# NATIONAL WATER-QUALITY ASSESSMENT PROGRAM, WESTERN LAKE MICHIGAN DRAINAGES–SUMMARIES OF LIAISON COMMITTEE MEETING, GREEN BAY, WISCONSIN, MARCH 28-29, 1995

**By C.A. Peters, Compiler**

U.S. GEOLOGICAL SURVEY
Open-File Report 95-163

Madison, Wisconsin
1995

**U.S. DEPARTMENT OF THE INTERIOR**
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Information regarding the National Water-Quality Assessment (NAWQA) Program is available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resource Locator (URL) at:

<URL:http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html>

# FOREWARD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, waste-water, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society, we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units, and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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# INTRODUCTION

The Western Lake Michigan Drainages (WMIC) study unit, under investigation since 1991, drains 20,000 square miles ($mi^2$) in eastern Wisconsin and Upper Michigan (fig. 1). The major water-quality issues in the WMIC study unit are: (1) nonpoint-source contamination of surface and ground water by agricultural chemicals, (2) contamination in bottom sediments of rivers and harbors by toxic substances, including polychlorinated biphenyls (PCB's), other synthetic organic compounds, and trace elements, (3) nutrient enrichment of rivers and lakes resulting from nonpoint- and point-source discharges, and (4) acidification and mercury contamination of lakes in poorly buffered watersheds in the northwestern part of the study unit.

A study-unit liaison committee, which includes representatives of Federal, State, university, and private and citizen organizations, has met annually since 1991 to review plans and results and guide the investigators toward policy-relevant efforts. The results of research conducted in the WMIC study unit by U.S. Geological Survey (USGS) and non-USGS researchers were presented at the liaison committee meeting held in Green Bay, Wis., on March 28-29, 1995. This report contains summaries of the oral presentations given at the WMIC 1995 liaison committee meeting.

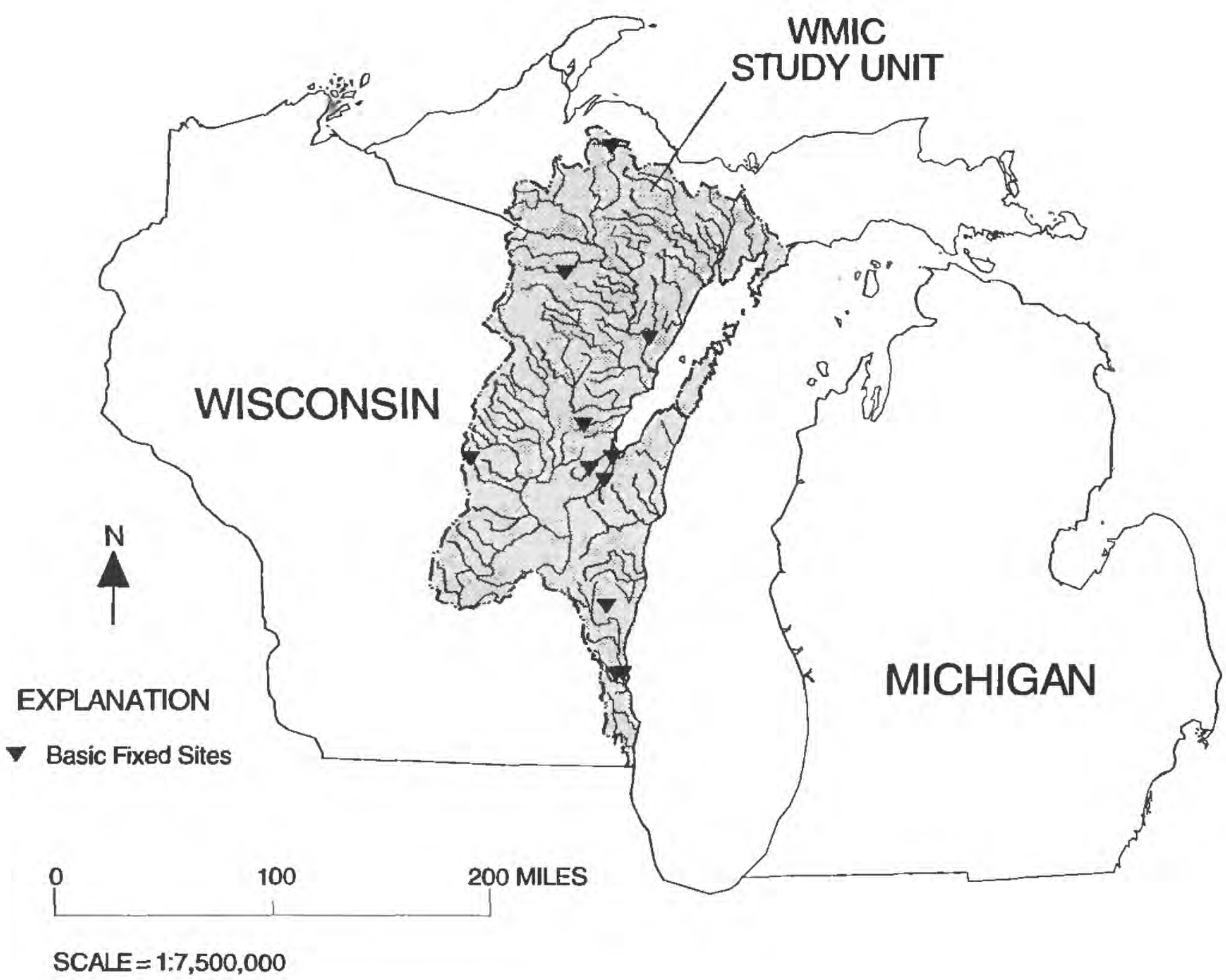


**Figure 1.** Location of Western Lake Michigan Drainages and basic fixed sites.

## ACKNOWLEDGMENTS

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# SESSION 1--NAWQA OVERVIEW AND GIS

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# Overview of the U.S. Geological Survey National Water-Quality Assessment Program

Michael C. Yurewicz[1]

As the National Water-Quality Assessment (NAWQA) program continues into its fourth year, it is providing relevant findings at the local, regional, and national levels, and is further implementing the second set of 20 study units. Major issues and milestones associated with the Program are summarized below.

- Although there are many initiatives to downsize the Federal government, the President's budget for next fiscal year (1996) includes continued support and expansion of NAWQA. The President's budget request for next fiscal year includes the necessary funds (total requested funds of 64.463 million dollars) to implement the first intensive sampling year for all 20 study units initiated in Federal fiscal year 1994.

- A national-level retrospective analysis of nutrients in ground and surface water has been conducted and a report will be published soon. Analysis of existing data provide a broad picture of variability in nutrients in the Nation's waters and factors that affect variability.

- Collaborative and cooperative programs are being established with other agencies, including the National Park Service and the National Biological Service. Such programs include establishing water-quality and hydrologic stations and comparing protocols between programs.

- NAWQA is demonstrating its ability to address emerging environmental issues. The USGS developed and implemented a national-level sampling and analysis program for the pesticide acetochlor which was approved for application in 1994. Another emerging issue which is being considered is environmental presence and distribution of methyl tert-butyl ether (MTBE), a component of reformulated gasoline. Recent sampling in urban settings indicate broad presence of this compound.

- Analysis of ecological samples has proven to be a major issue because of the need to provide quality-assured results on a timely basis. To provide sufficient oversight of this component of the program, a quality assurance unit has been established at the USGS National Water-Quality Laboratory in Arvada, Colo.

[1]U.S. Geological Survey, Reston, Va.

- To ensure that findings can be reported on a timely basis, a report pilot program has been established. The pilot program will implement and evaluate streamlined, team-based approaches to report planning and production.

- Additional program components continue to be developed. These components include the low-intensity phase of each study unit, a national periodic water summary of results of the Program, and innovative outreach programs.

- As the USGS begins final stages of on-site testing of its new National Data Storage and Analysis program (NWIS-II), implementation strategies are being finalized to ensure a smooth transition to the new system.

# Accomplishments in the Western Lake Michigan Drainages in FY 1994

Charles A. Peters[1]

Accomplishments in the Western Lake Michigan Drainages NAWQA study unit in FY 1994 included surface-water quality and biological sampling, observation well installation and water-quality sampling, data compilation and analysis, and report writing and data presentation.

Surface-water quality field work included monthly water-quality sampling and stream-discharge measurements at 11 basic fixed sites (BFS). Weekly water-quality sampling was done at six of the BFS during the growing season (April-September). Short-term studies (synoptic studies) done at high-flow conditions were conducted in three indicator basins (basins of relatively homogenous geology, soil texture, and land use) and in the Fox/Wolf River Basin. These studies involved water-quality sampling of between six and twelve tributary sites in each basin during storm runoff. Short-term studies were also conducted at low-flow conditions in six indicator basins and in the Fox/Wolf River Basin. This involved water-quality sampling of between five and eleven tributary sites in each of these basins during low-flow conditions. To compare results obtained by two sampling methods, three streams were sampled at four flow conditions (two high flow and two low flow), by the Wisconsin Department of Natural Resources (WDNR) and NAWQA.

Biological field work included sampling for trace elements and organics in bed sediments and in plant and invertebrate tissues at the eight indicator basin BFS. The second consecutive year of biological sampling was conducted at the eight indicator sites. Three stream reaches were sampled at each of three sites and one reach at each of five other sites. The sampling included the collection of algae, invertebrates, and fish for community analysis and the collection of data for habitat descriptions. Tissue, blood, and organ samples were obtained from carp at two sites in the Milwaukee River Basin as part of a national endocrine-disruption study.

Ground-water field work included the installation of ten wells, one mini-piezometer, and three lysimeters along a flow-path transect. Water-quality samples were collected from eight of the flow-path wells, the mini-piezometer, and one lysimeter. Forty-three wells were installed and sampled for water quality in two land-use study areas. The well selection process for a study-unit survey was begun.

[1]U.S. Geological Survey, Madison, Wis.

The data for surface- and ground-water quality and the accompanying quality-assurance data are up-to-date in the data base through sampling completed as of September 1994. The data for trace elements and organics in bed sediments and tissues are up-to-date through August 1994. The habitat and fish community data are up-to-date. No algae or invertebrate community data have been received from contract labs.

Geographic information system (GIS) data base development is ongoing. A GIS coverage containing locations of all surface-water quality, biology and ground-water quality collection sites has been completed. The drainage-basin boundaries for all the BFS, except the Menominee River, have been digitized; basin digitizing of the synoptic surface water sites is about 51 percent (53 of 104) complete. Land-cover data for the indicator BFS (except for the Popple and Peshekee Rivers) and for the ground-water land use and flow-path study locations are complete. Current land-cover layers are being developed for the surface-water synoptic basins and are about 86 percent (90 of 104) complete.

Ten abstracts were prepared and presentations were made at five conferences. A poster was prepared and presented at four conferences. A fact sheet of retrospective data on nitrates in ground water is in press. Two proceedings papers were prepared and presented at conferences. A newsletter was prepared, published, and distributed. A retrospective report on nutrients and suspended sediment was prepared and is in the final stages of review. Eleven papers were prepared and presented at the 1994 liaison committee meeting.

# Workplans for the Western Lake Michigan Drainages for FY 1995

Charles A. Peters[1]

The workplan for the Western Lake Michigan NAWQA study unit for fiscal year 1995 includes surface-water quality and biological sampling, ground-water instrument installation and water-quality sampling, data compilation and analysis, GIS activities, and report writing and data presentation.

Surface-water quality field work will include continued monthly sampling and streamflow measurement at 11 Basic Fixed Sites (BFS) through April 1995. Beginning in May, water quality and flow will be measured at a limited number of the BFS as a part of the low-intensity phase of the study. An automatic water sampling system will be installed at Duck Creek to collect water samples during four storm events. These samples will be analyzed for nutrients, suspended sediment, and triazine herbicides. A short-term study will be conducted to provide information concerning how well the BFS represent water-quality conditions throughout the Western Lake Michigan drainages. In this study, five sites within each of the eight indicator BFS and three sites within each of the 20 relatively homogeneous units (RHU's) that do not have a BFS associated with them will be sampled at low flow for field parameters, nutrients, and suspended sediment. A comparability study of collection methods may be continued with the Wisconsin Department of Natural Resources (WDNR) at three sites in the basin at high and low flows.

Biological field work during 1995 will include sampling for trace elements and organics in bed sediments and biotic tissues at six BFS. A third consecutive year of ecological assessments will be conducted at single reaches of each of the indicator BFS. These assessments include collection of algae, invertebrates, and fish populations for community analyses and the collection of data for habitat descriptions. A synoptic study will be completed at 20 relatively pristine streams in agricultural areas. This study will include the collection of fish population information and water-quality samples. Coordinated sampling of benthic invertebrate communities with the WDNR at either the BFS or the synoptic sites may be conducted for comparison of sampling methods. Vegetation plots will be established and surveyed at each of the eight indicator BFS. Elevation surveys will be conducted at each of the indicator sites as a part of the habitat characterization studies.

Ground-water field work will include completing sampling in the flow-path and land-use areas and beginning and completing work on a study-unit survey. Work at 56 agricultural land-use wells will include performing slug tests to determine horizontal hydraulic conductivity. Fieldwork at the flow-path study area will include the installation of seven mini-piezometers, and several suction lysimeters and the sampling of these

[1]U.S. Geological Survey, Madison, Wis.

installations and eight previously installed wells. Seepage runs will be conducted in the stream at the end of the ground-water flow path to determine ground-water input to the stream. Cores will be collected from four locations along the flow-path transect; several of these cores will be analyzed for mineralogic composition. Additionally, water levels will be determined in all wells and elevation levels will be run to all wells. A study-unit survey will be conducted to determine water-quality conditions in the Cambrian-Ordovician aquifer, the major water-supply aquifer in the study unit. Thirty wells will be randomly selected for sampling to represent this aquifer. The selected wells will be sampled for determination of numerous water-quality parameters.

The data base of surface- and ground-water quality and quality assurance and quality control for those data will be completed for samples collected through September 1995. The bed-sediment and tissue data and the habitat and fish community data bases will be completed for samples collected through September 1995. Algae and invertebrate data bases will be completed for samples collected through September 1994.

Geographic information system (GIS) data base development will continue. The site location GIS coverage will be updated to include all new synoptic sites and new ground-water study-unit survey and flow-path study sites. The drainage basin GIS coverage will be completed for all surface-water sites. A land-cover GIS coverage will be completed for all the surface-water synoptic basins. A pilot study to identify the best process for compiling cropping and pesticide and fertilizer application rates over the three year high-intensity phase of the study will be initiated and completed for an agricultural subbasin. This process will be extended to the five agricultural indicator sites if feasible. Soils and elevation coverages will be examined for their utility for water-quality interpretation. Coverages for other anthropogenic features (landfill, sewage-treatment plant, underground storage tank, etc. locations) will be compiled where available.

The nutrient retrospective and environmental setting reports will be published. Six Water-Resources Investigations Reports will be written. A fact sheet, an Open-File Report, and a journal article are also planned. Another edition of the newsletter will be prepared and distributed.

# Developing a Current Land-Cover Data Layer for the Western Lake Michigan Drainages

Jana S. Stewart[1]

The relation between land use and land cover and water quality is being investigated by the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS). This is being investigated at a number of different scales, ranging from national to study unit to subbasin level, across a variety of landscapes. As a result, NAWQA is developing a land-cover data layer which must meet a number of criteria: it must be of sufficient resolution to support the needs of individual study units across a wide variety of environmental and climatic regimes, it must serve as a baseline of conditions for future updates, it must provide a classification system which is comparable at a national level, compatible with other classification systems, and it must be hierarchical to support varying degrees of land-cover specificity.

The only data which meet most of these criteria are the USGS Land Use and Land Cover Digital (LUDA) data which were interpreted from air photos during the period 1970-80. These data exist as a national digital coverage at a scale of 1:250,000 with a minimum mapping unit of 10 acres in urban and 40 acres in rural areas. The land-use/ land-cover categories are based on the Anderson Classification System which is hierarchical, providing a greater specificity at higher levels. The USGS LUDA data were used in the Western Lake Michigan Drainages (WMIC) NAWQA study unit during initial stages to characterize the basins and aquifers for site selection. The LUDA data were overlaid with bedrock geology and surficial geology to subdivide the study area into relatively homogenous units (RHU's). As a result, each unit contained similar features thought to affect surface- and ground-water quality. This overlay was accomplished using thematic digital maps in a geographic information system (GIS). Potential stream- and ground-water sampling sites were selected using these relatively homogenous units. Anderson's Level I classification categories provided sufficient detail for this process. While the LUDA data were useful for stratification, NAWQA requires more current data with increased spatial resolution to better assess relations with water-quality data.

Classified satellite imagery acquired during 1992 and 1993 by the Landsat Thematic Mapper (TM), combined with ancillary data in the context of a GIS, are being used to meet these needs as well as provide updates for the historic LUDA data. The Landsat TM data will satisfy the requirements for broad characterization of all 60 study units and can serve as a spatial framework for periodic updates as well as more detailed land-cover data. A land-cover classification using these data can be produced at a scale of 1:24,000. The proposed classification system is a modification of categories used by the

[1]U.S. Geological Survey, Madison, Wis.

National Oceanic and Atmospheric Administration's (NOAA) Coastwatch Change Analysis Program (C-CAP). This system is also hierarchical and compatible with the Anderson Classification System.

Since these classifications have yet to be completed, the WMIC study unit will temporarily utilize a number of regional classifications which were completed over portions of the study unit using 1989-92 Landsat TM imagery. These include the classification which resulted from the Lake Michigan Ozone study (LMOS), a classification of the Fox/Wolf River Basin, and a classification of the Upper Peninsula of Michigan. The LMOS classification was completed as part of a comprehensive land use and land cover inventory to be used for modeling smog ozone over a 74-county region adjoining Lake Michigan. The Fox/Wolf River Basin was classified as part of a graduate research project at the University of Wisconsin-Madison in an attempt to improve land-cover classification accuracy of large study areas through stratification of Landsat TM imagery using regional landscape patterns. Finally, the Upper Peninsula of Michigan was classified as part of a comprehensive inventory of deer habitat by the Michigan Department of Natural Resources. Although each of these projects used a different classification system, each of the classifications can be aggregated to a compatible classification system.

Although land-cover data derived from the Landsat TM will provide a nationally consistent data base which can be updated periodically, it will not necessarily provide the level of detail required for regional water-quality investigations. However, by integrating this layer into a GIS, related ancillary data such as population densities and detailed agricultural management practices can be added to specific locations within the land-cover layer. These data will be compiled from such sources as county Agricultural Stabilization and Conservation Service (ASCS) crop reports and photo logs, U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) mylar overlays of soil surveys, state digital wetlands inventory, digital ortho photography, and information from county extension agents, farm cooperative managers, and individual growers. These ancillary data can be easily modified and updated as required, and will support NAWQA investigations throughout their cycle.

# Overview of the Upper Midwest GAP Analysis Program

Daniel Fitzpatrick[1]

The conventional approach to maintaining biological diversity has often been to proceed with one species or one threat at a time. Gap analysis is a methodology to identify gaps in the representation of biodiversity in areas managed exclusively or primarily for the long-term maintenance of populations of native species and natural ecosystems. By overlaying vegetation and species richness maps with public ownership and management maps, gaps in the management of biodiversity can be identified. The goal is to ensure that all ecosystems and areas rich in species diversity are adequately represented in the planning and management for biodiversity. Gap analysis is conducted by combining the distribution of actual vegetation mapped from satellite imagery and other data sources with distributions of vertebrate and other taxa as indicators of biodiversity. These data layers are developed, displayed, and analyzed using a geographic information systems (GIS) technique. An additional GIS layer of public ownership and management status is also developed.

The Upper Midwest Gap Analysis Program (GAP) is in the initial stages of implementation. Upper Midwest GAP is a partnership designed to avoid duplicating efforts while meeting the diverse information needs of the participating state and federal cooperators. Cooperative agreements are in place with the Departments of Natural Resources of Michigan, Minnesota, and Wisconsin to develop current vegetation maps and public ownership and management maps. The three-state effort is being coordinated by the Environmental Management Technical Center (EMTC), National Biological Service (NBS) in Onalaska, Wis.

Satellite imagery from the Landsat Thematic Mapper (TM) is being received from the EROS Data Center of the U.S. Geological Survey (USGS) under the Multi-Resolution Land Characteristic Consortium. These scenes are being reviewed and archived by the EMTC before being forwarded to each state for computer-assisted processing and classification. A proposed image-processing protocol for the Upper Midwest GAP has been developed. Among the technical approaches being evaluated are: (1) the use of multidate GIS-assisted stratification into urban and non-urban and upland and lowland categories, (2) the use of an extendable classification scheme which can be cross-walked to other classification systems, (3) stratification into spectrally consistent geographic units for classification based on regional ecoregions, (4) the use of hybrid classification techniques for non-urban uplands, and (5) the use of geographically stratified systematic sampling for the collection of training and accuracy assessment data.

[1]Environmental Management Technical Center, Onalaska, Wis.

Gap analysis is a "bottom-up" approach that allows for creativity and collaboration at the state and local level to meet their respective needs. National standards are, however, of enormous importance if we are to provide ecologically meaningful information that is useful at the ecoregion or multistate scale. That is, GIS information layers that are consistent across the entire range of a species or vegetation type of occurrence are needed. Toward that end, one of the objectives of the national GAP is to generate and distribute digital thematic maps of existing land cover vegetation types and distributions of terrestrial vertebrates. These vector coverages will be of uniform scale and format, meeting Federal Geographic Data Standards. They will be made publicly available and distributed through the Internet. In addition, Upper Midwest GAP plans to make available the original satellite-derived raster coverages of current vegetation at full resolution.

As Upper Midwest GAP evolves and moves into the species range modeling and gap analysis phases, steering committees comprised of cooperating agency and organization staff will be integral to advancing a program that successfully meets cooperator needs. The EMTC is committed to facilitating that process and encourages the participation of additional partners in the GAP process.

# SESSION 2--BIOLOGY

 (page 17 follows)

# Plans for Analysis and Comparison of Two Benthic Invertebrate Population Data Bases

Bernard N. Lenz[1] and Stephen J. Rheaume[2]

Benthic-invertebrate data have been compiled by Dr. Stanley Szczytko and his students at the University of Wisconsin-Stevens Point from 1984 to the present. These data were collected from streams throughout Wisconsin. Additional benthic-invertebrate data are being collected as a part of the Western Lake Michigan Drainages (WMIC) NAWQA study. This paper describes the planned approach for analysis of these data.

The invertebrate data in the Szczytko data base were collected using a rapid assessment style designed to obtain information on the health and distribution of the invertebrate populations. A program in the data base calculates a wide variety of richness, enumeration, and community diversity indices from the population data. The data base also includes qualitative estimates of habitat and water quality.

Benthic-invertebrate communities are evaluated using quantitative techniques as a part of the ecological component of the NAWQA study. These benthic invertebrate community data are collected along with fish, algae, habitat, and chemical data to assess water-quality conditions and to develop an understanding of the factors that affect water-quality conditions locally, regionally, and nationally. Data from 15 WMIC NAWQA sites, located in 3 agricultural land use areas with varying surficial deposits and bedrock geology, will be compared to data from 283 Szczytko sites. Relatively homogeneous unit 1 (clayey surficial deposits over carbonate bedrock) and relatively homogeneous unit 3 (sandy surficial deposits over carbonate bedrock) are in adjacent agricultural areas in the Southeastern Wisconsin Till Plains Ecoregion. Relatively homogeneous unit 26 (sandy surficial deposits over sandstone bedrock) is in a mixed forest and agricultural land use area in the North Central Hardwood Forests Ecoregion.

Analysis of the Szczytko data base will include: (1) preparing a GIS coverage of data collection locations in the WMIC study area, (2) limiting the data base analysis to include only the data from the three relatively homogeneous units (RHU), (3) conducting regression analyses using invertebrate population data and qualitative water quality, and habitat variables, (4) overlaying the GIS location coverage of the sites with invertebrate data with the coverage of site locations where quantitative water quality data was collected, (5) pairing the invertebrate data with the most appropriate quantitative water-quality data (using proximity, flow conditions, collection date, etc., as determinants of appropriateness), (6) conducting regression analyses of invertebrate data and the paired quantitative water-quality data, (7) comparing the results of the regression analyses using the qualitative and

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[2]U.S. Geological Survey, Lansing, Mich.

quantitative water-quality data, (8) using clustering techniques and principal component analyses to cluster the invertebrate data to describe various community types, (9) analyzing these clusters to be sure that they are not based on spurious assumptions (for example, seasonality), and (10) calculating average water-quality conditions for each cluster (community).

Analysis of the WMIC NAWQA data base will include: regression analyses of the invertebrate community data and the physical and chemical data, clustering of the invertebrate communities, and computing average water-quality conditions associated with each cluster (community). Results of separate analysis of the two benthic invertebrate data bases will be compared to determine if the data bases predict water quality similarly.

Progress to date includes: completion of the GIS coverage for the Szczytko data base, reduction of the data base to include only data from the three RHU's, regression analyses of the Szczytko invertebrate data with qualitative water-quality data, and overlaying the Szczytko and quantitative water-quality data base location coverages.

Results of the regression analysis indicate that the substrate types, gravel, rubble, boulders, and bedrock were positively correlated in both places with invertebrate summary variables; the substrate types, sand, debris, muck, and clay and silt were negatively correlated. Stream velocity was positively correlated with percent EPT (mayflies, stoneflies, and caddisflies), temperature, and species richness. A plot of fine substrate and percent EPT showed low values of percent EPT were associated within areas dominated by fine substrate. Results of boxplot analyses indicated: highest diversity associated with Spring, highest diversity associated with riffles, most degraded water quality associated with RHU number 1, and the lowest HBI values associated with spring sampling.

# Effects of Season, Habitat, and an Impoundment on 25 Benthic Community Metrics Used to Assess Water Quality

Stanley W. Szczytko[1]

Aquatic macroinvertebrates were sampled at eight sites in three high-quality trout streams in central Wisconsin to determine effects of season, habitat, and an impoundment on the variability and reliability of 25 commonly used benthic community measures. Monthly samples were collected for one year from six riffle and two snag habitat sites, except when ice and snow conditions prevented access.

Values for the Biotic and Family Biotic Index (BI and FBI), four Ephemeroptera-Plecoptera-Trichoptera measures (EPT's), Species and Generic richness (SR and GR), Margalef's diversity index (DIV), and 16 Trophic-Function measures (TFM's) were determined. Significant differences ($p<0.05$) occurred between fall and summer values for BI, FBI, 3 EPT's, and 7 TFM's, and between spring and fall values for FBI, EPT, and 3 TFM's. Significant differences occurred among all measures from snag and riffle samples in the same stream. Hilsenhoff (1987) water-quality classifications based on BI and FBI values usually indicated poorer water quality at snags than at riffles in the same stream. These results suggest that the use of benthic community measures should be restricted to specific habitats to increase their reliability as indicators of streamwater quality. Results from snag habitats should not be compared directly with riffle habitats. BI, FBI, one EPT measure, and 5 TFM's had significantly different mean annual values between the upstream and below-dam sites, and BI, FBI, DIV, 2 EPT's, and 4 TFM's had significantly different mean annual values between the downstream and below-dam sites. Water-quality classifications based on BI and FBI values usually indicated poorer water quality below the dam than upstream or downstream.

Season, habitat, and the impoundment had little effect on measure variability. BI, FBI, DIV, SR, GR, 2 EPT richness measures, and 3 TFM's had relatively low variability (coefficients of variation = 8.5 to 16.7 percent) and appear to be more reliable than EPT enumerations and other TFM's.

[1]College of Natural Resources, University of Wisconsin-Stevens Point.

 (page 20 follows)

## Trace Elements in Caddisflies and Streambed Sediments

Barbara C. Scudder[1], Faith A. Fitzpatrick[1], Stephen J. Rheaume[2], and Daniel J. Sullivan[1]

Elevated concentrations of trace elements in streams of the Great Lakes region are of concern because of their potential bioavailability to aquatic organisms. Sampling was conducted by the U.S. Geological Survey as part of the National Water-Quality Assessment program in 1992 and 1994 to determine the presence of a broad suite of trace elements in caddisfly larvae and fine-grained streambed sediments in selected streams in the Western Lake Michigan Drainage. A geographic information system was used to delineate relatively homogeneous units (RHU's) of land use/land cover, surficial deposits, and bedrock type. Sampling sites were primarily selected on streams whose drainage was indicative of each RHU (indicator sites) as well as on streams that integrated drainage from several RHU's (integrator sites). Eighteen sites, representing different RHU's, two reference or minimally-affected streams, and one stream receiving mine-drainage, were selected for sampling in 1992. Surficial (upper 1-2 cm) streambed sediments were composited from depositional areas and homogenized. One subsample was analyzed for particle size. A second subsample was wet-sieved, and the fraction less than 63 microns was analyzed for trace elements and organic carbon. Samples of caddisflies were collected from eleven sites using kicknets, composited, and analyzed for trace elements and moisture content. Caddisflies were not available in sufficient numbers at seven additional streams where fine sediments were sampled–primarily the mouths of major tributaries into Lake Michigan. No relation was observed between RHU type and trace-element concentration. Concentrations of chromium and nickel in caddisflies and sediments were much larger in most of the sampled streams than they were in reference streams; caddisflies and sediments from eight streams appeared to be enriched in selenium. Concentrations of lead were larger in sediments from the mouths of the Fox, Menominee, Milwaukee, and Sheboygan Rivers, and from two urban streams in the Milwaukee River basin than they were in reference streams. Positive correlations (Spearman's rho $> 0.6$) were calculated between trace-element concentrations in caddisflies and sediments with respect to chromium, lead, and selenium. Concentrations of chromium in caddisflies were positively correlated tó organic carbon concentrations in sediments (rho $= 0.6$). Within tissues of caddisflies, concentrations chromium and selenium positively correlated with each other (rho $= 0.7$), and concentrations of aluminum, copper, iron, and nickel positively correlated with each other (rho values $> 0.6$).

In September 1994, caddisflies, aquatic plants, and fine streambed sediments were collected from eight indicator sites, including three sites sampled in 1992: Duck Creek, Popple River, and the Tomorrow River. Samples are currently being analyzed. Future plans call for sampling of caddisflies and sediment at these three sites in August 1995 to provide information on temporal variations in trace-element concentrations. Caddisflies, if available, and sediments also will be collected from the Fox, Menominee, and Milwaukee Rivers at that time.

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# Zebra Mussel Impacts on Wisconsin Aquatic Systems

Clifford Kraft[1]

In less than five years, zebra mussels (*Dreissena polymorpha*) have escaped the anonymity of most freshwater molluscs and have become the subject of newspaper headlines. This mollusc attaches to and fouls hard substrates, particularly human-made structures. As of 1994, over four million dollars in capital costs had been spent to control zebra mussels in Wisconsin water-treatment plants along Lake Michigan. In addition, this invader has the potential to produce large ecological impacts on pelagic and aquatic benthic communities by altering nutrient cycling, contaminant cycling, and habitat features of aquatic environments.

After being brought to North America in the mid-1980's, zebra mussels established a strong presence in southern Lake Michigan during 1991 and 1992. Individual mussels were found in the waters of southern Green Bay in 1991. Zebra mussels did not become abundant in Green Bay until July 1993. Zebra mussels were first observed in the Mississippi River in 1991 and have since become increasingly abundant, but have not yet spread to other Wisconsin rivers. Zebra mussels were found in four Wisconsin inland lakes during the summer of 1994: Okauchee Lake (Waukesha County), Elkhart Lake (Sheboygan County), Racine Quarry (Racine County), and Silver Lake (Kenosha County).

Zebra mussels are well-suited for conditions associated with many industrial facilities–an attribute that causes them to be a great nuisance and expense for facility operators. Zebra mussels also have a prodigious capacity for removing suspended materials from water, which has led to speculation about their ability to influence water quality. Water-clarity improvements have been frequently observed in areas where zebra mussels have reached high densities. There is still great uncertainty regarding the extent to which zebra mussel-induced reductions in suspended material–including phytoplankton–will alter other biotic components of heavily-infested ecosystems.

Human concerns often focus upon organisms of commercial interest. Some early predictions about adverse effects of zebra mussels on sport fishes such as walleye may have been in error, but large-scale changes in pelagic/benthic cycling of energy and nutrients are still anticipated. It will take time to detect ecosystem changes caused by zebra mussels in the midst of other widely varying biotic and environmental influences. Based upon European experiences, zebra mussels will play a key role in many Wisconsin aquatic systems as they continue to spread through North American inland lakes and rivers for the next several hundred years.

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# SESSION 3--SURFACE WATER IN THE EAST AND FOX/WOLF RIVERS

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# Introduction to the Upper East River Watershed Project

Thomas McIntosh[1], Paul Baumgart[1], Dale Robertson[2], and Kevin Erb[3]

The southern section of Green Bay, Lake Michigan, was characterized as one of the areas of concern by the International Joint Commission. Since 1970, point-source discharges of nutrients from municipal and industrial sources have been significantly reduced; however, the nonpoint sources of nutrients and sediment, primarily from agricultural practices, have changed very little. A remedial action plan was developed by the Wisconsin Department of Natural Resources (WDNR) to examine nutrient and sediment loading in this area. Remedial programs include the East River Priority Watershed Project, sponsored by the State of Wisconsin, and the Water Quality Demonstration Project-East River sponsored by the U.S. Department of Agriculture. The National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey participated in both of these programs.

The Upper East River was designated by NAWQA as a basic fixed site. NAWQA is cooperating with the Institute for Land and Water Studies at the University of Wisconsin-Green Bay (UW-Green Bay) in an ongoing study of the Upper East River watershed.

Estimated loadings of phosphorus and sediment to streams associated with various farm-management practices are currently based on results of isolated studies of individual practices on small areas. Computer-assisted models can provide rapid, low-cost analysis of alternative agricultural land-management systems. When coupled with field observations for verification, these models can become powerful assessment tools.

The Agricultural Research Service (ARS) and the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, are developing a suite of models to assess the impact of land-management alternatives on water quality at the field, stream, and river basin scale. The Institute for Land and Water Studies at UW-Green Bay has used the Erosion Impact/Productivity Calculator-Water Quality Model (EPICWQ), a field-scale model, to evaluate effects of tillage and crop sequence on soil erosion. They found reduced tillage implemented by chisel plowing to be the most feasible method of reducing sediment losses on fields in the East River region. They also used the Simulator for Water Resources in Rural Basins Model (SWRRBWQ) to predict the impact of implementing reduced tillage on sediment yield from agricultural areas of the East River Basin. Results from SWRRBWQ indicated that implementing reduced tillage could significantly reduce basin sediment yield; however, several limitations in the SWRRBWQ model were found that severely limited its use for evaluating alternative management practices on dairy farms with respect to sediment and nutrient yields.

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The Soil and Water Assessment Tool Model (SWAT), being developed by the Agricultural Research Service, combines the comprehensive soil and crop management features of EPICWQ and the hydrologic-assessment features of SWRRBWQ with new routing and file-handling features. Preliminary results from SWAT suggest sediment reductions follow the same trend as found with the EPICWQ model. The Institute for Land and Water Studies at UW-Green Bay is working with the Agricultural Research Service at Temple, Tex., to beta test the SWAT model. A demonstration applying the model to the multiple basins of the East River Watershed is described by Baumgart in the following abstract in this series. SWAT has the potential to model individual fields or subbasins within a basin, thus, there is a significant potential for synergistic linkage of known land-management actions with NAWQA activities.

Thirteen subbasins with unique characteristics were identified in the Upper East River watershed. This watershed is 120 $km^2$ (47 $mi^2$) in area--about 32 percent of the total East River watershed area. It is relatively homogeneous with respect to land cover and land use (dairy farming). The region also included eleven farms participating in either the whole farm Water Quality Improvement Program or the field scale Improved Crop Management program sponsored by the Water Quality Demonstration Project-East River. NAWQA has established a basic fixed site in this basin and has conducted synoptic samplings throughout the basin.

To assess the impact of alternative management options on potential phosphorus loading to streams, the phosphorus flux into and within the farm unit(s) as well as within the watershed must be known. A mass-balance study was conducted to determine the phosphorus loadings. Estimates from the mass-balance analysis of case-study farms were used to calibrate a mass-balance model for 11 farms (991 hectares of cropland, 38 percent in row crops) in the Upper East River Basin. Substantially, more phosphorus (66 to 78 percent, or 14 kilograms phosphorus per hectare of cropland) is purchased by the 11 farm units as feed supplements and fertilizer by dairy farm operators than is recovered by sales of milk, cows, and calves. The mass-balance study also indicated that while phosphorus from feed supplements appears to exceed the dietary needs of the cow, the use of fertilizers is in substantial excess of plant requirements. The latter problem is linked to improper manure management, failure to allow credit for manure-phosphorus applied to crop fields, and failure to allow for carry-over of unused phosphorus, due to crop failure.

Quantitative evaluation of the non-economic exports of phosphorus is currently incomplete. Much of the excess phosphorus is apparently stored as sediment-bound phosphorus. Current soil-test levels for plant-available phosphorus are high to very high. Analysis of stream-bottom sediments, upland crop fields, and streamwater (NAWQA) suggest that some of the excess phosphorus is leaving farm units as phosphorus-enriched sediments and soluble phosphorus. Examination of sediment cores from a few stream channels revealed substantially more total phosphorus in the upper half of the core as compared to the lower half. The plant-available phosphorus in the core samples was only slightly lower than that in the surface soils in nearby agricultural fields and much higher than that available in the subsoils.

The 11 farms participating in either the Water Quality Improvement or the Improved Crop Management programs reduced phosphorus imports by more than 38 percent. The offsite non-point source pollution impact of less phosphorus being imported into the watershed is yet to be determined, but should be positive. Transport of eroded sediments with a lower phosphorus content should reduce the phosphorus loading to streams.

Coupling the computer-process models with the mass-balance study and NAWQA studies should yield insight into the magnitude of phosphorus sources, flow rates, and retention time in the watershed.

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# Application of Soil and Water Assessment Tool (SWAT) to the Upper East River Watershed

Paul Baumgart[1], Thomas McIntosh[1], Dale Robertson[2], and Kevin Erb[3]

The Soil and Water Assessment Tool Model (SWAT) is being applied to the Upper East River watershed (120 $km^2$) to simulate and evaluate the effects of implementing Agricultural Best Management Practices (BMP's). SWAT is a basin-scale model that simulates hydrologic and agronomic processes to estimate sediment, nutrient and pesticide yields from rural basins. A preliminary simulation of BMP implementation involving a switch from conventional moldboard-plow tillage to chisel-plow tillage estimated reductions in sediment loads by 22 percent (in a 6-year crop rotation) to 48 percent (in continuous corn). At this time, model predictions of sediment loads are only approximate, given that SWAT is still under development. Further calibration of the model will be conducted using data collected at the Upper Bower Creek monitoring station within the East River Watershed. The calibrated model will then be validated by comparing its predicted yields with that estimated by the National Water-Quality Assessment (NAWQA) Program at the East River basic fixed site (BFS). The model is presently being used to examine yields from 13 subbasins upstream of the BFS.

SWAT is a distributed parameter, daily time-step model that was developed by the U.S. Department of Agriculture, Agricultural Research Service to assess nonpoint source pollution on watersheds and large river basins. The model is designed to combine some of the better features of the Simulator for Water Resources in Rural Basins (SWRRB) and Erosion/Prediction Impact Calculator-Water Quality (EPIC) models. The EPIC model is a farm field-scale model that includes detailed management options, but hydrologic components within the model limit its use to single uniform fields for the simulation of sediment and nutrient loads. Previous applications of SWRRB to the East River Watershed revealed that SWRRB had limited capabilities in simulating nutrient, tillage, and crop management alternatives. These limitations do not permit the program to directly simulate the effects of BMP implementation on dairy farm operations in northeastern Wisconsin; therefore, indirect methods are required to circumvent the tillage/crop limitations. The file structure within SWAT allows for much greater flexibility than that offered by SWRRB. However, application of the SWAT model to the East River revealed that some of its features were not completely functional. We are working with the SWAT program developers in Temple, Tex., to correct these deficiencies. One important limitation of the current version of SWAT is that the program does not simulate the growth of perennial crops such as alfalfa.

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The Upper East River watershed was subdivided into 13 major subbasins based on variable agricultural practices. Average crop and tillage inputs to these basins were used in the preliminary development phase of the model; however, specific management records obtained from the Water Quality Demonstration Project-East River for 1993 and 1994 will be used to refine the model and allow comparison with NAWQA results.

Default Soil Conservation Service curve numbers were used for all cover and soil combinations. Curve numbers were altered to reflect seasonal changes in land cover due to planting, harvesting, or tillage operations. Forty-two years of daily rainfall and air temperature data from the Green Bay airport (1949 to 1990) were used in the model simulations.

Dairy-type agriculture was used as the dominant land-use practice (dairy) in lieu of specific land-use data for all subbasins. A six-year crop rotation that is typical for the dairy operations in the East River Watershed was simulated: (1) corn grain, (2) corn silage, (3) oats and alfalfa, (4) alfalfa, (5) alfalfa, and (6) alfalfa. Both manure and commercial fertilizer use can be evaluated as part of the crop rotation. For purposes of assessing the impacts of BMP's, it was assumed that conventional farming practices used moldboard-plow tillage; whereas, BMP's used chisel-plow tillage. For comparative purposes, a cropping sequence that involved continuous corn (harvested for grain) and another sequence with forest cover were included in the evaluations. Only commercial fertilizer (no manure) was applied with the continuous corn crop.

Simulations of BMP implementation with the SWAT model involving a switch from conventional moldboard-plow tillage to chisel-plow tillage gave smaller sediment load reductions for the Upper East River watershed than those found with the SWRRBWQ model. At this time, predictions are limited because the model does not properly handle perennial plant growth. One of our objectives is to relate at water quality modeled at the subbasin level with that collected as part of the NAWQA synoptic sampling studies. This linkage will help define the dominant sources of phosphorus within the watershed.

# Bottom Sediment Behavior and Composition as a Tool for Watershed Analysis: A Focus on the Upper East River Watershed

George W. Mason III[1], Marvin J. Tenor[1], Thomas H. McIntosh[1],
and Dale M. Robertson[2]

Excessive phosphorus and sediment loading into Green Bay, Lake Michigan, has caused water-quality problems, primarily algal blooms, and poor water clarity. Most of the loading of these constituents is from the Fox River. This study examines the composition and behavior of the bottom sediment in the Upper East River, Brown County, Wisconsin–a major tributary to the Fox River.

Sediment cores from five sites in the Upper East River watershed were examined for total and plant-available phosphorus content and a suite of elemental minerals and heavy metals. The stratigraphy and mineralogy of each core were examined to determine its composition and structure. Erosional (high-flow) and depositional (low-flow) events were visually determined using a petrographic scope. These stratigraphic units were separated and analyzed for particle distribution. A comparison was made between the bottom sediment and local soils to determine provenance relationships.

Both total phosphorus and plant-available phosphorus in the bottom sediment were present in very high concentrations. Phosphorus concentrations were stratified within the cores, with the upper half of the cores containing 20 percent more phosphorus than the lower half. The composition of elemental minerals in the sediment cores were similar to that of local soils and till fabric. Elemental mineral concentrations were also stratified within the sediment, with higher concentrations in the upper strata of the cores. Analysis for heavy metals revealed high concentrations of chromium, arsenic, and selenium. The presence of arsenic and selenium in the sediment may be due to the high levels of those metals found in the St. Peter Sandstone which outcrops to the west.

The mineralogy of the sediment cores reflected the local soils and till fabrics with carbonate inputs from the Mayville Dolomite, which is exposed locally. The presence of clastic carbonate materials decreased with distance from the local outcrop of the Mayville Dolomite. Well-rounded quartz grains revealed additional glaciofluvial inputs from the St. Peter Sandstone. Sharp discontinuities were followed by classical lag deposits with fining upward trends. Layers of leaf litter and other organic debris were present in several different cores. High- and low-flow events were separated out of the cores and particle-size distributions were measured. Particle-size distributions were normally distributed with the exception of a site draining an area with intensive agricultural practices. This core showed erosional and depositional events which were

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clearly visible under the petrographic scope, but revealed identical particle-size distributions after particle-size analysis. The cause of this anomaly was the presence of 0.75 to 1.5 mm clay clasts in the high-flow strata. During testing, these clasts broke down into clay-sized particles. In bottom sediments, these clasts may become blended with clay-size particles which fall out of entrainment after them, thus masking their presence.

Sediment-core analyses revealed information about the behavior of the watershed. High phosphorus content sediment is being eroded from the local fields and stored in river-bottom sediments. These sediments may be mobilized during high-flow events and moved farther downstream in successive slugs. The amount of bottom sediment being re-entrained is dependent on the magnitude of the flow and may be significant. Determining the lag time between the field erosion and the transport of nutrient-rich bottom sediment to Green Bay would greatly enhance our understanding of the effects of implemented control measures.

Further studies could entail the use of radiometric tracers to determine the overall time of transport as well as amount. Correlating leaf litter "varves" to given time periods or determining ages of discontinuity surfaces could also prove valuable. A synoptic sediment trap study would also prove valuable in determining the response of the system to high-flow events. If the contribution of re-entrained sediment is found to be significant in a given system, these types of analyses could provide information for tracking the effectiveness of control measures as well as monitoring overall trends in nutrient and sediment loads.

# Variability in Nutrient Concentrations and Transport Throughout the Upper East River Watershed During High- and Low-Flow Conditions

Dale M. Robertson[1]

The Upper East River watershed, located in east-central Wisconsin, drains 120 $km^2$ of primarily agricultural land underlain by clay surficial deposits on top of shale bedrock. Water quality at the mouth of this basin has been monitored by the National Water-Quality Assessment (NAWQA) Program since the spring of 1992. This site is referred to as one of the "indicator" basic fixed sites (BFS), a site which represents a unique combination of land use, surficial texture, and bedrock. Although over 90 percent of the land in this basin is used for agricultural practices, localized parts of the basin consist of wetlands and urban areas. By examining the variability in water quality in smaller streams throughout the basin in conjunction with a subdivision land-use practices, a better understanding was obtained of why changes in water quality occur at this BFS and at other similar areas throughout the region. Five sites affected by specific factors (such as a wetland, urban area, or specific agricultural practice) with drainage basins of 5 to 12 $km^2$ (referred to as indicator subbasins) and six mainstem sites on the East River were sampled during a spring high-flow event and summer low flow to better understand what the causes of variability in nutrient concentrations and loads at this BFS. The spring high-flow sampling occurred during the largest flow event in 1994 and was expected to transport a significant percent of the total annual load of nutrients from this area. The summer low-flow sampling represented base-flow conditions.

The high-flow sampling was conducted in late April 1994, following an extensive rainfall event. The magnitude and intensity of this rainfall event had a recurrence interval of once in 10 years. Each of the sites throughout the basin were attempted to be sampled near its peak flow for the event; however, due to the flashiness of flow in this area, most indicator subbasins were sampled shortly following peak flow. Two of the mainstem sites were sampled the day following peak flow, which significantly affected both the flow and water quality; therefore, data from those sites were of limited use. Flows at the mouth of the basin were estimated to have decreased by almost 50 percent by the second day. Peak flows throughout the basin were estimated using the flows measured at the indicator subbasins and compared well with those measured at mainstem sites sampled shortly after the rainfall.

Of all the indicator streams, phosphorus concentrations and loads during the high-flow event were greatest in the stream draining the area with urban influences and steep stream gradients, and least in the stream flowing through an extensive wetland. The different types of agricultural practice appeared to have little influence on phosphorus concentrations and loads. Phosphorus concentrations and loads, primarily the

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particulate fractions, were higher at the mainstem sites than at any of the indicator sites, suggesting that the river sediment may be a significant source of phosphorus during high-flow events. Nitrogen concentrations and loads were variable throughout the basin. No consistent pattern was observed with land use or stream gradient.

The low-flow sampling was conducted in late June, following several weeks with little rainfall, resulting in flow throughout the basin representing base-flow conditions. During this period, flow was only observed at three of the mainstem sites. Pools of water were observed at most of the indicator sites, but all had negligible flow. Therefore, during low-flow conditions, most of the drainage area has no effect on the water quality observed at the BFS.

# Variability in Nutrient Concentrations and Transport Throughout the Fox/Wolf River Basin During High- and Low-Flow Conditions

Dale M. Robertson[1]

The Fox/Wolf River Basin, located in east-central Wisconsin, drains 16,500 $km^2$ of land with various land-use practices and types of surficial deposits. The Fox and Wolf Rivers drain approximately 85 percent of this area into Lake Winnebago prior to the Lower Fox River flowing into Green Bay. The Lower Fox River has been shown to be the primary source of nutrients to Green Bay. Water quality at the mouth of the Lower Fox River was monitored by the National Water-Quality Assessment (NAWQA) Program during 1994. This site is referred to as one of the "integrator" basic fixed sites (BFS), sites draining areas with various land-use practices on various surficial deposits, and bedrock types. Nine "indicator" sites (sites dominated by a specific land use, specific soil texture, and specific bedrock type with drainage basins of 50 to 250 $km^2$) and five mainstem sites were sampled during a spring high-flow event and summer low flow to better understand the causes of variability in nutrient concentrations and loads at this BFS. The spring high-flow sampling represented one of the largest flow events in 1994 and was expected to transport a significant percentage of the total annual load of nutrients from the area. The summer low-flow sampling represented base-flow conditions.

The high-flow sampling was conducted in late April 1994, following an extensive rainfall event. Although most of the basin received substantial rainfall, the far northern and southern reaches of the basin received less rainfall than the rest of the area. Therefore, rivers in the far northern and southern areas had relatively less flow. During this event, much of the water from the basin was retained in the Winnebago Pool system. Phosphorus concentrations and loads were highest in rivers draining areas dominated by agriculture, and lowest in areas dominated by forests and areas with a mixture of forest and agriculture. Nitrogen concentrations and loads were highest in areas dominated by agriculture, moderate in areas with mixed agriculture and forest, and lowest in areas dominated by forested land. Much of the phosphorus and nitrogen load being transported was deposited into Lake Winnebago. It was not possible to determine the effects of the different soil textures that occur in the basin because of the variable rainfall and resulting variable flow during this high-flow event.

The low-flow sampling was conducted in early June following several weeks with little rainfall resulting in flow throughout the basin representing base-flow conditions. During this period, the highest flow occurred in rivers located in areas with permeable deposits, such as the rivers in the southwestern part of the basin. Very little flow occurred in rivers located in areas with clay deposits. Phosphorus concentrations were highest in rivers draining areas dominated by agriculture and lowest in areas dominated by forests and

[1]U.S. Geological Survey, Madison, Wis.

areas with a mixture of forest and agriculture. The various surficial deposits appeared to have little effect on phosphorus concentrations; however, it was an important factor influencing total-nitrogen concentrations. Rivers in areas with permeable deposits had the highest nitrogen concentrations. Land use was also an important factor for total-nitrogen concentrations. Rivers in areas with permeable deposits and agricultural practices had the highest nitrogen concentrations. Phosphorus and nitrogen loads were highest in rivers in permeable deposits with agricultural practices. During this period Lake Winnebago was a source of phosphorus, and a sink for nitrogen.

During low flow, nitrate concentrations in the surface water of the basin were very similar to those found in ground water. The highest concentrations in surface and ground water were found in the extreme southern part of the basin where permeable deposits and extensive agricultural practices are present. Concentrations of nitrate in rivers located throughout each type of surficial deposit were very similar after adjusting for the variable intensity of agricultural practices.

# SESSION 4--SURFACE-WATER PROGRAMS AND PESTICIDE STUDIES

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# Overview of Wisconsin's Nonpoint Pollution Abatement Priority Watershed Program

Robin McLennan[1]

The Wisconsin Nonpoint-Source Pollution Abatement Program was established in 1978 to reduce rural and urban nonpoint-source pollution discharges to the waters of the State. To date, 62 large-scale priority watershed projects and 15 small-scale or lake projects have been initiated. Twenty-seven of these lie within the Lake Michigan watershed.

Most priority watershed projects are administered through county land conservation departments. County staff are employed by State funding to inventory pollution sources, assist in setting water resource objectives and pollution reduction goals, and to design and oversee the installation of cost-shared best management practices for cooperating landowners.

Recent information suggests that croplands are not only the most significant source of sediment in watersheds, it is also the largest source of phosphorus. In response to this, the Priority Watershed Program is evolving and placing more emphasis on cropland sediment control needs.

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# Watershed Restoration Activities of the Oneida Tribe of Indians of Wisconsin

Michael Finney[1]

A long-term goal of the Oneida Nation is the restoration of Duck Creek and its tributaries. The Oneida Nation has initiated comprehensive and long-term actions to this end. Additional restoration activities will occur in the future, which is consistent with the long-term "seven generation" vision of the Oneida Nation.

The actions already planned go beyond typical watershed-restoration activities and may eventually provide valuable information for the restoration of other waterways. For example, these projects may provide valuable information about the impact of buffers on sediment and nutrient loadings, or whether large-scale transition to "organic fertilizers" and avoidance of commercial pesticides can improve water quality.

The following actions are being taken to restore Duck Creek:

1. Open space plan

   This "natural areas" designation and preservation plan is watershed based. Buffer area setbacks are established along all waterways which will be preserved or restored to a "natural habitat." Farming and development will be prohibited in buffer areas. Buffer areas on each side of a waterway will range from 50 ft, on intermittent drainage ways common in farm fields, to 625 ft on Duck Creek. Setback distances are set to provide watershed protection and enhance wildlife habitat. Approval for the plan is expected in 1995 when implementation will begin on all tribal-owned lands.

2. Storm-water drainage

   A storm-water drainage hierarchy has been adopted for all tribal projects. This hierarchy requires consultants and planners to consider drainage options starting with "most desired" options first then moving down the list to "least desired," in effect, encouraging surface drainage of storm water over vegetated areas and discouraging subsurface storm water pipes to waterways.

[1]Oneida Tribe of Indians of Wisconsin, Environmental, Health and Safety Department, Oneida, Wis.

3. Rural drainage

Low summer flows and storm/runoff flows have been a problem on Duck Creek. Past practices of ditching and draining have contributed to the problem. One tributary of Duck Creek with historical flood problems is being analyzed to consider options to ditching. Moving homes, detention ponds, and other options are being explored.

4. Oneida integrated food systems

It has been proposed that tribal farm lands be used to provide organically grown food for use by the community and its enterprises. It is hoped that the avoidance of pesticides, herbicides, and traditional water-soluble fertilizers will have a positive impact on water quality.

5. Priority watershed project

Duck Creek and Apple-Ashwaubenon Creek have been designated priority watersheds. The Oneida Tribe, Brown County, and Outagamie County are administering and implementing the 10-year State funded watershed project. During the first two years, urban and rural water-quality impacts are assessed and rated. A plan is then developed to reduce major impacts. During the next eight years, cost-sharing grants are offered to farmers, municipalities, and others for impact-reducing projects and activities.

6. Duck Creek task force

A fisheries habitat assessment of Duck Creek is being planned. The Oneida Tribe is working with the U.S. Fish and Wildlife Service and the Wisconsin Department of Natural Resources on this project.

# Pesticides in Surface Waters of the Western Lake Michigan Drainages, Wisconsin and Michigan

Daniel J. Sullivan[1]

The presence of pesticides in both surface and ground water is a national topic for the first round of NAWQA study units. The initial sampling phase for pesticides in streams of the Western Lake Michigan Drainages study unit consisted of low-flow sampling at eight sites to measure background concentrations of pesticides in various streams. These streams drain areas of varying land use including agriculture, forest, urban, and mixed land uses. The low-flow sampling was followed by intensive sampling in 1993 and 1994 at three sites draining agricultural areas underlain in each case by relatively homogeneous surficial deposits, and one site draining an area of mixed land use and heterogeneous surficial deposits. Samples were collected during periods of storm runoff to coincide with the timing of the largest expected concentrations of pesticides in streams.

Atrazine was detected at every site except the primarily urban site during low-flow sampling, and was detected in 124 of 128 samples (97 percent) collected in both sampling phases in 1993 and 1994. The next-most prevalent pesticides in streamwater samples were simazine (82 percent of all samples), metolachlor (80 percent), cyanazine (73 percent), prometon (59 percent), alachlor (52 percent), and EPTC (41 percent). Deethylatrazine, a breakdown product of atrazine, was detected in 76 percent of all samples collected.

Maximum concentrations of atrazine and metolachlor of 7.4 and 50 µg/L (micrograms per liter), respectively, were detected in storm-runoff samples at an agricultural site in July 1994. The observed maximum concentrations of alachlor and cyanazine of 4.9 and 4.7 µg/L, respectively, were also detected in storm-runoff samples collected at another agricultural site during June 1993. The maximum concentrations of all other analyzed pesticides were below 1 µg/L. The largest median concentration was for atrazine (0.09 µg/L).

The sampled streams are not generally used as sources of drinking water; however, comparison of observed pesticide concentrations to U.S. Environmental Protection Agency maximum contaminant levels (MCL's) for drinking water may be useful for reference purposes. Atrazine concentrations exceeded the MCL of 3 µg/L in nine streamwater samples collected during periods of storm runoff at two sites where agricultural activity is the dominant land use. Alachlor concentrations exceeded the MCL of 2 µg/L in two of the samples in which atrazine concentrations exceeded the MCL.

[1]U.S. Geological Survey, Madison, Wis.

The relation of pesticide concentrations to discharge was similar for most pesticides. In general, following a rainfall event, pesticide concentrations increased during periods of increasing streamwater discharge, followed by coincident decreases in both concentrations and streamflow. This pattern is consistent with patterns observed in other studies conducted in the midwestern part of the United States.

Pesticide concentrations observed in streamwater in the WMIC were compared to pesticide concentrations in other NAWQA basins in the Midwest. The results indicate large variations in pesticide concentrations in surface waters throughout the region. Maximum atrazine concentrations ranged from only 0.37 µg/L in the Red River of the North study unit in northern Minnesota and North Dakota to 100 µg/L at a site in the White River basin in Indiana. These differences may be due to varying intensities of agriculture, pesticide-application rates, soil permeability and erodibility, climatic conditions, or other factors.

Additional sampling is planned at one of the agricultural sites in 1995. An automatic sampler will installed to collect frequent samples over several runoff events early in the growing season. The increased temporal resolution will provide more complete information on the timing of pesticide concentrations in relation to streamflow.

# Pesticides in Duck Creek

Kristin Girvin[1]

Herbicides are frequently detected in ground and surface water discharging to Green Bay, Lake Michigan. This study assesses the temporal variation of herbicide input in surface water and wetlands associated with Duck Creek, draining an agricultural basin and flowing into southwestern Green Bay, Lake Michigan. The impact of single herbicides, or combinations of herbicides, has been evaluated with respect to both the local or regional aquatic ecosystems in an agricultural watershed. Several herbicides were detected at concentrations below 30 μg/L in Duck Creek during 1993 and 1994 storm events. Atrazine, cyanazine, and metolachlor were detected at the highest concentrations. Episodic increases of herbicide concentrations were characterized during intense rain events when runoff was high. Initial reconnaissance of the wetland revealed no obvious herbicidal impacts, but ecosystem effects were expected to be difficult to detect. Laboratory bioassays were used to assess the effects of these herbicides over a range of concentrations representative of expected environmental conditions. Aquatic target species representative of biota in Duck Creek, including *Ceriodaphnia dubia*, *Selenastrum capricornutum*, *Chlamydomonas rienhardtii*, and *Lemna minor*, were selected for study. The results of the study did not indicate direct effects on these organisms due to cumulative herbicide exposure at peak herbicide concentrations measured during storm runoff.

This study is funded by the University of Wisconsin Sea Grant program, and is being conducted in conjunction with the U.S. Geological Survey National Water-Quality Assessment Program.

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# SESSION 5--GROUNDWATER

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## Hydrologic Importance of the Sinnipee Group in the Lower Fox River Valley

Terrence D. Conlon[1]

The Sinnipee Group, a hydrologically important rock unit consisting of the Galena Dolomite, Decorah Formation, and Platteville Formation, subcrops beneath the lower Fox River Valley in northeastern Wisconsin. Two urban areas, the Fox Cities area and the metropolitan Green Bay area, are located within the lower Fox River Valley. Most of the communities in these areas obtain their water supply from deep wells that penetrate the Sinnipee Group and withdraw water from the underlying sandstones and carbonate rocks, commonly called the "sandstone aquifer." The U.S. Geological Survey has been and continues to be involved in studies that simulate regional ground-water flow in the sandstone aquifer beneath the Sinnipee Group in this area.

Modeling of the aquifer system requires knowledge of recharge to the sandstone aquifer. Recent data suggests that the Sinnipee Group limits recharge to the sandstone aquifer. The Sinnipee Group yields little water according to results of packer tests. Caliper logs show that fractures are less common in the Sinnipee Group than they are in underlying formations. Water levels in wells located near surface-water bodies are approximately 100 ft below surface-water levels. These observations, in conjunction with ground-water modeling, support the idea that the Sinnipee Group is a confining unit. Preliminary results of ground-water flow modeling indicate that measured heads in the sandstone aquifer underlying the lower Fox River Valley can be simulated by limiting most of the recharge to an area west of the subcrop of the Sinnipee.

The confining nature of the Sinnipee Group is beneficial because it probably limits infiltration of surface contamination to the underlying sandstone aquifer. However, the confining nature of the Sinnipee Group is detrimental in terms of water levels in the aquifer because, by limiting recharge to the aquifer, the drawdown in water-supply wells is large.

[1]U.S. Geological Survey, Madison, Wis.

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# Pesticides and Nutrients in Ground Water of Two Agricultural Land-Use Areas in the Western Lake Michigan Drainages

David A. Saad[1]

The Western Lake Michigan Drainages NAWQA study unit drains a 20,000 square mile area in eastern Wisconsin and Upper Michigan. One of the most important factors affecting ground-water quality in the study unit is agricultural land-use practices. The primary land use in more than 37 percent of the study unit is agriculture, but its effects on ground-water quality are not the same everywhere. Factors such as intensity of land use, texture of surficial deposits, and depth to the water table determine the effects of land use on the quality of the ground water.

Two areas in the study unit, designated Area 3 and Area 20/26, were chosen to assess the effects of agricultural land use on shallow ground-water quality. Area 3 is located in eastern Wisconsin, mainly in the counties of Fond du Lac, Sheboygan, and Washington. Area 20/26 is located in central Wisconsin, just east of the drainage divide between the Fox/Wolf and Wisconsin Rivers, in a narrow band from eastern Adams to western Shawano counties. The rate of fertilizer and manure nitrogen application in the two areas is generally similar, 175 to 210 kilograms per hectare (kg/ha) in Area 3 and 160 to 230 kg/ha in Area 20/26. The texture of surficial deposits, however, are quite different in the two areas. Area 3 is underlain by mostly sand and clay of low permeability, whereas Area 20/26 is underlain by highly permeable sands and gravels. Beginning in 1992, application rates in Wisconsin for the pesticide atrazine were limited by law to 0.89 to 1.34 kg/ha per year on medium/fine soils, which are typical of Area 3, and 0.67 kg/ha per year on coarse soils, which is typical of Area 20/26. Estimates for both areas, from 1985 and 1991 data, show that the application rates for atrazine were higher in the past and that Area 3 generally had higher rates than Area 20/26. The depth to the water table also differs in the two areas. The water table is fairly shallow, generally 5-15 ft in Area 3, and generally 12-35 ft, but as much as 103 ft deep in Area 20/26.

Sampling locations were chosen by a random, stratified selection method in each area. Wells were installed by the U.S. Geological Survey and were generally screened within 10 to 15 ft of the water table in locations were the immediate upgradient land use included corn and (or) alfalfa crops. Water samples were collected from 26 and 30 wells, in Area 3 and Area 20/26, respectively. Samples collected in 1993 and 1994 were analyzed for two phosphorus species, four nitrogen species and approximately 100 pesticides. Dissolved phosphorus and orthophosphorus (as P) concentrations were very low in both areas (median = <0.01 milligrams per liter). Nitrogen in both areas was primarily in the form of nitrate. Even though fertilizer and manure application rates were similar in the two areas, nitrate concentrations were significantly lower in Area 3 than in Area 20/26. In Area 3, 7 percent of the ground-water samples contained nitrate (as N)

[1]U.S. Geological Survey, Madison, Wis.

concentrations that exceeded the Wisconsin State drinking-water enforcement standard (ES) of 10 milligrams per liter (mg/L) and 32 percent exceeded the State preventive action limit (PAL) of 2 mg/L. In Area 20/26, 37 percent exceeded the ES and 83 percent exceeded the PAL.

Nitrate concentrations generally decreased with increasing depth to the water table in Area 20/26, but this relation was not apparent in Area 3. Both areas did however show a trend in nitrate concentration with depth below the water table. In Area 3, concentrations were greatest (up to 25.0 mg/L as N) from about 0 to 10 ft and very low (generally less than 1.0 mg/L as N) from 10 to 55 ft below the water table. In Area 20/26, concentrations were relatively low (less than 7.0 mg/L as N) from 0 to 10 ft, greatest (up to 33.0 mg/L as N) from 10 to 20 ft, and lower again (7.0 to 12.0 mg/L as N) from 20 to 50 ft below the water table. In Area 3 and Area 20/26, the most commonly detected pesticides in ground water were atrazine and one of its metabolites de-ethyl atrazine. Even though atrazine application rates have generally been greater in Area 3 than in Area 20/26, atrazine and de-ethyl atrazine concentrations are significantly lower in Area 3. Seventy three percent of the water samples from wells had detectable concentrations of atrazine and (or) de-ethyl atrazine in Area 3, and 93 percent in Area 20/26. The PAL for atrazine plus de-ethyl atrazine (total chlorinated atrazine residues) of 0.30 micrograms per liter (μg/L) was exceeded in 12 percent of the wells in Area 3, and 30 percent of the wells in Area 20/26. Concentrations generally decreased with depth to the water table in Area 20/26 but not in Area 3. As observed for nitrate, concentrations of atrazine plus de-ethyl atrazine changed with depth below the water table. Concentrations were greatest (up to 0.65 μg/L) from 0 to 10 ft below the water table in Area 3 and up to 1.5 μg/L, from 10 to 20 ft, in Area 20/26. There were also some high concentrations (up to 3.9 μg/L) in Area 20/26 at greater than 20 ft below the water table.

The relation of nitrate and atrazine plus de-ethyl atrazine with depth below the water table in Area 20/26 may indicate that the shallowest part of the saturated zone (0 to 10 ft) may be diluted by frequent recharge events through the permeable sands and gravels. These permeable materials also allow relatively high concentrations of nitrates and atrazine to move deep (up to 50 ft) into the saturated zone. Some of the highest measured dissolved oxygen concentrations (10.0 to 11.0 mg/L) in Area 20/26 are at more than 20 ft below the water table. These aerobic conditions prevent denitrification from occurring which also helps to explain why nitrate concentrations can remain fairly high (7.0 to 12.0 mg/L) at depth. In Area 3, nitrate, atrazine plus de-ethyl atrazine do reach the water table but the high concentrations there indicate that the less permeable sands and clays limit recharge thus reducing or eliminating the dilution effect. These less permeable materials also restrict movement of nitrates and atrazine deeper into the saturated zone. Dissolved oxygen concentrations in Area 3 also decrease with depth below the water table which indicates that in addition to restricted downward movement there may also be denitrification occurring with depth.

# Fate and Transport of Nutrients and Pesticides Along a Ground-Water Flow Path in the Western Lake Michigan Drainages

David A. Saad[1]

In the fall and winter of 1993-94, as part of the Western Lake Michigan Drainages NAWQA Program, a series of multiple-depth well nests were installed in an agricultural land-use area near the North Branch Milwaukee River in Sheboygan County, Wisconsin. The wells were installed as part of a study to determine the fate and transport of nutrients and pesticides along a ground-water flow path. Water-quality samples were taken from the wells in order to study changes in the ground-water quality as it relates to the overlying or upgradient land uses as well as with depth and distance from a source. The wells were located along a 2,500-ft transect from near a local ground-water divide to the discharge area near the river. An upgradient well nest (UW) was located slightly downslope from the ground-water divide and consists of three wells 44, 64, and 75 ft deep, screened in fine sand and clay. The water level in the three wells was 15.4, 39.1, and 41.9 ft below land surface, respectively. A suction lysimeter was located near UW and installed at a depth of 10 ft. A midgradient well nest (MW) was located about halfway between the ground-water divide and the river and consists of three wells 31, 43, and 53-ft deep, screened in coarse sand and gravel. The water levels in these three wells was 16.7, 16.4, and 28.4 ft below land surface, respectively. A suction lysimeter was located near MW and installed at a depth of seven feet. A down gradient well nest (DW) was located near the river and consists of two wells 14.5 and 21 ft deep, screened in clayey coarse sand and gravel. The water level in the two wells at DW are 4.1 and 4.0 ft below land surface, respectively. A suction lysimeter was installed at a depth of 4 ft near DW. In addition to the three nests of wells and lysimeters, a small diameter mini-piezometer (MP) was installed down gradient from DW near the river edge to a depth of 5 ft below the river bottom. The water level in the MP was slightly higher than the level of the river water surface.

Land use and land cover both change along the length of the transect. The area from UW to the ground-water divide is used for agricultural purposes. The land cover consists of crops having a 2-4 year rotation of mainly alfalfa, corn, and oats. This is the only area along the transect where both manure and pesticides are applied to the land surface. The area between UW and DW is only used to grow alfalfa, and according to the landowner no pesticides have been applied there in 30 years. The area between DW and the river is unused lowland covered with grasses and small trees.

[1]U.S. Geological Survey, Madison, Wis.

In June 1994, wells at UW, MW, and DW were sampled and analyzed for field parameters, major ions, nutrients, dissolved organic carbon (DOC), pesticides, oxygen and hydrogen isotopes, tritium, and chlorofluorocarbons (CFC's). The MP was sampled for all constituents except CFC's. Only one suction lysimeter, that near DW, worked properly and was sampled for nutrients.

The results of the analyses show that phosphorus concentrations are low everywhere and that nitrogen occurs in several different forms. The forms and concentrations of nitrogen differ with depth and between well nests. At UW, nitrogen is primarily in the forms of ammonia plus organic N and concentrations increase with depth from 0.70 to 2.70 milligrams per liter (mg/L as N). At MW, nitrogen is primarily in the form of nitrate and concentrations decrease with depth (4.10 to <0.05 mg/L as N). There is however still some nitrogen at MW in the form of ammonia which increases with depth (0.01 to 0.36 mg/L). At DW, it is mainly in the form of nitrate and concentrations slightly increases with depth (1.90 to 2.10 mg/L as N). The suction lysimeter at DW had the highest concentration of nitrogen (10 mg/L) and was primarily in the form of ammonia plus organic N. The MP had nitrogen mainly in the form of ammonia plus organic N, but at a much lower concentration (0.70 mg/L).

There are several possible sources of nitrogen along the flow path which make it difficult to determine its fate and how it moves through the system. Nitrogen could be coming from manure and (or) fertilizer applied to the crops upgradient from UW. Throughout the length of the flow path nitrogen could be coming from fixation by alfalfa, atmospheric deposition, or other natural sources. Another complication is the fact that nitrogen can be changing into different forms along the flow path. Further analysis and data collection needs to be done to determine the sources of the nitrogen to each well nest in order to better understand how it changes and moves through the system.

The only pesticides detected at the flow path wells were atrazine and its metabolite de-ethyl atrazine. Atrazine was last applied upgradient from UW in 1992. Samples from UW showed that only the two deepest wells had detectable concentrations of atrazine and de-ethyl atrazine, 0.013 and 0.014 micrograms per liter (μg/L), respectively. The middle well had a very low concentration of de-ethyl atrazine (0.003 μg/L) while the shallow well had no detectable pesticides. It was difficult to tell whether atrazine was present at MW due to a high detection limit (0.017 μg/L). However, de-ethyl atrazine was detected in the two shallowest wells. At DW, the highest concentrations of atrazine plus de-ethyl atrazine (0.025 and 0.038 μg/L for the shallow and deep wells respectively) were found. No pesticides were detected in the MP at the river.

These results indicate that even though pesticides were only applied upgradient of UW, they are being transported all the way to DW. The lack of atrazine or de-ethyl atrazine detections in the MP at the river may indicate one or more of several things such as: (1) the MP at the river may not be sampling the end of the flow path as it extends horizontally and (or) vertically from DW to the river, (2) atrazine or its metabolite may not be reaching the river due to length of travel time or sorption onto organic materials between DW and the river, and (3) the MP may not truly be sampling the ground water entering the river if it was not properly installed. At UW the lack of atrazine and de-ethyl atrazine in the shallow well indicates that the pesticides are moving through preferential ground-water flow paths above and (or) below the screen and probably also by overland and shallow subsurface flow above it. The water in the shallow well here may be confined in a dense lens of relatively less permeable materials. Age dating of ground water done at UW indicate that water in the shallowest well is up to 20 years older than that in the deepest well. CFC's were not sampled for at the middle-depth well. Modeled CFC recharge dates for the shallowest well is early 1960's compared to early 1980's for the deepest well. For this to be true there must be more permeable or fractured materials upgradient from UW that would allow water to move vertically and horizontally to the deep well faster than water moving vertically from the land surface to the shallow well. Further investigation is needed to determine if this is the case. CFC modeled recharge dates for MW wells, from shallowest to deepest are, early 1980's, late 1960's, and early 1960's. Recharge dates at DW are mid-1980's for the shallow well and early 1980's for the deep well. These recharge dates indicate that most of the water at DW and the shallowest well at MW is probably recharging relatively close to the well nests. If it entered the ground-water system far upgradient, such as near UW, then the recharge dates at DW and the shallowest well at MW should be older than the youngest water near UW. The water sampled at both DW wells, for example, is not older than any water at UW. This means that for atrazine and de-ethyl atrazine to move from near UW to DW it must be moving by overland and (or) shallow surface flow or even fast movement along the water-table surface from UW to DW, and then mixing with more locally recharging waters near DW.

Current plans call for the flow-path site to be visited again in the summer of 1995. Additional mini-piezometers near the river and water samples, as well as several core samples, will be taken to help answer questions resulting from previous work.