 (1)	28.7 (48)	41 (68)	-9.8 (-16)	31
2002	2.5 (10)	2.4 (10)	9.0 (38)			4.2 (17)	6.0 (25)	3.1 (13)			20.9 (87)	52
2003	2.0 (10)	2.4 (11)	12 (57)			4.7 (22)		5.7 (27)		32 (153)	-16.9 (-80)	35
2004	3.8 (10)	2.4 (6)	32 (84)					2.8 (7)	5.5 (14)	24 (63)	6.1 (16)	41

* End of year minus beginning of year mass of TP in the lake water column.

Table 5.13: Model lake nutrient budget summary for East Okoboji Lake (metric tons, (% of Total Inputs)

Nutrient	Inputs					Outputs			Annual Water Column Storage*	Nutrient Mass In Lake Water Column at End of Year
	Rain	Dry Dep.	Watershed	Adjacent Lake (Minn. L)	Sediment to Lake Flux	Adjacent Lake (Minn. L)	Lake to Sediment Flux	Milford Creek		
TP										
1999	0.03 (1)	0.05 (1)	1.06 (22)	2.04 (42)	1.70 (35)			4.95 (101)	-0.07 (-1)	0.11
2000	0.03 (10)	0.05 (16)	0.19 (58)		0.05 (16)	0.36 (110)		0.00 (0)	-0.03 (-10)	0.07
2001	0.04 (1)	0.05 (1)	2.94 (83)	0.50 (14)			0.49 (14)	2.99 (85)	0.04 (1)	0.12
2002	0.03 (2)	0.05 (4)	0.29 (23)		0.88 (70)	1.24 (100)		0.01 (1)	-0.01 (-1)	0.11
2003	0.02 (4)	0.05 (9)	0.41 (76)		0.06 (10)	0.54 (99)		0.00 (0)	0.00 (1)	0.12
2004	0.05 (2)	0.05 (2)	1.49 (52)	0.40 (14)	0.90 (31)			2.81 (97)	0.08 (3)	0.20
TN										
1999	0.3 (0)	0.3 (0)	18 (28)	31 (47)	16 (24)			66 (100)	-0.04 (0)	2.1
2000	0.4 (5)	0.3 (4)	4 (51)		3 (40)	9 (114)		0 (0)	-1.1 (-14)	1.1
2001	0.4 (1)	0.3 (1)	33 (53)	28 (46)			11 (19)	49 (81)	0.4 (1)	1.5
2002	0.3 (3)	0.3 (3)	6 (52)		5 (42)	11 (96)		0.2 (1)	0.2 (2)	1.7
2003	0.3 (1)	0.3 (2)	8 (44)		10 (53)	19 (100)		0.0 (0)	-0.02 (0)	1.7
2004	0.5 (1)	0.3 (1)	22 (52)		19 (46)	8 (18)		33 (79)	1 (3)	2.8

* End of year minus beginning of year mass of TP in the lake water column.
† Two outlier TP concentrations of >0.5 mg/L (one in 2000 and another in 2004) were set to 0.2 mg/L to better match temporally adjacent measurements.

Table 5.14: Model lake nutrient budget summary for Lower Gar Lake (metric tons, (% of Total Inputs)). (Quantification of Nutrient Inputs into the Iowa Great Lakes, 2005)

West Okoboji Lake 1999 to 2004 Nutrient Budget

The West Okoboji model results indicate that wet and dry deposition together provide about 37 to 77 percent of the annual input of TP while the watershed inputs vary from about 12 to 60 percent of the total for this time. TP input from adjacent East Okoboji varies from zero to just less than 20 percent of the total input. The model indicates that TP flux to the lake sediment varies considerably from about 10 to 200 percent of the total input TP with TP being removed from the lake water column during years when more TP is deposited to the sediment than is input to the lake. Rarely is there any net TP exported from the lake, at least during the relatively dry years. The water column appears to have sufficient storage capacity to store or release as much TP as is input to the lake during the course of a year.

The model indicates that wet and dry deposition together provide about 16 to 60 percent of the annual input of TN. TN input from adjacent East Okoboji varies from zero to 25 percent of the total input. The model indicates that net TN flux to the lake sediment varies considerably from zero to over 400 percent of the total input TN with TN being removed from the lake water column during years when more TN is deposited to the sediment than is input to the lake.

During 1999 and 2002 there was a net TN flux from the lake sediment to the water column that provided about half of the TN input to the lake for each of those years. A net TN export from the lake occurs only during 1999 and this amounts to 10 percent of the TN input. The water column appears to have the capacity to store all of the TN input to the lake during a year, or to release a quantity greater than the annual TN input to the lakebed sediment.

East Okoboji Lake 1999 to 2004 Nutrient Budget

The East Okoboji model results indicate that wet and dry deposition together provide about 19 to 53 percent of the annual input TP while watershed inputs vary from 17 to 71 percent of the total for this time period. TP input from adjacent lakes varies from zero to about 30 percent of the total input. The model indicates that some years show significant TP flux from the water column to the sediment while other years show a net flux of TP from the sediment to the water column, although T flux to the lake sediment is generally substantially greater. Some years show significant net TP export downstream to Upper Gar, while other years show no net output to the lower lakes in the system.

The model results indicate that wet and dry deposition together provide about 9 to 36 percent of the total for this period. TN input from adjacent lakes varies from zero to about 35 percent of the total input. The model indicates that TN flux to the lake sediment varies considerably from zero to over 150 percent of the total input TN while a net TN flux from the sediment to the lake of up to 25 percent occurs in some years. Annual net TN export from East Okoboji to the lower lake system varies from zero to 98 percent of the total TN input.

Lower Gar Lake 1999 to 2004 Nutrient Budget

The Lower Gar model results indicate that wet and dry deposition together provide about 2 to 26 percent of the annual input TP while the watershed inputs vary from 22 to 83 percent of the total for this period. TP input from adjacent Lake Minnewashta varies from zero to 42 percent of the total input. Most years show significant TP flux from the lakebed sediment to the water column. However, in 2001, which was the wettest year during 1999 to 2004, shows a significant net flux of TP from the water column to the sediment. During years when a significant amount of water overtops the spillway, most of the TP input to the lake is exported downstream to Milford Creek.

The Lower Gar results indicate that wet and dry deposition together provide about one to nine percent of the annual TN input while the watershed inputs vary from about 28 to 53 percent of the total input for this time period. TN input from adjacent lakes varies from zero to 47 percent of the total input. The model indicates that TN flux from the lake sediment to the water column varies considerably from zero to over 50 percent of the total input TN. During 2001, the wettest year of the period, shows a significant net flux of TP from the sediment to the water column. Annual net export from Lower Gar to Milford Creek varies from zero to 100 percent of total input.

Nutrient Budget Summary

Lake nutrient budgets indicated that rainfall and dry deposition are major sources of total phosphorous (TP) and total nitrogen (TN) to West Okoboji Lake and East Lake Okoboji Lake, but contribute only a minor amount of the nutrients to Lower Gar Lake. Surface water runoff contributes a substantial proportion of nutrients to all of the lakes, but there is considerable annual variability in contribution from runoff depending on the amount of precipitation between dry and wet years. Lake to lake flow is a significant factor in the movement of nutrients between lakes, and sediment flux a significant factor in the movement of nutrients within individual lakes, but both demonstrate considerable variability from year to year in the amount and direction of net nutrient flow.

Generally, West Okoboji and East Okoboji sediment appear to be a net TP and TN sink, while Lower Gar sediment appears to be a source of nutrients to the water column; however, these results were based on a dry six-year time period. Sufficient nutrient concentration data to assess the role of sediment as a nutrient source or sink during wetter years is not available from this study.

Potential sources of error for the nutrient budget include:

Lake water samples collected only seven times during 2004 between June and September for nutrient analyses are used to characterize the lake nutrient mass and temporal variability in lake mass for the entire year. Lake TP concentration data collected by Bachmann and Jones (1974) indicate that systematic concentration shifts may occur during the course of a year with lower TP concentrations during the spring, and that variation within and between years may be significant. Data collection throughout the year, particularly for late fall, winter, and early spring, is generally lacking in IGL studies available for this work.

It is not clear how well equations developed based on flow-weighted TN as a function of percent cropland and TP concentration as a function of discharge coupled with estimated surface runoff from Ocheyedan water yield can be expected to approximate actual nutrient concentration inputs. However, data are insufficient estimate total inputs so some type of approximation is necessary.

There is a significant year-to-year variability in the annual nutrient budgets that may not accounted for in this study. This may be especially true for relatively wet years such as the 1992 to 1995 period. The relatively dry years examined in this study may not adequately reflect the nutrient budget for wetter years.

SUMMARY

Based on data collected by Hickock and Associates from 1971-1972, total phosphorous was found to be the critical element in the IGL systems. There was a linear relationship between TP inputs and algal levels, so that a halving of the TP input to a given lake might be expected to reduce the algal population by one-half. There is a lower limit to this relationship for if all inputs were removed; there would still be phosphorous recycled from the sediments.

High amounts of surface runoff correlated to the highest phosphorous concentration in the streams, the greatest input of phosphorous to the lakes, and the highest levels of summer algal blooms in the lakes. The number of animal units in a watershed had a significant correlation with the amount of phosphorous delivered by that watershed, indicating that livestock were a significant source of phosphorous to the IGL in 1971-1972.

The results for nitrate-N concentrations were less clear-cut. There was a significant negative correlation for the percent of watersheds in marshlands and a positive correlation for animal units. However, when the two factors were combined in a multiple regression analysis, no significant correlation was found for animal units. An earlier analysis of 1971 data produced a significant relationship between nitrate-N and percent of watersheds in row crops and a negative relationship with percentage of watersheds in marshland. No significant relationship was found between ammonia-N and any of the watershed land uses.

Data collected by Stenback, Crumpton, and van der Valk from 1999-2004 indicated that while small lake elevation differences produce alternating flow direction between lakes, there is a net long-term flow of water from the upper to lower Iowa Great Lakes, with significant annual variability between wet and dry years. (Quantification of Nutrient Inputs into the Iowa Great Lakes, 2005)

During dry periods, nutrients from the smaller, shallower and more nutrient-rich Lower Gar, Minnewashta, and Upper Gar Lakes may flow up lake into East Okoboji Lake. In addition, during the dry periods East Okoboji Lake may exchange water with West Okoboji Lake. Because East Okoboji has greater TP and TN concentrations, it can be a significant source of nutrients to West Okoboji during periods of up lake water flow.

Rainfall and dry deposition are major sources of TP and TN to West Okoboji Lake and East Lake Okoboji Lake, but contribute only a minor amount of the nutrients to Lower Gar Lake. Surface water runoff contributes a substantial proportion of nutrients to all of the lakes. Lake to lake flow is a significant factor in the movement of nutrients between lakes, and sediment flux a significant factor in the movement of nutrients within individual lakes.

Generally, West Okoboji and East Okoboji sediment appear to be a net TP and TN sink, while Lower Gar sediment appears to be a source of nutrients to the water column; however, these results were based on a dry six-year time period. Sufficient nutrient concentration data to assess the role of sediment as a nutrient source or sink during wetter years is not available from this study.

The CLAMP data collected from 1999 to present indicates that West Okoboji and Big Spirit Lakes are the least productive of the IGL. West Okoboji is in the *mesotrophic* category. Most of the other lakes are in the *eutrophic* category. Little Spirit Lake and Silver Lake have the highest TSI scores, which indicate they are the most productive and are considered *hypereutrophic*.

The data show that nitrate concentrations are highest in the spring and early summer months before declining in the summer. This time coincides with spring applications of fertilizers as well as high amounts of rain. The data also show that water clarity is greatest in the spring before water temperatures increase and algal populations increase. Secchi depths are generally deepest in June and shallowest in August and September for the lakes. In general, East Okoboji, West Okoboji, Big Spirit, and Lower Gar have small decreasing Secchi depth trends, based on visual assessment, while Secchi depths in Upper Gar and Minnewashta have not changed over time.

The IDNR ambient lake-monitoring program differs from the CLAMP program in that the samples were collected and analyzed by professionals from 2000 to 2007. The ambient monitoring program characterizes current water quality in the monitored lakes and provides an opportunity to track trends in lake water quality. Some of the main factors are summarized below.

Stratification

Data collected through the ambient lake monitoring program indicated that West Okoboji is the only lake in the Iowa Great Lakes that stratifies regularly. The other lakes are too shallow and are susceptible to mixing by the windy conditions in that area of the state. One potential consequence of thermal stratification is anoxia (or low oxygen conditions) in the hypolimnion (the deep cold-water area) due to respiration. Hypolimnetic anoxia can lead to release of phosphorous from the sediment that can lead to algae blooms.

Turbidity

In general, the lakes in the Iowa Great Lakes region have lower turbidities and concentrations of total suspended solids (TSS) than other natural lakes in the state with the exception of Little Spirit, Lower Gar and Upper Gar Lakes.

Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO.

Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macro invertebrates. Sources of turbidity include soil erosion, waste discharge, urban runoff, eroding stream banks, large numbers of bottom feeders (such as carp), which stir up bottom sediments, and excessive algal growth.

Total Organic Carbon (TOC)
Little Spirit and Center Lakes have relatively high levels of TOC, above the 75th percentile for all monitored, natural lakes. All other lakes in the Iowa Great Lakes fall below the 25th percentile for all monitored natural lakes.

Total organic carbon (TOC) is the sum of all organic carbon from decaying organic material, bacterial growth, metabolic activities of living organisms, and chemicals. Detergents, pesticides, fertilizers, herbicides, industrial chemicals, and chlorinated organics are synthetic sources of organic carbon. Levels of TOC can be used as a measure of organic contamination.

Conductivity
Center (571 µS/cm) Lake has the highest median specific conductance among the Iowa Great Lakes, which was above the 75th percentile for all monitored, natural lakes. Big Spirit (480 µS/cm) and West Okoboji (466 µS/cm) had the lowest median specific conductance among the Iowa Great Lakes.

Conductivity is useful as a general measure of stream water quality. Significant changes in conductivity can be used as an indicator that a discharge or some other source of pollution has entered a stream. Studies of inland fresh waters indicate that waters supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

Soluble Reactive Phosphorous (SRP)
Little Spirit (0.09 mg/L) and East Okoboji (0.04 mg/L) have relatively high SRP levels when compared to other monitored, natural lakes in Iowa (greater than the 75th percentile).
Soluble reactive phosphorous is the form of total phosphorous that is available for immediate uptake by algae. In phosphorous-limited situations, this form should be low to undetectable, as is the case in Big Spirit (0.003 mg/L) and West Okoboji (0.003 mg/L). As SRP increases, it implies that phosphorous is either not needed by algae or it is being supplied at a rate that is faster than the rate of biologic uptake. Ideally, soluble reactive phosphorous concentrations should be .01 mg/L or less at spring turnover to prevent summer algae blooms. Total phosphorous is considered a better indicator of a lake's nutrient status because its levels remain more stable than soluble reactive phosphorous. Total phosphorous includes soluble phosphorous and the phosphorous in plant and animal fragments suspended in lake water.
Total Kjeldahl Nitrogen (TKN)
Little Spirit (2.6 mg/L) and Center (2.0 mg/L) have TKN concentrations above the median for other monitored, natural lakes in Iowa (1.7 mg/L). Little Spirit, Minnewashta, Center, and Lower Gar have the highest median ammonia concentrations, while Big Spirit and West Okoboji have the lowest.

Total Kjeldahl nitrogen is the sum of organic nitrogen and ammonia in water. High concentrations of TKN in a water body are generally from organic pollution, such as sewage or manure discharges. Ammonia is also commonly used as an agricultural fertilizer. Ammonia can be toxic to fish and invertebrate populations when at high levels.

Phytoplankton
Most phytoplankton samples were dominated by cyanobacteria, which often dominate summer plankton in eutrophic lakes. The median phytoplankton wet mass ranged from 9.1 mg/L in West Okoboji to 36.0 mg/L in Upper Gar. All lakes in the Iowa Great Lakes had a lower median concentration than the median for all monitored, natural lakes in Iowa (39.7 mg/L).

Phytoplankton or algae are the photosynthetic organisms that form the base of the food chain in lakes. Phytoplankton wet mass and composition are measured to get a better understanding of the biological dynamics of each lake.

Zooplankton
The median zooplankton wet mass ranged from 94.1 mg/L in West Okoboji to 288.5 mg/L in Lower Gar. Zooplankton is the microscopic and macroscopic animals that float, drift, or swim weakly in the water column. Zooplankton is the primary consumers of algae and many fish rely on them as a food source.

5.3 WATER QUALITY IMPROVEMENT PLAN

Phosphorous is the limiting factor for all the lakes within the Iowa Great Lakes and is the primary reason for any impairment within the watershed. There are two lakes which are impaired due to high bacteria counts and those lakes impairments seem to stem from septic tank issues. Based on data collected by Hickock and Associates from 1971-1972, total phosphorous was found to be the critical element in the IGL systems. There was a linear relationship between TP inputs and algal levels, so that a halving of the TP input to a given lake might be expected to reduce the algal population by one-half. There is a lower limit to this relationship for if all inputs were removed; there would still be phosphorous recycled from the sediments.

High amounts of surface runoff correlated to the highest phosphorous concentration in the streams, the greatest input of phosphorous to the lakes, and the highest levels of summer algal blooms in the lakes. The number of animal units in a watershed had a significant correlation with the amount of phosphorous delivered by that watershed, indicating that livestock were a significant source of phosphorous to the IGL in 1971-1972. (Dickinson Soil and Water Conservation District, 2008)

There are 10 impaired water bodies in Dickinson County, Iowa that are listed on the State's List of Impaired Water Bodies. Figure 5.6 shows the impaired water bodies in Dickinson County, however, an argument can be made that each water body in Dickinson County is somewhat impaired in one way or another.

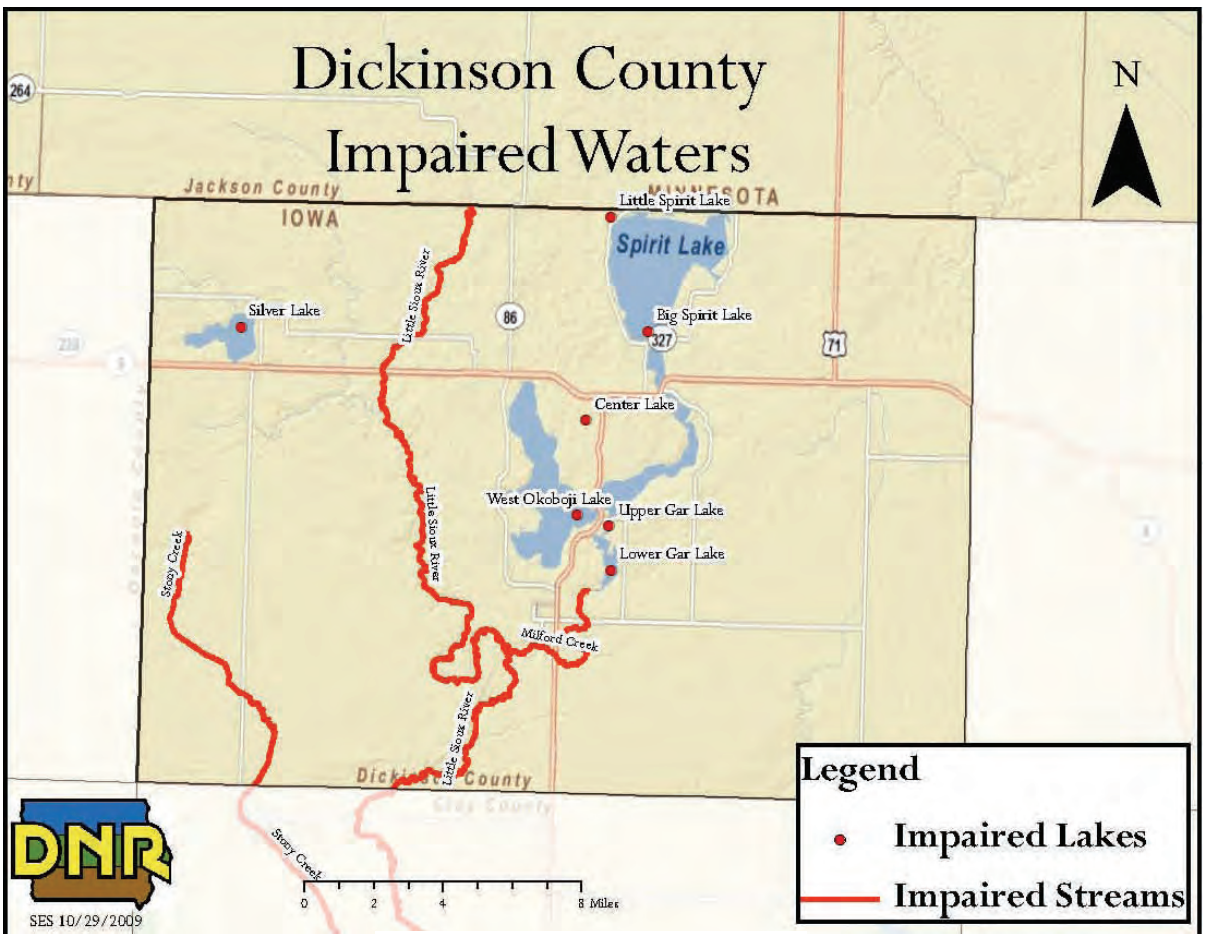


Figure 5.6 Dickinson County Impaired Water bodies

"Quantification of Nutrient Inputs into the Iowa Great Lakes"

Background

This study examined water and nutrient budgets for West Okoboji Lake, East Okoboji Lake, and Lower Gar Lake. The three lakes, along with Upper Gar Lake and Minnewashta Lake, form a series of interconnected lakes within the IGL system. The only surface outflow from these lakes is over a low-head dam at the south end of Lower Gar Lake. The purpose of the study was to better understand and quantify how water and nutrients move into, among, and out of the lake system. For a complete review of data collection, data analysis, and results see *Quantification of Nutrient Inputs into the Iowa Great Lakes*, submitted by Stenback, Crumpton, and van der Valk to the U.S. Environmental Protection Agency, December 2005. (Quantification of Nutrient Inputs into the Iowa Great Lakes, 2005)

In order to develop water and nutrient budgets, three additional types of monitoring were initiated to fill data gaps, including 1) inputs of nutrients in wet and dry depositions, 2) collection of lake and inflowing surface water samples for nutrient analyses, and 3) evaporation rates.

A thirteen-year numerical water budget model based on local daily rainfall data, watershed input from the nearby Ocheyedan River water yield and lake to watershed area, lake-to-lake water flow, and local pan evaporation data was developed for the period of January 1, 1992 to December 31, 2004. For each lake, total phosphorous (TP) and total nitrogen (TN) budgets were estimated each year from 1999-2004, using measured lake concentration data, modeled watershed inputs estimated from inflowing stream data, and wet/dry depositions.

The flow of nutrients into, among, and out of the lake system was estimated using the water budget model and nutrient concentration data. For each lake's nutrient budget, lakebed sediment was treated as a nutrient source or sink to maintain water column nutrient concentrations after accounting for all other inputs and outputs.

Spirit Lake, which was not a direct focus of this study, was modeled separately to obtain an estimate of lake discharge into East Okoboji Lake. The lake water budget model was developed as a component of a separate study to look at phosphorous cycling in portions of the lake system. Existing water monitoring programs provided much of the data needed to develop the water and nutrient budgets. Data on water and nutrient yields from different kinds of watersheds were used to estimate water and nutrient loads from each lake's watershed. In order to complete mass balance budgets for the lakes, additional monitoring was conducted to obtain inputs of nutrients in wet and dry deposition, nutrients in lake water and inflowing surface water samples, and evaporation rates.

Model Input and Data Sources

Watershed inputs to each lake include:

- Watershed input was modeled as the product of watershed area and water yield based on data from the Ocheyedan River near Spencer, IA (USGS Station 06605000).
- Rainfall directly to the lake surface using rain data Milford, IA (NOAA NNDC Climate Online Data Online, Station 135493).
- Spirit Lake model outflow was used as a water input into East Okoboji.

Watershed exports to each lake include:

- Evaporation from the lake surface, based on the product of a pan evaporation coefficient and pan evaporation data obtained online from University of Minnesota, Southwest Research and Outreach Center, Lamberton, MN (Station 23669). Lamberton is 50 miles north of the Iowa Great Lakes area. Pan evaporation data was also collected at the Lakeside Laboratory in 2003 and 2004. The Lakeside Laboratory data were significantly less variable ($p<0.0001$) than the Lamberton data and had a significantly lower mean than the Lamberton data (about 23% lower, $p<0.0001$) for the 180 days when both stations had measurements. The Lamberton data were used because they have a more complete record for the time of the study. The difference in average values between Lakeside and Lamberton data is compensated for by the application of the pan evaporation coefficient in the numerical model.

- Discharge from the lake outflow structure to Milford Creek and or into adjacent lakes.
- Groundwater inputs to and exports from the lake system are assumed to be negligible. Five stream monitoring sites were chosen for streambed stability and approximately U-shaped channels (see figure 3.6 on page 52). American Sigma 900 Max auto-samplers equipped with depth/velocity probes were used at each site to record average depth and water velocity at five-minute intervals. Stream cross-section profiles were completed at each probe location and an area versus stream water depth relationship was developed corresponding to one millimeter depth interval changes. Five-minute stream discharges were calculated as the product of the average velocity and the area associated with the average stream depth over each five-minute period. Daily stream discharges were calculated by summing the five-minute discharges for a 24-hour period.

- Evaporation and rainfall was identical for each day and each lake in the model. Rainfall and evaporation were applied directly to the lake surface area so that rainfall and evaporation affected change in the lake surface elevation identically for each lake. Because of this, rainfall and evaporation generally have no effect on modeled water movement between the lakes. One exception to this occurs if rainfall inputs raises lake surface elevation enough to cause discharge over the Lower Gar spillway at a sufficiently high rate to stop any upstream flow that might be occurring, and start downstream flow. The major effect of rain for the purpose of nutrient balance is as a source of nutrients, while the effect of evaporation is to concentrate nutrients already in the lake.

East Okoboji Lake
During relatively wet years, lake-to-lake flow accounts for more than 60 or 70 percent of the East Okoboji water budget. The quantity of water delivered to East Okoboji from both rain and watershed input are generally similar. Water input from West Okoboji to East Okoboji was always less (except in the 1993-flood year) than surface water input to East Okoboji from its watershed, and in relatively dry years, net flow was into West Okoboji from East Okoboji. Water input from Spirit Lake to East Okoboji may exceed surface water input during wet years, but during relatively dry years, Spirit Lake provides little or no flow to East Okoboji.

Water output to Upper Gar exceeds water input to East Okoboji from its watershed during wet years, but during the very dry years (2000, 2002, and 2003); Upper Gar was a net source of water to East Okoboji. While flow through East Okoboji varied considerably from year to year, and in some years more water flows into the lake than out of it, the outflow to Upper Gar indicates that sufficient water flows in and out of East Okoboji to completely replace the lake water every few years, except during extended dry periods such as 2002 and 2004. During the 1993 flood year, sufficient water flowed through East Okoboji to replace its volume nearly eight times.

Upper Gar Lake
During wet years, lake-to-lake flow accounts for more than 60 or 70 percent of the Lower Gar water budget. During 1992-2004, surface water flow from the watershed into Lower Gar exceeded the lake volume each year of the study. However, during three dry years (2000, 2002, and 2003), there was little or no outflow and net flow was upstream out of Lower Gar into Minnewashta.

During the dry years, watershed input and lake-to-lake flow dominated the water budget. With the exception of the dry years and 1998, sufficient water flowed in and out of Lower Gar to replace the entire lake volume more than ten times each year. During the 1993 flood year, approximately 200 lake volumes flowed out of Lower Gar to Milford Creek.

Water Budget Summary
While small lake elevation differences produce alternating flow direction between lakes, there is a net long-term flow of water from the upper to lower Iowa Great Lakes, with significant annual variability between wet and dry years. During wet periods, water flows from West Okoboji to East Okoboji and downstream through the lower lakes and out the overflow structure below Lower Gar Lake.

During relatively dry years, outflow from the upstream lakes may cease for periods lasting months to more than a year. During the dry periods, the water level in Lower Gar, which has a large watershed to lake ratio, rises at a greater rate than the upstream lakes. This causes reversed or up-lake flow.
Therefore, during dry periods nutrients from the smaller, shallower and more nutrient-rich Lower Gar, Minnewashta, and Upper Gar Lakes may flow up lake into East Okoboji Lake. In addition, during the dry periods East Okoboji Lake may exchange water with West Okoboji Lake. West Okoboji Lake is the largest, deepest and least nutrient enriched of the Iowa Great Lakes chain. Because East Okoboji has greater TP and TN concentrations, it can be a significant source of nutrients to West Okoboji during periods of up lake water flow.

During wet periods when a lake volume is overturned multiple times, particularly for Lower Gar and occasionally East Okoboji, the nutrient load of primary concern is that of the last lake volume because all of the preceding volumes have flowed through and out of the lake. Understanding water inputs and outputs is a first step towards understanding how nutrients that are dissolved or suspended in the water column move into, within, and out of the lake system.

2004 Nutrient Budget Model
Mass balance nutrient budgets were developed for TP and TN for 2004. The nutrient budget inputs to the lake water column include direct rain and atmospheric deposition, inflowing stream water, flux from the sediment, and input from adjacent lakes. Nutrients may be exported from a lake along with water flowing between lakes or discharged to Milford Creek from Lower Gar. Nutrients may be stored within the lake in lakebed sediments, elevated aqueous concentration or associated with suspended solids. Nutrient flux from the water column to lakebed sediment is considered an export from the lake water column even though the nutrients are stored within the lake system.

Mass balance models were constructed for nutrients using a daily time step for 2004. Initial conditions include the lake water volume determined from the water budget model and a lake water column nutrient mass determined from an initial lake nutrient concentration and water volume. The model assumes that once nutrients enter a lake, they are completely mixed within the lake. The mass of nutrients entering and exiting are determined at each daily time step and the resulting model lake nutrient concentration is determined.

When all non-sediment related nutrient inputs and outputs are accounted for, the model lake nutrient concentration is compared to the measured lake nutrient concentration. If the model lake concentration is greater than the measured lake concentration, nutrients are forced into the sediment to make up the difference. If the model lake concentration is less than the measured lake concentration, nutrients are taken from the sediment to make up the difference. Since daily measured lake nutrient concentrations are not available, a linear interpolation generated by ModelMaker was used to estimate a daily concentration value between each measured value.

Water samples were collected from inflowing streams from April 6 to October 4 during 2004 and analyzed for TP and TN. Stream discharge at these locations was measured daily, although occasional equipment failures occurred resulting in several data gaps. The data were evaluated using ModelMaker to estimate flow-weighted average (FWA) concentrations; however, because the data encompass less than a full year and the FWA concentrations are dependent on the particular flow events during this period of record, they may not be appropriate for use outside of this particular period. These data were utilized to estimate concentrations in inflowing water from surface runoff to the lakes.

The TP concentration data showed some tendency to increase with increasing discharge, although there is considerable scatter in the data. Differences in mean TP concentration and variation among sites at low discharge are minimal and concentrations at all sites show a similar tendency to increase with increasing discharge as would be expected for phosphorous concentrations associated with water carrying suspended particulate matter. Accordingly, the linear relationship between increasing total phosphorous concentration with increasing discharge was used to estimate a phosphorous concentration associated with discharge estimated from the product of the Ocheyedan water yield and the sub watershed area for watersheds within the main watershed for each of the lakes in this study.

There is a non-linear relationship between FWA TN concentration and percentage of the watershed area in row crop. The FWA TN concentrations were determined as the total TN mass load divided by the total water volume for the five sub watershed sites over the approximately six-month data collection period from early April to early October of 2004. The non-linear relationship between FWA TN and percent cropland was used to generate daily TN concentrations for surface water input in the nutrient budget models.

Watersheds were delineated using a D8 directional flow algorithm described by O'Callaghan & Mark (1984). One arc second elevation data was obtained from the USGS National Elevation Dataset (USGS). Percent row crop was derived by zonal statistics of each watershed based on a 2003 land cover dataset. Land cover information was obtained from the USDA National Agricultural Statistics Service.

An Aerochem Metrics Inc. Automatic Sensing Wet/Dry Precipitation Collector was used to collect wet-dry samples to estimate TP and TN inputs from both rainwater and dry deposition. Rainwater samples were collected during August to October 2003 and all of 2004. Lake TP and TN concentrations were available from the ongoing lake water quality-monitoring program, Cooperative Lakes Area Monitoring Program (CLAMP), a partnership between the local community and Iowa Lakeside Laboratory. The CLAMP data were used to estimate lake water nutrient concentrations for the nutrient budget. Initial lake (January 1, 2004) concentrations were determined by linear interpolation between the concentration determined for the last sampling event in 2003 and the first event in 2004. Final December 31, 2004 lake concentrations were set equal to the initial concentration.

West Okoboji Lake 2004 TP and TN Budgets

The model indicates that net TP inputs to West Okoboji for 2004 total 3.3 metric tons (t) with 22% from rain, 25% from dry deposition, 41% from surface runoff, and 12% from East Okoboji. The net input from East Okoboji is interesting because the net water movement during 2004 was primarily from East Okoboji to West Okoboji. This occurred because water flow was primarily from East Okoboji to West Okoboji during the early part 2004, while late in the year water generally moved downstream from west to east.

Because the TP concentration is greater in East Okoboji than in West Okoboji, the net flux of TP was from east to west even though the net flux of water was from west to east. Approximately 2.8 t TP was stored in the lake sediment (about 86% of the net TP input) and 0.5 t was stored in the water column (about 14% of the net TP input).

The model results indicate that net TN inputs to West Okoboji for 2004 total 35.5 t with 22% from rain, 14% from dry deposition, 59% from surface runoff, and 4% from East Okoboji. About 29 t TN (83% of the input TN) was deposited to the lakebed sediment and approximately 6 t TN was stored in the water column (about 17% of the net TN input).

East Okoboji Lake 2004 TP and TN Budgets

The model results indicate that net TP inputs to East Okoboji for 2004 total 21 t with 16% from rain, 18% from dry deposition, and 65% from watershed runoff. Spirit Lake did not overtop its outflow structure during 2004 so no TP phosphorous was contributed from that potential source. About 0.4 t TP (19% of the input TP) was output from East Okoboji to West Okoboji and 0.7 t TP (34%) of the net TP input was output to Lower Gar during 2004. Approximately 0.3 t TP (15% of the net TP input) was deposited to the lake sediment and 0.7 t TP (33% of the net TP input) was stored in the water column.

The model results indicate that net TN inputs to East Okoboji for 2004 total 38.5 t with 10% from rain, 6% from dry deposition, and 84% from surface runoff. About 2.8 t (7% of the input of TN) was output to West Okoboji and 5.5 t (14% of the input TN) was output to Upper Gar Lake. About 24 t of TN (63% of the input TN) was deposited to the lakebed sediment and approximately 6.1 t of TN was stored in the water column (about 16% of the net TN input).

Lower Gar Lake 2004 TP and TN Budget

The model results indicate that net TP inputs to Lower Gar for 2004 total 2.9 t with 2% from rain, 2% from dry deposition, 52% from surface runoff, 4% from Minnewashta Lake, and 41% released from the lakebed sediment to the water column. About 2.8 t TP (97% of the input TP) was output to Milford Creek and approximately 0.8 t TP (about 3% of the net TP input) was stored in the water column.

The model results indicate that net TN inputs to Lower Gar for 2004 total 42 t with 1% from rain, 1% from dry deposition, 52% from surface runoff, and 46% from lakebed sediment. About 33 t (79% of the input TN) was output to Milford Creek and 8 t of TN (18% of the input TN) was exported to Minnewashta Lake. Approximately 1 t of TN (about 3% of the net TN input) was stored in the water column.

2004 TP Budgets on a Mass per Lake Area and Mass per Lake Volume Basis

Because the lake areas and volumes vary, expressing the TP nutrient budget in terms of mass per lake area and mass per lake volume provides a different perspective on TP source load to the lakes and on between lake comparisons. The rain and dry deposition inputs are the same for each lake when evaluated on a per lake area basis.

However, on a per lake volume basis, the rain and dry deposition inputs are lowest for West Okoboji and highest for Lower Gar, which is the opposite of the order of actual mass input to these lakes. While the actual watershed input mass is similar for each lake, the per lake area watershed input is lowest for West Okoboji and highest for Lower Gar, and because of the relative lake depths, this effect is even more pronounced on a per lake volume basis.

1999 to 2004 Six-Year Annual Nutrient Budget Model

A temporal assessment of the nutrient budget was developed using CLAMP lake concentration data available from 1999 to 2004. Lake samples were collected on seven to ten days each year in each lake from 1999 to 2004. Spirit Lake did not contribute to the 2004 nutrient budget because there was no outflow from Spirit Lake that year. However, Spirit Lake did contribute water and nutrients to East Okoboji during 1999 and 2001. Adequate lake concentration data is not available for the years between 1992 and 1999 so the lake budget model could not be extended to years prior to 1999. Wet deposition for the six-year nutrient budget is based on 2004 wet/dry average TP and TN rain concentrations applied to daily ran data as described in the water budget model. The average 2004 dry deposition rate was used for the six-year modeling period. The TP and TN watershed inputs were based on the 2004 sampling data, the relative proportions of water inputs to each lake (watershed runoff, precipitation, and lake-to-lake flow) described for the thirteen-year water budget model, and TP estimated as a function of discharge coupled with estimated surface runoff from Ocheyedan water yield (R^2=0.379). Otherwise, watershed and from adjacent lake nutrient budgets were modeled as previously described. The resulting nutrient budgets are given in Tables 3.10-3.14.

Lake	Inputs					Outputs		Storage	Total Mass In Lake
	Rain	Dry Dep.	Watershed	Adjacent Lakes	Sediment Flux	Adjacent Lakes or Milford Creek	Sediment Flux	Stored in the Water Column*	Nutrient Mass in Lake Water Column at End of 2004
West Okoboji	0.047	0.052	0.086	0.026			0.18	0.030	0.35
East Okoboji	0.047	0.052	0.19			0.055 (WOL) 0.096 (UGL)	0.042	0.092	0.64
Lower Gar†	0.047	0.052	1.5	0.41	0.95	2.9 (Milford Cr.)		0.084	0.20

* End of 2004 minus beginning of 2004 mass of TP in the lake water column.
† One outlier TP concentration of 0.52 mg/L collected on August 2, 2004 was set to 0.2 mg/L to better match temporally adjacent measurements.

Table 5.10: Lake TP nutrient flux model budget summary for 2004 in mass per lake area (g/m2).

Lake	Inputs					Outputs		Storage	Total Mass In Lake
	Rain	Dry Dep.	Watershed	Adjacent Lakes	Sediment Flux	Adjacent Lakes or Milford Creek	Sediment Flux	Stored in the Water Column*	Nutrient Mass in Lake Water Column at End of 2004
West Okoboji	0.0041	0.0046	0.0075	0.0023			0.016	0.0026	0.031
East Okoboji	0.015	0.017	0.059			0.017 (WOL) 0.030 (UGL)	0.013	0.029	0.20
Lower Gar†	0.043	0.048	1.4	0.38	0.88	2.6 (Milford Cr.)		0.077	0.19

* End of 2004 minus beginning of 2004 mass of TP in the lake water column.
† One outlier TP concentration of 0.52 mg/L collected on August 2, 2004 was set to 0.2 mg/L to better match temporally adjacent measurements.

Table 5.11: Lake TP nutrient flux model budget summary for 2004 in mass per full lake volume (g/m3).

Nutrient	Inputs					Outputs		Annual Water Column Storage*	Nutrient Mass In Lake Water Column at End of Year
	Rain	Dry Dep.	Watershed	Adjacent Lake (EOL)	Sediment to Lake Flux	Adjacent Lake (EOL)	Lake to Sediment Flux		
TP									
1999	0.5 (20)	0.8 (35)	1.0 (45)			0.1 (5)	1.2 (53)	1.0 (43)	5.9
2000	0.5 (30)	0.8 (47)	0.2 (12)	0.2 (11)			0.2 (10)	1.6 (90)	7.5
2001	0.6 (15)	0.8 (22)	2.2 (60)	0.1 (3)			4.1 (111)	-0.4 (-11)	7.1
2002	0.5 (26)	0.8 (44)	0.3 (18)	0.2 (12)			3.8 (205)	-1.9 (-105)	5.1
2003	0.4 (20)	0.8 (41)	0.4 (22)	0.3 (17)			2.2 (108)	-0.2 (-8)	5.0
2004	0.7 (22)	0.8 (25)	1.3 (41)	0.4 (12)			2.8 (86)	0.5 (14)	5.5
TN									
1999	5 (8)	5 (8)	17 (28)		34 (55)	6 (10)		55 (90)	213
2000	6 (32)	5 (28)	4 (21)	3 (19)			83 (463)	-65 (-363)	148
2001	6 (14)	5 (12)	31 (73)	0.5 (1)			57 (134)	-14 (-34)	133
2002	5 (15)	5 (14)	6 (17)	3 (9)	16 (46)			36 (100)	169
2003	4 (19)	5 (22)	8 (35)	6 (25)			24 (107)	-2 (-7)	167
2004	8 (22)	5 (14)	21 (59)	2 (4)			29 (83)	6 (17)	174

* End of year minus beginning of year mass of TP in the lake water column.

Table 5.12: Model lake nutrient budget summary for West Okoboji Lake (metric tons, (% of Total Inputs)).

Nutrient	Inputs: Rain	Inputs: Dry Dep.	Inputs: Watershed	Inputs: Adjacent Lake (WOL)	Inputs: Spirit Lake	Inputs: Adjacent Lake (UGL)	Inputs: Sediment to Lake Flux	Outputs: Adjacent Lake (WOL)	Outputs: Adjacent Lake (UGL)	Outputs: Lake to Sediment Flux	Annual Water Column Storage*	Nutrient Mass In Lake Water Column at End of Year
TP												
1999	0.22 (10)	0.39 (17)	1.0 (45)	0.11 (5)	0.48 (21)		0.08 (3)		1.7 (75)		0.58 (25)	2.96
2000	0.25 (21)	0.39 (32)	0.21 (17)			0.36 (30)		0.19 (16)		0.69 (57)	0.33 (28)	3.29
2001	0.27 (8)	0.39 (11)	2.42 (71)		0.33 (10)			0.12 (4)	1.7 (48)	2.7 (78)	-1.02 (-30)	2.27
2002	0.23 (13)	0.39 (22)	0.32 (18)			0.26 (15)	0.58 (33)	0.22 (12)			1.56 (88)	3.83
2003	0.19 (15)	0.39 (31)	0.44 (36)			0.22 (18)		0.34 (28)		0.67 (54)	0.23 (19)	4.06
2004	0.3 (16)	0.4 (18)	1.4 (65)					0.4 (19)	0.7 (34)	0.3 (15)	0.7 (33)	4.75
TN												
1999	2.4 (5)	2.4 (5)	27 (53)	6.2 (12)	11 (22)		1.5 (3)		49 (98)		1.0 (2)	49
2000	2.7 (16)	2.4 (14)	5.8 (35)			5.8 (35)		3.4 (20)		21 (125)	-7.5 (-45)	41
2001	2.9 (5)	2.4 (4)	48 (80)		6.8 (11)			0.5 (1)	28.7 (48)	41 (68)	-9.8 (-16)	31
2002	2.5 (10)	2.4 (10)	9.0 (38)			4.2 (17)	6.0 (25)	3.1 (13)			20.9 (87)	52
2003	2.0 (10)	2.4 (11)	12 (57)			4.7 (22)		5.7 (27)		32 (153)	-16.9 (-80)	35
2004	3.8 (10)	2.4 (6)	32 (84)					2.8 (7)	5.5 (14)	24 (63)	6.1 (16)	41

* End of year minus beginning of year mass of TP in the lake water column.

Table 5.13: Model lake nutrient budget summary for East Okoboji Lake (metric tons, (% of Total Inputs).

Nutrient	Inputs: Rain	Inputs: Dry Dep.	Inputs: Watershed	Inputs: Adjacent Lake (Minn. L)	Inputs: Sediment to Lake Flux	Outputs: Adjacent Lake (Minn. L)	Outputs: Lake to Sediment Flux	Outputs: Milford Creek	Annual Water Column Storage*	Nutrient Mass In Lake Water Column at End of Year
TP										
1999	0.03 (1)	0.05 (1)	1.06 (22)	2.04 (42)	1.70 (35)			4.95 (101)	-0.07 (-1)	0.11
2000	0.03 (10)	0.05 (16)	0.19 (58)		0.05 (16)	0.36 (110)		0.00 (0)	-0.03 (-10)	0.07
2001	0.04 (1)	0.05 (1)	2.94 (83)	0.50 (14)			0.49 (14)	2.99 (85)	0.04 (1)	0.12
2002	0.03 (2)	0.05 (4)	0.29 (23)		0.88 (70)	1.24 (100)		0.01 (1)	-0.01 (-1)	0.11
2003	0.02 (4)	0.05 (9)	0.41 (76)		0.06 (10)	0.54 (99)		0.00 (0)	0.00 (1)	0.12
2004	0.05 (2)	0.05 (2)	1.49 (52)	0.40 (14)	0.90 (31)			2.81 (97)	0.08 (3)	0.20
TN										
1999	0.3 (0)	0.3 (0)	18 (28)	31 (47)	16 (24)			66 (100)	-0.04 (0)	2.1
2000	0.4 (5)	0.3 (4)	4 (51)		3 (40)	9 (114)		0 (0)	-1.1 (-14)	1.1
2001	0.4 (1)	0.3 (1)	33 (53)	28 (46)			11 (19)	49 (81)	0.4 (1)	1.5
2002	0.3 (3)	0.3 (3)	6 (52)		5 (42)	11 (96)		0.2 (1)	0.2 (2)	1.7
2003	0.3 (1)	0.3 (2)	8 (44)		10 (53)	19 (100)		0.0 (0)	-0.02 (0)	1.7
2004	0.5 (1)	0.3 (1)	22 (52)		19 (46)	8 (18)		33 (79)	1 (3)	2.8

* End of year minus beginning of year mass of TP in the lake water column.

† Two outlier TP concentrations of >0.5 mg/L (one in 2000 and another in 2004) were set to 0.2 mg/L to better match temporally adjacent measurements.

Table 5.14: Model lake nutrient budget summary for Lower Gar Lake (metric tons, (% of Total Inputs)). (Quantification of Nutrient Inputs into the Iowa Great Lakes, 2005)

West Okoboji Lake 1999 to 2004 Nutrient Budget

The West Okoboji model results indicate that wet and dry deposition together provide about 37 to 77 percent of the annual input of TP while the watershed inputs vary from about 12 to 60 percent of the total for this time. TP input from adjacent East Okoboji varies from zero to just less than 20 percent of the total input. The model indicates that TP flux to the lake sediment varies considerably from about 10 to 200 percent of the total input TP with TP being removed from the lake water column during years when more TP is deposited to the sediment than is input to the lake. Rarely is there any net TP exported from the lake, at least during the relatively dry years. The water column appears to have sufficient storage capacity to store or release as much TP as is input to the lake during the course of a year.

The model indicates that wet and dry deposition together provide about 16 to 60 percent of the annual input of TN. TN input from adjacent East Okoboji varies from zero to 25 percent of the total input. The model indicates that net TN flux to the lake sediment varies considerably from zero to over 400 percent of the total input TN with TN being removed from the lake water column during years when more TN is deposited to the sediment than is input to the lake.

During 1999 and 2002 there was a net TN flux from the lake sediment to the water column that provided about half of the TN input to the lake for each of those years. A net TN export from the lake occurs only during 1999 and this amounts to 10 percent of the TN input. The water column appears to have the capacity to store all of the TN input to the lake during a year, or to release a quantity greater than the annual TN input to the lakebed sediment.

East Okoboji Lake 1999 to 2004 Nutrient Budget

The East Okoboji model results indicate that wet and dry deposition together provide about 19 to 53 percent of the annual input TP while watershed inputs vary from 17 to 71 percent of the total for this time period. TP input from adjacent lakes varies from zero to about 30 percent of the total input. The model indicates that some years show significant TP flux from the water column to the sediment while other years show a net flux of TP from the sediment to the water column, although T flux to the lake sediment is generally substantially greater. Some years show significant net TP export downstream to Upper Gar, while other years show no net output to the lower lakes in the system.

The model results indicate that wet and dry deposition together provide about 9 to 36 percent of the total for this period. TN input from adjacent lakes varies from zero to about 35 percent of the total input. The model indicates that TN flux to the lake sediment varies considerably from zero to over 150 percent of the total input TN while a net TN flux from the sediment to the lake of up to 25 percent occurs in some years. Annual net TN export from East Okoboji to the lower lake system varies from zero to 98 percent of the total TN input.

Lower Gar Lake 1999 to 2004 Nutrient Budget

The Lower Gar model results indicate that wet and dry deposition together provide about 2 to 26 percent of the annual input TP while the watershed inputs vary from 22 to 83 percent of the total for this period. TP input from adjacent Lake Minnewashta varies from zero to 42 percent of the total input. Most years show significant TP flux from the lakebed sediment to the water column. However, in 2001, which was the wettest year during 1999 to 2004, shows a significant net flux of TP from the water column to the sediment. During years when a significant amount of water overtops the spillway, most of the TP input to the lake is exported downstream to Milford Creek.

The Lower Gar results indicate that wet and dry deposition together provide about one to nine percent of the annual TN input while the watershed inputs vary from about 28 to 53 percent of the total input for this time period. TN input from adjacent lakes varies from zero to 47 percent of the total input. The model indicates that TN flux from the lake sediment to the water column varies considerably from zero to over 50 percent of the total input TN. During 2001, the wettest year of the period, shows a significant net flux of TP from the sediment to the water column. Annual net export from Lower Gar to Milford Creek varies from zero to 100 percent of total input.

Nutrient Budget Summary

Lake nutrient budgets indicated that rainfall and dry deposition are major sources of total phosphorous (TP) and total nitrogen (TN) to West Okoboji Lake and East Lake Okoboji Lake, but contribute only a minor amount of the nutrients to Lower Gar Lake. Surface water runoff contributes a substantial proportion of nutrients to all of the lakes, but there is considerable annual variability in contribution from runoff depending on the amount of precipitation between dry and wet years. Lake to lake flow is a significant factor in the movement of nutrients between lakes, and sediment flux a significant factor in the movement of nutrients within individual lakes, but both demonstrate considerable variability from year to year in the amount and direction of net nutrient flow.

Generally, West Okoboji and East Okoboji sediment appear to be a net TP and TN sink, while Lower Gar sediment appears to be a source of nutrients to the water column; however, these results were based on a dry six-year time period. Sufficient nutrient concentration data to assess the role of sediment as a nutrient source or sink during wetter years is not available from this study.

Potential sources of error for the nutrient budget include:

Lake water samples collected only seven times during 2004 between June and September for nutrient analyses are used to characterize the lake nutrient mass and temporal variability in lake mass for the entire year. Lake TP concentration data collected by Bachmann and Jones (1974) indicate that systematic concentration shifts may occur during the course of a year with lower TP concentrations during the spring, and that variation within and between years may be significant. Data collection throughout the year, particularly for late fall, winter, and early spring, is generally lacking in IGL studies available for this work.

It is not clear how well equations developed based on flow-weighted TN as a function of percent cropland and TP concentration as a function of discharge coupled with estimated surface runoff from Ocheyedan water yield can be expected to approximate actual nutrient concentration inputs. However, data are insufficient estimate total inputs so some type of approximation is necessary.

There is a significant year-to-year variability in the annual nutrient budgets that may not accounted for in this study. This may be especially true for relatively wet years such as the 1992 to 1995 period. The relatively dry years examined in this study may not adequately reflect the nutrient budget for wetter years.

SUMMARY

Based on data collected by Hickock and Associates from 1971-1972, total phosphorous was found to be the critical element in the IGL systems. There was a linear relationship between TP inputs and algal levels, so that a halving of the TP input to a given lake might be expected to reduce the algal population by one-half. There is a lower limit to this relationship for if all inputs were removed; there would still be phosphorous recycled from the sediments.

High amounts of surface runoff correlated to the highest phosphorous concentration in the streams, the greatest input of phosphorous to the lakes, and the highest levels of summer algal blooms in the lakes. The number of animal units in a watershed had a significant correlation with the amount of phosphorous delivered by that watershed, indicating that livestock were a significant source of phosphorous to the IGL in 1971-1972.

The results for nitrate-N concentrations were less clear-cut. There was a significant negative correlation for the percent of watersheds in marshlands and a positive correlation for animal units. However, when the two factors were combined in a multiple regression analysis, no significant correlation was found for animal units. An earlier analysis of 1971 data produced a significant relationship between nitrate-N and percent of watersheds in row crops and a negative relationship with percentage of watersheds in marshland. No significant relationship was found between ammonia-N and any of the watershed land uses.

Data collected by Stenback, Crumpton, and van der Valk from 1999-2004 indicated that while small lake elevation differences produce alternating flow direction between lakes, there is a net long-term flow of water from the upper to lower Iowa Great Lakes, with significant annual variability between wet and dry years. (Quantification of Nutrient Inputs into the Iowa Great Lakes, 2005)

During dry periods, nutrients from the smaller, shallower and more nutrient-rich Lower Gar, Minnewashta, and Upper Gar Lakes may flow up lake into East Okoboji Lake. In addition, during the dry periods East Okoboji Lake may exchange water with West Okoboji Lake. Because East Okoboji has greater TP and TN concentrations, it can be a significant source of nutrients to West Okoboji during periods of up lake water flow.

Rainfall and dry deposition are major sources of TP and TN to West Okoboji Lake and East Lake Okoboji Lake, but contribute only a minor amount of the nutrients to Lower Gar Lake. Surface water runoff contributes a substantial proportion of nutrients to all of the lakes. Lake to lake flow is a significant factor in the movement of nutrients between lakes, and sediment flux a significant factor in the movement of nutrients within individual lakes.

Generally, West Okoboji and East Okoboji sediment appear to be a net TP and TN sink, while Lower Gar sediment appears to be a source of nutrients to the water column; however, these results were based on a dry six-year time period. Sufficient nutrient concentration data to assess the role of sediment as a nutrient source or sink during wetter years is not available from this study.

The CLAMP data collected from 1999 to present indicates that West Okoboji and Big Spirit Lakes are the least productive of the IGL. West Okoboji is in the *mesotrophic* category. Most of the other lakes are in the *eutrophic* category. Little Spirit Lake and Silver Lake have the highest TSI scores, which indicate they are the most productive and are considered *hypereutrophic*.

The data show that nitrate concentrations are highest in the spring and early summer months before declining in the summer. This time coincides with spring applications of fertilizers as well as high amounts of rain. The data also show that water clarity is greatest in the spring before water temperatures increase and algal populations increase. Secchi depths are generally deepest in June and shallowest in August and September for the lakes. In general, East Okoboji, West Okoboji, Big Spirit, and Lower Gar have small decreasing Secchi depth trends, based on visual assessment, while Secchi depths in Upper Gar and Minnewashta have not changed over time.

The IDNR ambient lake-monitoring program differs from the CLAMP program in that the samples were collected and analyzed by professionals from 2000 to 2007. The ambient monitoring program characterizes current water quality in the monitored lakes and provides an opportunity to track trends in lake water quality. Some of the main factors are summarized below.

Stratification

Data collected through the ambient lake monitoring program indicated that West Okoboji is the only lake in the Iowa Great Lakes that stratifies regularly. The other lakes are too shallow and are susceptible to mixing by the windy conditions in that area of the state. One potential consequence of thermal stratification is anoxia (or low oxygen conditions) in the hypolimnion (the deep cold-water area) due to respiration. Hypolimnetic anoxia can lead to release of phosphorous from the sediment that can lead to algae blooms.

Turbidity

In general, the lakes in the Iowa Great Lakes region have lower turbidities and concentrations of total suspended solids (TSS) than other natural lakes in the state with the exception of Little Spirit, Lower Gar and Upper Gar Lakes.

Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO.
Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macro invertebrates. Sources of turbidity include soil erosion, waste discharge, urban runoff, eroding stream banks, large numbers of bottom feeders (such as carp), which stir up bottom sediments, and excessive algal growth.

Total Organic Carbon (TOC)
Little Spirit and Center Lakes have relatively high levels of TOC, above the 75th percentile for all monitored, natural lakes. All other lakes in the Iowa Great Lakes fall below the 25th percentile for all monitored natural lakes.

Total organic carbon (TOC) is the sum of all organic carbon from decaying organic material, bacterial growth, metabolic activities of living organisms, and chemicals. Detergents, pesticides, fertilizers, herbicides, industrial chemicals, and chlorinated organics are synthetic sources of organic carbon. Levels of TOC can be used as a measure of organic contamination.

Conductivity
Center (571 µS/cm) Lake has the highest median specific conductance among the Iowa Great Lakes, which was above the 75th percentile for all monitored, natural lakes. Big Spirit (480 µS/cm) and West Okoboji (466 µS/cm) had the lowest median specific conductance among the Iowa Great Lakes.

Conductivity is useful as a general measure of stream water quality. Significant changes in conductivity can be used as an indicator that a discharge or some other source of pollution has entered a stream. Studies of inland fresh waters indicate that waters supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

Soluble Reactive Phosphorous (SRP)
Little Spirit (0.09 mg/L) and East Okoboji (0.04 mg/L) have relatively high SRP levels when compared to other monitored, natural lakes in Iowa (greater than the 75th percentile).
Soluble reactive phosphorous is the form of total phosphorous that is available for immediate uptake by algae. In phosphorous-limited situations, this form should be low to undetectable, as is the case in Big Spirit (0.003 mg/L) and West Okoboji (0.003 mg/L). As SRP increases, it implies that phosphorous is either not needed by algae or it is being supplied at a rate that is faster than the rate of biologic uptake. Ideally, soluble reactive phosphorous concentrations should be .01 mg/L or less at spring turnover to prevent summer algae blooms. Total phosphorous is considered a better indicator of a lake's nutrient status because its levels remain more stable than soluble reactive phosphorous. Total phosphorous includes soluble phosphorous and the phosphorous in plant and animal fragments suspended in lake water.
Total Kjeldahl Nitrogen (TKN)
Little Spirit (2.6 mg/L) and Center (2.0 mg/L) have TKN concentrations above the median for other monitored, natural lakes in Iowa (1.7 mg/L). Little Spirit, Minnewashta, Center, and Lower Gar have the highest median ammonia concentrations, while Big Spirit and West Okoboji have the lowest.

Total Kjeldahl nitrogen is the sum of organic nitrogen and ammonia in water. High concentrations of TKN in a water body are generally from organic pollution, such as sewage or manure discharges. Ammonia is also commonly used as an agricultural fertilizer. Ammonia can be toxic to fish and invertebrate populations when at high levels.

Phytoplankton

Most phytoplankton samples were dominated by Cyanobacteria, which often dominate summer plankton in eutrophic lakes. The median phytoplankton wet mass ranged from 9.1 mg/L in West Okoboji to 36.0 mg/L in Upper Gar. All lakes in the Iowa Great Lakes had a lower median concentration than the median for all monitored, natural lakes in Iowa (39.7 mg/L).

Phytoplankton or algae are the photosynthetic organisms that form the base of the food chain in lakes. Phytoplankton wet mass and composition are measured to get a better understanding of the biological dynamics of each lake.

Zooplankton

The median zooplankton wet mass ranged from 94.1 mg/L in West Okoboji to 288.5 mg/L in Lower Gar. Zooplankton is the microscopic and macroscopic animals that float, drift, or swim weakly in the water column. Zooplankton is the primary consumers of algae and many fish rely on them as a food source.

Load Allocations

Using the above data for West Okoboji Lake, East Okoboji Lake, and Lower Gar Lake, and approved TMDL's for Little Spirit Lake and Upper Gar Lake we can approximate a load estimate for Big Spirit Lake, Center Lake, and Lake Minnewashta. These load allocations can then be used to determine reductions in phosphorous loads.

Total P inputs to the state are estimated to be about 240,000 tons, or about 13 pounds per acre. Outputs are estimated to be about 270,000 tons. Input-output balances for individual watersheds are more variable for P than for N. Ag-related inputs from manure and fertilizer account for the majority of the P sources in Iowa, while crop harvest and grazing account for the majority of the outputs.

Stream outputs of P for the state were about 11,000 tons per year during the 2000-2002 period. As the 2000-2002 period was relatively dry, greater stream-P outputs likely occur in many years. As much P is 16 transported with sediment during infrequent runoff events, monthly monitoring for P likely results in an underestimation of total P losses in stream flow. The current estimate is equivalent to 0.7 pounds per acre.
For individual watersheds, the outputs ranged from 0.2 to 3.2 pounds per acre. (DNR, 2004)

West Okoboji Lake			
TP SOURCE (LAND USES AND OTHER INPUTS)	DESCRIPTIONS AND ASSUMPTIONS	EXISTING LOAD (LBS /YR)	TP LOAD (%)
ROW CROP	corn, beans, alfalfa	1,161	16%
WATER (LAKES)/INTERNAL	recycled from lake bottom and East Lake	2,836	39%
URBAN/RESIDENTIAL	residential land use	428	6%
PASTURE	animal pasture	31	0%
NATURAL AREAS	grassland, wetland, forested	379	5%
ROADWAYS	public and private owned roadways	122	2%
FARMSTEADS	farmsteads	1	0%
GOLF COURSES	golf courses	61	1%
STREAMS OR WATERWAYS	streams	0	0%
SALVAGE YARD, LANDFILL, QUARRY	salvage/landfills	1	0%
ANIMAL FEEDING OPERATION	feedlots, confinements	0	0%
ATMOSPHERIC	atmospheric deposition (rain)	1,601	22%
DRY DEPOSITION	dry deposition	655	9%
TOTAL		7,275	100%

East Okoboji Lake			
TP SOURCE (LAND USES AND OTHER INPUTS)	DESCRIPTIONS AND ASSUMPTIONS	EXISTING LOAD (LBS /YR)	TP LOAD (%)
ROW CROP	corn, beans, alfalfa	15,590	34%
WATER (LAKES)/INTERNAL	recycled from lake bottom	3,208	7%
URBAN/RESIDENTIAL	residential land use	3,428	7%
PASTURE	animal pasture	1,006	2%
NATURAL AREAS	grassland, wetland, forested	4,215	9%
ROADWAYS	public and private owned roadways	1,204	3%
FARMSTEADS	farmsteads	302	1%
GOLF COURSES	golf courses	1,602	3%
STREAMS OR WATERWAYS	streams	0	0%
SALVAGE YARD, LANDFILL, QUARRY	salvage/landfills	1	0%
ANIMAL FEEDING OPERATION	feedlots, confinements	1	0%
ATMOSPHERIC	atmospheric deposition (rain)	7,407	16%
DRY DEPOSITION	dry deposition	8,333	18%
TOTAL		46,297	100%

Lower Gar Lake			
TP SOURCE (LAND USES AND OTHER INPUTS)	DESCRIPTIONS AND ASSUMPTIONS	EXISTING LOAD (LBS /YR)	TP LOAD (%)
ROW CROP	corn, beans, alfalfa	1,646	26%
WATER (LAKES)/INTERNAL	recycled from lake bottom/Lake Minne-washta	2,877	45%
URBAN/RESIDENTIAL	residential land use	153	2%
PASTURE	animal pasture	43	1%
NATURAL AREAS	grassland, wetland, forested	1,197	19%
ROADWAYS	public and private owned roadways	119	2%
FARMSTEADS	farmsteads	1	0%
GOLF COURSES	golf courses	66	1%
STREAMS OR WATERWAYS	streams	1	0%
SALVAGE YARD, LANDFILL, QUARRY	salvage/landfills	33	1%
ANIMAL FEEDING OPERATION	feedlots, confinements	1	0%
ATMOSPHERIC	atmospheric deposition (rain)	128	2%
DRY DEPOSITION	dry deposition	128	2%
TOTAL		6,393	100%

Big Spirit Lake Watershed			
TP SOURCE (LAND USES AND OTHER INPUTS)	DESCRIPTIONS AND ASSUMPTIONS	EXISTING LOAD (LBS /YR)	TP LOAD (%)
ROW CROP	corn, beans, alfalfa	0	0%
WATER (LAKES)/INTERNAL	recycled from lake bottom/Lake Minne-washta	0	0%
URBAN/RESIDENTIAL	residential land use	0	0%
PASTURE	animal pasture	0	0%
NATURAL AREAS	grassland, wetland, forested	0	0%
ROADWAYS	public and private owned roadways	0	0%
FARMSTEADS	farmsteads	0	0%
GOLF COURSES	golf courses	0	0%
STREAMS OR WATERWAYS	streams	0	0%
SALVAGE YARD, LANDFILL, QUARRY	salvage/landfills	0	0%
ANIMAL FEEDING OPERATION	feedlots, confinements	0	0%
ATMOSPHERIC	atmospheric deposition (rain)	128	50%
DRY DEPOSITION	dry deposition	128	50%
TOTAL		256	100%

Figure 5.7 Simulated TP source loads for existing conditions

West Okoboji Lake			
TP SOURCE	EXISTING LOAD (LB/YR)	LOAD ALLO-CATION (lb/yr)	LOAD RE-DUCTION (%)
ROW CROP	1,161	750	65%
WATER (LAKES)/INTERNAL	2,836	2,200	78%
URBAN/RESIDENTIAL	428	325	76%
PASTURE	31	20	65%
NATURAL AREAS	379	150	40%
ROADWAYS	122	50	41%
FARMSTEADS	1		0%
GOLF COURSES	61	30	49%
STREAMS OR WATERWAYS	1		0%
SALVAGE YARD, LANDFILL, QUARRY	1		0%
ANIMAL FEEDING OPERATION	1		0%
ATMOSPHERIC	1,601		0%
DRY DEPOSITION	655		0%
TOTAL	7,277	3,525	48%

East Okoboji Lake			
TP SOURCE	EXISTING LOAD (LB/YR)	LOAD ALLO-CATION (lb/yr)	LOAD RE-DUCTION (%)
ROW CROP	15,590	10000	64%
WATER (LAKES)/INTERNAL	3,208	2200	69%
URBAN/RESIDENTIAL	3,428	3000	88%
PASTURE	1,006	700	70%
NATURAL AREAS	4,215	1500	36%
ROADWAYS	1,204	600	50%
FARMSTEADS	302	200	66%
GOLF COURSES	1,602	1300	81%
STREAMS OR WATERWAYS	1		0%
SALVAGE YARD, LANDFILL, QUARRY	1		0%
ANIMAL FEEDING OPERATION	1		0%
ATMOSPHERIC	7,407		0%
DRY DEPOSITION	8,333		0%
TOTAL	46,298	19,500	42%

Lower Gar Lake			
TP SOURCE	EXISTING LOAD (LB/YR)	LOAD ALLO-CATION (lb/yr)	LOAD RE-DUCTION (%)
ROW CROP	1,646	1000	61%
WATER (LAKES)/INTERNAL	2,877	2200	76%
URBAN/RESIDENTIAL	153	100	65%
PASTURE	43	20	47%
NATURAL AREAS	1,197	500	42%
ROADWAYS	119	80	67%
FARMSTEADS	1	0	0%
GOLF COURSES	66	33	50%
STREAMS OR WATERWAYS	1		0%
SALVAGE YARD, LANDFILL, QUARRY	33		0%
ANIMAL FEEDING OPERATION	1		0%
ATMOSPHERIC	128		0%
DRY DEPOSITION	128		0%
TOTAL	6,393	3,933	62%

Big Spirit Lake			
TP SOURCE	EXISTING LOAD (LB/YR)	LOAD ALLO-CATION (lb/yr)	LOAD RE-DUCTION (%)
ROW CROP	1	1	100%
WATER (LAKES)/INTERNAL	1	1	100%
URBAN/RESIDENTIAL	1	1	100%
PASTURE	1	1	100%
NATURAL AREAS	1	1	100%
ROADWAYS	1	1	100%
FARMSTEADS	1	1	100%
GOLF COURSES	1	1	100%
STREAMS OR WATERWAYS	1		0%
SALVAGE YARD, LANDFILL, QUARRY	1		0%
ANIMAL FEEDING OPERATION	1		0%
ATMOSPHERIC	7,500		0%
DRY DEPOSITION	8,500		0%
TOTAL	16,011	8	0%

Center Lake			
TP SOURCE	EXISTING LOAD (LB/YR)	LOAD ALLOCATION (lb/yr)	LOAD REDUCTION (%)
ROW CROP	153	75	49%
WATER (LAKES)/INTERNAL	2,500	2200	88%
URBAN/RESIDENTIAL	1,500	800	53%
PASTURE	1	0	0%
NATURAL AREAS	350	250	71%
ROADWAYS	55	35	64%
FARMSTEADS	1	0	0%
GOLF COURSES	1	0	0%
STREAMS OR WATERWAYS	32		0%
SALVAGE YARD, LANDFILL, QUARRY	1		0%
ANIMAL FEEDING OPERATION	1		0%
ATMOSPHERIC	128		0%
DRY DEPOSITION	128		0%
TOTAL	4,851	3,360	69%

6 POLLUTANT SOURCES

The sources of pollution for the Iowa Great Lakes varies from lake to lake only in the percentage of pollutant comes from specific sources. There are two major sources of pollution for the Iowa Great Lakes and they are agriculture based and urban based pollutants. The pollutant loading for Big Spirit Lake, for instance is mostly due to agricultural sources but the pollutant load for Center Lake is nearly from all urban sources. In order to properly identify the pollutant sources each lake or group of lakes will be discussed individually.

The primary pollutant in the Iowa Great Lakes is phosphorous but is also closely tied to sediment delivery. Since agriculture has the greatest amount of area in the Iowa Great Lakes it is considered the greatest threat to water quality in the Iowa Great Lakes. However, even though urban areas are relatively small in comparison, these areas produce an exceedingly large amount of sediment and phosphorous that is delivered almost directly to the lake adjacent to it. Urban pollution should be considered equally important to agriculture pollution because of this.

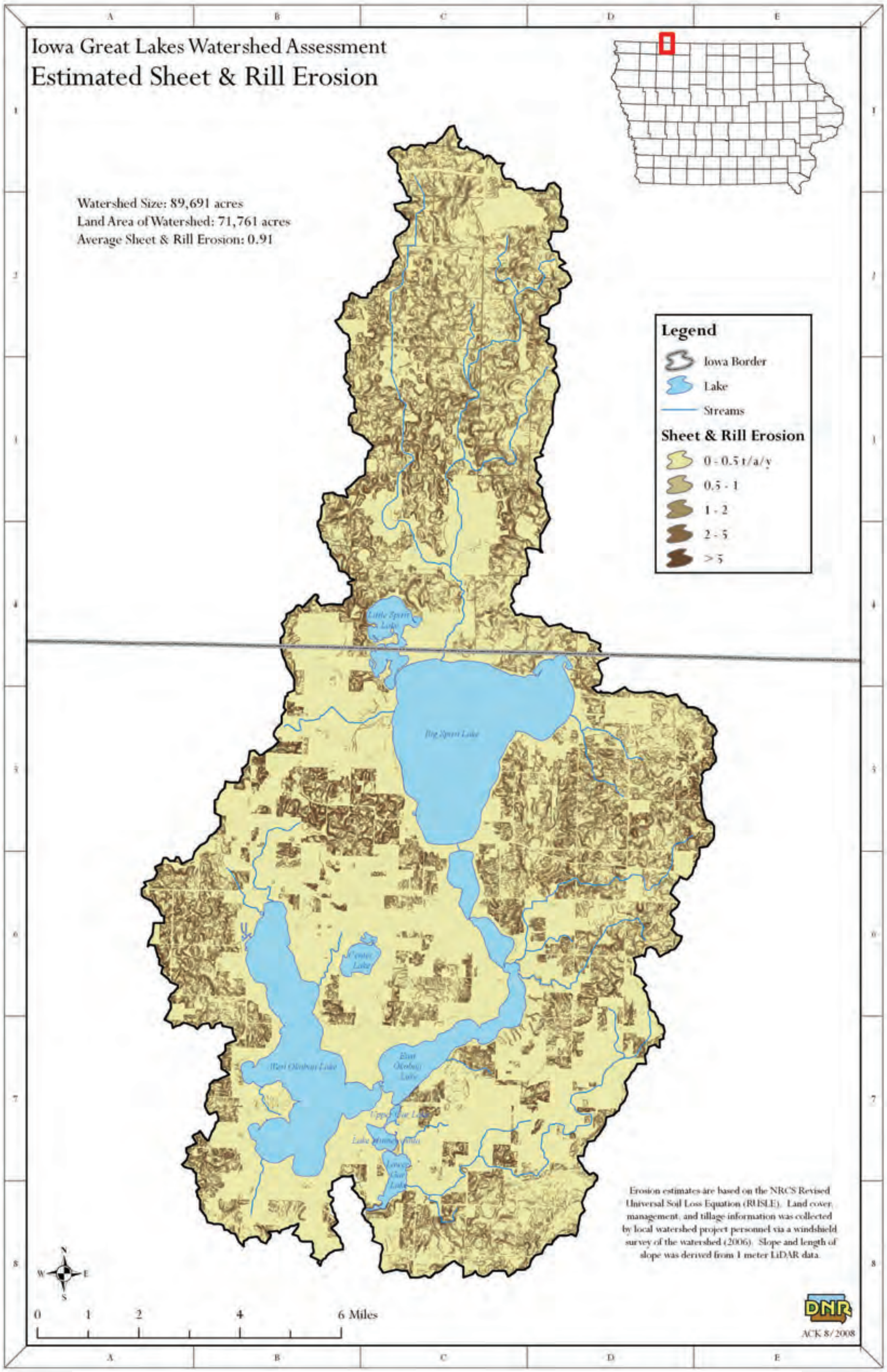


Figure 6.1 Estimated Sheet and Rill Erosion for the Iowa Great Lakes

6.1 ASSESSMENT

> "To waste, to destroy, our natural resources, to skin and exhaust the land instead of using it so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them."
>
> *— Theodore Roosevelt*

LAND COVER

As part of a proper assessment, the land cover data is utilized heavily. The results of the 2006 land survey can be found in Chapter 4.3 starting on page 25 of this Management Plan.

SHEET AND RILL EROSION

Throughout this assessment, many maps and graphics will be used to reinforce and support the data given. These maps were created using LiDAR (Light Detection and Ranging) data and GIS. The quality of this data is unmatched for this type of work and the Iowa Great Lakes watershed will prove to benefit from this work. Dickinson County and the Iowa Great Lakes is host to one of the state's unique environments. Agriculture is one of the primary economic engines in the county. The Iowa Great Lakes watershed is in the prairie pothole region of Iowa and Minnesota. The Clarion-Nicollet, Nicollet-Clarion, and Canisteo-Nicollet-Okoboji associations comprise approximately 80% of the soil types in the watershed. These soils are level to strongly sloping, somewhat poorly drained to very poorly drained. These soils are loamy and silty soils formed in the glacial till uplands. The low impounded areas are commonly referred to as potholes. These potholes require drainage before they can be productive for row crops. Most of these soils have been drained and are in intensive row crops. The primary crops are corn and soybeans. This crop rotation of corn and soybeans is a standard in Iowa and has been shown to be profitable to the landowner/operator.

There are approximately 44,328 acres of cropland in the watershed. As in the rest of the state, the number of farms in the watershed continues to decline at a steady pace. Farming operations continue to grow larger which in turn lead to intense row crop production. The Natural Resources Conservation Service (NRCS) and the Dickinson and Jackson, MN Soil and Water Conservation Districts have done a great amount of planning and applying conservation practices and land retirement programs in the watershed. Farm programs such as Conservation Reserve Program (CRP), Environment Quality Incentive Program (EQIP), Wetlands Reserve Program (WRP) and several state and local cost share programs have been very popular with landowners to assist them in controlling soil erosion. The farmers in the Iowa Great Lakes watershed have accepted conservation tillage and to a limited extent, no-till. These farmers tend to move away from these practices, when conditions do not seem to favor a dry year. Dickinson County is fortunate to have some of the most nutrient rich black topsoil in the state, therefore keeping land values higher than statewide averages.

Most farmers use some type of conservation tillage system in their crop rotation. The majority of the watershed is not highly erodible which allows farmers to use as much tillage as they deem suitable. Unfortunately, with the high commodity and land prices, land retirement programs are becoming less popular to landowners in the watershed. There is approximately 5% of the watershed enrolled in the CRP Program. The contracts are due to retire and it is doubtful that many of these acres will be reenrolled in CRP if the trends in high commodity and land prices continue.

In discussing Sheet and Rill Erosion we will examine each sub-watershed of the Iowa Great Lakes independently because the watershed as a whole will not give us as much detail as the individual watersheds can show us on maps and independent study. The watersheds of the Iowa Great Lakes have been separated into six separate watersheds and they are: Loon Lake, Big Spirit Lake, West Okoboji Lake, Center Lake, East Okoboji, and the Gar Chain Watershed.

Loon Lake Sub Watershed

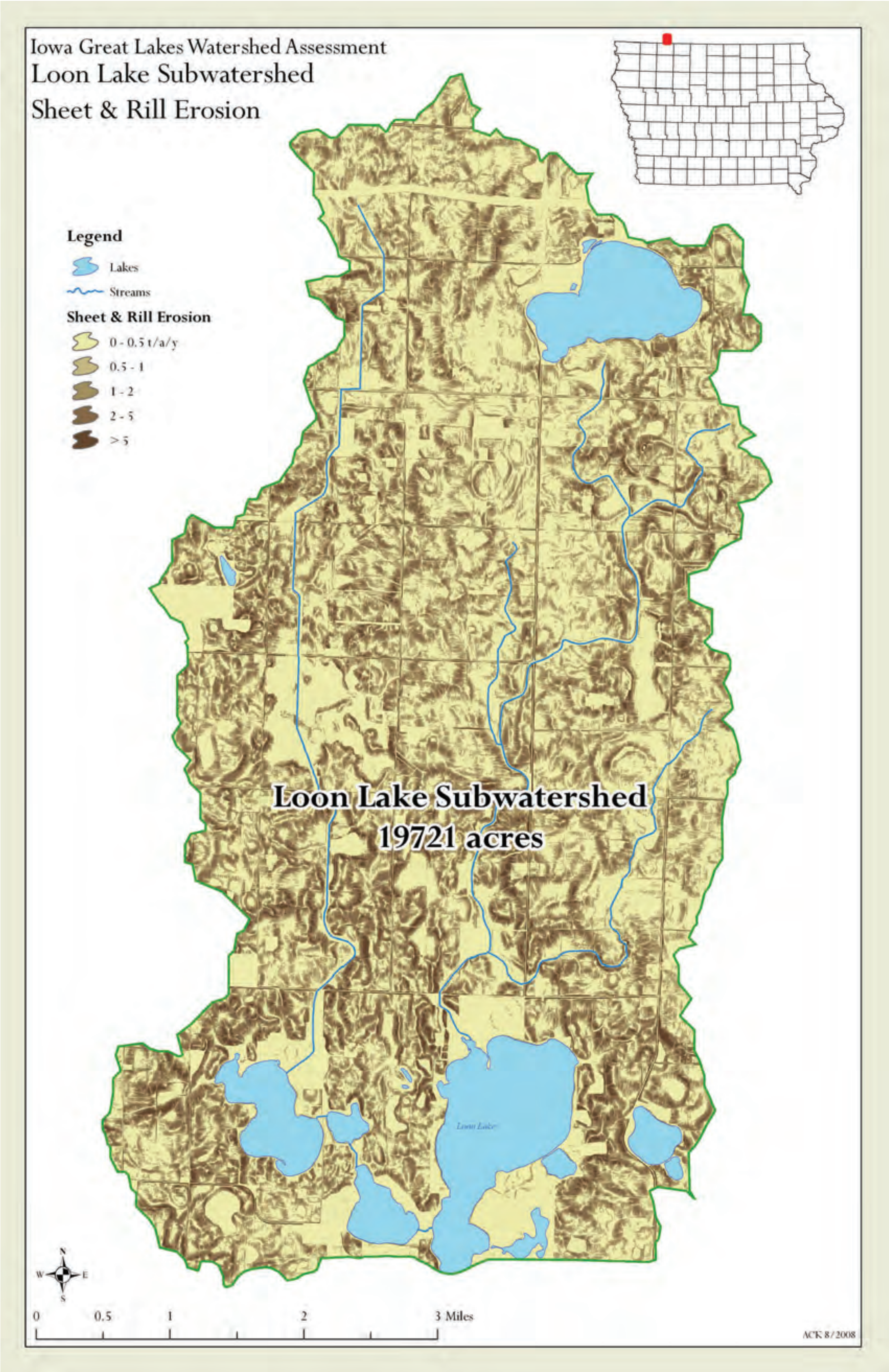


Figure 6.2: Loon Lake Sheet and Rill Erosion. Courtesy of Iowa DNR

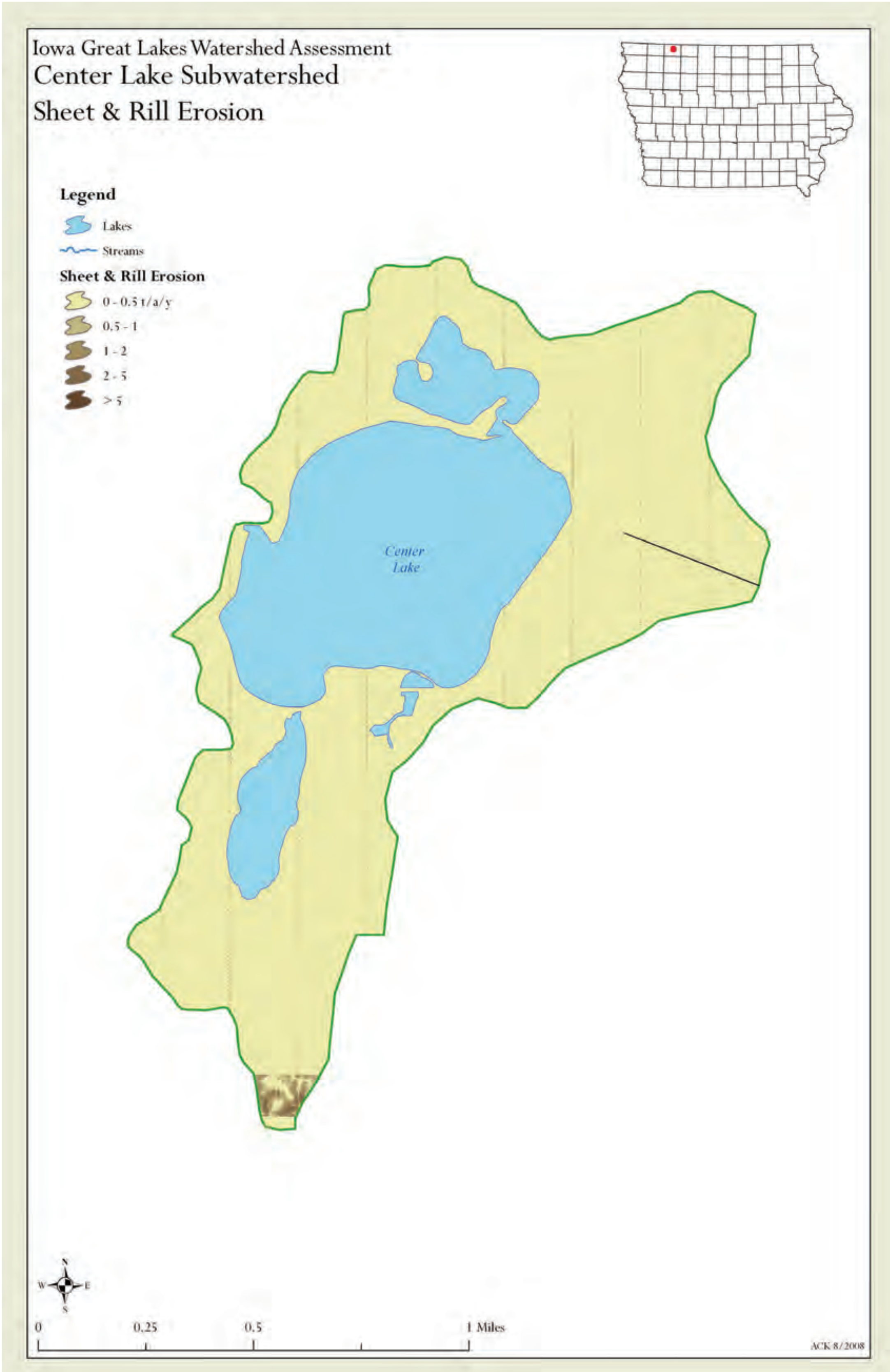
Big Spirit Lake Sub watershed

Figure 6.3 Big Spirit Lake Sheet and Rill Erosion. Courtesy of Iowa DNR.

East Okoboji Lake Sub watershed

Figure 6.4 East Okoboji Sheet and Rill Erosion**.** Courtesy of Iowa DNR

Center Lake Sub Watershed



[**Figure 6.5** Center Lake Sheet and Rill Erosion. Courtesy of Iowa DNR].

West Okoboji Lake Sub Watershed

Figure 6.6 West Okoboji Sheet and Rill Erosion. Courtesy of Iowa DNR.

Gar Chain Sub Watershed

Figure 6.7 Gar Chain Sheet and Rill Erosion. Courtesy of Iowa DNR.

SEDIMENT DELIVERY

Sediment delivery is defined as the amount of net erosion that is delivered to a specific location, typically the outlet of a watershed. Sediment delivery modeling incorporates the beneficial impacts of watershed improvement practices such as sediment basins or grassed waterways to estimate the amount of sediment reaching the water body of interest.

It has been estimated that an average of 0.91 tons sheet and rill erosion per acre per year of soil occurs in the Iowa Great Lakes watershed using the Revised Universal Soil Loss Equation (RUSLE). Using this model the Iowa Great Lakes Watershed realizes a total average erosion rate of 65,302 tons of sediment per year on the 71,761 land area acres within the watershed.

Each sub watershed shall be investigated separately so more detail may be seen using the mapping provided by the Iowa DNR.

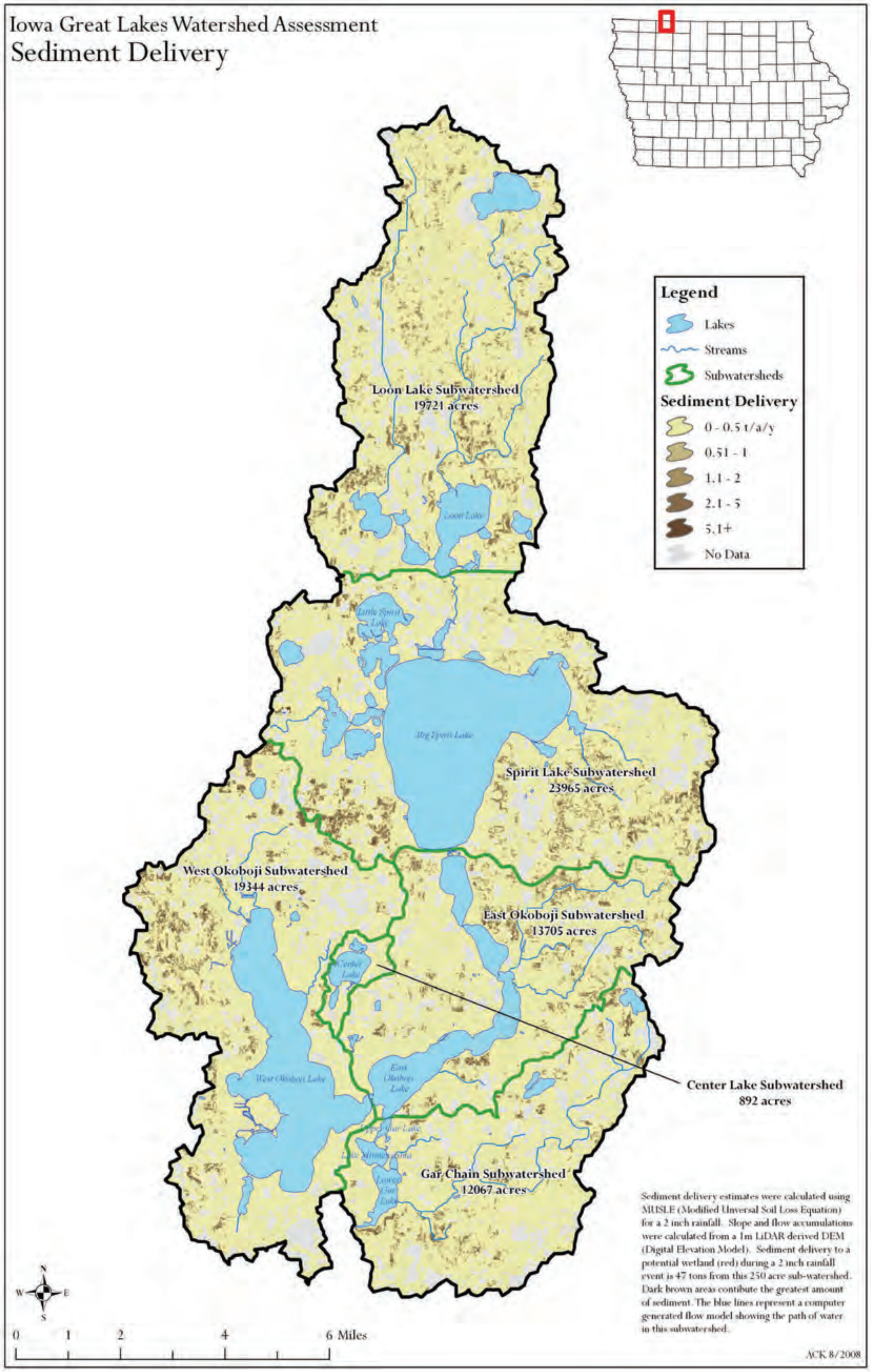


Figure 6.8 Iowa Great Lakes Watershed Sediment Delivery. Courtesy of Iowa DNR.

Loon Lake Sub-Watershed

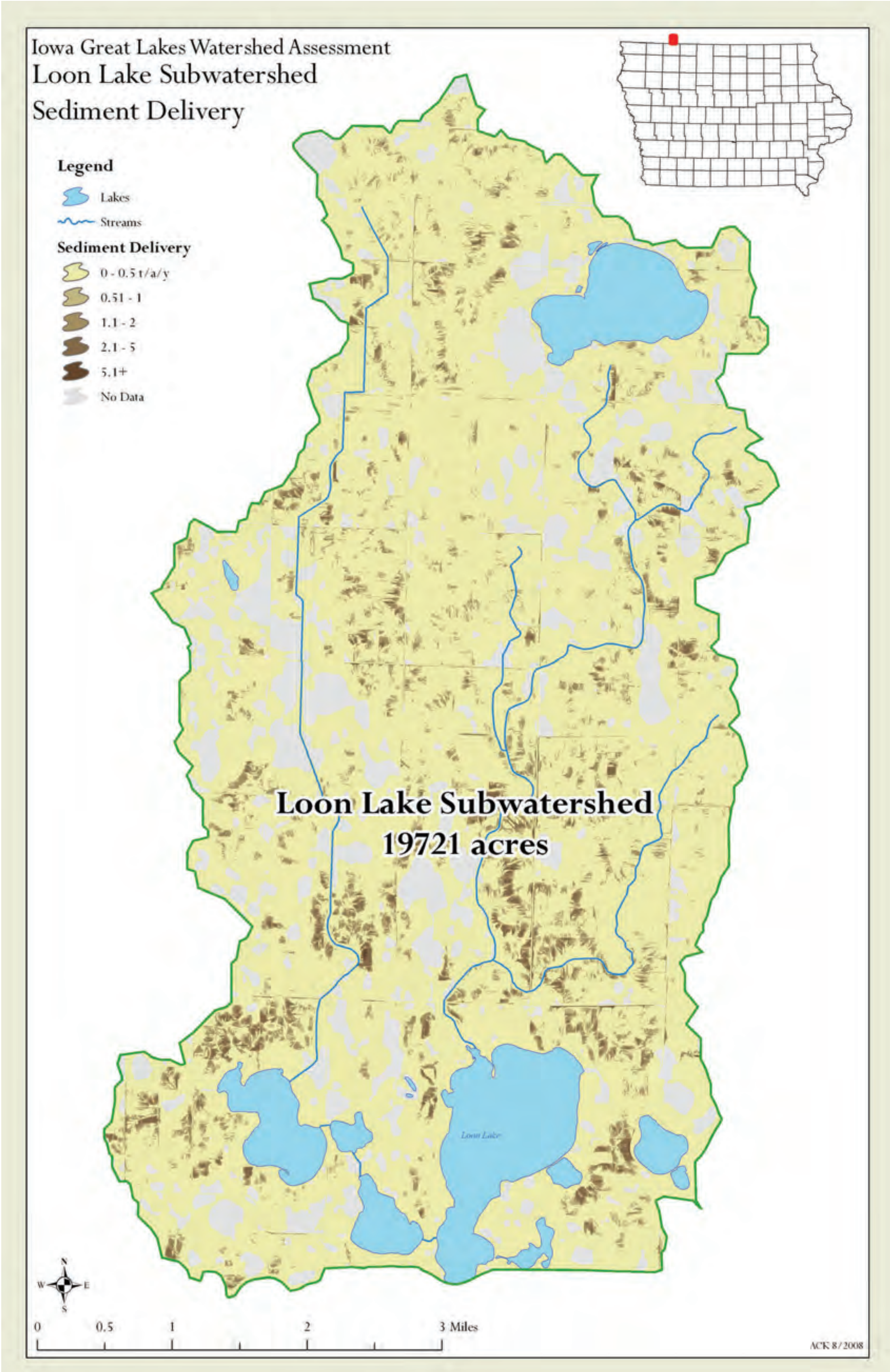


Figure 6.9 Loon Lake Sediment Delivery. Courtesy of Iowa DNR

Big Spirit Lake Sub-Watershed

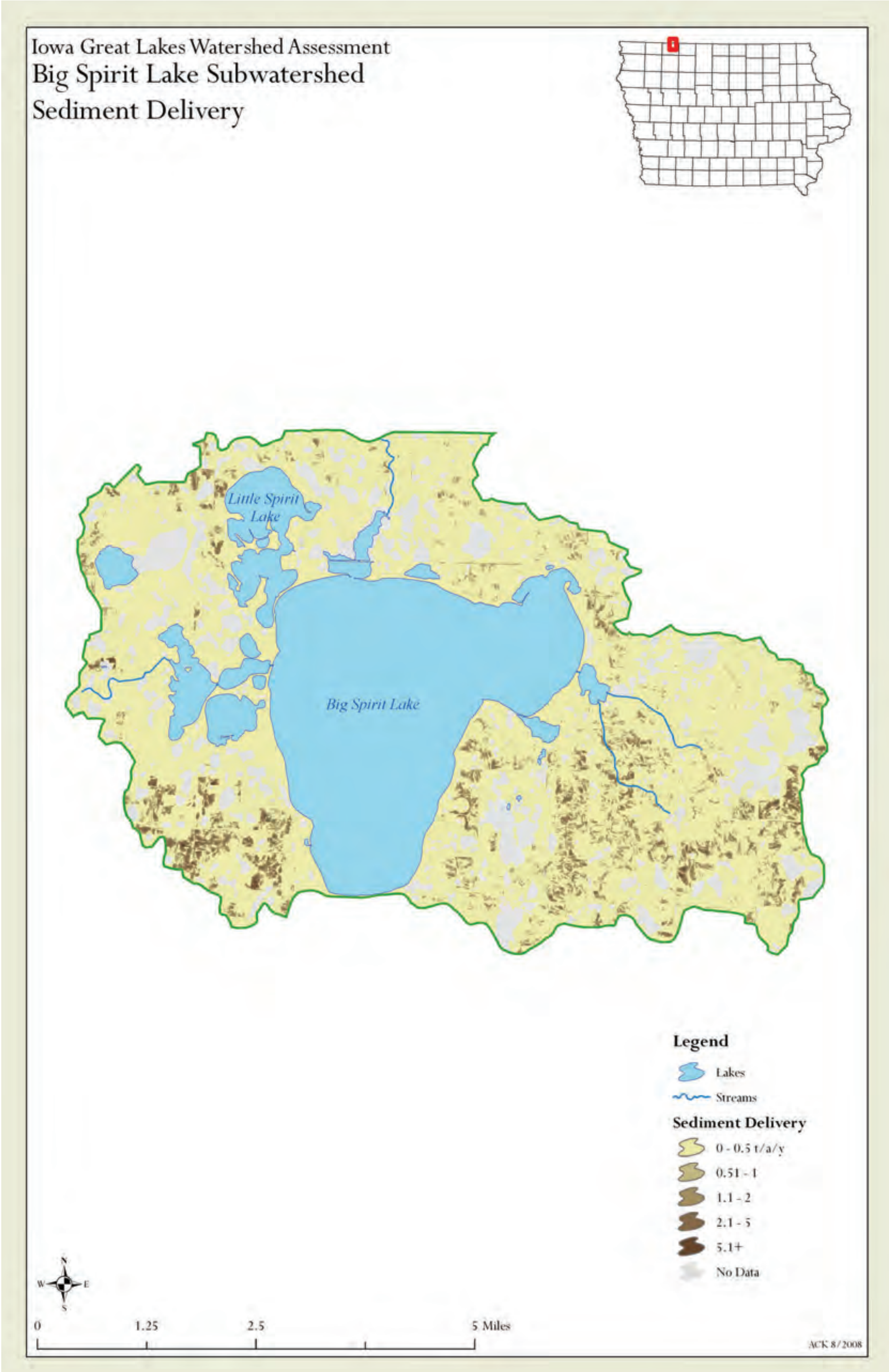


Figure 6.10 Big Spirit Lake Sediment Delivery. Courtesy of Iowa DNR

East Okoboji Lake Sub-Watershed

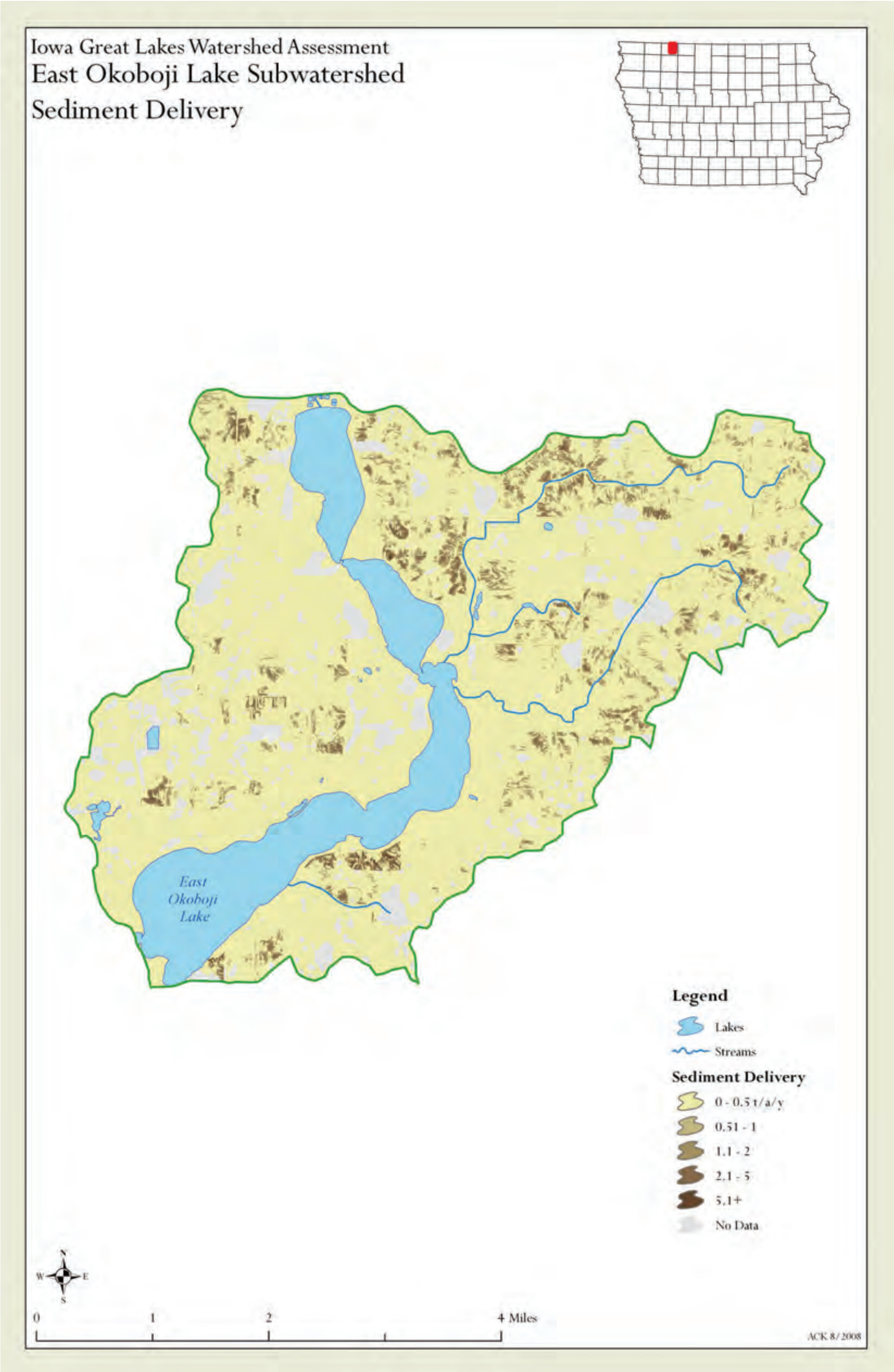
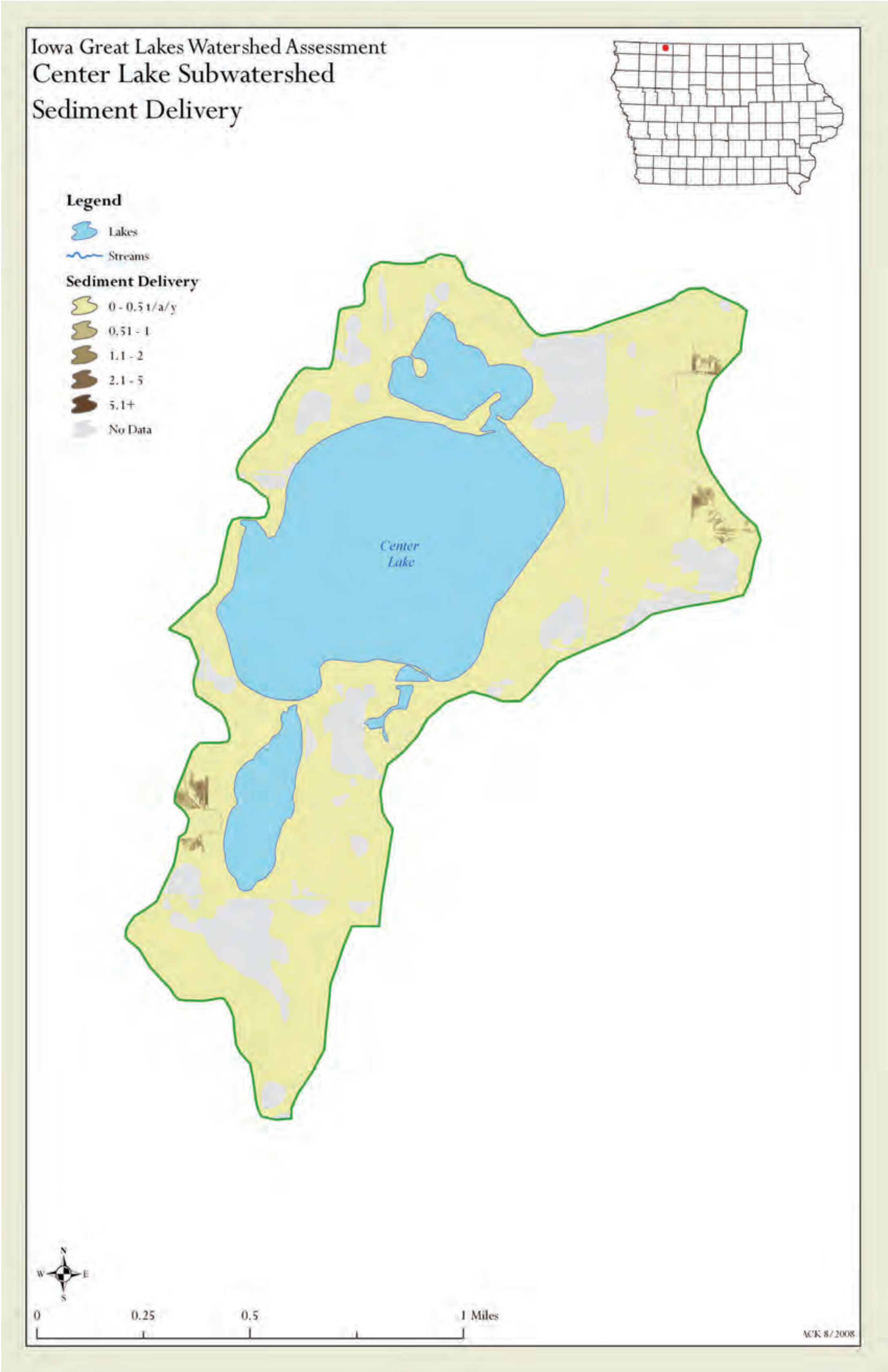


Figure 6.11 East Okoboji Lake Sediment Delivery. Courtesy of Iowa DNR

Center Lake Sub-Watershed



[**Figure 6.12** Center Lake Sediment Delivery. Courtesy of Iowa DNR.]

West Okoboji Lake Sub-Watershed

Figure 6.13 West Okoboji Lake Sediment Delivery. Courtesy of Iowa DNR

Gar Chain Sub-Watershed

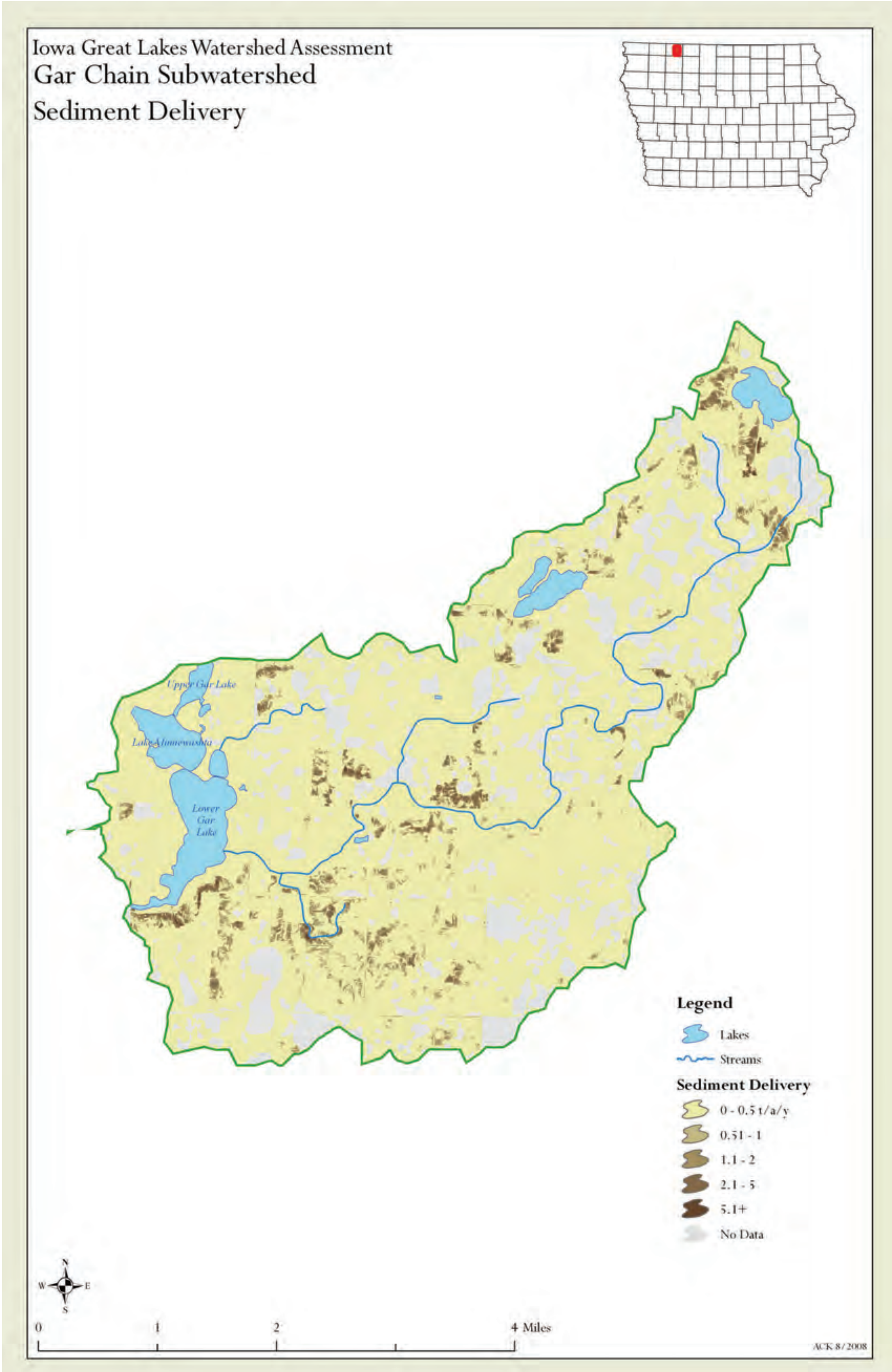


Figure 6.14 Gar Chain Sediment Delivery. Courtesy of Iowa DNR.

Gully Assessment

Problems with gully erosion have occurred in 3 primary locations within the Iowa Great Lakes. These areas are primarily areas with concentrated flow and heavily treed. The deepest of these gullies is 20 plus feet and 30 or more feet across. These gullies will continue to cut back and wider as there is no restriction on them. The areas are identified on the following maps.

FIGURE 6.14 IGL Areas of Gully Formation

FIGURE 6.15 Echo Bay Area of Gully Formation

FIGURE 6.16 Maywood Area of Gully Formation

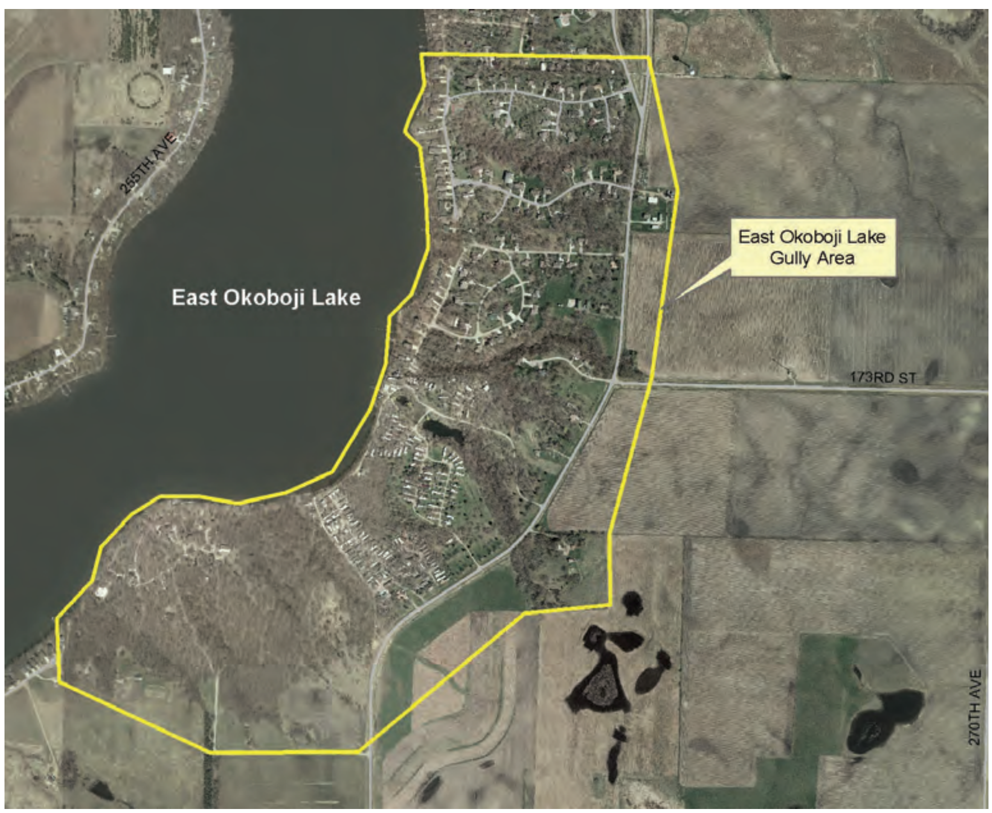


FIGURE 6.17 Camp Foster to Arthur Heights Area of Gully Formation

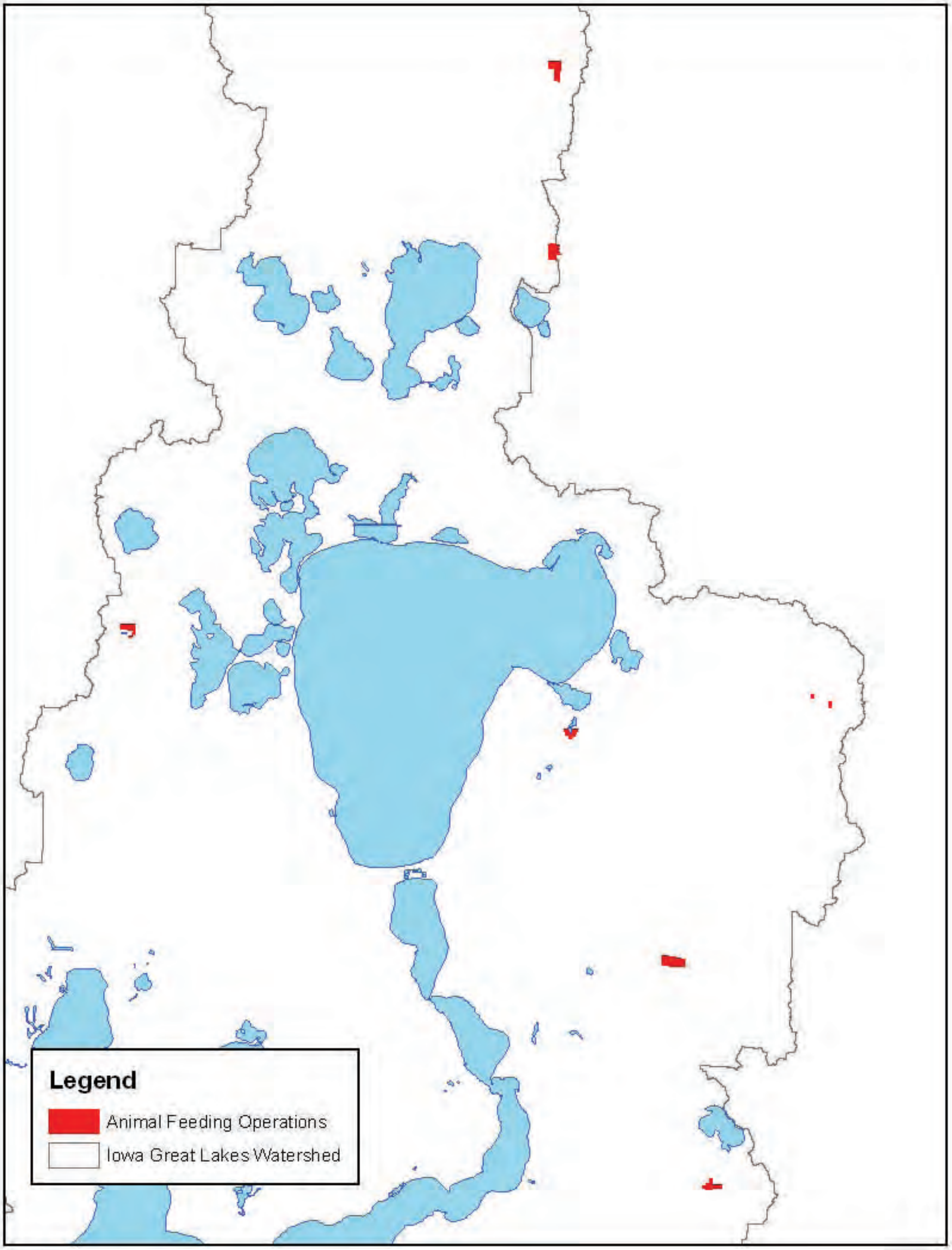


Figure 6.18 Animal Feeding Operations in the Iowa Great Lakes. Courtesy Iowa DNR

URBAN ASSESSMENT

Urban conservation is a new concept to most communities across Iowa but it is a critical part of the state's environmental protection if we are serious about water quality improvement and protection. As areas become urbanized the urbanized areas hydrology changes due to filling of wetlands, compacting of soils, and the creation of impervious surfaces that create high runoff rates.

The Iowa Great Lakes pre-historic hydrology was such that up to 50% of the annual precipitation would have infiltrated and 40% evaporating and used by plants and 10% running off into water bodies. Typically, the 10% runoff that has been estimated on the historic landscapes occurred while the ground was frozen. On the other hand, urbanized landscapes generally have runoff rates of up to 50% of any rainfall event and infiltrate only about 15% with the rest evaporating. The "first flush" of the runoff is the most polluted with petroleum products, fertilizers, pesticides, heavy metals, chloride, and much more. In addition, the volume of water that is entering waterways is generally much more then the aquatic systems can handle due to the amount of pervious surfaces found in urban systems. This greater volume leads to eroded shorelines, de-vegetation of emergent and sub-emergent aquatic plants, and flooding. Heat is also a major issue with storm water from large sources of impervious surfaces. The heated storm water creates small dead zones at the outfalls where no life is usually sustained because of the great temperature fluctuation.

Ordinance and the implementation of those ordinances and Low Impact Development designs in urban developments are of major concern. New developments that are planned should have a better site design, which is based on working with the landscape rather than against it, using the counties soil survey for site design, and maximizing potential green space that will work to clean storm water. In the case of new or existing developments, which are not already connected to the sanitary sewer, steps should be taken to connect to the central sanitary sewer system. Septic systems are known to be large nutrient and bacteria contributors to watersheds.

Annual Runoff Potential has been determined for all urban areas within the Iowa Great Lakes Watershed. Those areas three concentrations have been identified with a greater than 60% runoff potential for these three locations. These three areas are already developed and it has been shown that very little rainwater infiltrates in these locations. Map 8.1 shows the locations very clearly with the highest density being North and East of Center Lake (Polaris area), a second the West side of Spirit Lake (Lakes Mall area), and a third Highway 71 from Arnolds Park to Milford (Hwy 71 area). Figure 6.6 (below) shows the runoff potential of the urban areas in the IGL Watershed and identifies the areas with the 60% runoff potential.

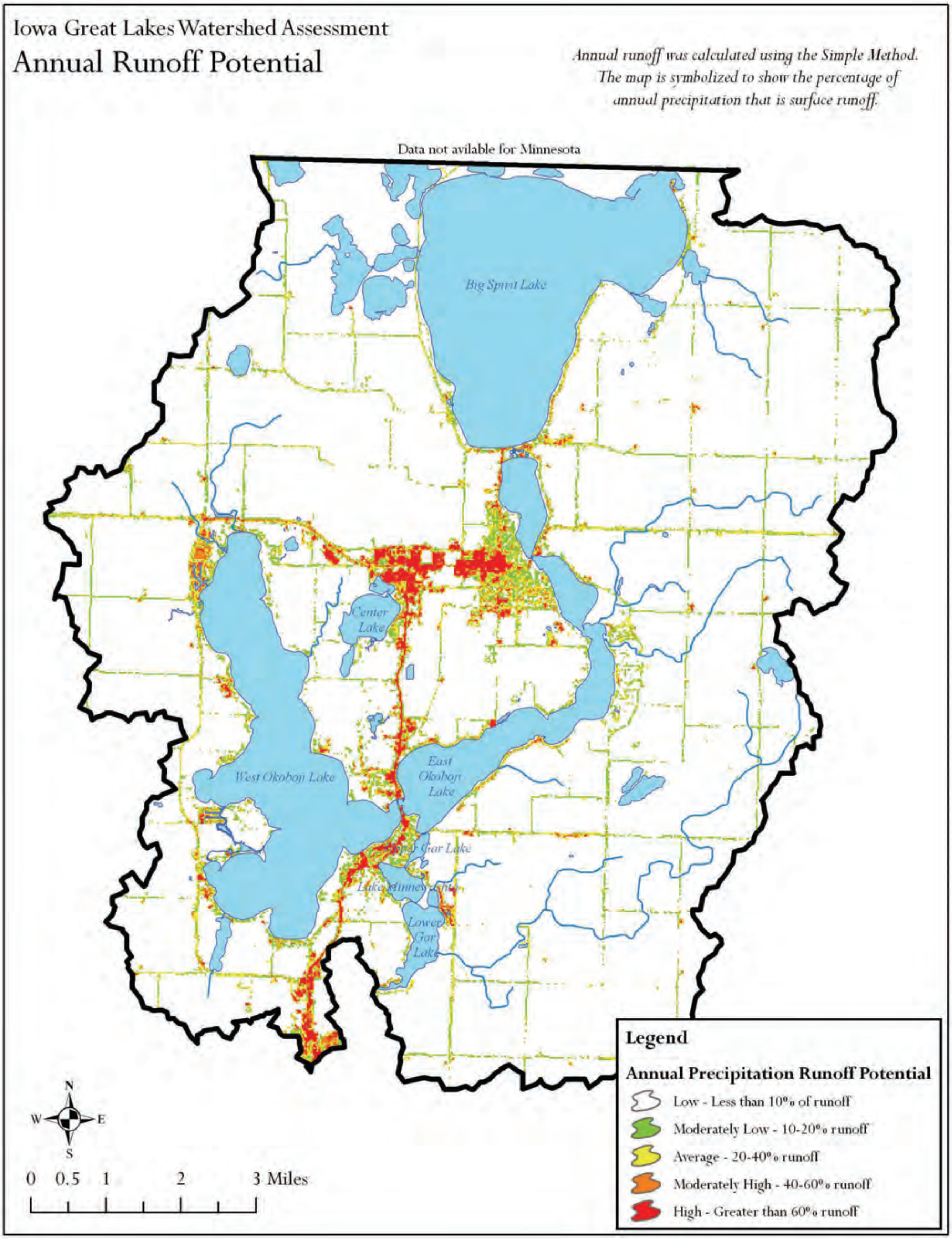


Figure 6.19 Runoff Potential on Urban Areas in the Iowa Great Lakes

Construction Site Erosion

Water quality issues from the urban areas of the watershed are due sedimentation from improperly protected construction sites for erosion and sediment control. Although locally there is a silt fence (sediment control) ordinance in place, enforcement usually occurs on a complaint basis only. Federal rules come into play and can be enforced for construction sites of over an acre in size. These rules are enforced by the Iowa DNR field office in Spencer, but with minimal staff time allowed these regulations are enforced but typically only by complaint basis. Due to the limited enforcement and the lack of subsequent follow up by contractors, developers and engineers erosion and sediment from construction sites is causing water quality violations in the lakes. As found by the EPA in a national study, on average the largest soil loss comes from construction sites.

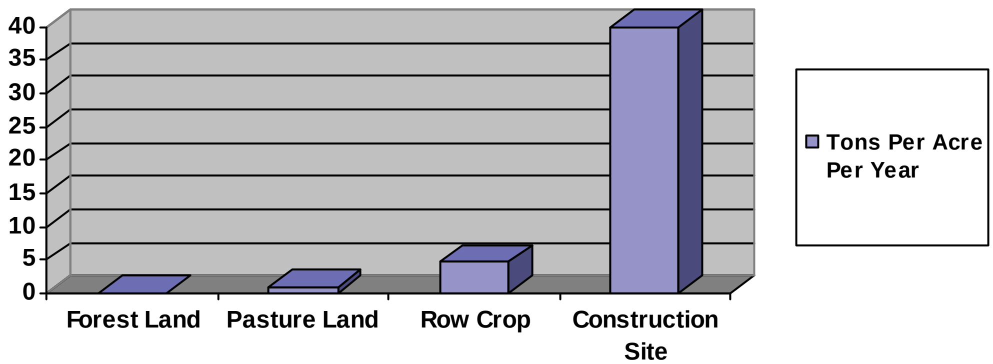


Table 6.1: Construction Site Erosion. Courtesy of EPA January 2007.

This sedimentation from construction sites is leaving the site as sheet and rill erosion, tracking off site and dewatering. This sedimentation is a violation of ordinances and state and federal law but usually occur unchecked and this short fall should be picked up by the local jurisdictions. A compounding problem is the multiple jurisdictions within the watershed and how they enforce or interpret erosion and sediment control regulations.

Sanitary Sewage Management

In the Iowa Great Lakes Watershed, the Iowa Great Lakes Sanitary District (IGLSD) has a very large collection system that covers all the shoreline and the majority of the urbanized areas within the watershed. The Iowa Great Lakes Sanitary District (IGLSD) has over 65 lift stations throughout the watershed. The district has done a good job of preventing untreated sewage from getting into the lakes. The lift stations have back-up generators, alarm systems and phone systems to help prevent discharge to the lakes. There is possible need for public education about all the work that is done by the IGLSD and the preventive measures taken by the to prevent discharge into the lakes. The training should focus on what citizens need to do if they hear or see an alarm going off at one of the lift stations. The sooner a lift station that is not functioning correctly can be identified, the better the chances are that it will not discharge untreated wastewater onto the ground, into the lakes or into a building. Another educational program that is needed is to teach private citizens and businesses what should not be put into the sanitary system. Things like cooking grease can building up in pipes or lift stations and reduce its ability to function properly. Items like petroleum or other volatile products should not be placed in the system due to explosion hazards.

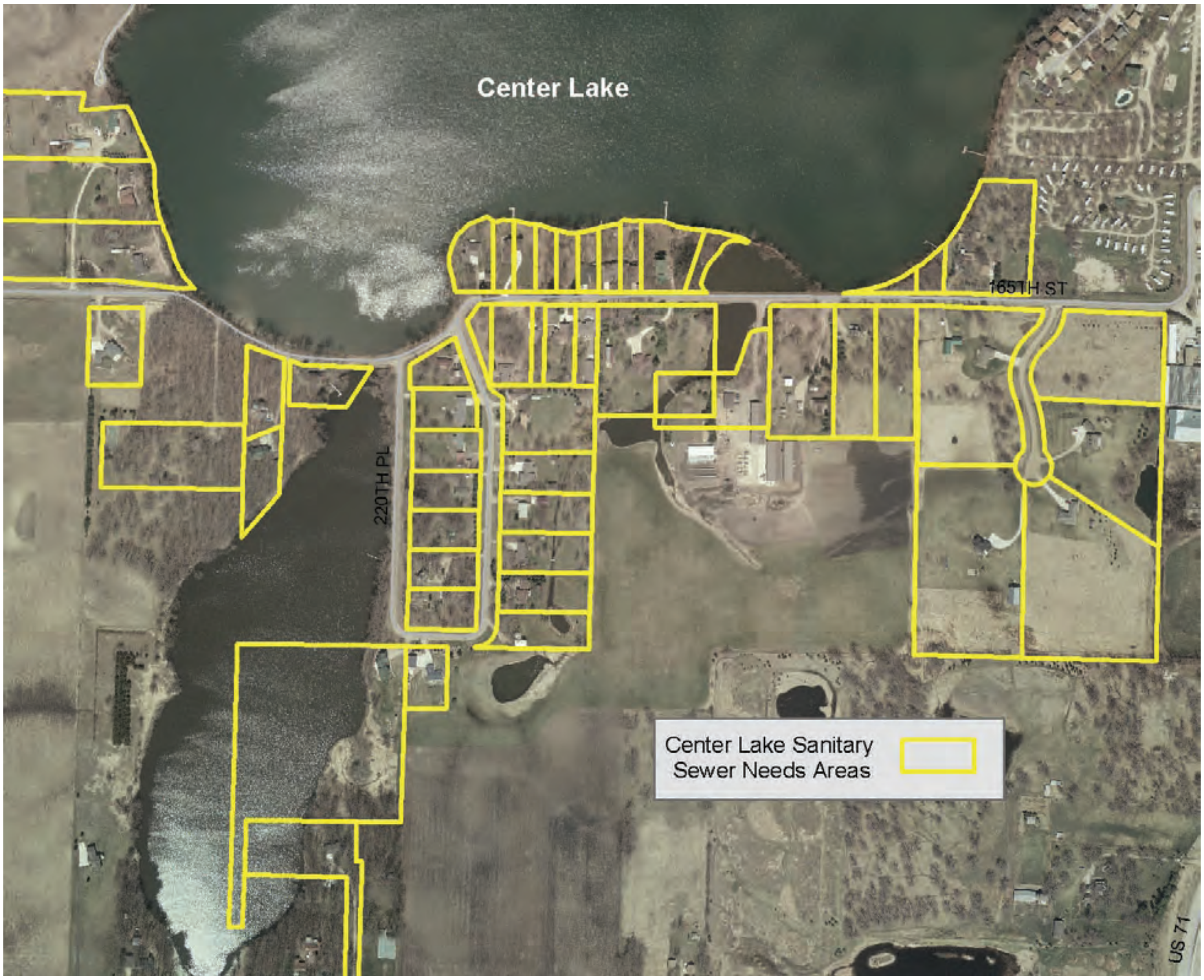
The entire collection system within the Iowa Great Lakes watershed is not owned or managed by the IGLSD. Some cities have ownership of the collection system within their jurisdiction. With some of these systems originally installed in the 1930’s and 1940’s the piping is old and out dated. The City of Spirit Lake had a problem with infiltration through these old lines and was passing wastewater into private residences. To prevent this the city would pump the wastewater out of the city collection system and into a storm sewer drain to the lake with direct access to the lake. Many believed that the cause was due to sump pumps illegally connected to the sanitary collection system. The city proceeded to find these sump pumps which were illegally connected to the system but also worked on cleaning and lining the collection pipes. After this work was completed, the discharges have ceased.

Although there is an extensive sanitary collection system, there are still areas with septic systems within the Iowa Great Lakes watershed. Four areas are identified and have yet to be connected to the IGLSD collection system. Many of these areas have been identified in the past but due to local political issues have not been connected to the IGLSD collection system. Questions exist about the homes that are not currently connected to the system and who will pay for expansion of the system to the areas that are not connected.

The areas that are not currently connected to the IGLSD are the South end of Center Lake, an area West of Emerson Bay, and two areas on Little Spirit Lake. The south end of the Center Lake has many homes which have septic systems in an area with a water table that is controlled by the lake level. With this area south of Center Lake under county jurisdiction, however, the closest collection system is operated by the City of Spirit Lake. In order for the IGLSD to connect these homes, they would have to run a main line to the area from the City of Spirit Lake.

The second site with septic systems that need to be attached to the sanitary district is West of Emerson Bay State Park. This area has private systems and at least one commercial system and a joint system with several trailer homes connected. This site has been identified as one of the possible sources of bacteria for the Emerson Bay impairment. There is at least one private well in this area that has had issues with e-coli found in the water in the past. Water from a stream, which delivers water into Emerson Bay, has recently been diverted away from the beach. This temporary solution has controlled the bacteria on the beach but has not solved the bacteria problem. In order to resolve the bacteria problem at Emerson Bay two things need to occur as soon as is possible. First, the site's septic tanks need to be brought into compliance with County Regulations and State laws or they should be connected to the IGLSD collection system. Second, the current sanitary district lines to the lift station need to be inspected to ensure they are not leaking into the streambed and causing the problems.

FIGURE 6.20 SEPTIC TANK AREAS ON WEST OKOBOJI.



Map 6.21 Close up of the sanitary sewer needs on the south end of Center Lake.
Courtesy USDA, NRCS

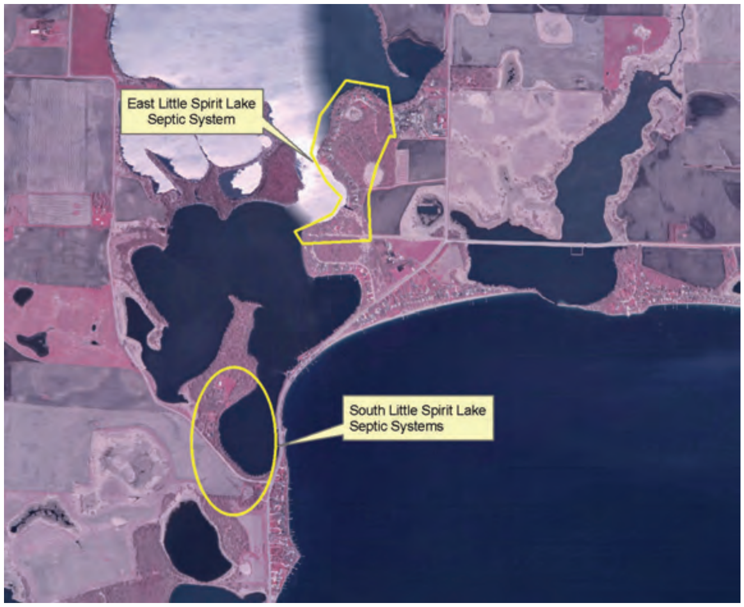
Map 6.22 Close up of the sanitary sewer needs for the Emerson Bay area on West Okoboji. Courtesy USDA, NRCS

The third and fourth area that predominately has homes with septic tanks is located on Little Spirit Lake. One site is on the south side of Little Spirit Lake. There are up to 5 lots that should be connected to the IGLSD system at this site. Homes in this area are newer and have more modern septic systems that should be operating properly. Normal maintenance of these tanks is essential or in the future these homes should be connection to the IGLSD collection system.

The fourth and location in the watershed, which needs to be connected to the sanitary sewer, is on the east side of Little Spirit Lake in the Leisure Beach area. Part of this area has recently been connected to the IGLSD collection system but it only goes to the state line. There are homes in Minnesota that are now on individual septic systems and not part of the joint collection system. The IGLSD has decided not to go into Minnesota because of the concern that they could not collect user fees.

These are the primary sites that are mainly homes with septic tanks. There may be other areas that are not currently connected to the IGLSD but would be primarily individual homes and businesses. These areas should be investigated to find out what it would take to get these sites connected to the system. If there are viable options or funds to assist to connect these systems to the IGLSD system, it should be done instead of rebuilding a septic system.

Of the four sites, the Center Lake and Emerson Bay sites are the highest priority because of the amount and type of pollutants they produce. Emerson Bay has been listed as an impaired waterway because of E-coli contamination and to reduce that impairment the septic tanks need to be removed or repaired. With a main trunk a matter of several hundred feet from this location, it would make more sense to connect this area to the sanitary district.



Map 6.23 Septic Systems on Little Spirit Lake

Map 6.24 Close up of the south sanitary sewer needs area on Little Spirit Lake. Courtesy USDA, NRCS

Storm Water Management

Management of storm water in the area has been focused primarily on flood control. In the past few years, however, a few cities and the county have been addressing water quality concerns through ordinances within their boundaries. The focus of these ordinances has been on management of storm water using the Iowa Storm Water Management Manual. Dickinson County is the first county in the state that is requiring post construction storm water management for water quality or LID storm water management. These ordinances need to keep the core standards and specifications for definitions and design as stated by the Iowa Storm Water Management Manual.

Many of the existing urban construction sites need to be retrofitted with Low Impact Development practices to reduce storm water run off. Ordinances are addressing existing structures when additional construction is built in an area but there is no standard to guide the ordinances and there is no standard from jurisdiction to jurisdiction. The built out areas can be modeled using GIS. The models show which areas will produce the highest volumes of water that will be generated for the water quality volume WQv or 1.25 inches of rain. There is also the Watershed Forestry Management Information System that can help prioritize areas for water quality concerns.

The areas that generate the most storm water runoff are located in three areas; the City of Spirit Lake, the Cities of Okoboji through Arnolds Park, and the South end of West Okoboji, encompassing the cities of West Okoboji, Wahpeton, and Milford. The areas with the highest runoff volume rates are the highest priority for storm water management. By treating these areas with practices such as Low Impact Development (LID), the large volumes of water going quickly to the lakes can be reduced. The LID practices include but are not limited to rain gardens, pervious pavement systems, soil quality restoration, infiltration trenches and green roofs. These LID practices reduce run off and cool the runoff down prior to it getting to the storm sewer and finally into the lakes.

The existing sub-divisions that do not have hard surface roads are another major source of sediment loading that needs significant attention. These sub-divisions are primarily found on the east side of East Okoboji Lake with steep hills and gravel roads. These areas are hard to properly model with computer modeling and GIS due to the continued maintenance they need to stay functional and safe for public use. The primary concern is the roads in this area as they have gullies that form but are continually maintained. Many of these roads can have up to 2 foot wide and 1-foot deep gullies that will start up towards the top of the hill and run to the lakeshore. These gullies next to the road are not safe for the public so they are refilled and then allowed to erode back into the lake during the next rain event. What is needed is alternative drainage systems that infiltrate the water from these gravel roads or to pave the roads and use infiltration based storm water management practices.

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water from these gravel roads or to pave the roads and use infiltration based storm water management practices.

Shoreline Stabilization

Photo 6.1 Hunting on Marble Lake in the Vegetation. Courtesy David Thoreson, Blue Water Studio

The native shoreline around the lakes has been impacted dramatically by urban growth throughout the watershed. The IGL Lakes Watershed once had native prairie almost entirely except a few areas that had an oak savannah on the upland parts of the shoreline. In the lake, there were native emergent plants like bulrushes, sedges, and burr reeds, among other aquatic plants. The majority of these plants have been removed, destroyed, sprayed or displaced from the shoreline. This has led to more shoreline erosion less lake bottom stabilization, and less aquatic plant diversity. Ultimately, this has led to a reduction in water quality. The lack of these aquatic plants leads to stirring of the bottom muck, wave action on the shoreline, and excess nutrients left available for algal use.

The easiest place to do these restorations would be in areas of the lake that have public access to the lake. These plants can be restored on points, in shallow areas, and in low boat traffic areas as well as areas like state parks. On Big Spirit Lake and West Okoboji Lake, there is possibility of up to eight sites per lake. East Okoboji Lake will be limited to about four sites and the lower chain of lakes would only have one or two areas. The restoration of these vegetative species would help repopulate the plants that are so vital to the health of the lakes. By re-vegetating these plants, they may have the opportunity to spread and disperse seeds into the lake. The re-vegetation of the shoreline may be something that can occur on private lands but in doing so, there needs to be very specific guidelines on how the work is done. Any work on lakeshore vegetation restoration should be done only with local eco-type plants. These sites can be good educational tools to show the public the benefit of native plants to water quality in the lakes.

6.2 POLLUTANT DATA ANALYSIS

Water Quality Improvement Plans (TMDL's) have been written for Little Spirit Lake, Upper Gar Lake, and Lower Gar Lake. The lakes that have been determined to be impaired by the Iowa DNR but have no Water Quality Improvement Plan are Big Spirit Lake (Marble Beach), Center Lake, and West Okoboji (Emerson Bay). This Pollutant Data Analysis will include all the lakes mentioned above in addition to East Okoboji Lake and Lake Minnewashta, which is part of the Lower Gar Chain of lakes.

The following map shows the impaired water bodies in Dickinson County.

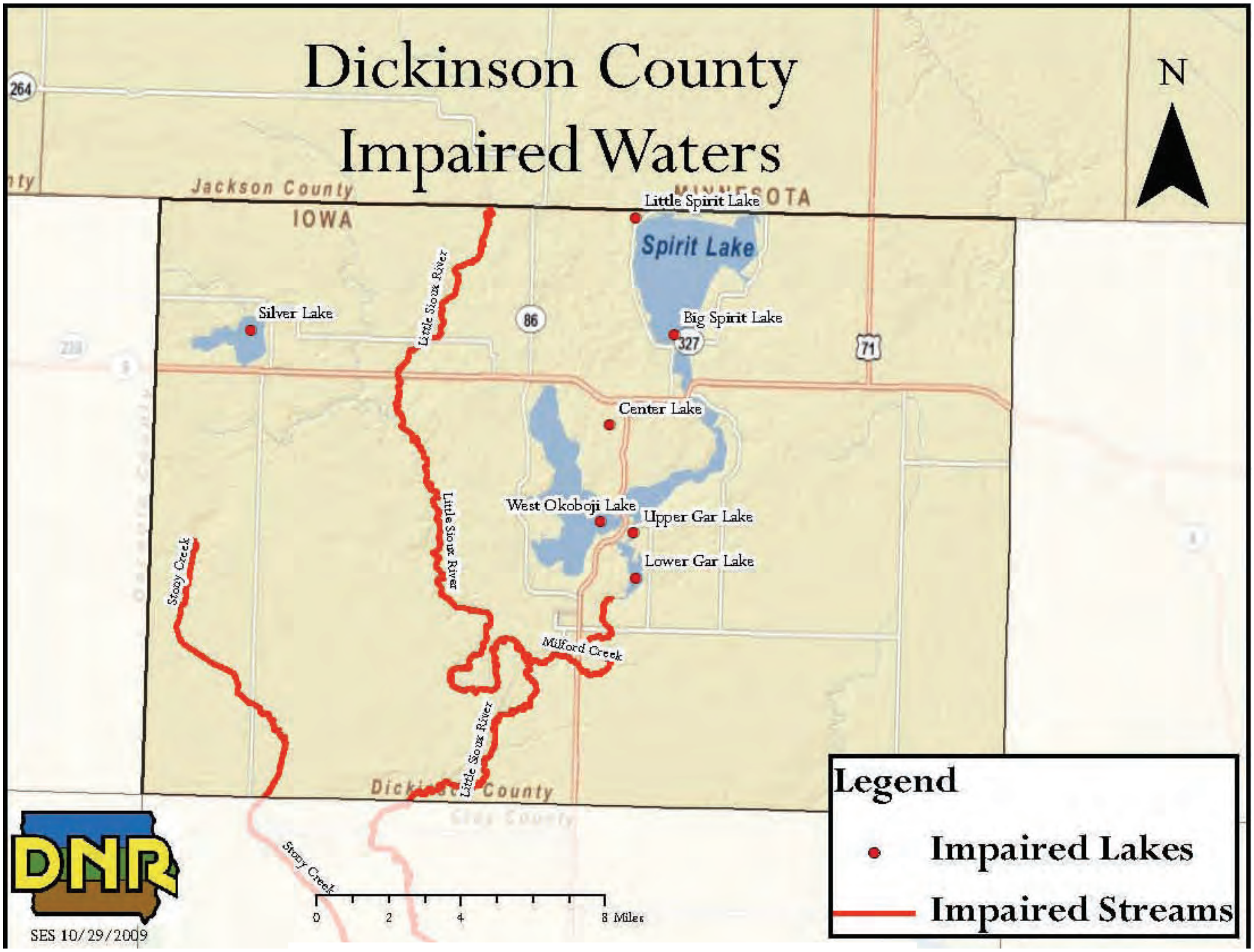

Figure 6-25 Dickinson County Impaired Waters

In all the impaired water bodies, the impairment is related to sediment delivery to the water body and the attached nutrient, phosphorous except Big Spirit Lake (Marble Beach) and West Okoboji Lake (Emerson Bay). West Okoboji Lake and Big Spirit Lake are impaired because of high bacteria, which are an indicator of potential health risks. In most cases these high bacteria counts throughout the state are caused by animal wastes.

However, these two locations do not have a significant source of animal waste applied. It must, therefore, be assumed the cause of these high bacteria counts are due to septic tank emissions. The maps on pages 113 to 116 show the locations of concentrated septic tanks that are still present in the Iowa Great Lakes. These tanks, if they are non-functional, pose a significant threat to the Iowa Great Lakes in the form of potential pathogens and in nutrient emissions to the lake.

In completing modeling of the Iowa Great Lakes Watershed, several forms of modeling have been attempted. "The Iowa Great Lakes topography is not suited to traditional modeling methodology and several considerations were made to allow for accurate prioritization of key sub-watersheds" (Michael Hawkins, IA DNR) of the Iowa Great Lakes. In attempting to model the Iowa Great Lakes, an attempt was made to develop a linear relationship between annual soil loss estimates and sediment delivery. Since sediment loss has been calculated for the entire IGL Watershed, the relationship was used to predict sediment delivery in portions of the catchments of depressed areas not included in the original analysis.

Typically, to prioritize a watershed for wetland restoration and agricultural BMPs the goal would be accomplished through a combination of sediment and nutrient delivery monitoring and modeling. In the case of the Iowa Great Lakes Watershed, water quality monitoring is part of a long-term plan, but not included in this assessment. Because of the complexity of the hydrological landscape of the IGL Watershed modeling performed in this assessment was needed to focus future monitoring efforts.

Priority areas identified in this plan have been developed from using a process through discussions with project partners and should guide watershed protection and enhancement efforts. The prioritization of the Iowa Great Lakes follows three steps:

1. Identification of priority Tier 1 watersheds based on high average sheet and rill erosion values.
2. Targeting of wetland restoration and agricultural BMP's within priority Tier 1 sub-watersheds using sediment delivery modeling.

Identification of high delivery and sediment loss areas within direct contribution zones.

Tier 1 Sub-watersheds

Several Tier 1 watersheds have been identified as having high average soil loss estimates (Map 7.33). These priority Tier 1 sub-watersheds correspond well with known problem areas in the watershed. Sediment delivery (MUSLE) modeling and RUSLE completed within these priority sub-watersheds to determine the top 25 percentile of sub-watersheds with a high than normal MUSLE sediment delivery as well as a higher than normal RUSLE soil erosion rate (Map 7.34). The two models, it was found, do correlate very well and from there areas could be prioritized using this correlation.

Although environmental issues may not be at the forefront of residents' attention, when asked to evaluate the seriousness of specific issues facing Iowa, "pollution of rivers, lakes, and streams" is second only to "a lack of affordable health care."
Sustainable Funding for Conservation in Iowa

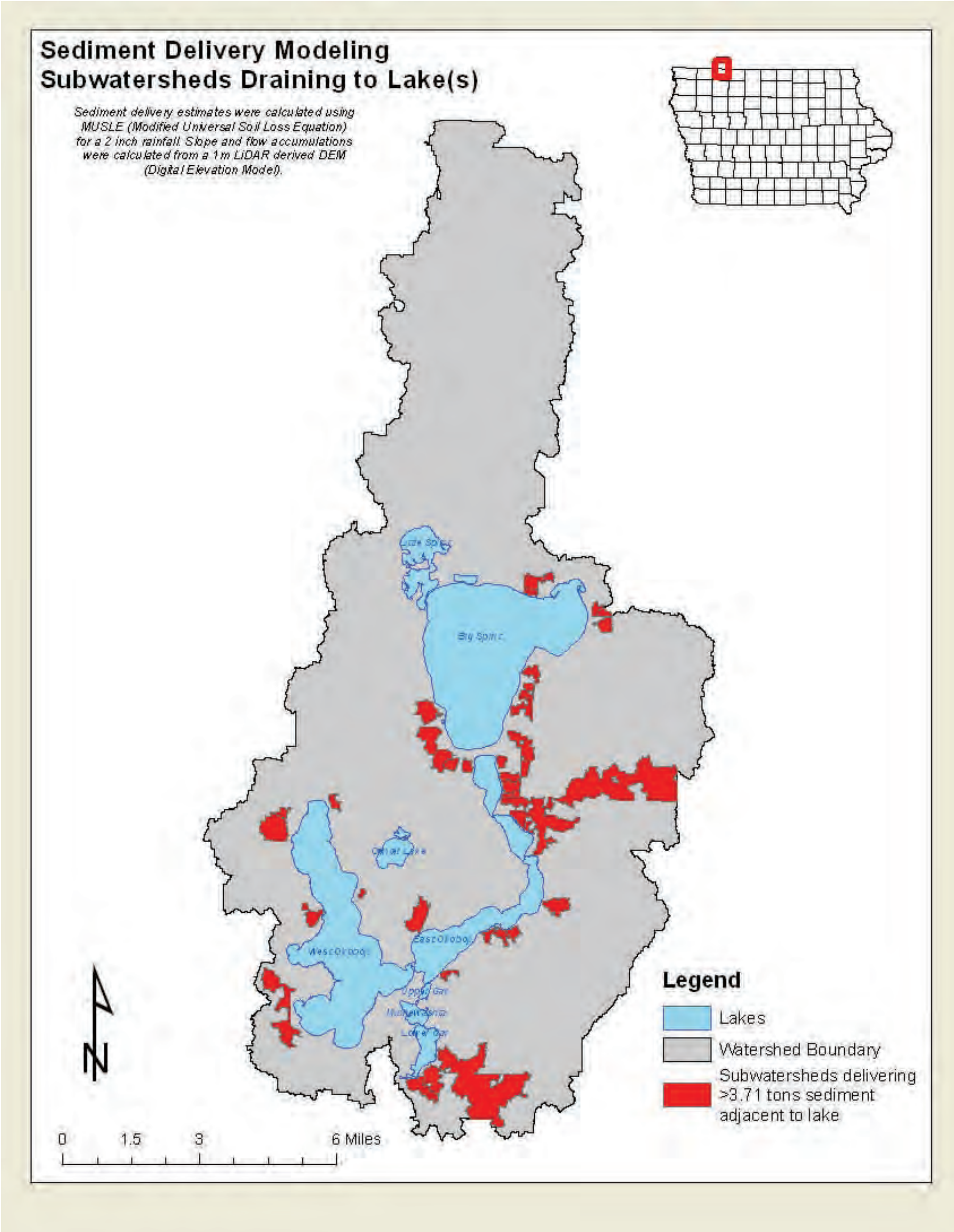

Figure 6.26 Highest Sediment Delivery Rates adjacent to lake, Courtesy IA DNR.

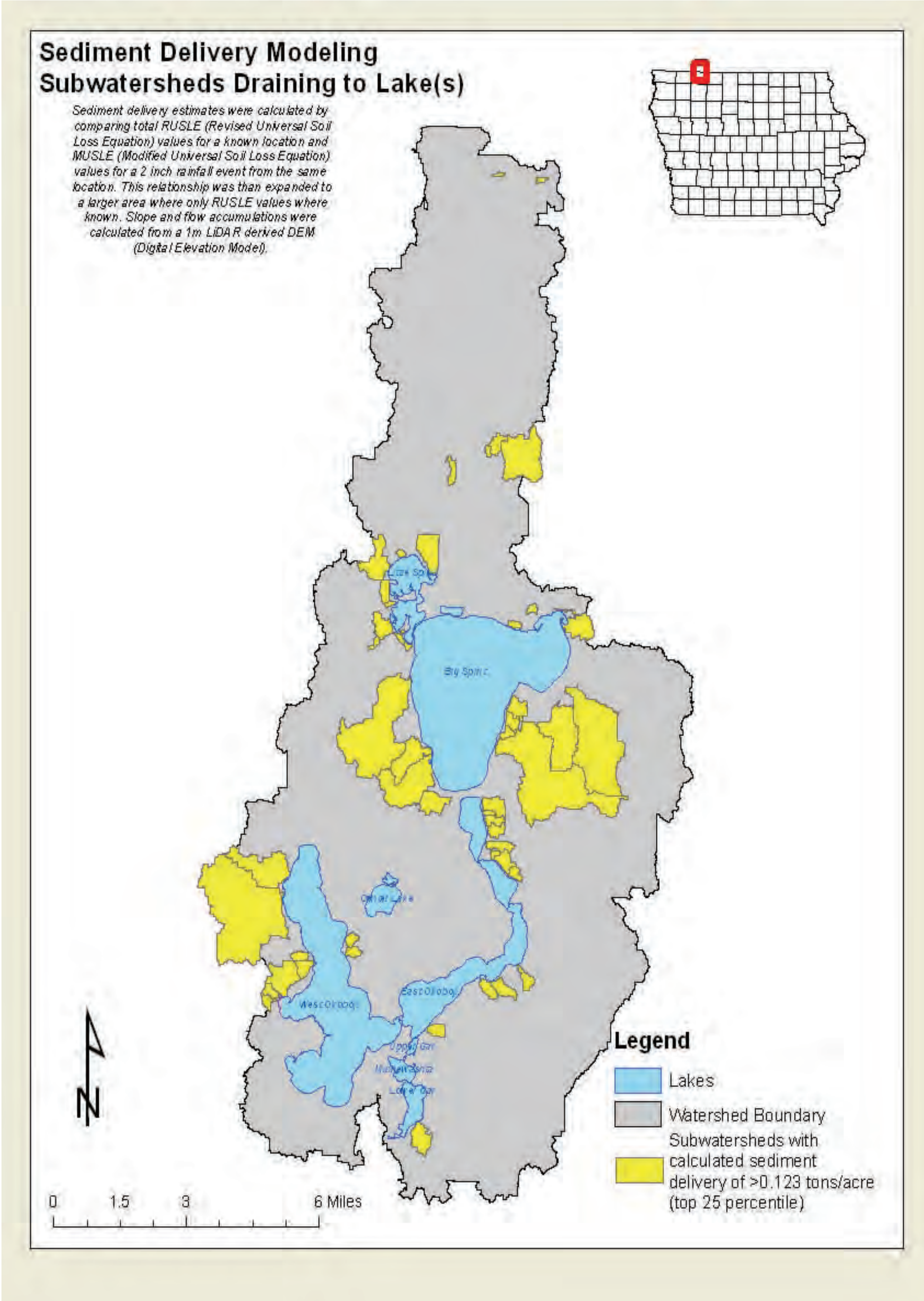

Figure 6-27: Top 25% sub-watersheds that deliver sediment to a basin or the lake using the relationship between RUSLE and MUSLE, Courtesy IA DNR.

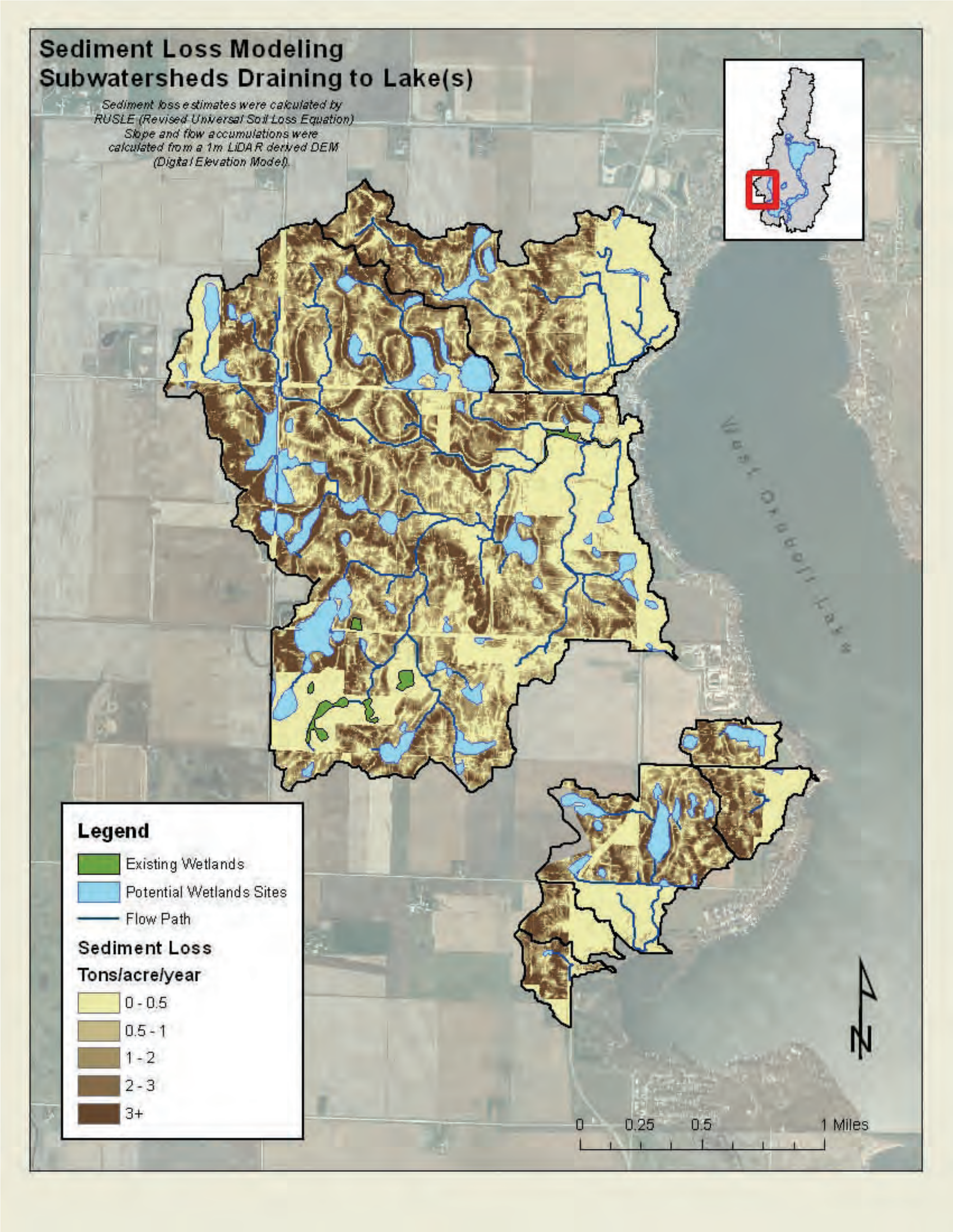

Figure 6-28: Lazy Lagoon Priority Sub-watershed Cluster, Courtesy IA DNR.

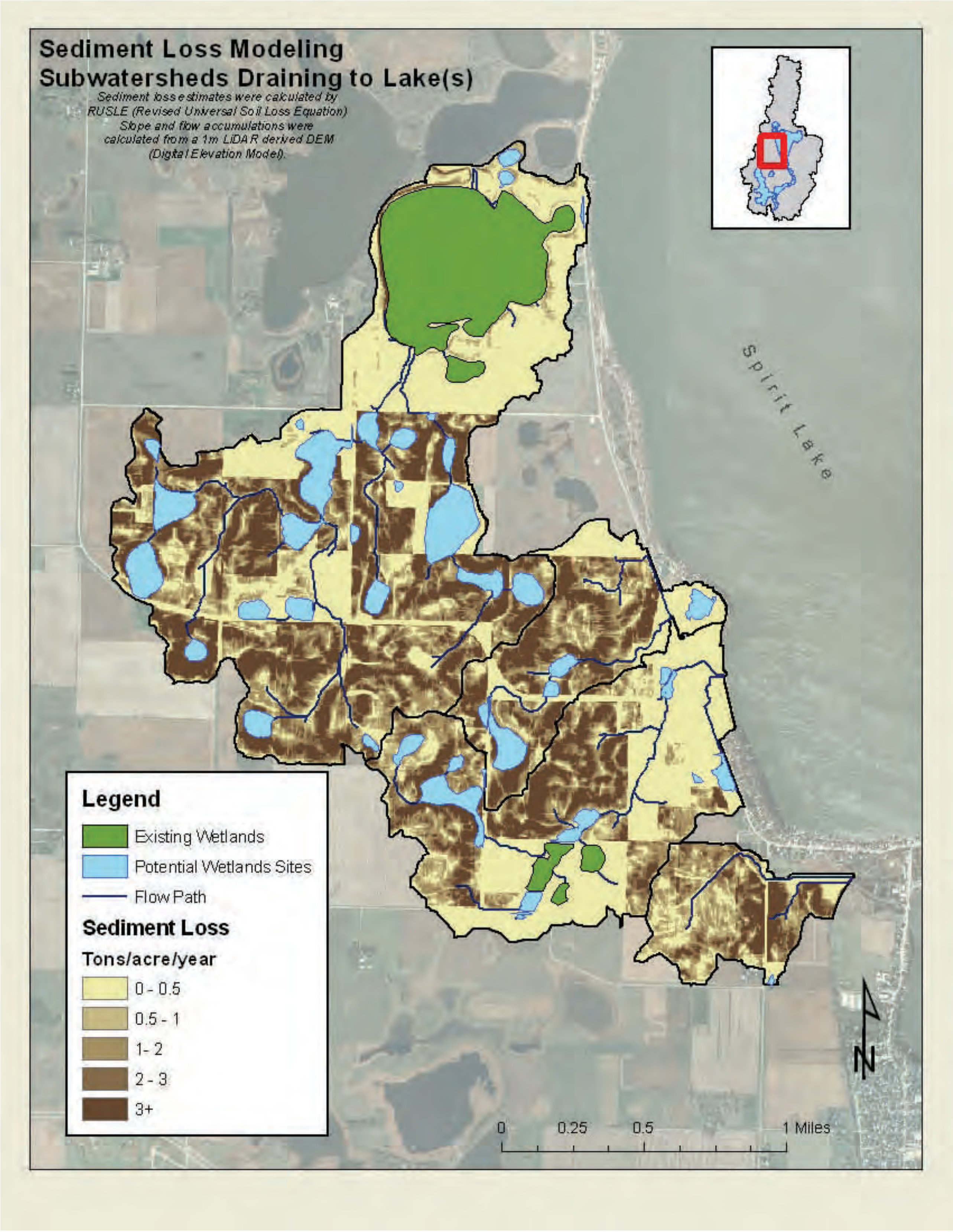

Figure 6-29: Templar Park Priority Sub-watershed Cluster, Courtesy IA DNR.

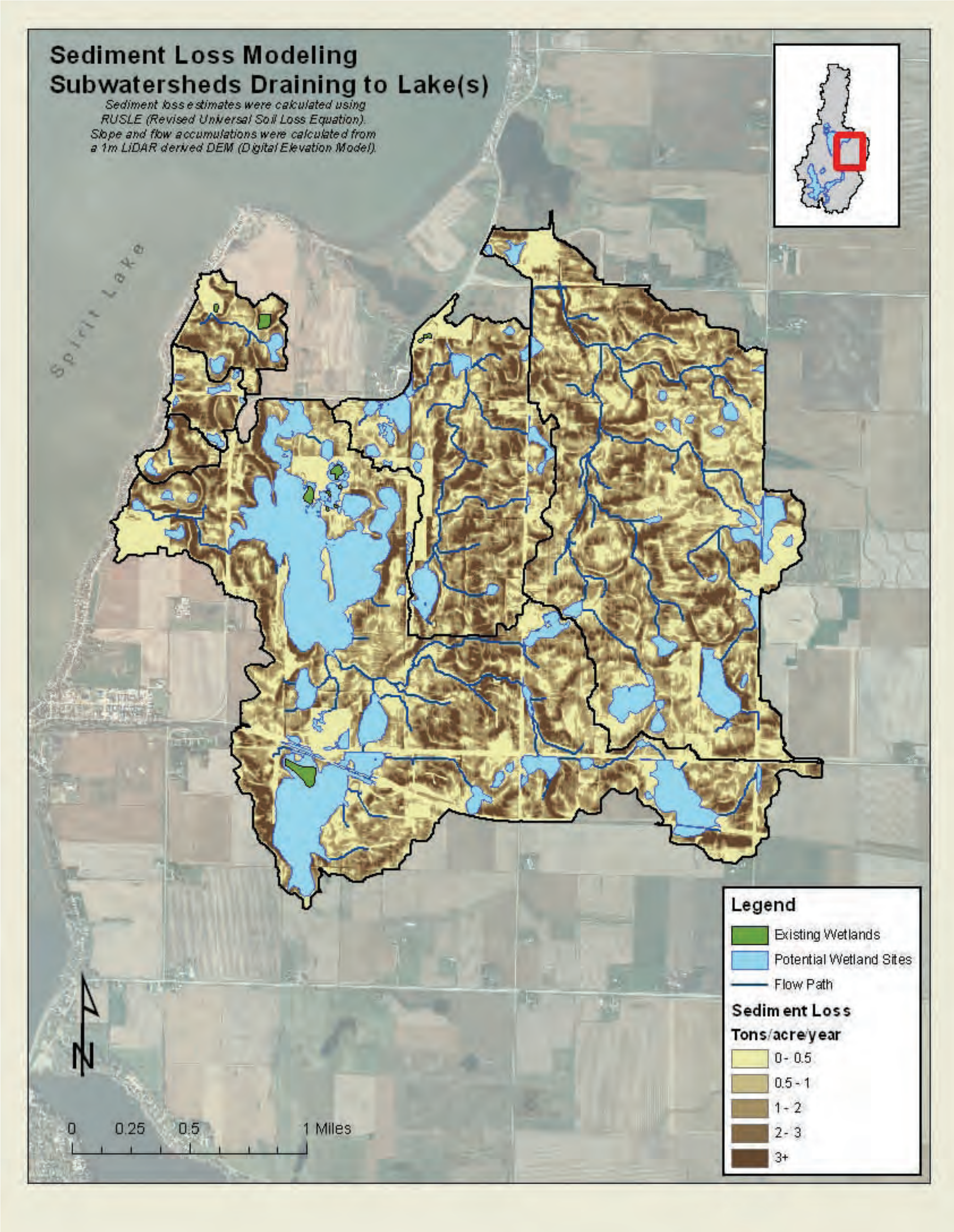

Figure 6-30: Reeds Run Priority Sub-watershed Cluster, Courtesy IA DNR.

In addition to the 3-priority sub-watershed clusters that have been identified as producing the greatest amount of sediment, based on the modeling, there are some individual sub-watersheds that are worthy of making a priority because of their location. These sub-watersheds, for the most part are located on a lake or water body, which allows any sediment delivery to be nearly a direct delivery to that water body. One of these sub-watersheds, on Lower Gar Lake, should have special attention paid to it as it produces a large amount of sediment and Lower Gar is an impaired water body because of sediment and nutrient input.

7.0 WATERSHED MANAGEMENT PLAN AND OBJECTIVES

The Iowa Great Lakes has been studied and researched a great deal in its recent history. The modern era of research began in the early 1970's and continues through today. Vegetative surveys of the Iowa Great Lakes have been done since the early 1900's. One survey was conducted in the late 1800's. With this history of research, there is much information available to make decisions and to show trends.

Photo 7.1 Fireworks over West Okoboji. Courtesy David Thoreson, Blue Water Studio

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> **A nearly-unanimous 97 percent of Iowans polled agree, that "all of Iowa residents have a personal responsibility to protect the state's natural resources."**
>
> ***Sustainable Funding for Conservation in Iowa***

7.1 STATEMENT OF GOALS AND OBJECTIVES

Agriculture

Goal: To reduce the impact of agricultural sources of sediment and nutrients on the water resources of the IGL Watershed.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Complete Agricultural Environmental Management (AEM) Plans for farms in the IGL Watershed priority areas, identify best management practices (BMPs) from those AEMs, look for assistance to implement these BMPs, and measure the effectiveness of these BMPs. AEM is a voluntary, incentive-based program that helps farmers make common-sense, cost-effective and science-based decisions to help meet business objectives while protecting and conserving the State's natural resources. Farmers work with local AEM resource professionals to develop comprehensive farm plans
- Create a non-partisan "AEM Review Board" for farmers to go to voluntarily for advice, information, and recommendations for their AEM farm plans and AEM farm plan development.
- Encourage farmer participation in state and federal programs that relate to water quality and issues in IGL Watershed and pursue forms of assistance such as continued federal and state grants and cost share programs.
- Provide incentives and programs for farmers and landowners to install, maintain and manage buffers adjacent to stream banks, lakeshore, and other sensitive areas such as tile intakes.
- Encourage farmers to join the Conservation Reserve Program.
- Produce signs for lake friendly farmers or watershed friendly farmers.
- Provide public education and monthly news articles/columns on agriculture and the environment online.
- Encourage use of whole farm plans.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Hazardous waste collection days for farm pesticides.
- Develop a "Farm of the Year" award.
- Encourage agri-tourism.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Monitor streams above and below identified farms.
- Examine purchasing development rights or providing tax incentives in exchange for development rights.
- Towns and county could encourage alternative agricultural uses of land, such as rotational grazing, organic farming, etc.
- Towns and county could change local laws to allow additional business enterprises on farms.
- County farmland protection plans should be updated regularly and within these plans there should be recommendations to facilitate alternatives to farmers going out of farming.
- Take advantage of new technologies to deal with agricultural waste.

Urban

Goal: Reduce the impact urban pollutants have on the Iowa Great Lakes.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Involve the public in addressing runoff problems associated with development and raising awareness of how an individual's activities contribute to runoff pollution.
- Work with local businesses and developers to provide information and incentives for the implementation of Best Management Practices for pollution prevention and control.

- Implement watershed awareness and water quality educational programs for City staff, community planning groups, the general public, and other appropriate groups.
- Apply water quality protection measures to land development projects early in the process-during project design, permitting, construction, and operations-in order to minimize the quantity of runoff generated on-site, the disruption of natural water flows and the contamination of storm water runoff.

Goal: Increase on-site infiltration, and preserve, restore or incorporate natural drainage systems into site design.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Direct concentrated drainage flows away from the storm sewer system and open space areas. If not possible, drainage should be directed into low impact development (LID) practice prior to draining into the storm sewer system or open space areas.
- Reduce the amount of impervious surfaces through selection of materials, site planning, and street design where possible.
- Increase the use of vegetation in drainage design.
- Maintain landscape design standards that minimize the use of pesticides and herbicides.
- Apply land use, site development, and zoning regulations that limit impacts on, and protect the natural integrity of topography, drainage systems, and water bodies.
- Enforce maintenance requirements in development permit conditions.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Avoid development of areas particularly susceptible to erosion and sediment loss (e.g., steep slopes) and, where impacts are unavoidable, enforce regulations that minimize their impacts.

Goal: Require contractors to comply with accepted storm water pollution prevention planning practices for all projects.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Minimize the amount of graded land surface exposed to erosion and enforce erosion control ordinances.
- Continue routine inspection practices to check for proper erosion control methods and housekeeping practices during construction.

Goal: Continue to participate in the development and implementation of Watershed Management Plans for water quality purposes.

Goal: Assure that City and County departments continue to use "Best Management Practice" procedures so that water quality objectives are routinely implemented.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Incorporate water quality objectives into existing regular safety inspections.
- Follow Best Management Practices and hold training sessions to ensure that employees are familiar with those practices.
- Educate City/County employees on sources and impacts of pollutants on urban runoff and actions that can be taken to reduce these sources.
- Ensure that contractors used by the City/County are aware of and implement urban runoff control programs.
- Serve as an example to the community-at-large.

Goal: Continue to encourage "Pollution Control" measures to promote the proper collection and disposal of pollutants at the source, rather than allowing them to enter the storm drain system.

Suggested Actions:
Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Promote the provision of used oil recycling and/or hazardous waste recycling facilities and drop-off locations.
- Review plans for new development and redevelopment for connections to the storm drain system.
- Follow up on complaints of illegal discharges and accidental spills to storm drains, waterways, and canyons.

Goal: Manage floodplains to address their multi-purpose use, including natural drainage, habitat preservation, and open space and passive recreation, while also protecting public health and safety.

Goal: Pursue a storm sewer utility in the cities and county to fund low impact development retrofit of existing storm sewer systems.

Stormwater and Sediment Control

Goal: To reduce the potential impacts of stormwater runoff on IGL and throughout the IGL Watershed.
Suggested Actions:
Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Continue hydro-seeding assistance programs for towns and villages in critical areas, such as road ditches, and promote the program to increase use throughout the watershed.
- Continue to conduct regional workshops on stormwater management to educate local decision makers, planning and zoning boards, Code Enforcement Officers, Highway Superintendents and residents about the use of recognized development BMPs to protect water quality and EPA Phase II rules.
- Provide model site design guidelines for contractors.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Have a Certified Professional Erosion and Sediment Control (CPESC) person review existing municipal land use regulations throughout the watershed (i.e. comprehensive plans, zoning codes, subdivision regulation, site plan review), as well as their implementation and enforcement, for adequacy in minimizing the impacts to water quality from development and recommend changes.
- Encourage towns in the watershed to create and enforce stormwater management and erosion control ordinances by providing a model laws and ordinances for stormwater and erosion control.
- Adopt a policy for County and city projects to develop erosion and sediment control plans independent of pending EPA Phase II rules and lead by example. Encourage towns and the county to adopt similar policies by providing sample policies and/or ordinances.

Aquatic Vegetation

Goal: Management of aquatic vegetation.
Suggested Actions:
Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Inventory and map aquatic vegetation in IGL, compare to historical data, and determine management needs. Publish findings as an educational tool. Search for funding for this inventory and mapping.
- Develop the best shoreline restoration procedures to ensure the most success in restoring shoreline habitat.
- Determine water quality, including phosphorus level, in IGL and the tributaries, and the effect it has on aquatic vegetation.
- Develop and implement a sampling plan for determining sources of phosphorus into IGL.
- Provide incentives and programs for farmers and landowners to install, maintain and manage buffers adjacent to stream banks, lakeshore and other sensitive areas (for further suggestions of Stream bank buffers, see Stream banks and Stream Corridor Management).
- Encourage the use of nutrient management plans for golf courses, parks, developments, etc. in the watershed.

- Educate the public and developers on how to reduce nutrient introduction to the lake.
- Examine alternative methods for aquatic vegetation control besides harvesting.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Review intake and other temperature data to see if the lake has been warmer which may cause algae to start blooming earlier and longer.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Examine reducing sources of phosphorus to IGL identified through sampling program.
- Examine dredging and explore funding opportunities to dredge the South end of IGL
- Examine spot dredging for very high nutrient areas.
- Examine the issue of harvesting aquatic plants and its potential negative impact on warm/cool water fish populations (Also under Fish and Wildlife Management).
- Teach volunteers to identify aquatic plant species and map them.

Chemicals

Goal: Responsible yard, garden and household chemical use. Proper waste disposal to minimize impacts on ground and surface waters, and sewage treatment systems. Also, reduce the number of hazardous material spills in the watershed and improve the effectiveness of spill response and reporting systems.

Yard, Garden and Household Chemical Use and Waste Disposal:

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Dickinson County continues household hazardous waste collection especially for fuel products
- Provide information on proper use and disposal of household chemicals; suggested media includes annual water quality reports by water providers, water bill messages, and direct mailings.
- Continue to search for ways to reduce hazardous materials releases in the watershed. For example, find ways to reduce mercury releases, such as collecting auto and household mercury switches and fluorescent bulbs.
- Promote pest management practices that reduce pesticide use in the watershed, including integrated pest management and non-toxic pest management.
- Examine ways to change people's attitudes about the "perfect lawn" through education and peer pressure.
- Provide Home*A*Syst type workshops to help homeowners prevent groundwater contamination; include wells, well maintenance, septic system use, yard waste, composting, etc.
- Provide incentives and programs for farmers and landowners to install, maintain and manage buffers adjacent to stream banks, lakeshore and other sensitive areas (for further suggestions on stream bank buffers, see Stream banks and Stream Corridor Management).

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Promote municipal level yard waste composting to move the nutrients contained in yard waste away from lakeshore and storm sewer intake areas.
- Create incentives to reduce the use of chemicals around the watershed by households, municipalities and utilities.

Hazardous Material Spills and Spill Response

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Have the Water Quality Management Agency or designated County agency develop, update and provide on an annual basis a listing of who to contact on water quality issues, including who to call to report spills.
- Survey fire departments and other agencies to verify who has materials for an immediate response to a hazardous material spill (spill response kits). Examine funding options where spill response kits are lacking.
- Identify types of spill response supplies that will work in fast moving streams and examine funding options.

- Explore options to control runoff from firefighting operations.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Compile and analyze existing information on hazardous material spills and use to tailor education for the public and businesses on hazardous material spill prevention and appropriate pollution prevention measures.
- Conduct first flush pesticide testing on tributaries of IGL.

Boating

Goal: To reduce boat and jet ski impacts on IGL.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Research the "carrying capacity" of boats and jet skis on the lake and study the level of pollution from motorized crafts.
- Research the impact of excessive wave action.
- Research the fuel storage of boats, slips, etc.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Explore options and public opinion of motorized watercraft.
- Provide public education on perceived problems of boaters, speed limit and boating setbacks.
- Provide information on safe and proper fuel storage of boats, slips, etc.
- Examine nighttime speed limit.
- Examine building a pump out station on the North and South end of the Lake.

Long term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Examine increasing the boating and jet ski setbacks from shore regarding the speed limit.
- Place buoys within 500 feet of water intakes to restrict boat travel as per existing watershed rules.

Education

Goal: To increase public knowledge and awareness of watershed issues and facilitate behavioral change that will enhance local water quality.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- The Dickinson County Clean Water Alliance should encourage and promote a coordinated approach to public education among its member organizations.
- Develop an on- going educational program on watershed and related issues to schools and school aged children.
- Make watershed issues more accessible to citizens by utilizing the internet, direct mailings, and media releases.
- Agencies and organizations that conduct public education programs should utilize the local media to its fullest extent to promote programs, highlight events, and draw larger audiences.
- Develop promotional campaigns that will interest a larger variety of participants in education programs.
- Institute an annual "IGL Day" to promote watershed and water quality awareness among City and County residents and visitors.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Agencies and organizations that promote water quality should enable trainers and educators to continually develop skills and expertise.
- Displays throughout the watershed to show protection and bank control pilot projects.

Aquatic Invasive Species Management

Goal: Address the problem of exotic, introduced and invasive species in the watershed.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Initiate a regular inventory and monitoring program for exotic, introduced and invasive species

in the lake and watershed.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Utilize expertise to monitor and control invasive species before they become established.
- A comprehensive public outreach effort-including but not limited to, facilitated public meetings, distribution of fact sheets, public service announcements, newspaper advertisements, rest area displays, traveler information systems, and gas pump toppers.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Investigate the variety of habitats around the lake for species diversity and assess the potential effect that might occur if damaged in any way.
- Research potential impact of zebra mussels, Eurasian Watermilfoil, and other invasive species on lake ecology.
- Active local partnerships to assist with developing watershed AIS management plans
- Permanent DNR-AIS program staff to conduct public education and volunteer programs
- Seasonal officers to conduct watercraft inspections and on-site public education
- Support for research that identifies pathways to limit the spread of AIS and identifies new AIS control methods
- Education of recreational users (boaters and anglers)

Fish and Wildlife Management

Goal: Sustain a healthy and diverse fish and wildlife population in the IGL watershed.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of other objectives.

- Determine water quality, including phosphorus level, dissolved oxygen and chlorophyll, in IGL and the tributaries and the effect it has on aquatic vegetation, fish and wildlife.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Implement stream bank and lakeshore stabilization on severely eroding banks.
- Provide incentives and programs for farmers and landowners to install, maintain and manage buffers adjacent to stream banks, lakeshore and other sensitive areas.
- Educate on the value of managing wildlife by hunting, fishing and trapping.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Work with area golf courses to minimize their use of water from streams during low flow periods.
- Expand awareness of wildlife harvest as a component of ecosystem management.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Examine the issue of emergent aquatic plants and the potential impact on fish populations
- Explore dredging some areas of the IGL, especially the Lower Gar Chain and the North part of East Okoboji Lake..
- Redesign State Dam to provide for lake level control.
- Provide for water control and fish control structures to allow for shallow lake/wetland restoration and management.
- Determine current status of rough fish and undesirable fish population in IGL.
- Promote increased access to significant fish and wildlife habitat for hunting and fishing.
- Examine the necessity and feasibility of ecosystem restoration in IGL and the IGL watershed.

Funding Options

Goal: Find funding for projects in the IGL Watershed.

Suggested Action:

- Explore full range of funding alternatives; examples include surcharge to users, franchise fees, use of percentage of revenues from septic system inspections, grants, loans, etc.
- Conduct a survey of County residents and visitors to the IGL to determine the amount they are willing to

pay and a preferred method to pay that amount for the conservation of our lakes.

Highway Deicing

Goal: Reduce delivery and minimize the impact of deicing salts, originating from the maintenance activities associated with roads, to the tributaries and IGL.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Conduct a survey of highway departments to see who has salt storage structures and contained mixing areas and where they are needed.
- Survey salt policies and procedures for each municipality yearly.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Explore funding options for those that need salt storage structures and contained mixing areas.
- Promote public awareness and education about safe winter driving.
- Examine using road weather information systems to reduce salt use and make it more efficient.
- Examine the use of pretreatment practices that use chemicals to depress the freezing point.
- Encourage use of sand and salt, not just salt, on the roads.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Monitor salt concentrations during winter runoff events for IGL and tributaries of concern.

Highway Maintenance

Goal: Reduce delivery and minimize the impact of sediment, nutrients, etc., originating from the construction and maintenance activities associated with roads, to the tributaries and IGL.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Conduct a roadside erosion potential inventory.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Encourage and provide information on timely revegetation of road ditches and banks.
- Encourage use of structural controls of sediments on steep roads, road banks and in high flow ditches.
- Encourage use and provide information on structural measures to control sediments and other pollutants from stormwater runoff.
- Encourage use of and provide information on best management practices (BMPs) to reduce road bank erosion.
- Provide an annual informational report for highway superintendents and workers in the watershed.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Organize local training programs through Soil and Water Conservation District.
- Examine the use of infiltration trenches, detention ponds, siltation ponds, basins, vegetated swales and filter strips in critical areas and in demonstration projects.
- Examine ways to prevent sediment eroded from plowed fields by wind and water from ending up in the ditches to the lake; especially during heavy rainfalls.
- Explore why roadside ditches are deepening and develop methods of prevention.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Encourage the use of erosion and sediment control standards in all highway construction and maintenance plans, bids and contracts.
- Encourage local code enforcement officers and local planning boards to establish and enforce site and construction standards and erosion control measures for private roads.

Lakeshore Erosion

Goal: Reduce the impacts of shoreline erosion on IGL.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Conduct an assessment of shoreline erosion and related problems.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Promote and distribute existing shoreline erosion control guidebooks and information sheets with specific information on plantings that will help reduce shoreline erosion.
- Distribute landscaping for erosion control information to all contractors and nurseries as well as individual homeowners and realtors.
- Conduct Lakeshore Homeowner Workshops on shoreline erosion, vegetative options, yard waste management, etc.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Provide assistance to design and implement preventative measures for shoreline erosion.

Land Use

Goal: To minimize potential impacts to water quality, scenic vistas, wildlife and other values due to land use changes.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Create a directory of zoning provisions and other development regulations of towns and villages, and provide the directory on a webpage.
- Inventory wetlands and open space resources in the watershed.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Propose a procedure for providing technical and professional support in reviewing development applications, or plans.
- Educate planning boards about land use issues such as drainage, buffer zones, stormwater runoff, etc.
- Have the County conduct a development suitability analysis using GIS.
- Provide assistance to towns and county to design, adopt, improve and/or implement standards and guidelines; provide model ordinances, regulations, standards, and guidelines.
- Use GIS to strategically target conservation easement and fee acquisitions for land trust.
- Conduct an assessment to what the watershed can handle in regards to new development.
- Explore opportunities to protect stream bank areas.
- Encourage adoption of land use plans that address strategies to protect IGL.

Long term objectives: Implementation is feasible and/or should be done in the next 5to 25 years.

- Target specific open space areas for an open space system.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Propose bond financing or some other funding mechanism to support the purchase of development rights.
- Propose a County Land Trust. Use GIS to strategically target conservation easement and fee acquisitions for land trust.
- Examine the development of a credit or point based system for development.
- Restrict construction and development on or near the lake.

Private and Municipal Wastewater Treatment

Goal: To reduce nutrient and pathogen impacts of on-site household and municipal wastewater treatment systems on surface and groundwater.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Develop a more complete assessment of the wastewater treatment and water supply needs in problematic locales.
- Explore federal or state assistance to replace or upgrade septic systems of people with limited incomes.
- Encourage the use of water conservation measures through education, financial incentives and appropriate regulations.
- Provide educational workshops on on-site septic systems for residents.

- Conduct a yearly tour of the water treatment plant and watershed to educate watershed.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Encourage the adoption of comprehensive use plans that describe the capacity of public facilities and services required to serve new development and discourage growth where adequate facilities and services are not available.
- Explore what grants and loans are available for water and waste disposal systems for rural communities by using the Catalog of Federal Domestic Assistance.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Examine using the EPA Office of Wastewater Management's "Small Communities Team" for technical assistance, financial assistance, and education to small communities.
- Examine using New York Rural Water Association's on site technical assistance for small and rural wastewater and treatment collection systems through the Wastewater Technical Assistance Program and Wastewater Training and Technical Assistance Program.
- Explore the possibility of upgrading the Groton Wastewater Treatment Facility.
- Examine building a sewer system in Locke and other towns, and pursue funding opportunities.

Public Access

Goal: To encourage public access while minimizing its environmental impact within the IGL Watershed.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Research if increasing access would have a negative effect on water quality.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Explore public-private partnerships for public access.
- Improve the canoe and small craft launches in IGL.
- Encourage low impact activities in the watershed like hiking, canoeing and fishing instead of motorized use.

IGL Recreation and Tourism

Goal: To encourage recreational activity and tourism while minimizing their environmental impact within the IGL Watershed.

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Encouraging recreation and tourism while minimizing the impact on water resources in the area.
- Encourage hiking, canoeing, and fishing in the IGL.
- Encourage linkages of businesses in IGL.
- Develop sustainable tourism activities that cause little or no harm to the people
- Develop an educational program for visitors to the IGL that explain what they can do to stop pollution in the IGL.

IGL Shoreline and Stream Corridor Management

Goal: To increase the amount of permanently preserved riparian buffer areas and to stabilize stream banks to reduce the delivery of sediments and nutrients to IGL.

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.

- Conduct stream bank erosion assessments throughout the watershed.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Implement bank stabilization practices on the most severely eroding banks, as quickly as feasible.
- Develop a comprehensive stream management program including debris assessments and fishery needs.

- Funding sources need to be identified for comprehensive shoreline restoration and management programs.
- Provide incentives and programs for farmers and landowners to install, maintain and manage buffers adjacent to stream banks, lakeshore and other sensitive areas. Find funding opportunities for buffer installation, management and maintenance.
- Promote the use of Best Management Practices (BMPs) in the watershed such as livestock exclusion from streams and vegetative filter strips.
- Develop educational programs on the protection of stream areas and stream maintenance (i.e. What are landowners allowed to do without permits, when are permits needed, and who to contact).
- Continue having staff members of the Soil and Water Conservation District (SWCD) and the Natural Resource Conservation Service (NRCS) assist in future preparation of grant and cost share applications to reduce stream bank erosion and implement buffering.
- Provide model buffer and stream corridor protection ordinances to the municipalities.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.
- Conduct tours, put up signs and provide information on demonstration projects for stream bank erosion and stream buffering.

Other objectives: Implementation depends on future resources or identification of additional concerns.
- Develop a program to plant buffers; provide seedlings, education and instructions.
- The Counties or municipalities may want to consider providing tax relief for planting buffer zones along riparian corridors based on comprehensive management plans.

Waste Sites

Goal: To minimize the impact of inactive (closed) landfills, inactive hazardous waste sites, illegal dumps and roadside dumping on the water quality of the IGL Watershed.

Landfills, Inactive Hazardous Waste Sites and Solid Waste Management

Suggested Actions:

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.
- The conditions of the seven closed solid waste landfills and the inactive hazardous waste site should be inspected by a designated Dickinson County agency annually for changing site conditions. Any significant changes should be reported to the DEC.
- Discourage open burning and provide alternatives such as pay by the bag programs for residential solid waste disposal.
- Educate the public about the hazards of backyard burn barrels and burn barrel ash.

Other Waste Sites

Suggested Actions:

Watershed assessment: Research or data that will assist the achievement of objectives.
- Inventory all on-site waste disposal sites including farm exempt, private exempt, private illegal and others.
- Inventory farm machinery scrap piles that exceed predetermined criteria.
- Inventory junkyards.
- Inventory permitted and abandoned sand, gravel, and other mines.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.
- Examine providing old farm scrap collection programs.
- Assess water quality impacts of junkyards.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.
- Determine environmental risk of all on-site waste disposal sites including farm exempt, private exempt, private illegal and others.
- Determine the environmental risks of permitted and abandoned sand, gravel, and other mines.

Roadside and Illegal Dumping

Suggested Actions:
Watershed assessment: Research or data that will assist the achievement of objectives.

- Create an inventory of roadside dumping hot spots and illegal dumping along watercourses.
- List all municipal codes and ordinances for roadside and/or illegal dumping.

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Monitor inventoried roadside and illegal dumps and measure amounts and types of wastes deposited.
- If a municipality does not have a code or ordinance for roadside and/or illegal dumping, provide a sample code or ordinance. For those that do, encourage raising fines and increasing persecution.
- Organize cleanup campaigns with media involvement such as Clean-A-Ravine campaigns.
- Encourage town cleanup days.
- Put up signs to discourage dumping.
- Communicate illegal dumping problems to the public and how to anonymously report dumping activities.

Long term objectives: Implementation is feasible and/or should be done in the next 5 to 25 years.

- Examine funding options for education, special projects or demonstrations.
- Provide a county wide tire amnesty day.

Other objectives: Implementation depends on future resources or identification of additional concerns.

- Examine other County's roadside dumping law and implementation system. Determine if Dickinson County should enact such a law.

Biodiversity Goals

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years.

- Maintain an undeveloped, forested condition on most of IGL land holdings.
- Work to identify all uncommon or rare species present on IGL lands, and provide habitat conditions and levels of protection recommended for perpetuating these species.
- Where feasible and applicable, and on limited acreage, maintain early successional forested and non-forested habitats on IGL lands.
- Work to identify and eliminate invasive species from IGL properties.
- Maintain forest reserves on a portion of IGL holdings.

IGL greatest single contribution to regional biodiversity is the maintenance and management of large areas of undeveloped, prairie and wetland habitat. These habitats, in general can contribute to soil and water conservation, while providing habitat for a range of indigenous plants and animals, aesthetic values, and recreational opportunities. The protection from development that results from IGL ownership contributes significantly to the long-term viability of a variety of organisms and natural communities.

Rare and uncommon species contribute to the biological complexity of a landscape or region.
Efforts to identify and protect rare or endangered species or habitats occur continually in and around the IGL. Future studies to locate and classify rare natural communities may be initiated. Actions to protect and enhance these species and habitats will provide critical protection of important components of biodiversity.

Invasive species are commonly recognized as a major threat to native flora and fauna and biodiversity. In extreme cases, invading exotics can out-compete and exclude native vegetation, resulting in a monoculture of the invasive plant. The result is a tremendous loss of native plant and associated animal diversity. In the IGL the goal is to strive to identify, control and eliminate invasive species from IGL lands, within the limits imposed by water quality protection or limitations of resources and personnel.

Cultural Resource Protection Goals

Short term objectives: Implementation is feasible and/or should be done in the next 3 to 5 years

- Identify significant cultural resources on watershed lands.
- Prevent degradation of cultural sites and resources.

Cultural resources are fragile and non-renewable. Once destroyed, they are gone forever. They cannot be regrown, rebuilt or repaired. Similar to endangered and threatened species of flora and fauna, the fragility of these resources places a value on them that is difficult to calculate. Preservation legislation is designed to ensure that future generations will have the opportunity to understand, appreciate, and learn about the past. Cultural Resource Management is concerned with locating and assessing the condition of both historic and prehistoric cultural resources, and generating plans for protecting those resources that are considered unique or are otherwise significant.

Photo 7.2 Sailboats on West Okoboji, Courtesy David Thoreson, Blue Water Studio

7.2 TARGETS AND LOAD REDUCTIONS

Three of the Lakes in the Iowa Great Lakes have already had target and load reductions identified in the written and approved TMDL. Little Spirit Lake, Upper Gar Lake, and Lower Gar Lake have and identified load and targeted load reduction. Those identified loads and reductions will be used in this Management Plan. The other lakes, Big Spirit Lake, Center Lake, West Okoboji Lake, East Okoboji Lake, and Lake Minnewashta have not had a targeted load reduction assigned through the TMDL process. Modeling for these lakes has been done by the Iowa DNR for this management plan.

Little Spirit Lake

The existing mean values for Secchi depth, chlorophyll a and total phosphorus based on 2000 - 2003 CLAMP sampling are 0.4 meters, 120 ug/L and 330 ug/L, respectively. Based on these values, a minimum in-lake increase in Secchi transparency of 75% and minimum in lake reductions of 73% for chlorophyll a and 71% for total phosphorus are required to achieve and maintain lake water quality goals and protect for beneficial uses. The estimated existing annual total phosphorus load to Little Spirit Lake is 1,870 pounds per year. The total phosphorus loading capacity for the lake based on lake response modeling is a function of the relative contribution of internal and external loads. Nonpoint and atmospheric deposition (background) sources and internal recycling of phosphorus from the lake bottom sediments are identified as the cause of impairments to Little Spirit Lake. The total phosphorus load allocation for the nonpoint sources is shown in Table 2. This includes 200 pounds per year attributable to atmospheric deposition.

Little Spirit Lake was included on the impaired water list due to the presence of noxious aquatic plants. The noxious aquatic plant impairment was removed in 2002 based on new data, but the lake remains on the 303(d) list due to algae and turbidity impairments. The Iowa Water Quality Standards do not include numeric criteria for algae or turbidity but they do include narrative standards that are applicable to Little Spirit Lake stating that "such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor, or other aesthetically objectionable conditions". Therefore, the impaired water quality assessment was made based on measured chlorophyll and transparency values indicating algae and turbidity conditions that are producing objectionable color, odor, or other aesthetically objectionable conditions. (DNR, 2004)

The high phosphorus and inorganic suspended solids levels at Little Spirit Lake indicate the likelihood of a significant internal loading. The existing load predicted by the Nurnberg Model also indicates a significant internal load. Therefore, use of the Loading Function estimate with the Nurnberg Oxic Lake Model was selected as the basis for determining the existing load. The Nurnberg Model was also used to determine load targets as a function of the relative contribution from internal and external sources.

The annual total phosphorus load to Little Spirit Lake is estimated to be 1,870 pounds per year based on the Loading Function and Nurnberg Oxic Lake models. This estimate includes 1,080 pounds per year from external nonpoint sources in the watershed, 590 pounds per year attributable to internal loading, and 200 pounds per year from atmospheric deposition.

The Nurnberg Model indicates that internal loading makes up approximately 32% of the existing total phosphorus mass loading to the lake. However, the internal load has a much greater effect on in-lake total phosphorus concentrations on a pound for pound basis. The model relationship shows that one pound of internal loading is equivalent to 5.3 pounds of external loading. In terms of lake response, the internal load is estimated to comprise approximately 71% of the total load.

Reduction of Phosphorous

The following implementation plan is not a required component of a Total Maximum Daily Load but can provide department staff, partners, and watershed stakeholders with a strategy for improving Little Spirit Lake water quality. Any projects designed to improve water quality in the lake should include communication with and cooperation from stakeholders in Jackson County, Minnesota. Without a cooperative effort, it will be difficult to substantially improve the condition of the lake. The estimated existing phosphorus loading from watershed sources is approximately 0.8 pounds/year/acre. Depending on the internal recycle load reduction achieved, the watershed loading would need to be reduced to a maximum of 0.7 pounds/year/acre. Because reductions in internal recycling and watershed loading will require management practices that take time to implement, the following timetable is suggested for improvements:

- Reduce watershed and recycle loading from 1,900 pounds per year to 1,400 pounds per year by 2015.
- Reduce watershed and recycle loading from 1,400 pounds per year to 900 pounds per year by 2020.
- Reduce watershed and recycle loading from 900 pounds per year to 500 pounds per year by 2035.

The final target of 500 pounds per year assumes that reductions in internal and external loads will be roughly proportional. It should be noted that the final total target load may vary depending upon the internal and external load reductions achieved as shown in previous sections of this report. Although gross soil erosion and sediment delivery in the Little Spirit Lake watershed is relatively minimal, it is believed that phosphorus dissolved in surface runoff and/or attached to fine sediment entering tile through surface inlets is contributing to the phosphorus loading of the lake. The following recommendations are listed, in order of impact, to reduce the nonpoint source delivery of phosphorus to Little Spirit Lake. These practices should be applied even though gross soil erosion may be currently calculated to be less than the tolerable soil loss level "T".

- Nutrient management on production agriculture ground to achieve the optimum soil test range. This soil test range is the most profitable for producers to sustain in the long term.
- Incorporate or subsurface apply phosphorus (manure and commercial fertilizer) while controlling soil erosion. Incorporation will physically separate the phosphorus from surface runoff.
- Continue encouraging the adoption of reduced tillage systems, specifically no till and strip tillage.
- Initiate a fall-seeded cover crop incentive program. Target low residue producing crops (e.g. soybeans) or low residue crops after harvest (e.g. corn silage fields). This practice increases residue cover on the soil surface and improves water infiltration.
- Through incentives, add landscape diversity to reduce runoff volume and/or velocity through the strategic location of contour grass buffer strips, filter strips, and grass waterways, etc.

In addition to the recommended best management practices on agricultural land, there are practices that need to be implemented in the residential areas as well. These include use of low or no-phosphorous fertilizers on lawns and use of appropriate erosion controls on construction sites. The internal nutrient component is due in large part to wind and wave action continually mixing the lake. Little Spirit Lake is a shallow natural lake and does not readily stratify. Minimizing the impact of wind and wave action on the lake could be accomplished through the installation of a wind break on the northwest edge of the lake to reduce wind fetch across the lake. Increasing the mean depth to at least 3 meters would allow the lake to stratify, reducing the internal mixing. This option may not be feasible due to limitations in the morphometry of the lake as well as cost prohibitive. In addition to wind and wave action continually stirring the lake, a large rough fish population comprised of bullheads and carp degrade water quality by eliminating aquatic macrophytes that take up available nutrients and by stirring up bottom sediments aiding in sediment and nutrient re-suspension. Commercial harvesting of the rough fish population would improve water quality by reducing the impact these fish have on mixing of the water column and macrophyte populations in the lake.

Upper Gar Lake

The Iowa Water Quality Standards (8) list the designated uses for Upper Gar Lake as Primary Contact (Class A1), Secondary Contact (Class A2), Aquatic Life (Class B(LW)) and High Quality (HQ). In 1999, Upper Gar Lake was included on the impaired water list due to the presence of noxious aquatic plants. In 2002, the Class A designated use for Upper Gar Lake was assessed as "fully supporting/threatened." Since 1994, the Class B designated use has been assessed as "partially supporting." The 2002 assessment was based upon the 2000-01 ISU lake survey, an ISU report on lake phytoplankton, and information from the DNR Fisheries bureau.

Nonpoint and atmospheric deposition (background) sources and internal recycling of phosphorus from the lake bottom sediments are identified as the cause of impairments to Upper Gar Lake. The total phosphorus load allocation for the nonpoint sources and internal recycle is 2,780 pounds per year including 10 pounds per year attributable to atmospheric deposition.

Water quality in Upper Gar Lake is influenced only by nonpoint sources and internal recycling of pollutants from bottom sediments. Nonpoint source categories identified in this TMDL include inflow from East Okoboji Lake combined with internal recycle, atmospheric deposition and watershed loads in the immediate Upper Gar watershed. There are no point source discharges in the watershed.

For the Loading Function and export watershed delivery estimates, the phosphorus contribution of East Okoboji Lake was calculated using the 1999 - 2003 average total phosphorus value for the southernmost CLAMP sampling point (Site # 57) and estimated average annual flow from East Okoboji Lake as follows:
Load from E. Okoboji = 124 ug/L x 15,310 acre-ft/yr x 2.72E-3 = 5,160 lbs/yr The Canfield-Bachmann Natural Lake Model resulted in the value closest to the Loading Function and export estimates while remaining within the parameter ranges used to derive it when applied to Upper Gar Lake. Therefore, the Canfield-Bachmann Natural Lake relationship was selected as the best-fit empirical model.

There are three quantified phosphorus sources for Upper Gar Lake in this TMDL. The first is the phosphorus load attributable to inflow from East Okoboji Lake and phosphorus recycled from lake sediments within Upper Gar Lake. The second source is the watershed area that drains directly into the lake. The third source is atmospheric deposition directly onto the lake. Note that load contributions from groundwater influx have not been separated from the total nonpoint source loads.

The annual total phosphorus load to Upper Gar Lake is estimated to be 6,080 pounds per year based on the selected lake response model. Of this, 5,980 pounds per year is attributable to inflow from East Okoboji Lake and internal recycle within Upper Gar Lake. The remaining 100 pounds per year is divided into inputs from the immediate Upper Gar watershed (90 pounds per year) and atmospheric deposition (10 pounds per year). Due to the sensitivity of the load calculation for East Okoboji Lake to estimated flow (see *Section 3.2, Modeling Approach of the TMDL*), the influent load from East Okoboji Lake was not separated from the Upper Gar internal recycle load.

Reduction of Phosphorous
Excluding background sources, the average annual phosphorus load to Upper Gar Lake originates entirely from nonpoint sources (including East Okoboji Lake) and internal recycling. To meet the TMDL endpoint, the annual nonpoint source contribution to Upper Gar Lake needs to be reduced by 3,000 pounds per year. The load Allocation (LA) for this TMDL is 2,780 pounds per year of total phosphorus distributed as follows:

- 2,770 pounds per year allocated to influent from East Okoboji Lake, internal recycling of phosphorus from

lake bottom sediments, and the immediate Upper Gar Lake watershed.
- 10 pounds per year allocated to atmospheric deposition.

Due to the small size of the immediate Upper Gar Lake watershed relative to the watersheds of the lake system that feeds it, the major phosphorus loads to the lake are influent from East Okoboji Lake (to which West Okoboji Lake is a tributary) and internal recycling. Because the load calculation for East Okoboji Lake is very sensitive to the accuracy of the estimated flow, the influent load from East Okoboji Lake was not separated from the Upper Gar internally recycled load, which could be significant. Among the mechanisms of re-suspension are bottom feeding rough fish such as carp, wind-driven waves and currents, and boat propellers. Methods are needed to evaluate the magnitude of the phosphorus load from internal recycling, preferably by direct measurement of re-suspension and recycling from lake bottom sediment. The department is investigating methods of measuring sediment phosphorus flux by evaluating lake sediment cores. This work is being done at Iowa State University and is supported by an EPA grant. Because of the uncertainty as to how much of the phosphorus load is attributable to influent from East Okoboji and how much is recycled from lake bottom sediment, an adaptive management approach is recommended. In this approach management practices to reduce upstream watershed loads and recycled loads are incrementally applied and the results monitored to determine if water quality goals have been achieved. Also, the reductions in watershed loads will require land management changes that take time to implement. For these reasons, the following timetable is suggested for watershed improvements:

- Reduce watershed and recycle loading from 6,100 pounds per year to 5,000 pounds per year by 2025.
- Reduce watershed and recycle loading from 5,000 pounds per year to 3,900 pounds per year by 2030.
- Reduce watershed and recycle loading from 3,900 pounds per year to 2,800 pounds per year by 2045. (DNR, 2004)

Lower Gar Lake

The turbidity TMDL for Lower Gar Lake will:
- Identify the adverse impact that nutrient induced turbidity is having on aquatic life use and link this to water quality criteria compliance.
- Identify an acceptable phosphorous load capacity that ensures attainment of the lake's aquatic life use.
- Estimate how much the existing phosphorous load exceeds the load capacity.
- Identify phosphorous sources and allocate a load to each source.
- Provide a brief implementation plan to guide the IDNR, other agencies, and stakeholders in efforts to reduce loads to acceptable levels.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, the water body load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available. A monitoring plan will determine if prescribed load reductions are successful and whether or not the target values are sufficient to attain designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or water body modeling.

The Lower Gar Lake TMDL has two phases. Phase 1 will consist of setting a specific and quantifiable target for turbidity expressed as Carlson's trophic state index (TSI). Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

A total phosphorous load allocation for the nonpoint source categories was developed to achieve compliance with the Lower Gar Lake load capacity. The nonpoint source categories are inflow from Lake Minnewashta, runoff from the 11,000 acres that drain directly to Lower Gar, and re-suspended sediment and recycled phosphorous.

Lower Gar Lake was put on the 1998 impaired waters list for turbidity. Recent and historical measurements of in-lake conditions indicate that accelerated eutrophication caused by excessive nutrient loading and sediment re-suspension is the cause of the Lower Gar Lake water quality impairment. The connection between highly eutrophic and hyper-eutrophic conditions and water quality impairments is well documented and recognized by the scientific community. These conditions promote heavy algal blooms throughout the summer, the prevalence of blue-green algae, severely limited clarity, floating algal scum, and the predominance of rough fish. Excess nutrient loading is often expressed as turbidity for assessment purposes.

Reduction of Phosphorous
The estimated annual total phosphorus load to Lower Gar Lake is 16,000 pounds per year. The Lower Gar Lake capacity for total phosphorous is 8,000 pounds per year based on lake response modeling. To achieve and maintain lake water quality goals and protect for beneficial uses, an average loading reduction of 8,000 pounds per year is required.

There are three Lower Gar Lake phosphorous sources. The first is the discharge from Lake Minnewashta. The second is from the watershed areas that drain directly into the lake. The third source is re-suspension of sediment and entrained phosphorous. The loads from these sources will be evaluated as follows:

- The estimated load from Lake Minnewashta will be the average Lake Minnewashta phosphorous concentration times the annual Lake Minnewashta discharge.
- The load from direct drainage will be estimated using watershed modeling.
- The load from recycling of re-suspended phosphorous will be what is left after the other two sources have been subtracted from the estimated total load.

The annual total phosphorus load to Lower Gar Lake is estimated to be 16,000 pounds per year. Of this, 6,100 pounds per year is delivered directly to Lower Gar Lake from the upstream lake system and watershed through Minnewashta Lake, 3,100 pounds per year from the watershed that drains directly to Lower Gar Lake, and 6,800 pounds per year from re-suspension and recycling of previously settled phosphorous.

The Phase 1 targeted load capacity for Lower Gar Lake is 8,000 pounds of total phosphorous per year based on lake response modeling. To achieve and maintain Phase 1 water quality goals and protect for designated uses, a loading reduction of 50% is required.

Lake Minnewashta and the Upstream Lake System. The TP load (6,100 pounds per year) from this source was estimated using the average TP concentration (132 ug/l) in Lake Minnewashta and the estimated annual flow (17,000 acre-feet) into Lower Gar Lake.
Watershed. The total phosphorus load from the watershed draining directly to the lake was estimated to be 3,100 pounds per year using a runoff volume of 3,700 acre-feet. This run-off volume equates to 4 inches per year in a watershed that has many wetlands, potholes, lakes, and ponds to absorb and slow runoff. A significant portion of the watershed is managed by IDNR for wildlife.
Re-suspension and Recycling. The total phosphorous load from recycling of previously settled bottom material is estimated to be 6,800 pounds per year. This was determined by subtracting the contributions from the other two sources from the total load of 16,000 pounds.

The Load Allocation (LA) for this TMDL is 8,000 pounds per year of total phosphorus and is distributed among the identified nonpoint source categories as follows.
3,000 pounds per year allocated to Lake Minnewashta and the upstream lake system.
2,600 pounds per year allocated to the 11,000 acre watershed that drains directly to Lower Gar Lake.
2,400 pounds per year allocated to re-suspension and recycling of previously settled phosphorous.

Big Spirit Lake

A total phosphorous load allocation for the nonpoint source categories was developed to achieve compliance with the Big Spirit Lake load capacity. The nonpoint source categories are inflow from the Big Spirit Lake Watershed, which includes areas into Minnesota and re-suspended sediment and recycled phosphorous.

The connection between highly eutrophic and hyper-eutrophic conditions and water quality impairments is well documented and recognized by the scientific community. These conditions promote heavy algal blooms throughout the summer, the prevalence of blue-green algae, severely limited clarity, floating algal scum, and the predominance of rough fish. Excess nutrient loading is often expressed as turbidity for assessment purposes.

Reduction of Phosphorous
The estimated annual total phosphorus load to Big Spirit Lake is 9,565 pounds per year. The Big Spirit Lake capacity for total phosphorous is 8,000 pounds per year based on lake response modeling. To achieve and maintain lake water quality goals and protect for beneficial uses, an average loading reduction of 8,000 pounds per year is required.

There are five Big Spirit Lake phosphorous sources. The first is the discharge from its large watershed. The second and third is from atmospheric deposition (both wet and dry). The fourth source is urban sources. The fifth and final source of phosphorous is from groundwater sources.

The annual total phosphorus load to Big Spirit Lake is estimated to be 9,565 pounds per year. Of this, 4,577 pounds per year is delivered directly to Big Spirit Lake from its watershed, 138 pounds per year from ground water, 4,832 pounds from atmospheric deposition, and 18 pounds per year from urban sources.

The targeted load capacity for Big Spirit Lake is 8,000 pounds of total phosphorous per year based on lake response modeling. To achieve and maintain water quality goals and protect for designated uses, a loading reduction of 50% is required.

The Load Allocation (LA) for this TMDL is 8,000 pounds per year of total phosphorus and is distributed among the identified nonpoint source categories as follows.
3,500 pounds per year allocated to Big Spirit Lakes Watershed and the upstream lake system.
10 pounds per year allocated to the urban portion of the watershed.

Center Lake

A total phosphorous load allocation for the nonpoint source categories was developed to achieve compliance with the Center Lake load capacity. The nonpoint source categories are inflow from the Center Lake Watershed.

The connection between highly eutrophic and hyper-eutrophic conditions and water quality impairments is well documented and recognized by the scientific community. These conditions promote heavy algal blooms throughout the summer, the prevalence of blue-green algae, severely limited clarity, floating algal scum, and the predominance of rough fish. Excess nutrient loading is often expressed as turbidity for assessment purposes.

Reduction of Phosphorous
The estimated annual total phosphorus load to Big Spirit Lake is 516 pounds per year. The Big Spirit Lake capacity for total phosphorous is 250 pounds per year based on lake response modeling. To achieve and main-

tain lake water quality goals and protect for beneficial uses, an average loading reduction of 240 pounds per year is required.

There are five Center Lake phosphorous sources. The first is the discharge from its large watershed. The second and third is from atmospheric deposition (both wet and dry). The fourth source is urban sources. The fifth and final source of phosphorous is from groundwater sources.

The annual total phosphorus load to Big Spirit Lake is estimated to be 516 pounds per year. Of this, 168 pounds per year is delivered directly to Big Spirit Lake from its watershed, 30 pounds per year from ground water, 231 pounds from atmospheric deposition, and 87 pounds per year from urban sources.

The targeted load capacity for Big Spirit Lake is 240 pounds of total phosphorous per year based on lake response modeling. To achieve and maintain water quality goals and protect for designated uses, a loading reduction of 50% is required.

The Load Allocation (LA) for this TMDL is 240 pounds per year of total phosphorus and is distributed among the identified nonpoint source categories as follows.
160 pounds per year allocated to Big Spirit Lakes Watershed and the upstream lake system.
80 pounds per year allocated to the urban portion of the watershed.

West Lake Okoboji

A total phosphorous load allocation for the nonpoint source categories was developed to achieve compliance with the West Lake Okoboji load capacity. The nonpoint source categories are inflow from the West Lake Okoboji Watershed, which includes areas into Minnesota and re-suspended sediment and recycled phosphorous.

The connection between highly eutrophic and hyper-eutrophic conditions and water quality impairments is well documented and recognized by the scientific community. These conditions promote heavy algal blooms throughout the summer, the prevalence of blue-green algae, severely limited clarity, floating algal scum, and the predominance of rough fish. Excess nutrient loading is often expressed as turbidity for assessment purposes.

Reduction of Phosphorous
The estimated annual total phosphorus load to Big Spirit Lake is 8,273 pounds per year. The West Lake Okoboji capacity for total phosphorous is 3,700 pounds per year based on lake response modeling. To achieve and maintain lake water quality goals and protect for beneficial uses, an average loading reduction of 3,700 pounds per year is required.

There are five Big Spirit Lake phosphorous sources. The first is the discharge from its large watershed. The second and third is from atmospheric deposition (both wet and dry). The fourth source is urban sources. The fifth and final source of phosphorous is from groundwater sources.

The annual total phosphorus load to Big Spirit Lake is estimated to be 8,273 pounds per year. Of this, 4,121 pounds per year is delivered directly to Big Spirit Lake from its watershed, 512 pounds per year from ground water, 3,416 pounds from atmospheric deposition, and 224 pounds per year from urban sources.

The targeted load capacity for Big Spirit Lake is 3,700 pounds of total phosphorous per year based on lake response modeling. To achieve and maintain water quality goals and protect for designated uses, a loading reduction of 50% is required.

The Load Allocation (LA) for this TMDL is 3,700 pounds per year of total phosphorus and is distributed among the identified nonpoint source categories as follows.
3,500 pounds per year allocated to Big Spirit Lakes Watershed and the upstream lake system.
200 pounds per year allocated to the urban portion of the watershed.

East Lake Okoboji

A total phosphorous load allocation for the nonpoint source categories was developed to achieve compliance with the East Lake Okoboji load capacity. The nonpoint source categories are inflow from the East Lake Okoboji Watershed.

The connection between highly eutrophic and hyper-eutrophic conditions and water quality impairments is well documented and recognized by the scientific community. These conditions promote heavy algal blooms throughout the summer, the prevalence of blue-green algae, severely limited clarity, floating algal scum, and the predominance of rough fish. Excess nutrient loading is often expressed as turbidity for assessment purposes.

Reduction of Phosphorous
The estimated annual total phosphorus load to East Lake Okoboji is 5,413 pounds per year. The East Lake Okoboji capacity for total phosphorous is 2,700 pounds per year based on lake response modeling. To achieve and maintain lake water quality goals and protect for beneficial uses, an average loading reduction of 2,700 pounds per year is required.

There are five East Lake Okoboji phosphorous sources. The first is the discharge from its large watershed. The second and third is from atmospheric deposition (both wet and dry). The fourth source is urban sources. The fifth and final source of phosphorous is from groundwater sources.

The annual total phosphorus load to East Lake Okoboji is estimated to be 5,413 pounds per year. Of this, 3,201 pounds per year is delivered directly to East Lake Okoboji from its watershed, 141 pounds per year from ground water, 1,573 pounds from atmospheric deposition, and 498 pounds per year from urban sources.

The targeted load capacity for Big Spirit Lake is 2,713 pounds of total phosphorous per year based on lake response modeling. To achieve and maintain water quality goals and protect for designated uses, a loading reduction of 50% is required.

The Load Allocation (LA) for this TMDL is 2,700 pounds per year of total phosphorus and is distributed among the identified nonpoint source categories as follows.
2,300 pounds per year allocated to Big Spirit Lakes Watershed and the upstream lake system.
400 pounds per year allocated to the urban portion of the watershed.

Minnewashta Lake

A total phosphorous load allocation for the nonpoint source categories was developed to achieve compliance with the Minnewashta Lake load capacity. The nonpoint source categories are inflow from the Minnewashta Lake Watershed.

The connection between highly eutrophic and hyper-eutrophic conditions and water quality impairments is well documented and recognized by the scientific community. These conditions promote heavy algal blooms throughout the summer, the prevalence of blue-green algae, severely limited clarity, floating algal scum, and the predominance of rough fish. Excess nutrient loading is often expressed as turbidity for assessment purposes.

Reduction of Phosphorous
The estimated annual total phosphorus load to Big Spirit Lake is 213 pounds per year. The Minnewashta Lake capacity for total phosphorous is 80 pounds per year based on lake response modeling. To achieve and maintain lake water quality goals and protect for beneficial uses, an average loading reduction of 133 pounds per year is required.

There are five Big Spirit Lake phosphorous sources. The first is the discharge from its large watershed. The second and third is from atmospheric deposition (both wet and dry). The fourth source is urban sources. The fifth and final source of phosphorous is from groundwater sources.

The annual total phosphorus load to Big Spirit Lake is estimated to be 213 pounds per year. Of this, 76 pounds per year is delivered directly to Minnewashta Lake from its watershed, 15 pounds per year from ground water, 107 pounds from atmospheric deposition, and 15 pounds per year from urban sources.

The targeted load capacity for Big Spirit Lake is 133 pounds of total phosphorous per year based on lake response modeling. To achieve and maintain water quality goals and protect for designated uses, a loading reduction of 50% is required.

The Load Allocation (LA) for this TMDL is 80 pounds per year of total phosphorus and is distributed among the identified nonpoint source categories as follows.
70 pounds per year allocated to Big Spirit Lakes Watershed and the upstream lake system.
10 pounds per year allocated to the urban portion of the watershed.

7.3 BEST MANAGEMENT PRACTICES (BMPS)

Based upon the extensive watershed assessment findings, it has been determined that the following practices would provide the most benefit for dollar expended and that would have the greatest chances for meeting the goals established for the Iowa Great Lakes Watershed. A brief description has been included below to illustrate specific application of some of the practices with respects to this project.

Agricultural Related Practices:

Grassed Waterways

The need for this practice in crop fields was identified during the assessment in areas of concentrated flow where waterways have never been installed or the practice has been abandoned. It is common throughout the agriculture sector to have this practice abandoned due to a slow degradation of the waterway from inadequate maintenance or where the vegetation is has been eradicated due spraying operations. Funding for this practice will primarily utilize the Conservation Reserve Program (CRP) due to lucrative incentives offered. Local REAP allocations will also be used to fund the practice in areas that are not eligible for CRP, livestock grazing restrictions conflicts arise, or in situations where other obstacles prevent a landowner from participating in the program.

Due to the nature of the landform, this practice is of particular importance since the ephemeral gullies that develop in these areas of concentrated flow often result in extremely high sediment delivery rates. Sediment that is mobilized in these areas has little chance of being captured by other BMP's resulting in direct loads being delivered to the receiving water body.

Water and Sediment Control Basins

This practice is being suggested as an alternative in many instances where waterways may not fit into an individuals farming operation. Some areas of concentrated flow within crop fields would require a waterway system that has significant impacts upon the row pattern of the field, which may prevent a landowner from adopting any practice at all to address the concern. These sediment basins can and often are designed using the NRCS terrace program and are for all practical purposes simply shorter terraces. Basins are an effective alternative to waterways, which also allows the landowner, maintain a farmable row pattern. Since much the slope of the land is not steep enough to require extensive terrace systems, in many instances, this practice, will have higher trapping efficiencies and is well-received by landowners.

Further enhancing the adoption of this practice, traditional intake risers will be replaced with buried intakes to enhance the trapping efficiency of the system. A significant amount of sediment is often flushed through the traditional riser but will be trapped in an underground matrix of soil and rock without interrupting row patterns. This concept has been widely accepted throughout the county in the past and may well be the key aspect of the practice to entice landowner participation.

In other instances the where areas of concentrated flow are delivering high loads of sediment; this practice will be utilized in the more traditional sense as a catchment to trap pollutants and slow water. These basins will be strategically located in small drainage areas where significant loading is occurring. Under certain circumstances when inadequate protection can be obtained, these basins will also be utilized to cleanse runoff before reaching open water.

Grade Stabilization Structures

Classic gullies have been identified throughout the project area and this practice will be located in these sites to control as well as to filter runoff in the associated drainage areas. This practice will also be used in areas where grade is not an issue to trap runoff where adequate upland treatment cannot be obtained on private lands.

Wetland Restoration

The land use of the IGL Watershed has undergone dramatic changes post settlement with the bulk of the wetlands that once dominated the landscape now drained and converted to row crop production. Many of these tile systems associated with these converted wetlands are brought to the surface directly into receiving water bodies flushing contaminants directly into the lakes. These direct conduits for contaminants will be eliminated through the restorations or buried intakes will be installed for filtering purposes. The Wetland Reserve Program will be used to fund the majority of these restorations but project funding may be used for some buried intakes.

Conservation Cover

The Conservation Reserve Program and all of its options for different conservation cover programs will be used to provide cover to key areas that perhaps are difficult to farm or should not have been farmed to begin with because of poor soil types or slopes.

Filter Strips

Filter strips promoted in critical locations and funded through the CRP program or similar programs. Filter strips are used to slow runoff water and allow it to infiltrate into the soil. Filter strips can be used on streams, lakeshores, tile inlets, storm sewers, and other areas with direct access to surface water.

Lakeshore Revegetation

Due to the limited amount of shoreline vegetation found around most of the lakes, this practice will be implemented to stabilize windswept shorelines, filter contaminants from reaching the main body of the lake and to sequester nutrients while promoting aquatic habitat.

Nutrient and Pesticide Management and Residue Management.

This practice will be implemented in identified priority areas to manage the amount, placement, and timing of crop inputs. Due to the sensitive nature of this aquatic environment and the sheer amount of crop inputs applied throughout the watershed, it is imperative that an intense campaign be enacted to modify these activities. Project sponsors will interface with producers and partners in addressing this issue through the support of project funding to encourage a higher level of stewardship.

Urban Related Practices:

Construction Site Management

Urbanization is an ongoing issue in the IGL Watershed and additional incentives are needed to stimulate continued adoption of Low-Impact Development BMP's. Although ordinances have been adopted throughout much of the project area, instances still arise where incentives and cost-share are needed to meet overall project objectives.

Bioretention Cells, Bioretention Swales, Permeable Pavers, and Soil Amendments

Due to the vast amount of urban area within the project area, incentives are needed to retrofit these practices in identified priority areas to manage stormwater at the source. In some areas that have already been developed, no other mechanisms are currently in place to encourage the adoption of these principals so that this vast amount of runoff can be brought up to an adequate level of treatment before entering the lake system.

Septic System Inspection and Septic System Renovation Demonstration

Rural residence septic systems throughout the watershed in some instances have not been adequately maintained and may not be functioning properly. This may be a significant issue due to impermeable soils found throughout the region, which may result in systems being connected directly to field drainage tile. Due to the difficult nature of assessing and detecting these faulty systems, project sponsors intend to launch a voluntary inspection incentive campaign to encourage rural residents to begin to address the issue. Three areas of interest in the Iowa Great Lakes Watershed that do not have sanitary sewer and the human wastes are disposed of via septic tanks. The connection of these three areas to the sanitary district is a key in preventing the listing of two sites in the Iowa Great Lakes onto the States impaired waters list. Emerson Bay on West Okoboji and Marble Beach on Big Spirit Lake are both located near one of these areas with septic tanks and both are proposed to be on the 2009 list of threatened waters list.

Shallow Lake Restoration Practices:

Outlet Structure Construction

Check with Mike on this and other practices.

Fish Exclusion Structure

Check with Mike on this

Emergent Vegetation Restoration

Check with Mike on this

8 WATER MONITORING PLAN

We will never know the worth of water till the well is dry.

The goal of developing the Iowa Great Lakes monitoring program is to positively affect the quantity and quality of data and ultimately, the information available for the effective protection and management of all of the region's water resources by enabling the following activities:

1. The development of appropriate monitoring and assessment methods for all the waters in the IGL.
2. A periodic assessment (status and trends) of the condition and stressors of the IGL waters.
3. The identification and monitoring of the impaired waters of the IGL.
4. The development of appropriate TMDL's for IGL's impaired waters.
5. An assessment of the effectiveness of management activities and programs toward meeting resource management goals (before, during and after management activity action).
6. The setting of appropriate water quality and biological standards for protection of waters in the IGL.
7. Reporting of water resource conditions to the citizens of Dickinson County and visitors to the IGL.

(DNR, Iowa)

Picture 8.1 Bikers on a Trail. Courtesy David Thoreson, Blue Water Studios

8.1 QUALITY ASSURANCE PROJECT PLAN (QAPP)

While data collected through the IDNR and IOWATER Program will be incorporated into overall data collection activities, those data are not included as part of this QAPP. Water sampling results will be incorporated into the water quality database that has been established for the Iowa Great Lakes.

Samples will be taken from various sites within the IGL and those samples will have a spectrum of samples taken and will be sampled after each rainfall event of 1.25 inches of rain. The use of first flush samplers and an automatic sampler will be used for these sample sites in addition to grab samples.

Sites will be monitored before, during, and after the installation of agricultural best management practices and low impact development practices. These samples will consist of TSS, Nitrate/Nitrite, total P, pH, and temperature. More parameters may be added or some may be deleted dependent upon each situation.

The list of parameters that will fall under this QAPP include:

Analyte	Matrix	Sample Container	Preservative	Holding Time	Analytical Method
Ammonia Nitrogen	water	250 ml plastic	H_2SO_4 to pH < 2; Cool to 4 ° C	28 days	LAC10-107-06-1J
Carbonaceous BOD	water	500 ml plastic	Cool to 4 ° C	48 hours	SM5210B
Chloride, Field	water	None	None	Immediate	Hach® brand, Silver nitrate titrant, Range: 30-600 mg/L
E. coli Bacteria	water	100 ml clear plastic bottle	Cool to 4 ° C, 0.008% $NA_2S_2O_3$	<6 hours >6 still report	EPA1603 (modified mTEC)
Nitrate+Nitrite-Nitrogen	water	250 ml plastic	Cool, 4°C H_2SO_4 to pH<2	28 days	EPA 353.2
Phosphate, Total	water	250 ml plastic	Cool, 4°C H_2SO_4 to pH<2	28 days	LAC10-115-01-1D
Total Suspended Solids	water	1 quart plastic	Cool, 4°C	7 days	USGS I-3765-85
Dissolved Oxygen, Field	water	None	None	Immediate	ALPHA 4500
Temperature, Water	water	None	None	Immediate	ALPHA 2550
pH	Water	None	None	Immediate	sampler
Turbidity	water	Glass vial	None	Immediate	ALPHA 2130 BEPA 180.1

mg/L = milligrams per liter
CFU = Colony Forming Units
μmhos/cm = micromhos per centimeter
NTU = Nephelometric Turbidity Units

Table 8.1 List of Parameters

High quality water is more than the dream of the conservationists, more than a political slogan; high quality water, in the right quantity at the right place at the right time, is essential to health, recreation, and economic growth.
Edmund S. Muskie, U.S. Senator, speech, 1 March 1966

8.2 WATER MONITORING PLAN

Surface water in Dickinson County is the single most important reason for the county's current economic prosperity and tourism industry. Dickinson County water resources are an important source of drinking water, recreation, wildlife habitat, and aesthetic enjoyment for residents and visitors. Because of the importance of surface water to the county and its residents, there are many individuals, groups and organizations currently working to educate residents and businesses in the area about protecting water quality.

The prairie potholes and marshes adjacent to the lakes are ground water recharge areas, and serve as a natural filtration system for the Iowa Great Lakes (IGL) by filtering and capturing contaminants carried in stormwater runoff, and infiltrating runoff from surrounding developed land. In the past, wetlands have been drained in favor of agriculture and urban developments, but it has more recently been recognized that wetlands are an integral part of a complex ecological system. In addition to the parks and recreation activities within Dickinson County, the wildlife and natural areas provide wildlife habitat and opportunities for walking, hiking, and bird watching.

We shall never achieve harmony with land, any more than we shall achieve absolute justice or liberty for people. In these higher aspirations, the important thing is not to achieve but to strive.
Aldo Leopold

The primary threats to the water quality of the Iowa Great Lakes are sedimentation, excess nutrients, human and livestock waste, stormwater contaminants and loss of natural wetlands. Agricultural runoff contributes contaminants such as sediment, commercial fertilizers, pesticide, herbicides and feedlot effluent. Potential spills of hazardous waste and invasion of aquatic Invasive species are also a concern.

Increased urban development has presented stormwater quality and quantity problems. Urban stormwater runoff carries contaminants such as sediment, excess nutrients, pesticides and herbicides, heavy metals, and road salt. There is increasing pressure on drinking water supplies by the growing permanent population base and an expanding summer seasonal population. Good water quality is vital to the region's economy and quality of life for those who visit or live within the area.

The Iowa Great Lakes are a system with many differing problems but overall the lakes primary problem is sediment and phosphorous. The goals of the water sampling program in the IGL are to:

- Establish baseline conditions for determining stream and lake health based on chemical, physical, habitat, and biological parameters.
- Assess the health of the watershed and target areas within the watershed in need of water quality improvement.
- Assist local watershed councils and partners in making environmental management decisions in their local and regional watersheds.
- Enlist community involvement in their local watershed.
- Collect data that may aid in the prioritization of watershed areas for Best Management Practices (BMPs).

Standard Methods for Collection

Water is collected at the sampling point using one of the following methods depending upon physical accessibility; sample is taken from a bridge using a HDPE plastic bucket or directly from the stream into the sample container. When sampling from a bridge the sample will be collected on the upstream side of the bridge over the middle of the channel. When sampling directly from the stream the sample will be collected from the middle of the stream facing upstream. Equipment cleaning and Decontamination and preservation methods as directed by the analyzing laboratory.

When grab sampling is suitable, samples should be collected along the sample site cross-section. Take the sample at a point that best represents the water quality of the total flow at the cross section of the stream. Avoid sampling points that are poorly mixed or affected by local temporary conditions such as ponding across part of the stream width, obviously disproportionate sediment load, or backwater conditions. If a site is poorly mixed across the stream, integrated sample across the stream width should be used, or another site should be chosen that is well mixed across the stream width.

Sampling is designed to collect baseline data that will aid in the identification of problems that exist in the watershed. This data will serve as a guideline for future implementation of suggested conservation practices. Monitoring for this purpose will continue through the fall of 2012 and depending upon funding for even longer. Information from other sampling and monitoring done in Dickinson County will be considered and used during this project.

The sampling design will allow for collection of data during varying flow conditions, including ambient, base flow and storm conditions. Storm conditions that will be sampled include any storm with over 1.25 inches of rain or a significant amount of rain in a 24 hour period. The samples will be taken using first flush samplers, grab samples, and automatic samples. Monitoring sites were selected by the Dickinson SWCD and Clean Water Alliance Project Coordinator.

Depending on the sampling site and conditions, samples will either be collected directly from the stream or lake or in a container from a bridge. Prior to sample collection, each lab sample container is labeled in the field with a permanent waterproof marker. Lab sample container labels include site name, date and time of sample collections, and the collector's name.

Sampling will be conducted in a manner that minimizes the chances of contamination. Lab samples will be collected in sterile, unused sample containers provided by UHL. Table 5 lists the type of container in which each analyte is collected. Sample collection personnel will be instructed not to touch the insides of the sample containers or caps. Lab sample containers will be filled without pre-rinsing the container. Some lab sample containers contain a preservative (Table 5). When collecting samples in these containers, a small amount of air space will be left to ensure that the preservative is not lost or diluted.

If the lab sample is collected directly from the stream, the sample will be collected in the middle of the channel facing upstream. Samples will be collected directly into the lab sample container, immediately capped, and then stored on ice until packaged for delivery to the lab. Field parameters are then measured for dissolved oxygen, water temperature, chloride, and turbidity. The turbidity sample will be analyzed immediately at the site after calibrating the turbidity meter. To prevent contamination, the glass vial the turbidity sample is measured in will be rinsed with distilled water 3 times before each use. The dissolved oxygen/water temperature probe is lowered into the stream, ensuring that the probe is not making direct contact with the stream bed. Before making the field measurements, the sensors must be allowed to equilibrate with the water being monitored. The sensors have equilibrated adequately when the temperature measurement varies within ±0.2 ºC and the dissolved oxygen measurement varies within ±0.5 mg/L. The dissolved oxygen and water temperature measurements will be recorded on the field form (Appendix 6). Chloride is measured using a HACH Quantab^{Ò} test strip and by collecting a water sample directly from the stream using the sample cup provided.

If the lab sample is taken from a bridge, the sample will be collected on the upstream side of the bridge over the middle of the channel or where the flow is the greatest. A sample collection container that is made of a non-contaminating material, such as HDPE plastic, will be rinsed at the site a minimum of 3 times before samples are collected. The rinsing consists of lowering the container into the stream, letting it fill with water, lifting the container back to the bridge, and then pouring the contents of the container out. After completing the rinsing, water is poured from the water sample collection bottle directly into the lab sample bottles; bottles are immediately capped, and then stored on ice until packaged for delivery to the lab. The turbidity sample will be analyzed immediately at the site after calibrating the turbidity meter. To prevent contamination, the glass vial the turbidity sample is measured in will be rinsed with distilled water 3 times before each use. The remaining water in the water collection container is discarded and "fresh" sample is collected. This water is then used for the chloride test. The probe for the dissolved oxygen/water temperature meter is lowered into the stream. The probe will be gently stirred in the water while waiting for the sensors to equilibrate with the water. The sensors have equilibrated adequately when the temperature measurement varies within ±0.2 ºC and the dissolved oxygen measurement varies within ±0.5 mg/L. The stream measurements will be recorded on the field form (Appendix 6).

Grab Samples

Grab samples can be taken at selected sites in the container and volume appropriate for each particular analysis. In stream samples will be collected at mid depth for a well-mixed sample of water. The method used for any particular sample depends on several factors including flow rate, stream depth and width, and accessibility.

Regardless of collection method, the grab sample is stored and transported in a clean, labeled container. When sampling, enough volume should be collected to fill the appropriate size container, with the exception of a 1-inch headspace. The lab sample bottle is capped, stored in a cooler with ice packs until delivered to the laboratory within 24 hours.

The variations of the grab sampling method are described below.

Wading and Hand Collection

If the stream is safe to wade, the person collecting the sample wades with a lab sample bottle to the center of the stream or where the greatest flow exists. The sample collector should face upstream, taking care to ensure that any stream bottom debris disturbed by wading does not contaminate the sample. The lab sample bottle is tipped at a 45° angle, allowing the bottle to fill. If water levels or velocities cause concern for safety, DO NOT WADE!

Reach Pole Collection

When wading conditions are not safe in smaller streams, a grab sample may be collected using a reach pole. In this case, the water sample collection bottle is fitted into a wire cage attached to the end of a long, telescoping reach pole. The water sample collection bottle is tipped at a 45° angle, allowing the bottle to fill. The water sample collection device is filled and rinsed three times before water from it is used to fill the lab sample bottles.

Bridge and Rope Collection

A grab sample may be collected by using a water sample collection container that is made of a non-contaminating material, such as HDPE plastic. The water sample collection bottle should be rinsed at the site a minimum of 3 times before samples are collected. The rinsing consists of lowering the container into the stream from the bridge deck near the center of the bridge, letting it fill with water, lifting the container back to the bridge, and then pouring the contents of the container out. After completing the rinsing, water is poured from the water sample collection bottle directly into the lab sample bottles; bottles are immediately capped, and then stored on ice until packaged for delivery to the lab.

Field Equipment

Grab Sampling Equipment

The following equipment is or can be used for collecting grab samples. Equipment will vary due to site differ-

ences.
- Chest or Hip Waders
- Personal Flotation Device
- Sterile labeled sample bottles
- Telescoping Reach Pole
- Water sample collection container that is made of a non-contaminating material, such as HDPE plastic with a 25 foot Nylon rope
- Cooler and Ice
- YSI Dissolved Oxygen/Water Temperature meter
- HACH 2100 Portable Turbidimeter
- HACH QuantabÒ test strips

Field form, permanent markers, pens/pencils

9 IMPLEMENTATION PLAN

This Watershed Implementation Schedule is used to develop a more sustainable future for the resources, residences, and businesses located within the watershed by addressing all identified natural and wildlife resource concerns. The implementation of this plan also partially fulfills the mission of all stakeholders of the IGL Watershed.

The IGL Watershed is the very foundation for any and all economic prosperity in the region. The soils around the lake were originally deposited by historical glacial events. This rich soil sustains profitable farming operations and wildlife habitat for an abundance of terrestrial species. The aesthetic beauty of the watershed. In addition its recreational values make the watershed highly desirable for either primary or secondary homes.

The aesthetic value and the recreational opportunities also increase land values around the lake, further benefiting the landowners and county tax base. The lake itself provides drinking water to visitors and for residents. The non-agricultural related business in the watershed is sustained by the lake's popularity as a recreational area.

The first process in implementation is the identification of sites for treatment. This survey process was completed in December of 2009. Implementation plans for the watershed will then be developed. BMPs will be designed and engineered to USDA-NRCS specifications. Funding for implementation will then be identified, and once secured, each approved practice will be installed. Installation of BMPs will begin in 2009 and continue through 2039.

Like many other elements, phosphorus, is necessary to sustain all living organisms. Problems are typically created only when phosphorus is present at elevated levels in our lakes, as is the case for the IGL Watershed. High phosphorus levels in the IGL, along with sediment have resulted in undesirable growths of algae. Undesirable algae blooms have caused high dissolved oxygen levels in the daytime when plants are releasing oxygen during photosynthesis, and likely low dissolved oxygen levels at night when no photosynthesis is occurring, but plant respiration is high. This increase in plant growth and lower dissolved oxygen has caused a shift in the fish and invertebrate communities in the IGL to species that can tolerate these more stressful conditions. In addition, the nuisance algae growths tend to be undesirable for human use, drinking water, and potentially harmful due to cyanotoxins. Average secchi depth in the IGL has decreased significantly in the last 40 years.

Management Challenges

The Iowa Great Lakes are a difficult resource to protect. Over 85,000 acres in size, in two states, in two EPA Regions, and with multiple resource managers provides a problem on the best day. The treatment of the IGL has been underway since the early 90's and the water quality has improved. However with smaller budgets and greater need to see results, a more logical and systematic approach is needed. After much investigation to find the ideal management size in the watershed it was determined size is not so much the deciding factor as how and where to manage

Striving for success without hard work is like trying to harvest where you haven't planted – David Bly

It was decided that resource management areas were needed in the IGL to provide the focus for the systematic approach. The Iowa

Great Lakes was then divided into management areas dependent upon the major resource within that area but still based on sub-watersheds. In this way, the most significant resources can be protected and sustained. The following Resource Management Areas have been identified in the IGL and have been serve as the basis for how the IGL will be managed over the coming 40 years. Management of water-bodies is not a precise science because of the interconnectedness of the environment with the water bodies. When trying to manage a watershed the size of the Iowa Great Lakes it is very difficult to determine where the greatest benefit will achieved. If the watershed is broken into manageable resource areas or “resource management areas” with key resources being what is managed it is easy to see benefit and the interconnectedness is now working in the favor of resource managers.

The Resource Management Areas that have been identified and the implementation schedules that will be used in this Management Plan include areas that have been determined to be priority sub-watersheds. These priority sub-watersheds have been determined to produce 30% of the sediment into the Iowa Great Lakes each year. These priority sub-watersheds often are within a portion of a Resource Management Areas. Because these priority areas produce so much sediment they should still be treated as a priority. However, if the entire Resource Management Area is managed as a whole, a priority should be given to the priority as a way to manage each resource area.

The following are the Resource Management Areas within the Iowa Great Lakes that have been identified. Some of the Iowa Great Lakes have not been identified as part of a Resource Management Area, either because it is too small or because there is not a significant resource to associate it with. Those areas are not to be ignored but will be considered a “general” management area but lower on the priority list in most instances.

The Iowa Great Lakes and their watersheds are a complex and challenging resource to protect. Most lake watersheds can be easily compartmentalized based on a regular dendritic drainage pattern. Typically, small upland watersheds flow to create small tributaries which join to form a stream or larger watershed which eventually flows into a lake. A larger lake may have a few of these concentrated areas of inflow. These lake watersheds lend themselves to traditional modeling tools in which the watershed is broken down into smaller sub-watersheds, modeled, monitored, and analyzed for priorities.

The Iowa Great Lakes Watershed is young, geologically speaking, with a poorly defined drainage pattern. The larger lakes in this watershed are connected to each other and in turn are connected to a series of smaller lakes and large wetland complexes. The upland portion of the watershed is pock marked with wetlands (many of which have been drained through a dense network of drainage tiles). Complicating things further, some drainages are disconnected from the lake and will dead end in a wetland or closed basin. Some seem to dead end, but then enter drainage intakes and funnel to the lake through man-made drainage networks. One of the Iowa Great lakes may have as many as 40 to 50 small inflow areas draining from uplands, wetlands, or drainage and storm tile. The IGL watershed does not lend itself to traditional modeling techniques and when looked at in its entirety is overwhelmingly complex.

Historical efforts in the IGL watershed have focused on improving the water quality of the main lakes; however temporal variations and the interconnectedness of the lake system have made measuring success very problematic. Water quality measurements from many points in time have been recorded, but variation in that data makes assessment of long term trends problematic. An unconventional approach is needed to assess, plan, and implement water quality improvement and protection efforts.

The Iowa Great Lakes can be broken into smaller components or resource management areas (RMA’s). These RMAs are based on easily identified major sub-watersheds many of which contain key/significant natural resources complexes. Although an RMA’s drainage and management strategy may still be complex, RMAs can be recognized by stakeholders and resource professionals as important compartments of the watershed. This approach also allows for more easily defined goals. Attainment of these goals should provide the opportunity for measureable results within the RMA. Successful improvements to water quality within an RMA should lead to measurable impacts to the larger system to which they are connected.

The following RMA's have been identified in the IGLs. Management plans have been developed for each RMA and will serve as the basis for ongoing analysis and prioritization, community support, and funding. Inherently, some areas of the watershed will not be included in a specific RMA. General considerations for these areas have been created.

Resource Management Areas (RMA):

Little Spirit Lake:

Loon Lake:

Anglers Bay:

Sunset Beach:

Templar Park:

Hottes and Marble Lakes Resource Management Area (RMA)

Objective – Restore and maintain the Hottes Lakes and Marble Lake to clear water systems.
Description – Major changes in hydrology in the watersheds of this complex along with the introduction of common carp has led to slow degradation of water quality in these shallow lakes. Aquatic vegetation has nearly disappeared in Marble Lake and has receded dramatically in West Hottes Lake.

The Hottes/Marble Lake Complex and associated watershed represents nearly 15% of the watershed of Big Spirit Lake. When healthy, the shallow lakes making up the Hottes and Marble Lake RMA provide important watershed protection to Big Spirit Lake. These areas also provide critical fishery and wildlife habitats.
A holistic approach is needed to restore ecological health and water quality to this complex. A combination of both watershed and lake management practices is needed to reach the project objective.

Sediment, nutrients, and water volume loadings from the watershed should be reduced utilizing a prioritized plan through augmentation of existing landowner conservation programs, easements, and public acquisitions. Restoration of the lake to a clear water system can be accomplished through processes designed to mitigate watershed alterations and the introduction of common carp. To simulate natural drought conditions, managed water level draw downs are needed to stimulate growth of emergent aquatic vegetation and reduce or eliminate common carp populations.

Restoration Planning Components

<u>Watershed Practices</u>

Prioritized Sub-watershed (Figure 9.1)

Analysis has identified three priority wetland restorations in this sub-watershed (Figure 9.2). These wetland restorations have the potential to effectively intercept 793 acres (65% of the priority sub-watershed) of primarily agricultural runoff (Table 1). In lieu of restoration of these priority wetland areas, analysis has identified several locations for sediment retention basins or constructed wetlands. Discussions with individual landowners will determine if wetland restorations or sediment retention basins are more feasible. In the event neither wetland restorations nor sediment basins can be achieved, other management practices will be discussed to reduce sediment loss from the property.

High resolution aerial images from 2006 have helped identify 6.25 miles of ephemeral gully erosion within agricultural fields (Figure 9.3). By installing grassed waterways within each of these ephemeral gullies, 33 acres of upland habitat can be created and sediment loss from these areas significantly reduced.
Analysis has shown ten agricultural fields devoted to row crop production that exceed sediment loss thresholds (Figure 9.4). These fields, totaling 496 acres, account for 50% of the sediment loss within the targeted watershed. By implementing conservation/minimum tillage programs on these fields, this sediment loss could be significantly reduced.

Sediment loss can be reduced on 142 acres of row cropped fields by implementing alternative practices (i.e. permanent vegetation, sediment basins, and reduced tillage) where field slope is greater than seven percent. Eight acres have been identified and should have alternate land practices implemented because their slope is greater than 15% (Figure 9.5).

A total of 688 acres are currently being utilized for the production of corn and soybeans within the targeted watershed of Marble Lake. A nutrient and pesticide management plan should be set up with each individual landowner to ensure that over application and runoff of nutrients and pesticides is minimized. A plan should also be put into place to protect field tile intakes from excessive nutrients and sediment. Rock tile intakes with an additional 50 foot vegetative buffer should be discussed and implemented at all tile intake locations within the sub-watershed.

Outside Prioritized Sub-watershed (Figure 9.1)
Analysis has identified two priority wetland restorations in this portion of the sub-watershed (Figure 9.2). These wetland restorations have the potential to effectively intercept 380 acres (12% of the Hottes sub-watershed) of primarily agricultural runoff (Table 9.1). In lieu of restoration of these priority wetland areas, analysis has identified several locations for sediment retention basins or constructed wetlands. Discussions with individual landowners will determine if wetland restorations or sediment retention basins are more feasible. In the event neither wetland restorations nor sediment basins can be achieved, other management practices will be discussed to reduce sediment loss from the property.

Analysis of high resolution aerial images from 2006 has identified 4.15 miles of ephemeral gully erosion within agricultural fields (Figure 9.6). By installing grassed waterways within each of these ephemeral gullies, 39 acres of upland habitat could be created and sediment loss from these areas significantly reduced.
Analysis has shown four agricultural fields devoted to row crop production that exceed sediment loss thresholds (Figure 9.7). These fields, totaling 52 acres, account for 25% of the sediment loss within this portion of the watershed. By implementing conservation/minimum tillage programs on these fields, this sediment loss could be significantly reduced.

Sediment loss can be reduced on 73 acres of row cropped fields by implementing alternative practices (i.e. permanent vegetation, sediment basins, reduced tillage) where field slope is greater than seven percent. Six acres have been identified and should have alternate land practices implemented because their slope is greater than 15% (Figure 9.8).

A total of 440 acres are currently being utilized for the production of corn and soybeans within the second priority portion of the watershed for Hottes and Marble Lakes. A nutrient and pesticide management plan should be set up with each individual landowner to ensure that over application and runoff is minimized. A plan should also be put into place to protect field tile intakes from excessive nutrients and sediment. Rock tile intakes with an additional 50 foot vegetative buffer should be discussed and implemented at all tile intake locations within the sub-watershed.

Lake Restoration

Proper in lake management begins by controlling the movement of water and fish in/out of Marble Lake and the Hottes lakes. Electric water control devices including drain tiles should be placed at the outlets of Marble Lake and West Hottes Lake (Figure 9.9). These structures will allow for periodic draw downs that mimic historic drought conditions that are no longer occurring due to watershed changes. These water level fluctuations will allow managers to control fisheries populations and promote natural and diverse vegetation communities that benefit both fisheries and wildlife interests. At the same time and location the water control structures are placed; mechanical fish barriers should be installed to control the movement of fish in/out of these systems. Once control structures are in place, an initial extended drawdown should occur in order to firm up near shore bottom sediments and promote extensive plant growth before water levels are allowed to return. This drawdown will also allow managers to apply chemical treatments to Marble Lake and West Hottes to completely eliminate any existing fishery. Once water levels are allowed to return, managers should introduce Northern Pike and Yellow Perch to the Marble Lake system to re-establish the historic fishery. A long term management plan should be developed between fish and wildlife professionals that outline the criteria and plan for dewatering these basins in order to maintain a balanced ecosystem.

Welsh Lake:

Pikes Point:

Haywards Bay:

Omaha Beach:

Smiths Bay:

Maywood

Browns Bay:

Garlock Slough:

Emerson Bay:

Gull Point:

Millers Bay:

Manhatten Point:

Sandpiper Cove:

Harbor:

Triboji Beach:

Center Lake:

East Okoboji Slough:

Fish Hatchery:

Pioneer Beach:

Elinor Bedell State Park:

East Okoboji Beach:

Camp Foster:

Moores Beach:

Kellys Beach:

Chalstrom Beach:

Stakeout Road:

Lutheran Camp:

The Narrows:

Francis Sites:

Spirit Lake:

Upper Gar Lake:

Minnewashta Lake:

Pelican Ridge:

Pleasant Lake:

Lilly Lake:

Prairie Lake:

Spring Run Complex:

Woodlyn Hills:

Minnewashta Access:

Emerald Hills:

Lakeshore Area (buffered 1000 ft from lakeshore)

9.1 IMPLEMENTATION SCHEDULE

You can always amend a big plan, but you can never expand a little plan. I don't believe in little plans. I believe in plans big enough to meet a situation which we can't possibly foresee now.

Harry S. Truman

It is not likely that the water quality of the Iowa Great Lakes will ever equal or exceed that of pre-settlement. However, as in the picture below (Photo 9.1), from 1910, the water quality of our lakes has great potential to become sustainable and desirable for its highest and best use, which in many instances is contact.

Photo 9.1 Swimmers near Arnolds Park

The difficulty in assigning an implementation schedule for a watershed the size of the Iowa Great Lakes is trying to foresee any delays, human caused or weather related and how to understand the relationship of how fast a water body can react to treatment conditions. In some instances a 10% reduction of sediment may boost the water quality to a sustainable and desirable level but in another it may actually create a different problem than was being experienced prior to the treatment. In the second example, a new treatment schedule would need to be planned.

What can be done is create an implementation schedule that does not have firm dates but rather create an "order of importance" to it. For instance Figure 9.10 shows the agricultural areas in the IGL which produce 30% of the sediment that reaches a water body or basin. Those are the areas that need to be treated adequately, first, prior to moving onto new management areas. In addition to agricultural areas urban areas are a significant source of pollutants to the Iowa Great Lakes. The areas that produce at least 60% runoff from those urban areas are shown in Figure 9.11.

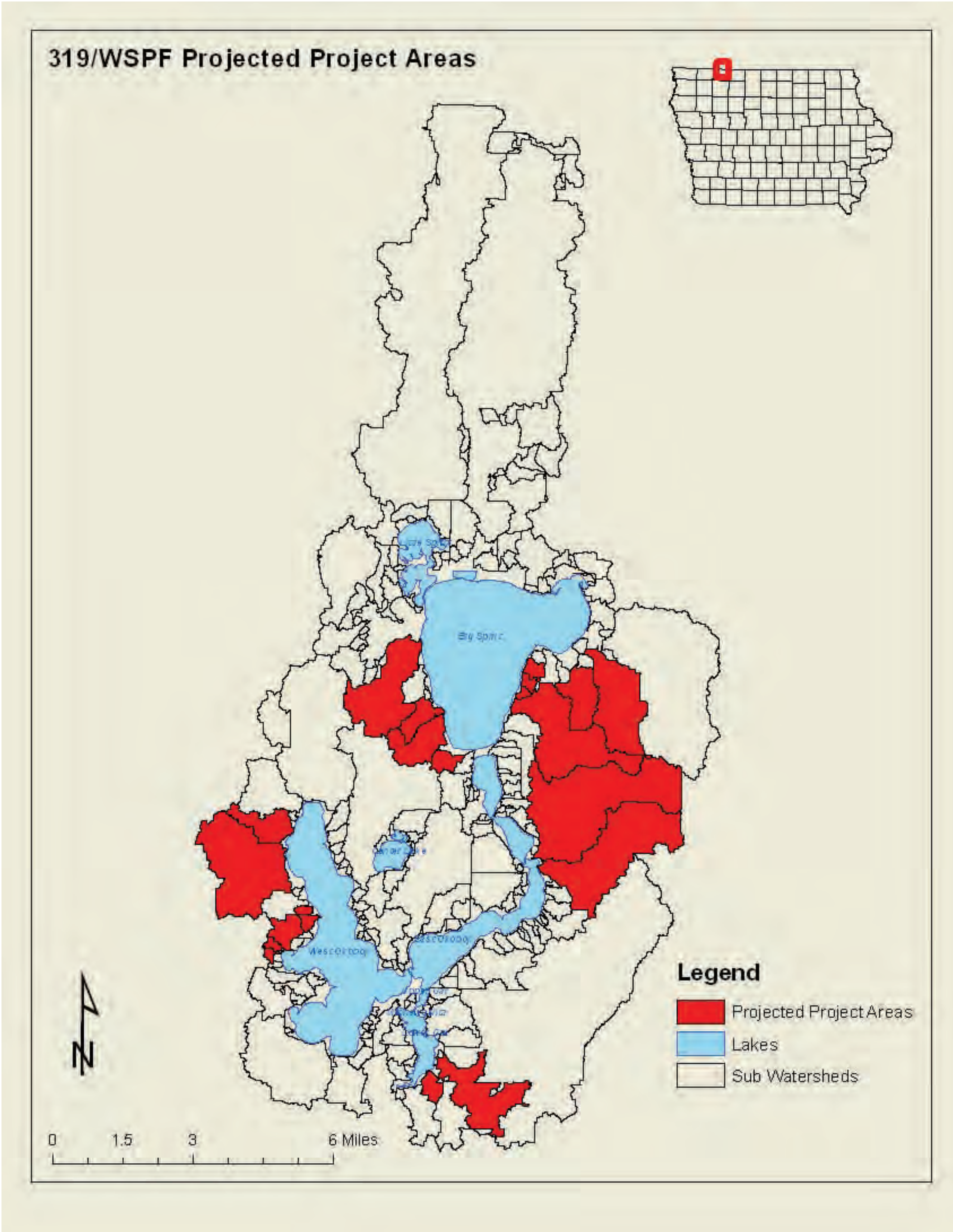

Figure 9.10 Sub-watersheds that produce 30% of sediment delivered to the Iowa Great Lakes each year.

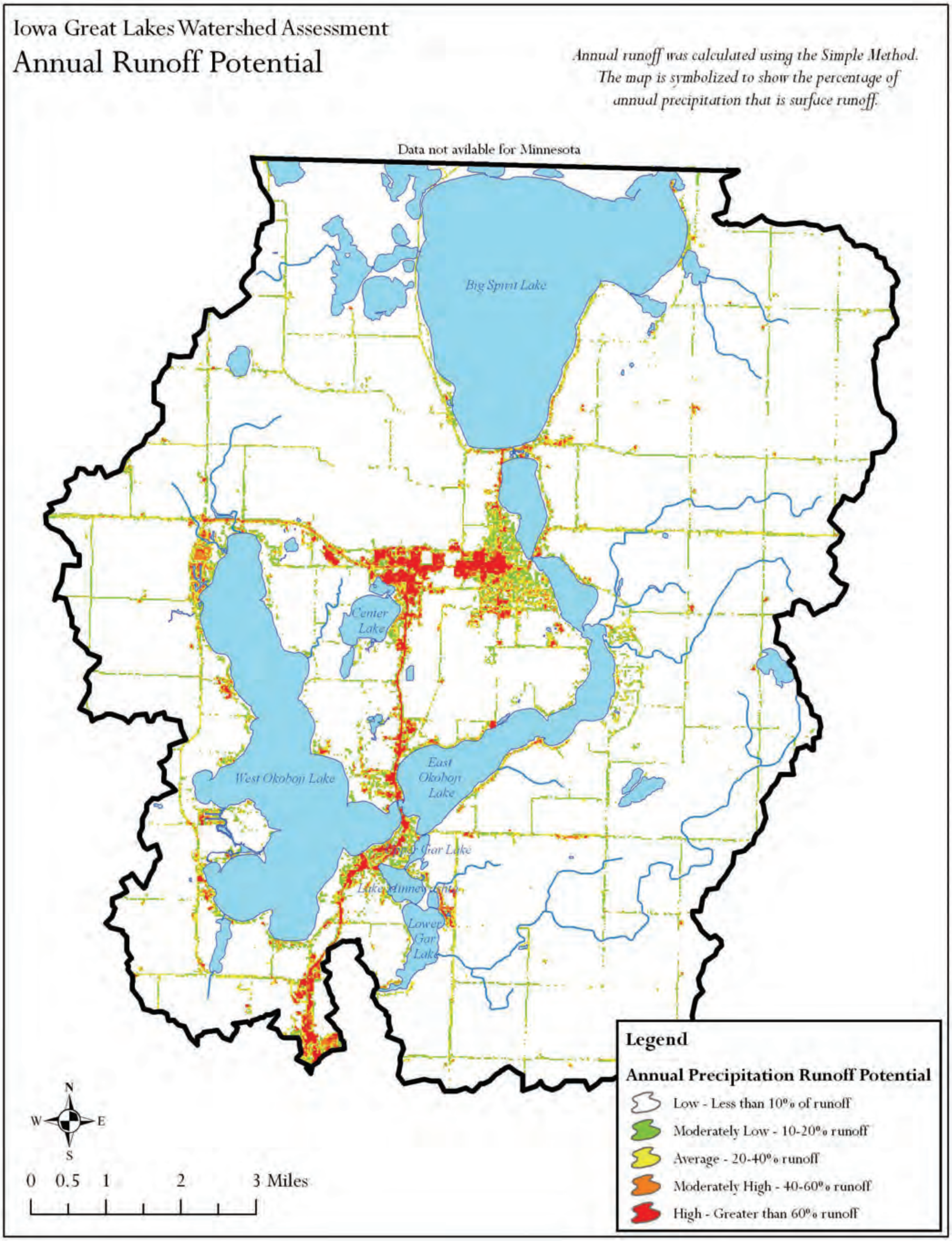

Figure 9.11 Annual Urban Runoff Potential

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