A Comprehensive Wetland Assessment, Monitoring, and Mapping Strategy for Minnesota

Minnesota DNR

Minnesota Pollution Control Agency

U.S. Fish & Wildlife Service

Minnesota Department of Agriculture — From the Farm to Your Family

Minnesota Board of Water & Soil Resources

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Table of Contents

Page

Lists of Figures and Tables .... **iii**
List of Acronyms and Technical Terms Used in the Strategy iv
Acknowledgements .... **v**
Executive Summary .... **vi**

Background **1**

Existing Approaches to Assessing Wetland Status and Trends **3**
- Wetland Quantity 3
  - Programmatic Tracking (permit and project data) 3
  - Wetland Mapping, Inventories and Sampling Efforts 4
    - National Wetland Inventory 4
    - National Resource Inventory 6
    - USFWS Status and Trends 6
- Wetland Quality 6
  - Function vs. Condition 7
  - Wetland Assessment Levels I, II and III 7
- Summary of Existing Monitoring Efforts 10

Developing a Comprehensive Wetland Assessment, Monitoring and Mapping Strategy for Minnesota **11**
- Organizational Structure 11
- Strategy Goals and Objectives 12
  - Overall Goal 12
  - Strategic Objectives 12

Comprehensive Wetland Assessment, Monitoring and Mapping Strategy for Minnesota **14**
- Wetland Quantity Assessment 14
  - Integrated Wetland Accounting System 14
  - Inventory Updates - Wetland Mapping 15
  - Sample Survey 19
    - Background/Process 19
    - Survey Design Specifications 20
    - Survey Minimum Detectible Units of Change 23
    - Ground-truthing Wetland Quantity Survey Data 23
- Wetland Quality Assessment 24
- Assessment Outcomes 28
- Data Management 28

Implementation **30**
- Roles and Responsibilities 30
- Schedule 30
- Funding 31

Literature Cited **34**

Appendix: Wetland Program and Data Survey **37**

Lists of Figures and Tables

Figures

Page

Figure 1 Wetland Conservation Act historic wetland area 1

Figure 2 Imagery age of the original National Wetlands Inventory in Minnesota............5

Figure 3 Organizational structure for developing the Comprehensive Wetland Assessment, Monitoring and Mapping Strategy...11

Figure 4 Proposed geographic reporting regions for CWAMMS 13

Figure 5 The CWAMMS conceptual data management and exchange flow diagram……… 28

Tables

Table 1 Wetland functions assessed by MnRAM 3.0..8

Table 2 Minnesota land-use categories for which emergy coefficients are being developed to test the applicability of the Landscape Development Index in Minnesota...9

Table 3 Imagery specifications typical for various applications 17

Table 4 Estimated number of plots needed to be sampled annually and the total number of plots needed to achieve a 90% confidence for detecting changes in wetland quantity with either a 20% or 15% error estimate in three- or four-panel sample designs..21

Table 5 Proposed sampling design for three-panel cyclical sampling with an estimated confidence of 90% and a +/- 20% error rate......................................22

Table 6 Strategic objectives addressed by (a) wetland quantity (A) and quality (B) monitoring approaches 27

Table 7 Roles and responsibilities of agencies and organizations in implementing the CWAMMS..32

Table 8 Estimated annual cost for proposed wetland survey for the first and subsequent cycles for two levels of allowable error and two cyclic panel designs..33

List of Acronyms and Technical Terms Used in the Strategy

BWSR	Minnesota Board of Water and Soil Resources
CIR	color infra-red
CWAMMS	Comprehensive Wetland Assessment, Monitoring and Mapping Strategy
DNR	Minnesota Department of Natural Resources
FGDC	Federal Geographic Data Committee
FQAI	Floristic Quality Assessment Index
GIS	Geographic Information System
GRTS	Generalized Random Tessellation Stratified design
IBI	Index of Biological Integrity
LDI	Landscape Development Index
LGU	local governmental unit
MDA	Minnesota Department of Agriculture
MPCA	Minnesota Pollution Control Agency
MnRAM	Minnesota Routine Assessment Method
NAPP	National Aerial Photo Program
NRCS	Natural Resource Conservation Service
NRI	National Resource Inventory
NWI	National Wetland Inventory
PSU	primary sample unit
RAP	Minnesota Department of Natural Resources Resource Assessment Program
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WCA	Minnesota Wetland Conservation Act

Acknowledgements

Project Lead Staff

Mark Gernes, MPCA
Doug Norris, DNR

Project Steering Committee

Michael Bourdaghs, MPCA
Matt Drewitz, MDA
Sue Elston, USEPA
John Genet, MPCA
Bruce Gerbig, DNR
Dan Girolamo, BWSR
Daniel Helwig, MPCA
Brian Huberty, USFWS
Thomas Mings, BWSR
Ray Norrgard, DNR
David A. Weirens, BWSR

Project Oversight Team

Ed Boggess, DNR
Paul Burns, MDA
John Guenther, DNR
Ron Harnack, BWSR
Marvin Hora, MPCA
Kent Lokkesmoe, DNR
Larry Nelson, DNR
Lee Pfannmuller, DNR
Mike Sandusky, MPCA
Tim Scherkenbach, MPCA
Dan Stinnett, USFWS
Bob Whiting, COE

Resource Assessment Program, DNR Forestry Division

Timothy Aunan
Bill Befort
George Deegan
David Heinzen

Executive Summary

Minnesota is fortunate to have a rich diversity of wetlands and, other than Florida, more wetland acreage than any other of the contiguous states. However, roughly half of Minnesota's original wetlands have been lost to drainage or filling. Beginning in the 1970s, public policy began to shift toward greater protection of wetland resources. This trend culminated with the passage in 1991 of the Minnesota Wetland Conservation Act (WCA), which called for no net loss in wetland quantity and quality and ultimately a net gain in wetland resources.

Existing efforts to assess wetland status and trends in Minnesota are inadequate. Data collected on proposed wetland loss and compensatory mitigation by state and federal wetland regulatory programs lack coordination, may not reflect actual (versus permitted) activities, and do not adequately account for exempt and illegal wetland loss. Data collected by government agencies and nongovernmental conservation organizations on voluntary wetland restorations are inconsistent and incomplete. National wetland and land-use monitoring efforts by the U.S. Fish and Wildlife Service (USFWS) and the Natural Resources Conservation Service (NRCS) do not sample intensively enough in Minnesota to draw accurate conclusions on the state's wetland status and trends.

Even less comprehensive data are available concerning the status and trends in wetland quality across the state. Essentially all that is known about Minnesota wetland quality comes from anecdotal observations, experience with a few local projects to improve or restore wetland habitat, data collected for local comprehensive wetland management plans, and limited data from initial efforts to develop wetland-quality assessment methods.

To address these deficiencies, a group of state and federal agencies collaborated to develop the Minnesota Comprehensive Wetland Assessment, Monitoring and Mapping strategy (CWAMMS). The primary agency participants were the Minnesota Board of Water and Soil Resources (BWSR), the Minnesota Department of Natural Resources (DNR), the Minnesota Department of Agriculture (MDA), the Minnesota Pollution Control Agency (MPCA), and the USFWS.

The overall goal of the CWAMMS is to develop a broadly understood, scientifically sound strategy for monitoring and assessing status and trends in wetland quantity and quality statewide. Under this goal there are five strategic objectives:

1. Establish accurate baseline data on wetland quantity and quality by wetland class (type) statewide and in each of four geographic regions: the Prairie Parkland, Eastern Broadleaf Forest, the Laurentian Mixed Forest, and the Paleozoic Plateau (figure 4).
2. Accurately assess future changes (trends) in wetland quantity and quality by wetland class in the four geographic regions listed in objective 1 and statewide.
3. Associate changes in wetland quantity and quality with causal mechanisms, such as urban and rural development, agricultural and silvicultural activities, transportation, mining, natural factors, conservation programs, and other activities.

4. Provide statewide reports of status and trends in Minnesota wetland quantity every three years beginning in 2009, and provide similar status and trends reports on wetland quality every two to three years in select regions beginning in 2009. The different reporting times reflect the differences in collecting and analyzing data for wetland quantity versus wetland quality. These reports will be used to assess the effectiveness of wetland regulatory and non-regulatory programs and will provide a sound basis for future state wetland policy and management decisions.
5. Contribute to the long-term understanding of Minnesota's wetland health (functions), distribution, structure and processes.

To assess status and trends in wetland quantity, three separate but complementary approaches are recommended:

- Develop and implement an integrated, geo-referenced, online database for tracking wetland permitting and conservation program activities.
- Update the National Wetland Inventory (NWI) in Minnesota on a regular basis.
- Initiate a statewide random-sample survey using remote sensing data to track wetland gain and loss.

Wetland quality assessment will be conducted at three scales (landscape, qualitative field observational, and intensive sampling in individual wetland basins) using appropriate assessment methods and utilizing the digital-coverage remote-sensing results from the random-sample survey developed for wetland quantity assessment.

Data from the various assessment approaches will be integrated and managed through several related geo-referenced databases maintained by participating agencies and partners. Collectively, these geo-databases will be accessible through a single wetlands data warehouse that can be queried by each partner agency and other users as appropriate.

The CWAMMS will be implemented through the collaborative efforts of local governments, state and federal agencies, and nongovernmental organizations.

Specific roles and responsibilities have been identified.

Partial funding for implementing the CWAMMS has been received from the USEPA (for three years) and through a state legislative appropriation to the DNR. The BWSR previously received a separate grant from the USEPA to plan the initial module of an integrated online permit and wetland accounting system. USEPA funds will also enable the MPCA to conduct pilot tests of wetland quality assessments. Initial stages of implementing the CWAMMS will begin in early 2006.

Background

Minnesota is a water-rich state. Even after more than a century of draining and filling, Minnesota's current 9.3 million acres of wetland (www.dnr.state.mn.us/wetlands/index.html) is second only to Florida's among the contiguous states in diversity and extent of wetlands. Considerable regional differences exist in Minnesota's remaining wetland resources (figure 1). Extensive agricultural drainage and urban development have greatly altered Minnesota's natural hydrology. These landscape-scale changes have brought great economic prosperity to the state and its citizens, but they have eliminated more than 90% of the wetlands in the southern and western regions of the state. In northern Minnesota, particularly north-central Minnesota, vast expanses of peatlands remain in a varied mosaic across the landscape.

These regional differences have been incorporated into the primary state wetland regulatory program, the Minnesota Wetland Conservation Act (WCA). Under the WCA, activities that impact wetlands in the northern and northeastern counties which still retain more than 80% of their historic wetlands are required to replace lost wetland acreage with new wetlands in a 1:1 acre ratio. In the rest of Minnesota, the WCA requires two acres of new wetland be restored for every acre lost.

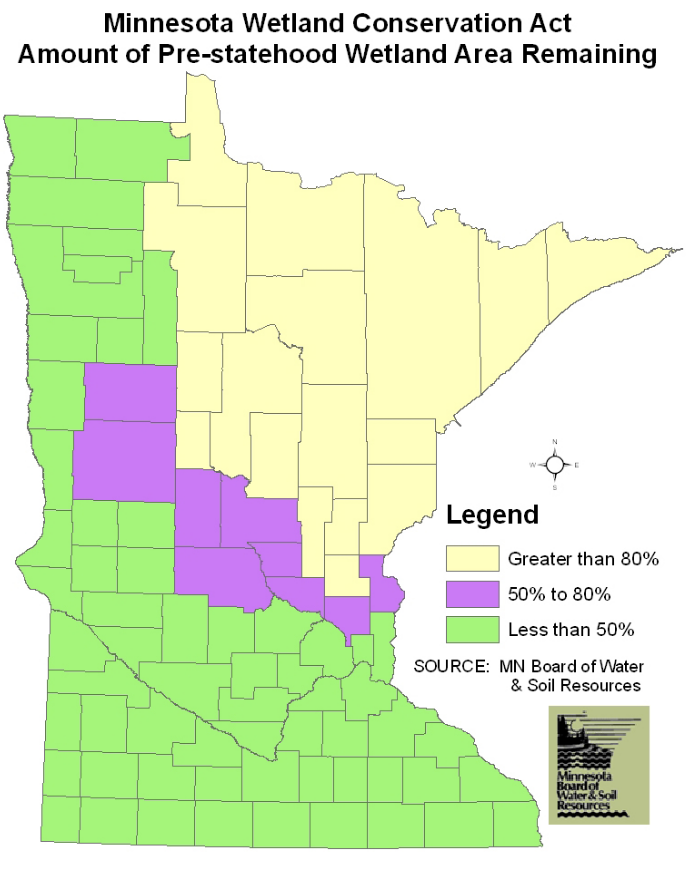

Figure 1 **Wetland Conservation Act historic wetland area**

At the time the federal Water Pollution Control Act (Clean Water Act) was passed in 1972, the federal government still encouraged farmers to drain wetlands to put more land into production. In urban areas, natural wetlands were routinely converted to regional stormwater ponds and surrounding smaller wetlands were connected to efficient drainage systems to increase flows and alleviate localized flooding, making more land available for development.

Wetland impacts continue today. Activities such as residential, commercial, industrial and agricultural practices as well as mining, transportation and utility projects result in several hundred acres of Minnesota wetlands being filled, drained and excavated each year (BWSR 2005).

Where wetlands remain on the landscape, wetland functions and biological quality are often impaired by stressors, such as invasion by non-native plants and unnatural fish communities, hydrologic changes, nutrient enrichment, sedimentation and toxic pollutants [see, for example, Gleason et al. (2003), Gustafson and Wang (2002), Wilcox et al. (1985), and Zimmer et al. (2003)].

Early in his presidency, President George H. W. Bush established an administrative policy of no net loss of wetlands. Later that policy was expanded to include a goal of achieving a net gain of wetlands. In 1991, with the passage of the WCA (Minn. Laws 1991, Chapter 354), Minnesota officially adopted a no-net-loss goal that states in part:

> "The Legislature finds that the wetlands of Minnesota provide public value by conserving surface waters, maintaining and improving water quality, preserving wildlife habitat, providing recreational opportunities, reducing runoff, providing for floodwater retention, reducing stream sedimentation, contributing to improved subsurface moisture, helping moderate climatic change, and enhancing the natural beauty of the landscape, and are important to comprehensive water management, and that it is in the public interest to:
>
> (1) achieve no net loss in the quantity, quality, and biological diversity of Minnesota's existing wetlands;
>
> (2) increase the quantity, quality, and biological diversity of Minnesota's wetlands by restoring or enhancing diminished or drained wetlands;
>
> (3) avoid direct or indirect impacts from activities that destroy or diminish the quantity, quality, and biological diversity of wetlands; and
>
> (4) replace wetland values where avoidance of activity is not feasible and prudent." (Minn. Stat. 103A.201).

Unfortunately, nearly 15 years after enactment of the WCA, we still do not confidently know whether we have reached the statutory goal of no net loss of wetland quantity and have very little data concerning wetland quality. The next section of this publication outlines existing wetland assessment efforts and their shortcomings. Only through a well-designed, comprehensive monitoring strategy will the state be able to accurately ascertain the status and trends of wetland quantity and quality.

Existing Approaches to Assessing Wetland Status and Trends

Although several programs and reporting systems currently provide important information about Minnesota's wetland resources, they fail to provide a comprehensive assessment of status and trends in wetland quantity or quality. Existing wetland-monitoring efforts are not well integrated and focus almost exclusively on wetland quantity, even though federal and state wetland laws explicitly require that wetland quality also be monitored, protected and restored.

Following are descriptions of several existing wetland-assessment efforts, along with discussion of their strengths and shortcomings.

Wetland Quantity

Programmatic Tracking (permit and project data)

Local governments administering the WCA are required by BWSR to enter data from wetland permit applications into a statewide database (www.bwsr.state.mn.us/outreach/eLINK/index.html). This database tracks information, such as acres proposed to be drained or filled, acres of proposed replacement, and acres of exempt impacts. Similarly, the St. Paul District of the U.S. Army Corps of Engineers maintains a database, called the Ombill Regulatory Module (ORM), which tracks wetland permit actions regulated under the Clean Water Act Section 404.

In addition to permit activity, Minnesota farmers and other landowners voluntarily restore thousands of wetland acres every year under a variety of conservation programs administered by federal and state agencies and nonprofit organizations, often working in partnership. These restoration efforts are tracked by each participating agency and organization involved, independent of other partners and using different methods. Restorations funded entirely by landowners, without financial or technical assistance from conservation agencies or organizations, are not tracked at all. Most wetland restorations in Minnesota have been funded primarily by U.S. Department of Agriculture (USDA) Farm Bill conservation programs or Reinvest in Minnesota programs.

The BWSR collects and compiles data from available data sources, including local government units and agency programmatic databases. These data are published in periodic state wetland reports to provide a picture of wetland gains and losses. The most recent state wetland report (BWSR 2005), covering the period 2001-2003, included the following findings:

- Through the WCA, 10,145 acres of proposed wetland impacts were avoided or minimized.
- Over 2,500 acres of wetland were filled, drained or excavated. This includes both regulated and reported exempt impacts and resulted in at least 1,500 acres of compensatory mitigation.

- A reported 45,000 acres of wetlands were restored under various conservation incentive programs, along with a similar acreage of associated uplands restored to native vegetation.

These summaries of activities have been very useful for wetland and related conservation planning. However, this method of accounting, by itself, does not yield a complete and accurate statewide assessment for the following reasons:

- Programmatic accounting does not fully account for wetlands filled or drained by unregulated actions, including exempted activities or wetlands eliminated illegally.
- Permit data are not certified and do not always accurately reflect what happens on the ground — more or less wetland acreage may be lost or restored than described in permit applications. Furthermore, economic pressures have reduced local government and agency budgets, resulting in reduced staff resources for regulatory review, monitoring and enforcement.
- Permit tracking does not adequately account for temporal loss of wetlands. Temporal loss results when an activity removes wetlands from the landscape before the replacement wetland is mature and fully functioning. A National Academy of Sciences (2001) review of wetland mitigation and restoration cited temporal loss as a leading reason the nation was not meeting the federal no net loss policy.
- Mitigation credits in some WCA permits include wetland preservation, establishment of upland buffers around replacement wetlands, construction of stormwater ponds, or enhancement of existing wetlands. Though these actions are important, they present a misleading picture of actual wetland replacement acres.
- Current permit tracking does not account for wetland quality changes due to urbanization or agricultural practices that often degrade wetlands by runoff containing nutrients, soil particles, salts and litter. These wetland stresses, along with altered water regimes, change the character and frequently the classes (type) of wetland present, often degrading wetland health or ecological condition.
- It is difficult to get an accurate count of wetland acres restored under conservation and incentive programs because many restoration projects are completed as public-private partnerships involving many organizations. This can result in the same project acres being credited more than once. Some restorations are done privately without the involvement of conservation organizations or natural resource agencies, and these wetland acres are not tracked at all in programmatic databases.

Wetland Mapping, Inventories and Sampling Efforts

National Wetland Inventory

The National Wetlands Inventory (NWI), operated by the USFWS, is a national effort to map and classify the wetland resources in the United States. The NWI has proven to be an extremely valuable resource; however, it is quickly becoming outdated as the landscape continues to change (USFWS 2002). NWI mapping for Minnesota was completed late in the 1980s. For most of Minnesota, the aerial photography on which the NWI was based dates from the early 1980s. However, a few 7.5 quadrangles in northwestern Minnesota and a much larger area in northeastern Minnesota were mapped based on 1970s black-and-white photography (figure 2). The northeastern portion of the Minnesota inventory is particularly problematic because this region of the state is almost entirely forested and mapping wetlands in forested regions is less accurate than wetland mapping in open landscapes because of the difficulty of detecting wetland indicators beneath a forested canopy using remote imagery.

Remote sensing technologies have greatly expanded and improved since the 1980s, when the Minnesota NWI was completed. Today most wetland mapping is done with high resolution at 1:40,000 or 1:10:000 scale using color infrared (CIR) imagery and processed electronically using an analyst-supervised heads-up review process.

Originally, the NWI used high-altitude, small-scale (1:60,000 - 1:80,000) black-and-white or CIR aerial photographs taken in stereoscopic pairs during leaf-off periods, usually in spring. These stereo pairs were then interpreted and wetlands delineated as polygons on Mylar sheets laid over USGS topographic quad maps. At the time, this was an efficient wetland-mapping method.

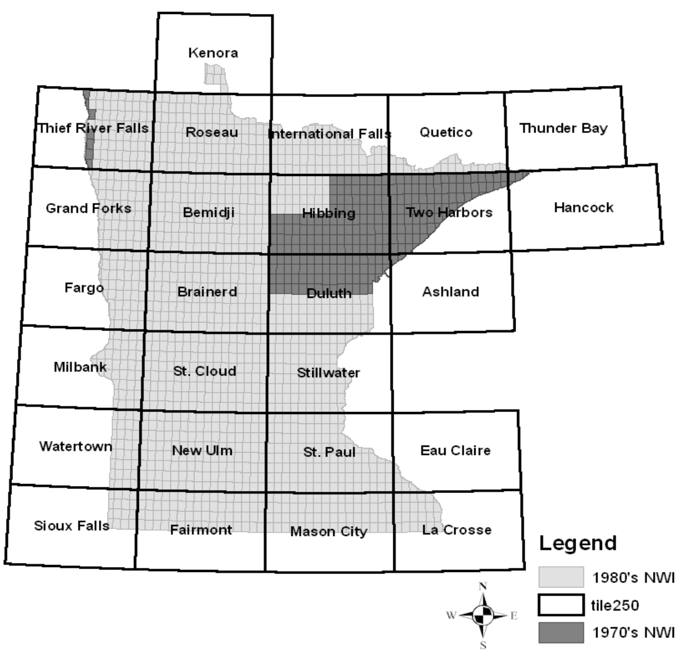

Figure 2 **Imagery age of the original National Wetlands Inventory in Minnesota**

In the 1990s, the NWI wetland map polygons were digitally scanned and rectified for use in GIS applications. The digital NWI data are now widely used for land use and environmental planning as well as regulatory purposes and are available at www.wetlandsfws.er.usgs.gov/ and at www.deli.dnr.state.mn.us.

Mapping wetlands provides a comprehensive assessment of wetland status at a given time, since it is a complete census. However, an updated NWI would not be an effective measure of trends because the newer mapping technologies are potentially more accurate than the original NWI, and this would confound comparison of wetland area changes against the original inventory. It may be appropriate to compare successive future updates if the mapping technologies are similar.

National Resources Inventory

Tracking conservation and agricultural practices on private land is the goal of the USDA's National Resource Inventory (NRI) (www.nrcs.usda.gov/technical/NRI/). Begun in its earliest form in 1958, the NRI is one of the older nationwide random-survey assessment programs. The NRI identifies land-use practices on nonfederal agricultural land using aerial photography of 160-acre primary sampling units. From this survey, status and trends in wetland extent on private lands have been estimated (www.nrcs.usda.gov/technical/land/nri03/nri03wetlands.html). Results from the NRI wetland findings were cited by President Bush in his April 2005 Earth Day presentation as evidence that the nation has achieved no net loss of wetlands. However, the NRI only is completed on nonfederal lands and is, therefore, not representative of the entire country. Since the NRI is a national survey, only limited data are available for individual states.

USFWS Status and Trends

In 1984, the USFWS initiated a nationwide survey specifically designed to track the status and trends in wetland acreage across the United States. This survey used aerial photography of over 4,000 randomly selected four-square-mile plots across the country. The survey has been conducted roughly every 10 years (Dahl and Johnson 1991, Dahl 2000). In his 2004 Earth Day address, President Bush requested the USFWS to begin issuing a wetlands status and trends report every five years beginning in 2005 (www.whitehouse.gov/news/releases/2004/04/print/20040422-1.html). The USFWS Status and Trends survey has only focused on wetland quantity and has not included any measures of wetland quality or condition.

Because it is designed as a national survey, the USFWS Status and Trends survey does not adequately represent the status and trends of Minnesota wetlands with acceptable statistical precision.

Wetland Quality

Compared to wetland quantity estimates, very little is known about wetland quality trends in Minnesota, other than a general understanding that there are many anthropogenic stressors which adversely affect wetland condition. A few examples of wetland stressors are hydrologic alterations from discharge of wastewaters, including stormwater; presence of undesirable/nuisance fish as well as exotic and/or invasive plants; and excessive loading of nutrients, sediments and toxics, such as heavy metals and deicing compounds.

Assessing wetland quality, whether measured by condition or as functional equivalents, is technically and operationally challenging and will require a suite of assessment methods.

Function vs. Condition

Wetlands support many biological, chemical and physical processes that directly or indirectly benefit humans. These processes have been categorized into several discrete wetland functions to help illustrate the importance of protecting wetlands and to facilitate wetland public policy development. The WCA recognizes the following wetland functions: water quality protection, including filtering of pollutants in surface and groundwater; utilization of nutrients; trapping sediments; shoreline protection; recharge of groundwater; floodwater and stormwater retention; public recreation and education; commercial uses; fish, wildlife and native plant habitats; and low-flow augmentation, as well as other functions, values and public uses of wetlands.

Condition assessment represents an evaluation of the integrity or health of wetlands. Condition is often closely associated with wetland water quality and is frequently assessed using biological assessment methods. These methods are based on the concept of biological integrity defined as "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981). Condition assessment requires comparison with regional reference (or least impacted) conditions. Functional assessment can also benefit from regional reference wetland assessment, though it is not required.

Wetland Assessment Levels I, II and III

Although assessment of wetland quality in Minnesota is technically feasible, assessing over nine million acres of wetlands with very limited available resources is a significant challenge. The USEPA has assisted states with developing comprehensive wetland-protection programs, including comprehensive wetland-assessment strategies. The USEPA has also supported development of wetland-monitoring and -assessment protocols and has published several documents to assist states and tribes with developing a wetland-assessment program (www.epa.gov/waterscience/criteria/wetlands/). In addition, the USEPA has drafted technical guidance for states and tribes on the elements of a state water-monitoring and -assessment program for wetlands (USEPA 2006). This guidance recommends monitoring and assessment of wetland condition at three different scales; commonly referred to as Level I, II and III.

Level I assessments are landscape-scale measures using geographic information systems and/or remote sensing techniques. While Level I methods generally have a relatively low level of assessment accuracy for individual wetland basin condition, an advantage of Level I methods is their ability to assess large areas or numbers of wetlands with a minimum of resources.

Level II assessments apply localized, field-scale assessments using rapid qualitative methods based on simple observational metrics specific to individual wetland basins. Level II assessments are generally moderately accurate in assessing individual wetlands. The advantage of Level II methods is that many field-scale assessments of individual wetland basins can be made with moderate resource expenditures.

Level III assessment methods are intensive site assessments based on quantitative field sampling. Level III methods are the most accurate assessments, but they are resource intensive and only a relatively small number of assessments can be done each year. The USEPA recommends using Level III methods to validate Level I and II assessment techniques. Once fully developed and validated, all three assessment levels can be used in conjunction with random surveys to make regional extrapolations about wetland condition.

Since the mid-1990s the MPCA has been developing methods for assessing wetland condition. Most of this time has been focused on developing quantitative indices of biological integrity (IBIs) for depressional wetlands, which is a Level III assessment method. At about the same time, an interagency workgroup began developing a rapid functional assessment method for Minnesota wetlands, called the Minnesota Routine Wetland Assessment Method (MnRAM), that relies on qualitative field observations and desktop-generated data and is able to assess 12 wetland functions (table 1). The MnRAM has gone through three significant revisions and has been widely used for many comprehensive wetland-planning projects by local governments in Minnesota. The MnRAM 3.0 and the associated Management Classification System can be accessed at www.bwsr.state.mn.us/wetlands/mnram/index.html. In most applications, the MnRAM is best characterized as a Level II assessment method.

Table 1. **Wetland functions assessed by MnRAM 3.0**

Vegetative diversity/integrity	Downstream water quality
Maintenance of hydrologic regime	Shoreline protection
Floodwater/stormwater attenuation	Maintenance of wildlife habitat structure
Aesthetics/recreation/education/cultural uses	Maintenance of fish habitat
Commercial uses	Maintenance of amphibian habitat
Maintenance of wetland water quality	Groundwater interaction
Additional information useful in certain applications	
Wetland restoration potential	Additional stormwater treatment needs
Sensitivity to stormwater and urban development	

Recently the MPCA has begun efforts to develop and validate two potential Level I wetland-assessment methods. The first Level I method, called the Landscape Development Intensity index (LDI), and is an approach to measure landscape impacts surrounding target wetlands. The LDI is derived from the nonrenewable energy (termed "emergy[1]") required to create and maintain given land uses (Brown and Vivas 2005). Scientists who study energy transfer rates are able to calculate emergy values for various land-use activities in different regions. The MPCA is collaborating with emergy experts at the USEPA Atlantic Ecology Division of the Office of Research and Development National Health and Environmental Effects Research Laboratory in Narragansett, Rhode Island, to develop emergy values for Minnesota land-use categories presented in table 2.

Table 2. **Minnesota land-use categories for which emergy coefficients are being developed to test the applicability of the Landscape Development Index in Minnesota**

Land-use Categories	
Natural	Residential low intensity
Ag low intensity	Residential-medium intensity
Ag medium intensity	Residential high intensity
Ag high intensity	Industry light
Paved roads	Industry heavy
Commercial/institutional single story	Intensive land utilization
Commercial/institutional 2 stories or greater	Managed open space/recreational

Index scores are calculated by multiplying the proportional area of a land-use category by the specific emergy value associated with that land use and summing the result for the different land uses within a specified area of influence around the wetland being assessed. The LDI has been found to be highly correlated with Level III wetland assessments in Florida (Brown and Vivas 2005) and is, therefore, an effective Level I assessment. Validation of this assessment method in Minnesota will be accomplished by examining the correspondence of results with Level III assessments.

The second Level I approach under development would assess wetlands based on the plant community structure and diversity as determined by the pixel diversity detected from multi-spectral remote imagery. Once developed, the pixel diversity variables will be examined for correlation with Level III field-based results similar to the validation process for the LDI index. Both of these Level I assessment methods are in the early research and development stages.

Another wetland assessment method, the Floristic Quality Assessment Index (FQAI), is currently being developed for Minnesota. The MPCA has retained a contractor who, with input from the DNR Natural Heritage and County Biological Survey programs, will develop coefficients of conservatism (*C*-values) for Minnesota's wetland plants. *C*-values, the basic measurement unit for the FQAI, represent the

[1] The term "emergy" derives from work by Howard T. Odum and colleagues to standardize energy transformations with applications to ecology. It essentially refers to "energy memory." www.dieoff.org/page232.pdf

spectrum of plant species suitability or fidelity to high-quality, unimpacted biological communities or low-quality impacted biological communities (Swink and Wilhelm 1994). Once *C*-values have been developed, they will need to be validated and the application of the FQAI as a Level II and/or III assessment method will be explored.

Summary of Existing Monitoring Efforts

Due to the complexity of assessing the status and trends of both wetland quantity and quality and deficiencies in existing techniques and programs, none of the approaches described above can individually be expected to adequately assess wetland status and trends in Minnesota.

Wetland quantity and quality monitoring are clearly distinct in concept and methods, requiring separate monitoring techniques to achieve the strategic objectives. Thus, an integrated approach will be needed, utilizing multiple data-collection techniques designed specifically for Minnesota.

The natural hydrology of many wetlands, like this one, in an urban location, has been altered.

Developing a Comprehensive Wetland Assessment, Monitoring and Mapping Strategy for Minnesota

In early 2002, representatives from the BWSR, the DNR, the MPCA, the MDA and the USFWS began discussing the need to accurately determine the status and trends in wetland quantity and quality in Minnesota. These representatives agreed to jointly apply for funding from the USEPA to develop the Comprehensive Wetland Assessment, Monitoring and Mapping Strategy (CWAMMS) for Minnesota. Partial funding for development of the CWAMMS was received from the USEPA as a State Wetland Program Development Grant (104b), Grant No. CD-965084-01 and work on the strategy began in late October 2003.

Organizational Structure

Development of the CWAMMS was conducted under a fairly simple organizational structure (figure 3).

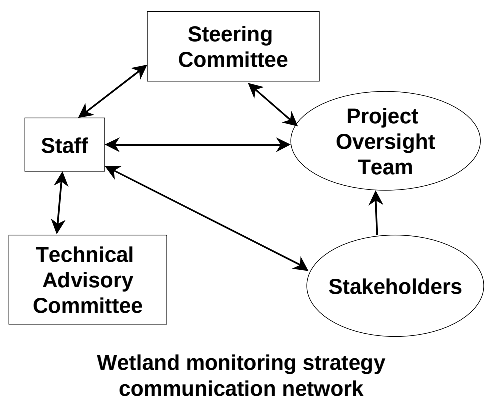

Figure 3. **Organizational structure for developing the Comprehensive Wetland Assessment, Monitoring and Mapping Strategy**

A Steering Committee, made up of technical and supervisory staff from each of the sponsoring agencies and departments, provided primary direction for the project. The Steering Committee met frequently over the course of the CWAMMS development process.

The Technical Advisory Committee consisted of technical experts from a wide variety of disciplines and agencies from whom technical input has been obtained on an as-needed basis.

Stakeholders consisted of groups and individuals having an interest in wetland management and regulation in Minnesota. Input from the stakeholders group was received mostly through e-mail and telephone conversations.

The Project Oversight Team consisted of senior managers and executives from the sponsoring agencies and departments. They generally met semi-annually and received periodic briefings from their respective staff representatives on the Steering Committee.

CWAMMS development was staffed primarily by the MPCA and the DNR. An initial, kickoff meeting was held in January 2004 where the Steering Committee, the Technical

Advisory Committee, and stakeholders met to discuss the project. A summary of existing wetland and related monitoring programs resulted from this meeting (Appendix).

Strategy Goals and Objectives

Early in the CWAMMS development process, a single overall goal and several associated strategic objectives for CWAMMS were proposed and adopted.

Overall Goal

Develop a broadly understood, scientifically sound strategy for monitoring and assessment of the statewide status and trends in wetland quantity and quality. Under this goal there are five strategic objectives.

Strategic Objectives

a. To establish accurate baseline data on wetland quantity and quality statewide and in each of four geographic regions: the Prairie Parkland, Eastern Broadleaf Forest, the Laurentian Mixed Forest and the Paleozoic Plateau (figure 4)[2], and by the following wetland classes found in Minnesota (based on Cowardin et al. 1979) and non-wetland classes:

Wetland Classes	**Non-wetland Classes**
Palustrine emergent	Agricultural
Palustrine forested	Silvicultural
Palustrine scrub-shrub	Urban
Palustrine aquatic bed	Rural development
Palustrine unconsolidated bottom	Deep water (aggregation of lacustrine and riverine waters)
	Natural
	Other

b. Associate changes in wetland quantity and quality with specific causal mechanisms, such as urban and rural development, agricultural and silvicultural activities, transportation, mining, natural factors, conservation programs, and other activities.

c. Provide statewide reports of status and trends in Minnesota wetland quantity every three to five years beginning in 2009 and provide similar reports on wetland quality status and trends every two to three years in select regions beginning in 2009. These reports will be used to assess the effectiveness of wetland regulatory and nonregulatory programs and will provide a sound basis for future state wetland policy and management decisions.

d. Accurately assess future changes (trends) in wetland quantity and quality statewide and in the geographic regions presented in figure 4 by wetland class.

e. Contribute to the long-term understanding of Minnesota's wetland health (functions), distribution, structure and processes.

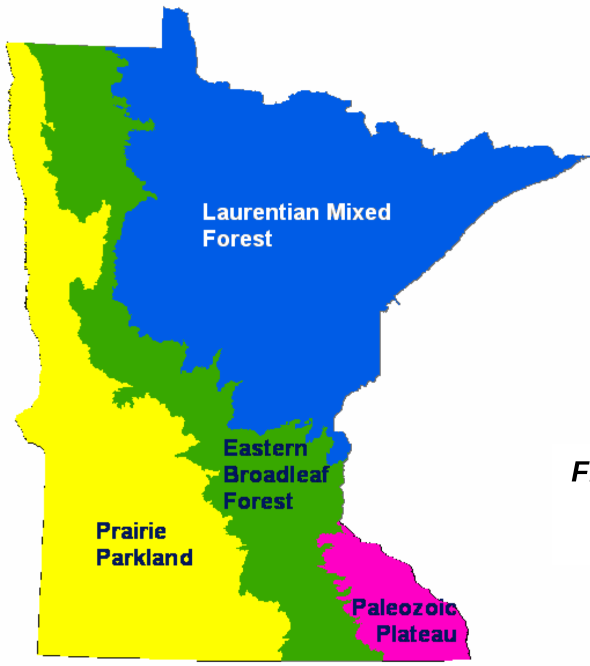

Figure 4. **Proposed geographic reporting regions for CWAMMS**

These four regions are approximated by the Province level of the Ecological Classification System (ECS), Minnesota Department of Natural Resources (www.dnr.state.mn.us/ecs/index.html) with the exception of the Paleozoic Plateau, which is an ECS Section. These regions were selected because the type and abundance of wetland resources in each of them is fairly distinct.

Comprehensive Wetland Assessment, Monitoring and Mapping Strategy for Minnesota

To assess status and trends in wetland quantity, three approaches are recommended:

1. improved programmatic accounting of wetland regulatory and nonregulatory programs,
2. comprehensive wetland mapping, and
3. survey sampling using remote sensing.

These three approaches are complementary and build upon existing wetland and natural resource assessment systems. To comprehensively assess wetland quality status and trends, monitoring approaches should follow the USEPA's recommended Level I, II and III methods. Ongoing efforts in Minnesota are focusing on continued development, testing and validation of assessment methods at these three scales to assure their applicability to Minnesota wetlands. Results of status and trends in wetland quantity and quality derived from each of these approaches will be integrated to provide a comprehensive analysis of wetland status and trends. Each of these approaches is discussed in greater detail below.

Wetland Quantity Assessment

Integrated Wetland Accounting System

The first component for assessing status and trends in wetland quantity is development and implementation of an internet-based, geographically referenced database and permit application-processing system for wetland project activity. This system will improve the completeness and ease of acquiring basic wetland accounting data from a variety of regulatory and non-regulatory programs.

Development of the integrated programmatic database should proceed in phases. Phase 1 will focus on an electronic wetland permitting system and include information regarding impact actions and compensatory mitigation. Mitigation monitoring and functional assessment data on mitigation wetlands, including wetland mitigation banks, will be built into the initial phase of the project to the extent possible. Subsequent versions of this wetland accounting system should integrate data related to wetland acreage restored and enhanced under voluntary or incentive-based conservation programs.

Complete and accurate program accounting will improve evaluation of the effectiveness of the wetland protection programs. Another benefit of a geo-referenced online permitting and accounting system is the ability to view wetland permitting information in real time and allow querying of permitting and related regulatory results by various geographic areas. Activities exempted by regulatory programs, however, would not be completely accounted for since they are not currently required to be reported. Illegal actions would also not be captured. Therefore, an online accounting database cannot be expected to completely and accurately represent wetland losses. However, a geo-referenced programmatic accounting system will make it easier to identify wetland violations when related to changes noted in NWI and sample survey plot updates.

Initial planning work for phase 1 (*wetland permitting actions)* of the online wetland accounting system is being completed by BWSR in collaboration with the DNR and the MPCA as part of a USEPA Wetland Program Development Grant and is expected to be completed by September 2006.

Inventory Updates - Wetland Mapping

Updating the NWI for Minnesota and building the operational infrastructure necessary for maintaining the inventory with current data is the second component for assessing wetland quantity status and trends. An up-to-date inventory will provide the current status of wetland quantity, and will also serve as a valuable resource to federal, state and local governments for implementing regulatory programs, conducting environmental modeling, and various planning needs. Updated NWI maps should follow federal wetland-mapping standards developed by the Federal Geographic Data Committee (FGDC).

Because the NWI is used for a variety of environmental planning purposes at various levels of government as well as by private enterprises, there is a real opportunity to share the cost of updating and maintaining the NWI. It is recommended that the agency partners that developed and endorse the CWAMMS cooperate with the Minnesota Governor's Council on Geographic Information to build a consortium of local, state and federal government entities along

A bottle trap can be used to sample invertebrate populations. Healthy wetlands have an array of invertebrate species.

with nonprofit organizations and private business to jointly sponsor and share the costs of updating the NWI. The Governor's Council on Geographic Information was formed to facilitate GIS data layers in Minnesota. Council members have experience in forming consortiums to update and develop stream and lake coverage in conformance with the National Hydrography Dataset. A consortium is successfully working with the Iowa Department of Natural Resources to update Iowa's statewide NWI coverage. Furthermore, the FGDC Wetlands Subcommittee is developing guidance and tools for states to use to develop local consortiums for wetland mapping.

In the Northeast Atlantic region of the country, the USFWS has added several new readily interpreted wetland attributes to the NWI classifications and has successfully used these attributes to assess wetland functional changes in the Nanticoke River watershed in Central Maryland and southwest Delaware (Tiner 2005). The additional attributes associated with the northeastern NWI updates include the following:

- landscape position, categorized by three aquatic landscapes: terrene, lentic or lotic
- landform descriptors, including slope, islands, fringe, basin, floodplain, flat or interfluve forms
- surface-water flow-path, including isolated, inflow, outflow, through-flow, and nontidal bidirectional

In addition, Tiner (2005) found it useful to derive a primary wetland basin polygon within which the NWI polygons of different wetland community types are aggregated. The primary basin polygon is useful for enumerating and identifying the number of wetland basins present in a given area or region. A primary basin polygon would also facilitate development of accurate wetland-basin sample frames for random surveys assessing wetland quality. It is recommended these additional NWI attributes be included in efforts to update the NWI for Minnesota.

In the last 20 years there has been a vast improvement in remote-sensing technologies, particularly expansion of imagery band widths, including radar, thermal, Light Detection and Ranging (LIDAR), multi-spectral, and hyperspectral techniques. Traditional CIR imagery is acquired routinely by airborne or satellite systems. Costs for imagery have declined since the first Minnesota NWI was produced. It could be more cost effective to use a combination of the traditional CIR imagery along with some of the new sensors to improve wetland mapping effectiveness and efficiency, but wetland mapping research has not kept up with the development of these new sensing technologies. These new technologies must be fully evaluated to find the most accurate and cost-effective imagery type and analysis method for locating and mapping wetlands.

Typically wetland mapping imagery is obtained during spring leaf-off condition when surface waters are usually at their highest (table 3). This is particularly critical in the forested regions of Minnesota where a clear view of ground features is obscured by tree canopies during the growing season. Even with current technologies using springtime leaf-off aerial photography, accurate wetland mapping under forested canopies is a challenge, and an investment in ground-truthing to estimate interpretation error will be needed.

In collaboration with the USFWS, several wetland mapping pilot projects were begun in 2004 and 2005 to test the effectiveness of newer remote sensing, image processing, and mapping technologies. In one pilot project near Duluth the USFWS examined the potential of using fall CIR imagery augmented with limited coverage of spring CIR imagery with new remote-sensing interpretation techniques. This pilot project covered approximately 250 square miles. For collateral data, USFWS contractors used black-and-white high-resolution summer aerial photography for about 100 square miles of the Fond du Lac Reservation and nearly 100 square miles of spring CIR imagery from the North Shore region, north and east of Duluth. The Ortho-rectified base layer used for digitizing the updates was large format, fall CIR imagery acquired originally for Forest Inventory Assessment (FIA) work. After the interpretation work was completed, nearly four times more wetlands were mapped using fall CIR imagery compared with the total wetland area mapped in the first-generation NWI. This difference is mostly attributable to the larger scale of the current imagery compared with the original 1:80:000 B&W imagery. These results support the potential to effectively use imagery collected for other program purposes such as FIA, which typically use CIR imagery but from a different season.

Table 3. **Imagery specifications typical for various applications**

Application	Imagery Type	Season	Pixel size (resolution)
Nonforested wetland	Color infrared	Spring – leaf off	1-2m
Forested wetland mapping	Color infrared / LIDAR / Radar / Thermal	Spring – leaf off	1-2m
Land use/land cover	Color infrared	Summer – leaf on	30m to lower
Restorable wetland mapping	Color infrared	Spring – leaf off	1-2m
Lake transparency	Color infrared / Hyperspectral	Late summer	30m to lower
River and stream transparency	Color infrared / Hyperspectral	Late summer	30m to lower, depending on size
General planning	Color	Spring/summer – leaf on / leaf off	Various
Agricultural compliance	Color	Summer – leaf on	1-2m
High-resolution digital elevation models	LIDAR	Various	1-2m

Additional NWI pilot update work is underway in the Redwood River watershed. Digital multi-spectral imagery for nine USGS topographic quads covering the western half of the watershed was acquired in September 2004 and then reacquired in mid-October 2005 because of problems with the 2004 imagery. The USFWS is still processing this imagery using E-cognition®, which is an object-oriented image-processing software that shows great promise to automate much of the image processing and polygon digitizing, improving efficiency and possibly accuracy for mapping wetlands. Once wetland object models are constructed, this software is able to identify and classify image results into objects based on similar spectral properties. These classified objects appear to the user as polygons and can be easily saved and edited if necessary. Having the computer draw the initial polygons without having to manually digitize boundaries will greatly improve mapping efficiency.

A third NWI updating pilot project is under way in the Twin Cities metropolitan area. The imagery for this pilot was acquired in the spring of 2005 in cooperation with the Metropolitan Council and Metropolitan Mosquito Control District. Plans are to update the Lake Elmo and St. Paul East quads as test quads before proceeding further with the rest of the metropolitan-area imagery. This pilot will examine the outcomes from mapping wetlands using multi-spectral imagery in urban environments.

These three NWI pilot projects will provide experience with different contemporary imagery types in diverse land uses, including developed urban areas, grassland/agricultural areas, and a forested area with extensive wetlands. Once these pilots are completed they will improve estimates of classification accuracy and costs for completing large-scale NWI updates in Minnesota.

Beyond updating the inventory, an additional challenge will be to maintain updated data and keep the data as current as possible. Two approaches are envisioned to keeping the inventory current. The initial approach would be to establish a plan for either statewide batch updates or regional rotating updates, either of which would assure updated coverage approximately every 10 years. The second approach is to dynamically update the NWI through linkages with a geo-referenced permit and accounting system. Though this is the preferred approach and ultimately likely the most cost effective, it is also technologically more challenging.

Because mapping technologies have advanced significantly since the original NWI, it will not be feasible to retroactively assess trends by comparing updated NWI maps to the original inventory. NWI updates using current technologies should be more accurate, and may, as in the case of the Hermantown and Duluth updates, mean more wetland area could be mapped than on the original NWI, even though significant wetland resources may have been lost since the original mapping. Nonetheless, an updated NWI in Minnesota would be the most accurate accounting of current wetland status and would be a valuable tool in managing the state's wetland resources.

Sample Survey

Background/Process

Short of conducting complete periodic censuses that use consistent technology, the most effective way to accurately assess wetland status and trends is through a sample survey. A sample survey assesses actual on-the-ground activity, including exemptions and illegal activities that are not adequately accounted for in programmatic accounting. Among the approaches recommended to assess wetland quantity, a random survey has the greatest potential to meet a high number of the strategy goals and objectives.

Northern leopard frog (*Rana pipens*)

The USFWS Wetland Status and Trends Program has successfully used a random survey of four-mile-square plots to estimate changes in wetland quantity in the continental United States (Dahl 2000). Since the national plots were established based on the area of the conterminous United States, state or regional sampling efforts require additional plots in order to provide a statistically valid sample for Minnesota. Intensified sampling efforts using USFWS methods have been used in the Texas Gulf Coast Region (Moulton et al. 1997), South Carolina (Dahl 1999) and Florida (Dahl 2005) to assess local status and trends with statistical rigor and precision similar to that of the nationwide USFWS program.

To help design a similar state-intensified, random sampling approach in Minnesota, the CWAMMS Steering Committee established a cooperative agreement with the DNR Resource Assessment Program (RAP) in Grand Rapids, Minnesota. The RAP has significant experience in developing random-sample survey designs for various forestry and related natural-resource assessment projects. The RAP investigated the effect of plot size, stratification, and alternative sampling schemes on the variability of wetland status and change estimates using USFWS data from the previously established 175 national four-mile-square plots in Minnesota from the 1985 and 1997 assessment periods (Resource Assessment Program 2005). The major findings from the RAP analysis were:

- Reducing the primary sample unit (PSU) size from four square miles to one square mile does not significantly increase the variability of wetland status and change estimates. Thus, it will be more cost effective to use the smaller plot size in the survey design (e.g., more plots can be completed for a given level of funding).

- Stratification by geographic region (figure 4) did not reduce the variability in the USFWS wetland status and change estimates for Minnesota. This suggested that pre-stratification might not have the desired effect of reducing the variability of estimates in a Minnesota wetland survey design and therefore is not recommended. Post-stratification could still be used for reporting purposes, though with reduced precision compared to the statewide design.
- There were no differences in wetland quantity estimates between polygon wetland delineation and a point-sampling interpretation method. Polygon wetland delineation involves digitizing wetland boundaries by the interpreter. Point sampling would use a grid of points and the interpreter only has to interpret the wetland/non-wetland status of each point (e.g., wetland or upland).
- The RAP recommended that the survey design use a rotating or cyclic panel approach, similar to the FIA and the NRI. Rotating panel sampling spreads the sampling effort over several years. Each panel is a randomly selected, statewide subset of the total number of plots required to meet the statistical confidence goals. One panel would be sampled each year. The number of panels (years) needed to sample all of the sample plots is based on available annual funding and desired reporting frequency. For example, in a four-panel design, one-fourth of the total number of statewide plots would be sampled in each of four consecutive years. In addition, a statewide subset of common plots would be sampled every year to assess annual variability. In this example, the first four years of sampling would represent the first cycle for the wetland quantity status estimate. Sampling would then rotate back to the first panel and the process would be repeated. After all the panels have been sampled a second time, changes in wetland quantity can be assessed.
- The RAP also recommended the sample plots be selected using a Generalized Random Tessellation Stratified (GRTS) sample design (Stevens and Olsen 2004). A GRTS sampling design assures a good geographic distribution of PSUs while maintaining a random selection essential to derive unbiased estimates from survey data. Using GRTS allows for any number of statistically valid post-stratification analyses and regional reporting options, including the ecoregions illustrated in figure 4.

Survey Design Specifications

The following survey design recommendations are based on the wetland survey design analysis completed by RAP (2005). The PSUs for the survey are planned to be one-square-mile plots. Efficiency gains, cost savings, and maintained statistical rigor all suggest using smaller plots compared to USFWS. The selection of PSUs from the finite population of all square-mile plots across Minnesota will be selected using a GRTS sample design (Stevens and Olsen 2004). Under this design, the plots will be randomly distributed across the state while assuring a good geographically balanced distribution. Each PSU will be sampled by interpreting wetland polygons within the plot using high-resolution true-color imagery and interpreted following procedures adapted from the USFWS (2004) technical procedures for wetland status and trends. The polygon approach is recommended over the dot-grid approach because, even though a point-sampling method would be more cost effective initially, over time it would be less cost effective and could turn out more expensive. Only a polygon coverage would provide an acceptable survey design template for assessing wetland quality within the PSU plots. In addition, digitizing wetland polygons within each sample plot will be much easier to explain and understand for nontechnical audiences. For these reasons, it is recommended that wetland polygons be interpreted in each primary sample unit plot.

Based on the variability estimates derived from the RAP analysis of USFWS plot data (RAP 2005), the Project Steering Committee investigated a number of sample designs representing various expected levels of statistical confidence and error (table 4). The recommended sample design is a three-panel design that is expected to achieve a confidence level of 90% with plus-or-minus 20% error. The actual confidence and error rates will not be known until an initial sampling cycle has occurred. The survey sampling design will consist of rotating panels of PSUs, where the total number of sample plots is divided equally into three panels, each representing a statewide subset of the

Table 4. **Estimated number of plots needed to be sampled annually and the total number of plots needed to achieve a 90% confidence for detecting changes in wetland quantity with either a 20% or 15% error estimate within three- or four-panel sample designs**

Number of Plots	**Number of Plots**			
	90%: ±20%		90%: ±15%	
	3 panels (Yr)	4 panels (Yr)	3 panels (Yr)	4 panels (Yr)
Number of plots sampled annually (including common plots)	1,830	1,435	3,080	2,415
Number of common plots sampled each year (5% of primary plots)	250	250	420	420
Total number of unique plot locations*	4,990	4,990	8,400	8,400
Total number of samples per cycle	5,490	5,740	9,240	9,660

* The total number of sample plots per cycle includes 5% common plots sampled annually.

Table 5. **Proposed sampling design for three-panel cyclical sampling with an estimated confidence of 90% and a +/- 20% error rate**

Panel	**Number of Plots Sampled Each Year**					
	2006	2007	2008	2009	2010	2011
1	1,580 T_1			1,580 T_2		
2		1,580 T_1			1,580 T_2	T_2
3			1,580 T_1			1,580 T_2
Common	250 C_1	250 C_2	250 C_3	250 C_4	250 C_5	250 C_6
Total Plots	**1,830**	**1,830**	**1,830**	**1,830**	**1,830**	**1,830**

total number of plots required (Urquhart et al. 1998). One panel of plots will be sampled each year, along with a number of common plots (5% of the total plot sample size) that are sampled every year to estimate annual variability. A multi-panel interpenetrating design improves the trend assessment by providing an estimate of inter-annual variation within the sample and has the advantage of reducing annual costs. Following the planned survey design table 5 illustrates the number of sample plots to be sampled from 2006 through 2011.

The sample plot numbers presented in table 4 represent the number of sample plots estimated to reach various levels of statistical precision. The total number of recommended sample plots exceeds the number typically used in other wetland status and trend surveys (Dahl 2005). The relatively large number of sample plots needed is due mostly to high coefficients of variation observed in the 175 USFWS plots in Minnesota (RAP 2005). Additionally, the statistical precision designed into this proposed survey is greater than many large-scale environmental surveys. The number of plots required to be sampled for the selected confidence and error limits may need to be adjusted after the initial sampling cycle.

In accordance with the strategic objectives, the wetland polygons mapped and tracked in the survey plots will be classified into one of five wetland classes based on Cowardin et al. (1979). Because of funding limitations, water regime and additional modifiers will not be interpreted. Water regime is recognized by the USFWS as the most difficult and costliest wetland attribute to interpret remotely and it is often prone to inaccuracies (Cowardin and Golet 1995; Brian Huberty, *pers. com.*). Water regime is not required to assess wetland extent. However, by not interpreting wetland water regime, it will not be possible to fully assess the effect of the regulatory exemptions in the WCA that are based on wetland type (USFWS Circular 39, Shaw and Fredine 1956).

The initial sampling cycle will provide the baseline for future assessments of wetland quantity (gain/loss). After the initial baseline assessment, statewide trends are expected to be assessed and reported every three years. Regional differences (figure 4) in wetland status and trends will be examined and reported along with the statewide trends. Once the baseline assessment is completed, retrospective assessments of wetland quantity may be possible by using various historic imagery and data sources, including the original NWI imagery and data, black-and-white aerial photography dating back to 1991 (when the Wetland Conservation Act was enacted), or possibly black-and-white aerial photos available for most of the state from the 1930s.

Survey Minimum Detectible Units of Change

The survey design technical procedures will follow the USFWS (2004) technical procedures. The USFWS minimum polygon mapping unit is 1.0 acre (0.4 ha), however wetlands as small as 0.1 acre (0.04 ha) are frequently identified and mapped. In accordance with the USFWS wetland status and trend technical procedures manual, any identifiable change in the polygon boundary that can be attributable to human activity is recorded. Some of these changes are very small, often much less than 1.0 acre.

Ground-truthing Wetland Quantity Survey Data

In the USFWS status and trends survey, ground-truthing or field verification of remotely sensed data is an important data quality-assurance and quality-control process to maintain a high level of confidence in the final results. The USFWS has identified three field verification priorities (Tom Dahl, *pers. com.*):

1. interpreter-flagged problems or plots with specific questionable interpretation,
2. areas with extensive wetland change, and
3. geographic coverage and overall classification accuracy.

The number of interpreter-flagged problem polygons would hopefully be small, but can't be gauged until the sample photo interpretation is well under way. For planning purposes, it is estimated that imagery interpretation issues will occur within about 3% (~50) of the PSUs and will require some level of field verification. Each verification effort would likely involve one or more polygons being reviewed in the field, but it is unlikely that all polygons within the entire PSU would need to be intensively reviewed.

The USFWS's second priority of ground-truthing areas with extensive changes will not apply in the first survey cycle because change detection or wetland trends will not be able to be assessed in the first cycle. However, in the second and subsequent survey cycles, ground-truthing will be required of approximately 50 polygons with large changes in wetland area between assessment periods.

Regarding the third USFWS ground-truthing priority, Congalton and Green (1999) offer a comprehensive discussion about assessing the accuracy of remotely sensed data. They recommend ground-truthing a minimum of 50 sample units per interpretation class to assess the overall classification accuracy. In the proposed survey design there are 12 interpretation classes, five of which are wetland classes and seven of which are non-wetland classes. Following Congalton and Green's minimum sample recommendations, 50 polygons should be ground-truthed in each of these 12 interpretation classes. Thus, 600 polygons (250 wetland and 350 upland) should be ground-truthed to assure a statistically valid error matrix. Selection of these polygons can be targeted to improve the cost effectiveness (e.g., ease of accessibility) of this portion of the ground-truthing requirements. The total number of polygons recommended for ground-truthing in the first cycle would likely be about 650, or approximately 220 per panel.

Wetland Quality Assessment

All of the wetland quality assessment methods discussed below, with the exception of depressional wetland IBIs for the Eastern Broadleaf Forest Province and the MnRAM

Forested wetlands are important to Minnesota's ecology and economy.

functional assessment method, are under development and have not been fully validated. Research into the application of wetland quality approaches is relatively new and will require ongoing support for the development and testing of additional assessment techniques.

Integration of the USEPA-recommended suite of wetland quality indicators (Levels I, II and III) is an emerging part of wetland quality monitoring and assessment. Recent research suggests that Level I indicators are suitable for broad-scale ambient monitoring (such as regional and/or statewide surveys) and Level II and III indicators are suitable for site-specific impact and restoration investigations that were identified from Level I monitoring (Brooks et al. 2004). Alternatively, Level I, II or III methodologies can also be used for regional assessments through survey techniques (MPCA 2006 and Whigham et al. 2003). As wetland quality indicators in Minnesota are fully developed and validated, the integration of assessment results from Levels I, II and III will continue to be examined to determine the best implementation and integration approaches for wetland quality assessment.

Two Level I (landscape scale) indicators are being tested and/or developed at the MPCA. The landscape development index (LDI; Brown and Vivas 2005) project is being done in cooperation with the USEPA and supported by a grant from that agency. Validation of the LDI as a reliable Level I assessment method will be accomplished by examining the correlation of the LDI results with results obtained from Level III methods (i.e., IBIs) for a set of wetlands representing a gradient of human disturbance. The initial evaluation of LDI as an acceptable Level I wetland assessment method should be completed by the end of 2006. If the initial evaluation indicates that the LDI is an acceptable method, additional testing and validation may be needed before this assessment method will be available for statewide applications.

Research is under way in cooperation with the University of Minnesota Remote Sensing Laboratory to use remote sensing techniques to assess wetland quality. This work is investigating the potential to develop an emergent wetland plant community/pixel diversity indicator from remote imagery. This research is using high-resolution hyperspectral airborne imagery in two four-mile-square areas in the St. Paul metropolitan area. Preliminary results are very promising, but significant testing and validation work will be needed beyond this initial effort before this method will be approved for wetland assessments. This initial remote sensing pilot project is also scheduled for completion by the end of 2006.

The MnRAM, a qualitative Level II assessment method, has been used widely throughout Minnesota in various applications, particularly associated with wetland comprehensive plans and permitting decisions. Statewide testing of MnRAM as a Level II wetland condition indicator is currently under way and is expected to be completed by mid-2006. The MnRAM assessment method is suitable to be used in all wetland classes and types found in Minnesota.

An adult dragonfly

The MPCA is developing statewide IBIs, which are considered Level III (site-based quantitative) indicators, for assessing depressional wetlands. IBIs developed for the Eastern Broadleaf Forest Province were completed in 2002 (Gernes and Helgen 2002) and further refined in 2004 (Genet et al. 2005). IBIs for the remainder of the state are scheduled for completion in late 2006 or early 2007.

The Floristic Quality Assessment Index (FQAI) is another Level III wetland quality assessment method in the early development stages in Minnesota, though it has been extensively tested and used in other states or regions. Following *C*-value development, testing and validation will need to be completed before the FQAI can be used for wetland assessments. Like the MnRAM, the FQAI has the potential to be able to assess all wetland classes and types found in Minnesota. This is one potential advantage over the Minnesota wetland IBIs which have been developed only for depressional wetlands. The earliest the FQAI would be available for use to assess wetland quality in at least some parts of Minnesota's wetland communities is expected to be May 2008.

Application of wetland quality indicators in a comprehensive assessment program is complicated by the extent and complexity of Minnesota's wetland resource. Even if an effective and universal Level I indicator were currently available, confidently assessing over nine million acres of wetland with a single indicator is not very likely or practical. Applying wetland quality indicators through a random survey can adequately represent this diverse resource. However, a substantial operational barrier needs to be addressed before a statewide wetland quality survey can be completed: an accurate wetland sample frame is needed from which to draw individual wetlands for a survey. The MPCA has adopted individual wetland basins as the wetland quality assessment unit, as opposed to wetland vegetation community polygons as represented in the NWI. An individual wetland basin may contain one to several vegetation community polygons. Therefore, the existing Minnesota NWI is a problematic sample-frame choice because (1) it is becoming increasingly inaccurate as wetlands continue to appear and disappear and (2) the NWI delineates wetlands by community type, not basins. Effective ways of aggregating wetland community-type polygons into unified wetland basin polygons must be developed before the NWI could be reliably used as a survey sample frame.

Building on the experience gained in the Redwood River watershed assessment project, the MPCA is planning a project that will continue to advance ambient, statewide wetland-quality monitoring and assessment in Minnesota. In early 2005, Minnesota was awarded a wetland demonstration pilot grant from the USEPA to further test the application of IBIs using random survey techniques. In this project the proposed one-square-mile wetland quantity PSUs with current wetland polygons will comprise the sample frame from which to randomly select wetland basins. Level III assessment methods (depressional wetland IBIs) will then be used to assess randomly selected wetland basins and wetland quality inferences can be generated. This project will be limited to depressional wetlands in the Eastern Broadleaf Forest Province (figure 4), where depressional wetland IBIs are fully developed.

Table 6. Strategic objectives addressed by proposed wetland quantity (A) and quality (B) monitoring approaches.

A. WETLAND QUANTITY ASSESSMENT			
Strategic Objectives	Monitoring Approaches		
	Integrated Programmatic Accounting	Inventory Updates	Sample Survey
Statewide and regional estimates of status		●	●
Statewide and regional estimates of trends		○	●
Regulatory and voluntary program tracking and assessment	●	○	○
Baseline data for local planning and modeling	○	●	
B. WETLAND QUALITY ASSESSMENT			
Strategic Objectives	**Monitoring Approaches**		
	Level I	**Level II**	**Level III**
Statewide and regional estimates of status	●	○[1]	○[1]
Statewide and regional estimates of trends	●	○[1]	○[1]
Regulatory and voluntary program tracking and assessment		●	○
Baseline data for local planning and modeling	○	●	●

† ● = Superior level of effectiveness for meeting strategic objective, ○ = intermediate level of effectiveness for meeting strategic objective.

[1] Applied through a random survey

Level I, II or other Level III assessment methods could be readily applied through random surveys. Beyond plans to apply IBIs (a Level III assessment method) within a sample survey, future projects should also incorporate assessments of Level I and II methods within random survey designs. Ultimately results from Level I, Level II and Level III assessment methods will need to be integrated into a uniform, single, final assessment, or applicability rules for assessment at different scales will need to be defined.

Assessment Outcomes

Multiple assessment approaches and methods are recommended to meet the CWAMMS objectives. Table 6 presents the relationship between the recommended assessment approaches and the CWAMMS strategic objectives. For example, to establish current status of wetland quantity, a sample survey will provide an estimate faster and more efficiently than comprehensive mapping data, and far fewer resources are needed to complete a survey. A useful analogy is that newspapers provide information on current affairs in a timely way; however, books, which take longer to produce and publish, typically provide a more comprehensive discussion including context and historic perspectives as well as future projections. Thus, comprehensive mapping provides more complete census information needed for effective local or regional modeling or planning needs.

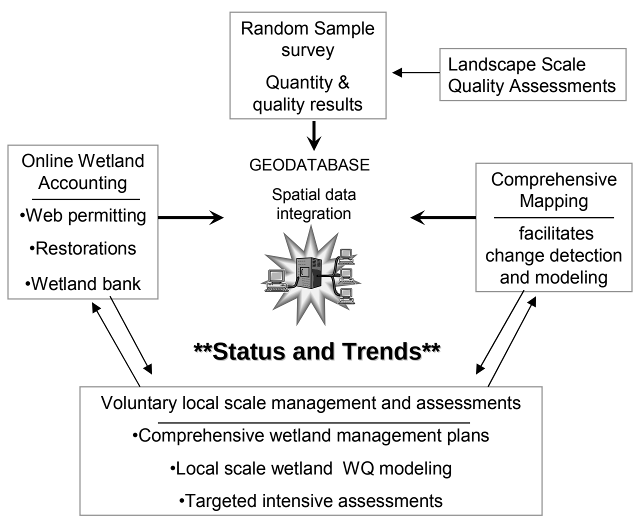

Figure 5. **The CWAMMS conceptual data management and exchange flow diagram**

Data Management

Comprehensive wetland quantity and quality assessment data within CWAMMS will need to be managed through several spatially linked databases. These geo-databases will likely be managed and maintained by different agencies, but will be developed to comprise a single, master wetland-data “warehouse” that can integrate data stored within each partner agency and participating LGU databases (figure 5). This system will provide a comprehensive view of wetland status and trends within Minnesota. Specific data-management protocols need to be identified and developed. It will be essential that all data collected under the CWAMMS be geo-referenced. Recording and tracking all project data by location will help to reduce, if not eliminate, duplicative records for voluntary wetland restoration, which has been a problem in the past. A geo-referenced address or identifier should serve as a common denominator for recording data from various agencies and programs.

A prairie depressional wetland

Implementation

Roles and Responsibilities

For the CWAMMS to meet the five strategic objectives discussed in Section III, local, state and federal government agencies, along with private conservation organizations and other stakeholders, will need to work collaboratively on project coordination, data collection, data management, and report writing. Table 7 presents the envisioned roles and responsibilities for various parties that will be necessary to further develop and implement the CWAMMS.

Some implementation activities may need to be contracted out to organizations outside of the core cooperating agencies. The appropriate lead state agencies will be responsible for coordinating CWAMMS contractual activities (table 7). Contractors may be needed to assist with data collection, database design and/or management, and data analysis and reporting.

Schedule

Funding is available to begin implementing the wetland quantity survey in 2006. The first cycle of the statewide survey will be complete by the end of 2008. An initial statewide wetland status report will be published in 2009. Estimates of wetland quantity trends based on the survey will not be able to be reported until 2012 and every three years thereafter, when subsequent iterations of the survey are completed.

The BWSR is currently planning the development of an online wetland accounting system. This planning and scoping project is scheduled to be completed by September 2006. Cooperating agencies will then build from that effort and the actual database programming can begin. An interim goal is to have the initial phase of an integrated geo-referenced accounting system online by 2008.

Pilot projects to update the NWI in Minnesota are ongoing. Updates for the Redwood River watershed are expected to be completed by March 2006 and additional updates in the Twin Cities metro area are expected to be completed in late 2006 or early 2007. These projects will provide valuable information on the effectiveness of emerging technologies and methods at mapping wetlands accurately and efficiently. Significant funding sources and partners will need to be found to further update a statewide wetland inventory.

In addition to the three primary targeted approaches for monitoring wetland quantity, it is expected that occasional special studies will be undertaken to address specific issues or questions. These studies are likely to focus on local-scale planning and modeling needs. Retrospective studies, which would target specific research or policy questions, may also be completed. For example, retroactive data could be collected from existing imagery taken before enactment of the WCA and compared to current status data to assess the effectiveness of the WCA in meeting no net loss. The CWAMMS intends to assess changes in both wetland quantity and quality, though it is likely that initial implementation will focus primarily on changes in wetland quantity. However, the ability to assess changes in wetland quality is of vital importance and is needed to fully ascertain progress in meeting the state's wetland goals.

The MPCA will continue to develop and validate wetland quality indicators, as well as begin to implement those indicators using survey techniques. A wetland quality survey using depressional wetland IBIs (Level III assessment) will be initiated first in the Eastern Broadleaf Forest Province in 2007, pending interpretation of wetland polygons in the first panel of the quantity survey plots in 2006. Depending on the effectiveness of the approach and funding, the survey could be repeated in both the Prairie Parkland and Laurentian Mixed Forest Provinces in subsequent years, giving a first statewide estimate of depressional wetland quality by 2010 or 2011. Both levels I (LDI and remote sensing) and II (MnRAM) assessment methods should continue to be developed and need to be integrated into a comprehensive wetland quality assessment and monitoring program as early as 2007.

Funding

Beginning July 1, 2005, the Minnesota Legislature appropriated $250,000 per year to the DNR's Ecological Services Division for CWAMMS implementation.

In October 2005, the USEPA awarded the State of Minnesota (with the MPCA serving as the administrator) a Wetland Demonstration Pilot Grant to begin implementation of the CWAMMS. This grant will provide $300,000 of federal funding each federal fiscal year through September 30, 2008. As the grant recipient, the MPCA will provide a minimum of an additional $100,000 in local in-kind match support for this project. The DNR funds described above are also being used as state match for the EPA grant.

In addition to the funding sources described above, the BWSR received a USEPA Wetlands Program Development Grant in Fiscal Year (FY) 2003, providing $45,000 to design an online wetland- and water-permitting application process for wetland and related water-permitting programs in Minnesota. The BWSR has agreed to match this with an equivalent of $15,000 in state funds for this project through September 30, 2006. Additional funds will be needed to develop and implement this component of the CWAMMS.

General cost estimates for the random survey design are provided in table 8. The cost is higher for the initial cycle because the first cycle will require considerable imagery interpretation and digitization of wetland polygons. Subsequent cycles will use the previous polygons as a base and look for changes with current imagery, effectively requiring edits only where changes are evident as described in the USFWS wetland status and trends technical procedures manual (USFWS 2004).

Table 7. Roles and responsibilities of agencies and organizations in implementing the CWAMMS

● – major or lead role; ○ – supporting role

Tasks	DNR						MPCA	BWSR	MDA	COE	USFWS	USDA	EPA	LGUs*	NGOs
	Waters	Ecological Services	Forestry	MIS	F&W	Parks									
Manage, coordinate CWAMMS implementation, including data analysis & reporting	○	●	○	○	○	○	●	○	○	○	○	○			
Develop online wetland permitting & integrated accounting system	○	○		○			○	●		○				○	
Use the online wetland permitting & accounting system to track wetland data	●	●					●	●	●	●		●		●	
Contribute data on wetland restorations to the online wetland permitting & accounting system					●	●		●	○		●	●			●
Contribute data on wetland quantity & quality developed through local wetland planning														●	
Manage & coordinate regular NWI updates in Minn.	○	○	○	○			○	○			●				
Manage & coordinate the wetland quantity sample survey, including contracting, data analysis & reporting	○	●	○	○			○	○			○				
Assist with ground-truthing sample survey plots	●				●			●			●				
Develop, implement wetland quality assessment methods at various landscape scales. Data analysis & reporting		○					●	○		○	○		○		

* includes state agencies administering the Wetland Conservation Act on state land

Table 8. **Estimated annual cost for proposed wetland survey for the first and subsequent cycles for two levels of allowable error and two cyclic panel designs**

Cost in First Cycle				Cost in Subsequent Cycles			
90%: ±20%		90%: ±15%		90%: ±20%		90%: ±15%	
3 panels (Yr)	4 panels (Yr)	3 panels (Yr)	4 panels (Yr)	3 panels (Yr)	4 panels (Yr)	3 panels (Yr)	4 panels (Yr)
$400,000	$300,000	$700,000	$550,000	$170,000	$130,000	$300,000	$220,000

Based on existing funds dedicated for implementation of CWAMMS, approximately $450,000 is expected to be available annually for implementing the random survey during the state fiscal years beginning FY 2006 and continuing through FY 2008.

Imagery acquisition for updating the NWI is estimated to cost $1,000 per 7.5-minute, 1:24,000 topographic quad. Imagery interpretation and inventory production is estimated to cost $2,500-3,000 per quad. There are roughly 1,745 quads in Minnesota. Including $200,000 for administrative/coordination costs, this equates to an estimated cost of $7 million to update the NWI statewide. It may be possible to spread these costs out through cooperative (multi-program) image acquisition and/or improving efficiencies in mapping technology. A number of local, state and federal programs acquire and/or use remote-source imagery (table 3). Collaboration among these programs as well as conservation organizations and regional consortiums should facilitate NWI updates.

Roughly $600,000 in existing state and federal resources will be directed toward wetland quality assessment applications from October 2005 through June 2008. It is expected this will be adequate to provide assessment of depressional wetland condition statewide.

Minnesota's recovering population of trumpeter swans depends on wetlands.

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APPENDIX **Wetland Program and Data Survey**

Existing data sets or programs that could be used as baseline data, or wetland model development, particularly for local comprehensive, wetland-management plans and potentially applicable in a wetland assessment, monitoring and mapping strategy.

Tier 1 Remote Sensing						
Title of program or data	**Application**	**Unit of analysis**	**Geographic scope****	**Outcome**	**Whose data**	**For more info, contact**
Restorable wetlands	Identify drained wetlands	County	PPR	Quantity	FWS/NRCS	Rex Johnson
National Resources Inventory	Land-use trend	Sample	Statewide / Nationwide	Quantity	NRCS	Susan Ploetz
Minn. Land Cover Classification System (MLCCS))	Inventory – Land-use planning	Polygon	Urban areas	Quantity and quality	DNR Metro	Bart Richardson
GAP Analysis Program	Land cover / Land use	Pixel-based 30m	Statewide	Quantity	USGS (DNR)	Bill Befort (DNR)
Soil Survey	Inventory	Polygon	Nationwide / Statewide	Quantity & quality	NRCS	Kim Steffen
National Forest	Inventory	Wetland basin	National forest	Quantity & quality	USFS	By forest
FIA (Forest Inventory & Analysis Program)	Inventory	Plot	Nationwide	Quality	USFS	Dennis May
National Land Cover Database	Land use / Land cover	Pixel-based 30m	Nationwide	Quantity	USGS	EROS Data Center Web site
NWI	Inventory	Wetland polygon	Nationwide	Quantity	USFS	Brian Huberty
USFWS Status & Trends	Statistical inventory	4-mi.2 sample unit	Nationwide	Quantity	USFWS	Tom Dahl
Forest Resources Remote Sensing Program	Wetland plant community changes relative to land use	Wetland basin	Targeted regional	Quality	Univ. of Minn. Remote Sensing Laboratory	Leif Olmanson

* local, county, regional, statewide, nationwide

Wetland Program and Data Survey (continued)

Tier 2 – Site-based Field Visit for Management and Planning Purposes						
Title of program or data	**Application**	**Unit of analysis**	**Geographic scope****	**Outcome**	**Whose data**	**Contact**
Public Waters Inventory	Identification of regulated wetlands	Wetland basin	Statewide	Quantity	DNR – Waters	Bruce Gerbig, Glenn Radde
Fond du Lac Reservation Wetland Program	Inventory & Assessment – MNRAM	CWDRN Wetlands Zones	Reservation	Quantity & quality	FDR	Rick Gitar
Forest Management Guideline Implementation Monitoring	Monitoring forest impacts on wetlands & water quality	Wetland basin	Statewide	Quality	DNR	Rick Dahlman
MMCD Inventory Program	Inventory	Wetland polygon	Metro Area	Quantity	MMCD	Nancy Reed
Lower St. Louis River Habitat	Habitat restoration plan	Estuary	Lower St. Louis River	Quality	St. Louis River Citizen Action Committee	Lynelle Hansen, Rick Gitar
Peatland Resource Inventory	Peat resource potential	Local peatland	North Central Minn. Peatlands	Quantity & quality	DNR Minerals Section	Renee Johnson, Dennis Martin
WRP Pilot	Wetland monitoring	Wetland basin	Easement statewide	Quantity & quality	NRCS	Tim Koehler
USDA Crop History Photos	Compliance	Wetland / Section	Statewide	Quantity	USDA/FSA	Dan Hockert
Continuous Stand Assessment (CSA) Inventory	Forest cover type inventory	Stand level	Statewide state land – some county land	Quantity	DNR	Gary Cummings

* local, county, regional, statewide, nationwide

Wetland Program and Data Survey (continued)

Tier 3 – Intensive Field Sampling						
Title: Program or data	**Application**	**Unit of analysis**	**Geographic scope****	**Outcome**	**Whose data**	**For more info, contact**
Wildlife Shallow Lake Surveys	Evaluate habitat	Lake	Statewide	Quality	DNR	Nicki Hansel-Welch
Wetland Index of Biological Integrity (IBI)	Evaluate wetland	Wetland basin	NCHF, NGP ecoregions	Quality	MPCA	John Genet, Mark Gernes
RWMWD Wetland Program IBI/MNRAM	Watershed management & permitting	Wetland basin	East Metro Watershed	Quality	RWMWD	Bill Bartodziej
Grand Portage Res. Bioassessment Program	Water Quality Standards – Biocriteria	Wetland basin	Grand Portage Res.	Quality	Grand Portage Res.	Katherine King
Peatlands Monitoring	Research	Wetland basin	Marcell Experimental Forest	Quantity & quality	USFS	Randy Kolka
County Biological Survey	Natural habitat protection	Site / County	Statewide	Quality	DNR	Carmen Converse
DNR Wetlands Unit	Wetland organism interactions & reference responses	Wetland basin	Targeted regions	Quality	DNR Wetland Research Unit	Mark Hanson
Past Univ. of Minn. LCMR wetland indicators project	Biological indicators of wetland integrity	Wetland	Regional wetland classes	Quality	Univ. of Minn.	Sue Galatowitsch

- local, county, regional, statewide, nationwide

Wetland Program and Data Survey (continued)

Database and Set-aside Programs						
Title: Program or data	**Application**	**Unit of analysis**	**Geographic scope****	**Outcome**	**Whose data**	**For more info, contact**
Permits database	DNR Waters Permits Program Tracking	Waterbody	Statewide	Quantity	DNR	John Fax
USDA Programs CRP/WRP/CREP	Database	Wetland basin	Statewide / Nationwide	Quantity & quality	NRCS	Tim Koehler
Wetland banking sites	Database	Wetland basin, account data	Statewide	Quantity & a bit of quality	BWSR	Natasha DeVoe, Bruce Sandstrom
RIM database	Easements database	Wetland basin / Easement area	Statewide	Quantity	BWSR	Tim Fredbo
Partners for Wildlife Program	Database	Wetland basin	Statewide	Quantity	FWS	Sheldon Myerchin (St. Cloud)
COE RAMS database	Track 404 permit decisions	Water body	Statewide (Nationwide)	Quantity	COE, St. Paul District	Mick Weburg
Metropolitan Surface Water Planning	Wetland functions & values	Wetland basin	Municipal / Metro	Quantity & quality	Met Council / BWSR	Judy Sventek (Met Council)
STORET (EPA database)	Water quality data	Wetland basin	Nationwide	Quality	MPCA/EPA	
E-link	On-ground activities: WCA & land-treatment projects by LGUs; annual program updates	Wetland / project local scale: GIS interface	Statewide	Quantity & quality	BWSR	Tim Ogg
Wetland Environmental Review database	Track environmental review projects affecting wetlands	Project specific	Statewide	Quantity	DNR Ecological Services	Doug Norris

* local, county, regional, statewide, nation