Institute of Water Research
Annual Technical Report
FY 2004

Introduction

The Institute of Water Research (IWR) at Michigan State University (MSU) continuously provides timely information for addressing contemporary land and water resource issues through coordinated multidisciplinary efforts using advanced information and networking systems. The IWR endeavors to strengthen MSUs efforts in nontraditional education, outreach, and interdisciplinary studies utilizing available advanced technology, and partnerships with local, state, regional, and federal organizations and individuals. Activities include coordinating education and training programs on surface and ground water protection, land use and watershed management, and many others. (An extended introduction can be found in our FY2001 Annual Technical Report.) We also encourage accessing our web site which offers a more comprehensive resource on IWR activities, goals, and accomplishments: www.iwr.msu.edu.

The Institute has increasingly recognized the acute need and effort for multi-disciplinary research to achieve better water management and improved water quality. This effort involves the integration of research data and knowledge with the application of models and geographic information systems (GIS) to produce spatial decision support systems (SDSS). These geospatial decision support systems provide an analytical framework and research data via the web to assist individuals and local and state government agencies make wise resource decisions. The Institute has also increasingly become a catalyst for region wide decision-making support in partnership with other states in EPA Region 5 using state-of-the-art decision support systems.

The Institute also works closely with the MSU Cooperative Extension Service to conduct outreach and education. USGS support of this Institute as well as others in the region enhances the Institute credibility and facilitates partnerships with other federal agencies, universities, and local and state government agencies. The Institute also provides important support to MSU-WATER, a major university initiative dealing with urban stormwater issues with funding from the university Vice President for Finance. A member of the Institutes staff works half-time in facilitating MSU-WATER activities so the Institute enjoys a close linkage with this project. The following provides a more detailed explanation of the Institutes general philosophy and approach in defining its program areas and responsibilities.

Research Program

Natural Resources Integrated Information System

Basic Information

Title:	Natural Resources Integrated Information System
Project Number:	2004MI42B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	Eighth
Research Category:	None
Focus Category:	Management and Planning, Water Quality, Models
Descriptors:	None
Principal Investigators:	Jon Bartholic

Publication

1. Bartholic, Jon. 2003. Midwest Groundwater Conference Lecture
2. Bartholic, Jon. 2003. 45th Annual Regulatory Studies Program (Presentation).
3. Bartholic, Jon. 2003. Digital Watershed: A Nationwide Web Application Tool for Effective Watershed Management presentation in Muskegon, Michigan at the Michigan State of the Lakes Conference, October 2003.
4. Ouyang, D., J. Bartholic, and J. Selegean. 2003. Assessing Soil Erosion and Sediment Load from Agricultural Croplands in the Great Lakes Basin, The Journal of Great Lakes Research. (In review).
5. Bartholic, J., 2003. Presented Water Supply and Resource Management at the 45th Annual NARUC Regulatory Studies Program sponsored by the Institute of Public Utilities of Michigan State University. August 10, East Lansing, MI.
6. Bartholic, J. 2003. Presented Pesticides: Its not just about bugs at the Agricultures Conference on the Environment. March 24, Lansing, MI.
7. Bartholic, J. 2003. Presented About Digital Watershed at the Lake Michigan State of the Lake 03 Conference. October 21-22, Muskegon, MI
8. Bartholic, J. 2003. Presented Models of Weather Patterns: Where Does Irrigation Water Go? Consumptive Use at the Michigan Irrigation Association Irrigation Workshop. December 4, Shipshewana, IN.
9. Bartholic, J. 2004. Presented at Michigan Land Use Summit sponsored by the Land Policy Program of Michigan State University. February 2-3, East Lansing, MI
10. Bartholic, J. 2004. Presented MSU 2003 Research Results on Drip Irrigation at the Southwest Michigan Irrigation Workshop. January 27-28, Benton Harbor, MI.
11. Shi, Y., J. Asher, J. Bartholic, et al. 2004. An Online WebGIS-based Hierarchical Watershed

Decision Support System for United States. Journal of Environmental Informatics. 7pp. In Review.
12. Allen, L.H. Jr., K.F. Heimburg, R.G. Bill Jr., J.F. Bartholic, and K.J. Boote. 2004. Remostely Sensed Temperatures and Evapotranspiration of Heterogeneous Grass and Citrus Tree-Canopy Surfaces. Soil Crop Science Society Florida Proceedings, Volume 63, pp. 1-20.
13. Kettren, L.P., S. Miller, P.K.B. Hunt, A. Simard, J. Bartholic. 2004. Investigating the Groundwater Quantity Effects on Ecosystems and Human Activities for Informed Groundwater Policy. Proceedings from UCOWR Conference, Portland, OR. 11 pp.
14. Kettren, L.P., S. Miller, P.K.B. Hunt, A. Simard, J. Bartholic. 2004. Investigating the Groundwater Quantity Effects on Ecosystems and Human Activities for Informed Groundwater Policy. Proceedings from UCOWR Conference, Portland, OR. 11 pp.

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General Statement

To deal successfully with the emergence of water resource issues unique to the 21st century, transformation of our knowledge and understanding of water for the protection, conservation, and management of water resources is imperative. Radically innovative approaches involving our best scientific knowledge, extensive spatial databases, and "intelligent" tools that visualize wise resource management and conservation in a single holistic system are likewise imperative. Finally, holistic system analysis and understanding requires a strong and integrated multi-disciplinary framework

Research Program

The management of water resources, appropriate policies, and data acquisition and modeling continue to be at the forefront of the State Legislatures agenda and numerous environmental and agricultural organizations. Our contribution to informing the debate involved numerous meetings, personal discussions, and most importantly, the enhancement of web-based information to aid in the informed decision-making process.

Unique Capabilities: Decision Support Systems As The Nexus

IWR, with its "extended research family," is exceptionally well-positioned to integrate research conducted within each of the three principal water research domains: hydrologic sciences, water resources, and aquatic ecosystems. Integrated decision support both reflects and forms the nexus of these three research domains. Expanding web accessibility to the decision support system nexus (formed by the intersection of the three research domains) will facilitate broad distribution of science-based research produced in these domains.

The Institute's extensive experience in regional and national networking provides exceptional opportunities for assembling multi-agency funding to support interdisciplinary water research projects and multi-university partnerships.

Using A Multi-Disciplinary Framework

Using a multi-disciplinary framework facilitates dynamic applications of information to create geospatial, place-based strategies, including watershed management tools, to optimize economic benefits and assure long-term sustainability of valuable water resources. New information technologies including GIS and computational analysis, enhanced human/machine interfaces that drive better information distribution, and access to extensive real-time environmental datasets make a new "intelligent reality" possible.

Effective watershed management requires integration of theory, data, simulation models, and expert judgment to solve practical problems. Geospatial decision support systems meet these requirements with the capacity to assess and present information geographically, or spatially, through an interface with a geographic information system (GIS). Through the integration of databases, simulation models, and user interfaces, these systems are designed to assist decisionmakers in evaluating the economic and environmental impacts of various watershed management alternatives.

The ultimate goal of these new imperatives is to secure and protect the future of water quality and supplies in the Great Lakes Basin and across the country and the world—with management strategies based on an understanding of the uniqueness of each watershed.

Natural Resources Integrated Information System

Basic Information

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Project Number: 2004MI42B
Start Date: 3/1/2004
End Date: 2/28/2005
Funding Source: 104B
Congressional District: Eighth
Research Category: None
Focus Category: Management and Planning, Water Quality, Models
Descriptors: None
Principal Investigators: Jon Bartholic

Publication

1. Bartholic, Jon. 2003. Midwest Groundwater Conference Lecture.
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Publications Resulting from Projects Prior to FY 2003

4. Nelson, S.A.C., P.A. Soranno, K.S. Cheruvelil, S.A. Batzli and D.L. Skole. 2003. Regional assessment of lake water clarity using satellite remote sensing, Journal of Limnology.
5. Cheruvelil, K.S., N.A. Nate, P.A. Soranno, M.T. Bremigan 2003. A field-test of the unimodal relationship between fish growth and macrophyte cover in lakes, Submitted to Ecological Applications.
6. Nelson, S.A.C., K.S. Cheruvelil, and P.A. Soranno. 2003. Remote sensing of freshwater macrophytes and the influence of lake characteristics. Submitted to Aquatic Botany

Pertinent Publications and Presentations

Ouyang, D., J. Bartholic, and J. Selegean. 2003. Assessing Soil Erosion and Sediment Load from Agricultural Croplands in the Great Lakes Basin, *The Journal of Great Lakes Research.* (In review).

Bartholic, J., 2003. Presented "Water Supply and Resource Management" at the 45th Annual NARUC Regulatory Studies Program sponsored by the Institute of Public Utilities of Michigan State University. August 10, East Lansing, MI.

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Michigan Institute of Water Research Water Research Institute Program Report for FY 2004
Submitted by Dr. Jon Bartholic, Director

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Project Number: 2004MI42B
Start: 03/01/04 (actual)
End: 02/28/05 (expected)
Title: Natural Resources Integrated Information System
Investigators: Jon F. Bartholic, Institute of Water Research, Michigan State University
Focus Categories: M & P, WQL, MOD
Congressional District: eighth
Descriptors: Data Analysis, Data Storage and Retrieval, Information Dissemination, System Analysis, Geographic Information Systems, Water Quality Management, Watershed Management

Areas of Relevant Research

The management of water resources, appropriate policies, and data acquisition and modeling continue to be at the forefront of the State Legislature's agenda and numerous environmental and agricultural organizations. Our contribution to informing the debate involved numerous meetings, personal discussions, and most importantly, the enhancement of web-based information to aid in the informed decision-making process.

Results and Benefits

Extensive investigation and research is needed to achieve effective coupling of human management needs with geospatial databases and decision support systems to assist better decision-making. Multiple research funding opportunities exist to support linking understanding of various phases of the hydrologic cycle with impacts on water use, management, and conservation. As a result, outstanding opportunities to develop scientific water management skills and techniques for the 21st Century are clearly within reach.

Development of geospatial decision support systems complement and build on the extensive scientific knowledge of the role of the hydrologic balance in the functioning of dynamic ecosystems. Based on current development of geospatial databases and modeling systems, a model of the hydrologic balance for the state can be developed to assist water management and conservation. By incorporating extensive geospatial data with the analytical capacity of decision support systems, university researchers are providing decision-makers and managers with a more refined understanding of the hydrologic cycle and water balance functions at watershed and statewide scales.

Our USGS investments over the past two years led to a two-year $540,000 grant from the Great Lakes Protection Fund awarded to Michigan State University and the Institute of Water Research (IWR) for a project entitled "Restoring Great Lakes Basin Waters Through the Use of Conservation Credits and an Integrated Water Balance Analysis System." The IWR is responsible for coordinating and collaborating multidisciplinary teams from various organizations including the World Resources Institute, Institute for Fisheries Research of the Michigan Department of Natural Resources, Public Sector Consultants of Lansing, US Geological Survey District Office, and MSU Departments of Agricultural Economics, Biosystems and Agricultural Engineering; Geography, Civil and Environmental Engineering; and the Community, Agriculture, Recreation and Resource Studies (CARRS).

The project will integrate three systems --Water Conservation Credit, Water Balance Analysis, and the User Assistance Interface, into a single Water Conservation Credits Implementation package. Large water users, including municipalities, corporations, and irrigation users, who are considering major new withdrawals can benefit from the Water Conservation Credits Implementation package by being able to access information on the watershed in which they have an interest, and use this information in their management decisions to guide potential conservation transactions. Individually, the Water Conservation Credits System provides analyses to support the development of an innovative system of water conservation credits which will help policy makers manage water resources to meet the demands of water uses, conservation, and the improvement of ecological sustainability. The Water Balance Analysis System integrates three existing hydrological models that incorporate surface, groundwater, and stream aquatic ecosystem models. The User Assistance Interface System couples the hydrologic models with spatial data to allow a decision maker to create various scenarios for management of water resources in Michigan and the Great Lakes Basin. Combined, these systems can be used to assess the ecological vulnerability of watersheds, the impacts of wells on groundwater levels, river and ecosystems, the effectiveness of conservation practices and associated water conservation credits, and other issues. State agencies in the Great Lakes Basin who are responsible for the improvement of water resources and the health of the Greater Lakes Basin ecosystems can use the system package to support development and implementation of state and regional water management policies. Products will be designed as simple online tools by integrating information and models with appropriate interfaces to the water analysis system. The entire study process is guided with inputs from an Advisory Team composed of leaders from a wide set of interest areas.

Our web-based offerings continue to expand. A Nation-Wide Digital Watershed web site has been developed to allow individuals from across the United States locate themselves by using their address, watershed, or by regional areas established by the EPA. The illustration shows the software developed in the IWR that can be applied to a national situation. The data used in the system was acquired from EPA Basin data via the web. The site for Michigan allows users to zero-in on the eight-digit watersheds and then down to the 12-digit watershed system known as "Know Your Watershed." A special web site was prepared for the Kalamazoo Watershed project to assist them in prioritizing and developing a watershed management strategy. A substantial effort has been completed using all the digital orthoquads (DOQQ) available across Michigan. These have been acquired and seamlessly integrated with quality control and compression algorithms. This information now serves as a backdrop on our "Know Your Watershed" web site. The DOQQ integrated data set is also used as a backdrop for soils information on IWRs new EZMapper web site. This site was specifically designed to aid with Comprehensive Nutrient Management Plan development for agricultural farms throughout the state. The system allows downloading of software to outline fields and utilize the available data. Recently, automatic extraction procedures were added to Digital Watershed to incorporate DOQQ's imagery on the fly across the U.S. from Microsoft Terra Server.

IWR, Purdue University, and EPA Region 5 organized a workshop that examined web-based tools for land use and watershed planning. The Mapper is now under way to serve-up these tools across all states within Region 5, along with obtaining the same data that would be common for each state.

The web-available Mapping is used extensively in IWRs Virtual Watershed Management courses. This past year we offered all four 3-credit modules of Watershed Management each semester in the series for Certification. There are now over 200 students registered per year in these courses.

This past year much effort was put into "The Great Lakes Natural Resource Gateway: Michigan State University and the National Park Service Great Lakes I&M Network." The scope of work for this project follows: The National Park Service's (NPS) Great Lakes Inventory and Monitoring Network (GLKN) is responsible for implementing a long-term ecological monitoring program for nine National Park Service (NPS) units in four states around the western Great Lakes. The GLKN has funding to begin planning the monitoring program as part of a nationwide effort by the NPS to phase in 32 similar networks. During the planning stage GLKN must locate, assess, summarize, and make readily available critical natural resource information for the nine parks. This includes information originating inside and adjacent to parks collected by the NPS and many other federal and state agencies and non-governmental organizations (NGOs). At the onset, GLKN needs to have ready access to ecologically important inventories and monitoring efforts that put the parks and their natural resources into context. For example, regional and localized weather patterns, lake levels, stream flow, point and non-point sources of air and water pollution, human development and land use patterns are all critical perspectives that must be assimilated into the planning process. Many agencies, NGOs, and Universities have tabular and spatial data that are of high value to GLKN for initial planning and for future reference during the monitoring phase. It is essential that the information gathered, cataloged, and synthesized be made readily available for review and comment by the parks and science advisors who are located across the Great Lakes region and the nation.

The Great Lakes Network has selected Michigan State University (MSU), Institute of Water Research, as a partner through the Great Lakes - Northern Forests Cooperative Ecosystems Studies Unit (CESU), to provide a wide range of support in collecting, synthesizing, and making available information for planning and implementing a long-term monitoring program.

Objectives of the Project

GLKN needs to make critical natural resource information readily accessible to the nine parks and their partners. This includes acquiring regionally significant datasets on climate, water and air resources, human population growth and land use. These important datasets need to be analyzed and summarized to reveal significant trends and concerns relevant to the nine park units. The Network and MSU will work cooperatively to do the following:

- Design and build an interactive web site that provides GLKN parks and partners easy access to a wide variety of natural resource information. We envision a "one stop" clearinghouse of raw data and summary information. This would provide needed information during the planning process in the short term and as a mechanism for serving monitoring data in the long term. The web site will include links to other important web sites, access to newly developed information, electronic reports, relational databases, and

large spatial themes. Where possible, raw data will be made accessible through an application interface that allows the user to create queries and sort routines to download data. This may involve using ArcIMS and a database platform such as Oracle or SQL Server, but the setup cost and maintenance of such a system will be carefully considered first. Issues of data format, structure, archival and choice of coordinate systems for spatial data will also be addressed.

- Seek out and acquire access to regionally significant data and then examine for trends and significant events, evaluate gaps, and make recommendations on what the nine parks should monitor in the future. Significant data, summary tables and graphs, and technical reports on this effort will be made available on the web site.
- Develop a long term plan for expanding the proposed web-based information system and determine who conducts maintenance and upkeep. This plan will explore various hosts and means of serving data and weigh the costs and benefits. Ideally, GLKN will be the sole host and maintainer of the system; however, cost and expertise will be considered. MSU will work closely with the Network to determine the most cost efficient method of providing easy and reliable access to information by the parks and partners.
- Create FGDC-compliant metadata for all databases and GIS products created and served under this agreement. Metadata will include documentation of stewardship and how products were developed.
- Participate in and help facilitate three workshops aimed at building the scientific credibility of GLKN's I&M program and developing lists of indicators to monitor in the Great Lakes parks.

Our work with the Michigan Department of Environmental Quality (DEQ) continues at a high level. With funding, between $700,000 and $1M dollars per year, it is largely the result of the Institutes' responsibilities being recognized statewide. This cooperation has led to a major role coordinated by the USGS Michigan Water Science Center and IWR; details follow. The U.S. Geological Survey (USGS) and Michigan State University (MSU) are leading a cooperative effort to assist Michigan Department of Environmental Quality (MDEQ) in meeting the requirements of Section 32802 of Public Act 148. Interim products, task-specific work plans, appropriate review and comment periods, and quarterly project meetings, or a t more frequent intervals, as requested by MDEQ or necessitated by project accomplishments.

The project activities are organized according to the parts of Section 32802. All project activities described below will be part of a team effort including MDEQ, USGS, and MSU. All activities, however, have an identified lead or co-lead role. Product completion dates, as well as timeframes for completing sub-activities necessary to meet completion dates, are identified. Also included is $1,150,000. MDEQ funds of $900,000 will be split equally between USGS and MSU. USGS Cooperative Water Program funds of $250,000 will be added to the USGS component of the project.

(a) Location and water yielding capabilities of aquifers in the state
(b) Aquifer recharge rates in the state
(c) Static water levels of groundwater in the state
(d) Base flow of rivers and streams in the state
(e) Conflict areas in the state

(f) Surface waters, including designated trout lakes and streams, and groundwater dependent natural resources, that are identified on the natural features inventory
(g) The location and pumping capacity of all of the following: (i) industrial or processing facilities registered under section 32705 that withdraw groundwater, (ii) irrigation facilities registered under section 32705 that withdraw groundwater, (iii) public water supply systems that have the capacity to withdraw over 100,000 gallons of groundwater per day average in any consecutive 30-day period
(h) Aggregate agricultural water use and consumptive use, by township

Our strategic plan for the Michigan Institute of Water Research (IWR) over the next five years has been developed and submitted to the Director of the Michigan Agricultural Experiment Station, the Dean of the College of Agriculture and Natural Resources at Michigan State University (CANR-MSU), and subsequently to the Office of the Vice President for Research and Development. The strategic plan outlines a number of key strengthening components for the MI IWR. (1) The affiliate positions within the Institute. These positions might be 25% time in the IWR and 75% in a discipline department. A group of affiliates would greatly strengthen the discourse relative to problems and techniques for solving them as well as the information dissemination. Additionally, adjunct faculty are generally somewhat less involved but enhanced mutual awareness of our programs would greatly enrich the pool of expertise of water scientists from which we could draw upon in order to more effectively address issues of concern within IWR. (2) Enhanced funding for the IWR: New Fiscal Support: Facilitating a competitive grants program in the water arena has been proposed. Preliminary discussions relative to the plan are leading to the strong possibility of adjunct and joint affiliate positions, but any new funding is on hold in light of the State's budget difficulties.

Related Research

We continue to obtain synergistic impacts by closely aligning our efforts with support from such organizations as the Corps of Engineers, USDA, US Forest Service and numerous other agencies and NGO's. This past year we received a grant from the Corps of Engineers for $60,000 which involves estimating sediment delivery from each of the eight-digit watersheds within the entire U.S. side of the Great Lakes Basin. This database is not only of value to the Corps in prioritizing their efforts but also provides us with a broad set of additional information that we can use in other programs, and for assisting with the prioritization of high risk areas for erosion throughout the region. USDA funds involve a coordinating effort of outreach and research among all states within the EPA Region V. IWR personnel are partially funded through this regional project which coordinates and facilitates the communication of research methodologies, approaches, and results from our research and aides with region-wide outreach programming.

Training Potential

New graduates and graduate training continue to be a high priority of IWR. Unfortunately, graduate stipends have increased to the extent that a 1/2 time graduate student with fringe benefits, requires from $30,000-$40,000 (per year). We will make every effort to continue incorporating graduate students but with the high cost, it is increasingly difficult to employ more than a few students at any given time. As part of our partnership philosophy, we have jointly supported numerous graduate students with other departments and units on campus.

Studying the Quantative Water Withdrawal Effects on Michigan's Water Supply and Distributing the Conclusions

Basic Information

Title:	Studying the Quantative Water Withdrawal Effects on Michigan's Water Supply and Distributing the Conclusions
Project Number:	2004MI47B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	Eighth
Research Category:	Not Applicable
Focus Category:	Water Quantity, Water Use, Education
Descriptors:	
Principal Investigators:	William J. Northcott, Steve Miller

Publication

Project Number: 2004MI47B FY 2004 Federal Funds: $15,000
FY 2004 Non-Federal Funds: $31,653
Start Date: 03/01/04 **End Date:** 02/28/05
Title: Studying the Quantitative Water Withdrawals Effects on Michigan's Water Supply and Distributing the Conclusions
Investigators: William J. Northcott, Asst. Professor, Dept. Ag Engineering
Co-PI: Steve Miller, Specialist, Institute of Water Research and Dept. Ag Engineering
Other PI's: Pam Hunt, Visiting Specialist, Institute of Water Research
Focus Categories: Water Quantity, Water Use, Education
Congressional District: Eighth
Descriptors: Hydrology, Water Use Conflicts, GIS, Groundwater

Studying the Quantitative Water Withdrawals Effects on Michigan's Water Supply and Distributing the Conclusions

Problem and Research Objectives

The public perception of a bountiful water supply and viable water resources is being altered by published events of conflicting water uses. Due to continued media coverage on conflicting water withdrawals from industry, mining operations and irrigators, past drought conditions, and water diversion, the public is now acutely aware of potential water conflict issues regarding quantity and quality of the water source. In accordance with protecting the water supply, the state of Michigan has recently passed legislation, Public Act 148 of 2003, to manage and protect the water resources with respect to water withdrawals. One of the mandates is to produce a Groundwater Inventory and Map to guide the policy makers to enact appropriate legislation. Through the compilation and integration of data and information resulting from the inventory and the subsequent map and combining the ongoing and proposed studies, outreach and educational opportunities will be developed and made accessible concerning hydrologic principles including water use, availability, quantity, and quality to legislators, policy makers and the nonscientific community. By utilizing existing technological and standard models, these educational materials can be maximized for dissemination to target audiences.

Methodology, Principal Findings, Significance

Recent high profile water use conflict issues have renewed the interest in water quantity management issues in Michigan. The focus of efforts in the FY 2004 grant was on developing and information on the impact of water use on groundwater and surface water. A number of meetings were held with MDEQ, MDA, and USGS. The meetings in the first part of the grant were to receive input on information outreach needs and in later part of the grant to provided information derived from this project and other related projects. An important tool in educating the nonscientific community on complex groundwater flow issues is the graphical capabilities of the Interactive Groundwater Model (IGW). A number of scenarios have been developed with the focus on large volumes of water withdrawal (PowerPoint presentations are attached).

Initiated in early 2004, the development of a web site, which focused on reporting water use data compiled by the Michigan Department of Environmental Quality into a county and watershed format maintained by IWR-MSU was updated for the water year 2002 and will be updated in the future for 2003. Michigan water use data can be retrieved by years, 1997-2003, for the five major sectors of water withdrawal: Thermoelectric Power Generation, Public Water Supply, Self Supplied Industrial, Agricultural Irrigation, and Golf Course Irrigation. This site sorts the water

withdrawal data by location and then respectively by category and years. The URL address is http://www.hydra.iwr.msu.edu/iwr/wateruse/index.html. A future goal of this web site is to enhance the data with graphical charts to illustrate the water withdrawal rates for the retrieved county or watershed.

In addition the following opportunities provided a forum to augment the delivery of outreach materials or gather comments for the distribution of the conclusions.

- GIS Training in March facilitated the understanding needed for the basic development of the web site to house the data inventory, query formula options, and projections of the map series required by the legislation.
- The State Science Olympiad in April was an avenue to teach and test middle and high school students on hydrogeological parameters. The Olympiad also provided feedback to what elements needed to be expanded for outreach initiatives, such as highlighting the State's groundwater and surface water resources locally and regionally.
- A half-day symposium with MDA to share with them our perspectives, information, and modeling efforts to aid in their deliberations to policy options related to the recent GW legislation and the proposed Water Legacy Act. The last agenda item was to solicit the educational needs - integration/system studies/education.
- Ag Expo is an annual event sponsored by Michigan State University (MSU) and is largest farm show in the State scheduled in July. Educational exhibits highlighting MSU research and extension have always been the mainstay of the expo. IWR featured two interactive web sites, EZ-Mapper and Know Your Watershed to illustrate imagery available by the internet. Additionally, a color printout of their farm or another point of interest was printed for the visitors depicting aerial photography presenting water bodies, topography and land use features. IWR-MSU brochures were made available to the expo participants emphasizing the education components of protecting one's water resources.
- In November, the MSU extension group, Area of Expertise (AOE) Water requested a presentation on the mandated requisites of Public Act 148. Through discussions with the group, materials needed at this time for the public audience are informational bulletins explaining base flow and water use in Michigan. Presently, the base flow brochure is in the review process.
- In January, through a focus group meeting, participants identified different techniques to employ to reach various target audiences.
- At the annual conferences for the Association of Townships and Michigan Association of Counties, respectively in January and February, the booth showcased digital watershed and watershed mapping. Watershed mapping tools were shown to over 250 people. Although water-related issues varied between the urban and rural settings, several water-related issues had common interest, wetland location, access to updated photos, and DEQ violations. The attendees expressed a need to access and utilizing GIS data for decision-making policy.

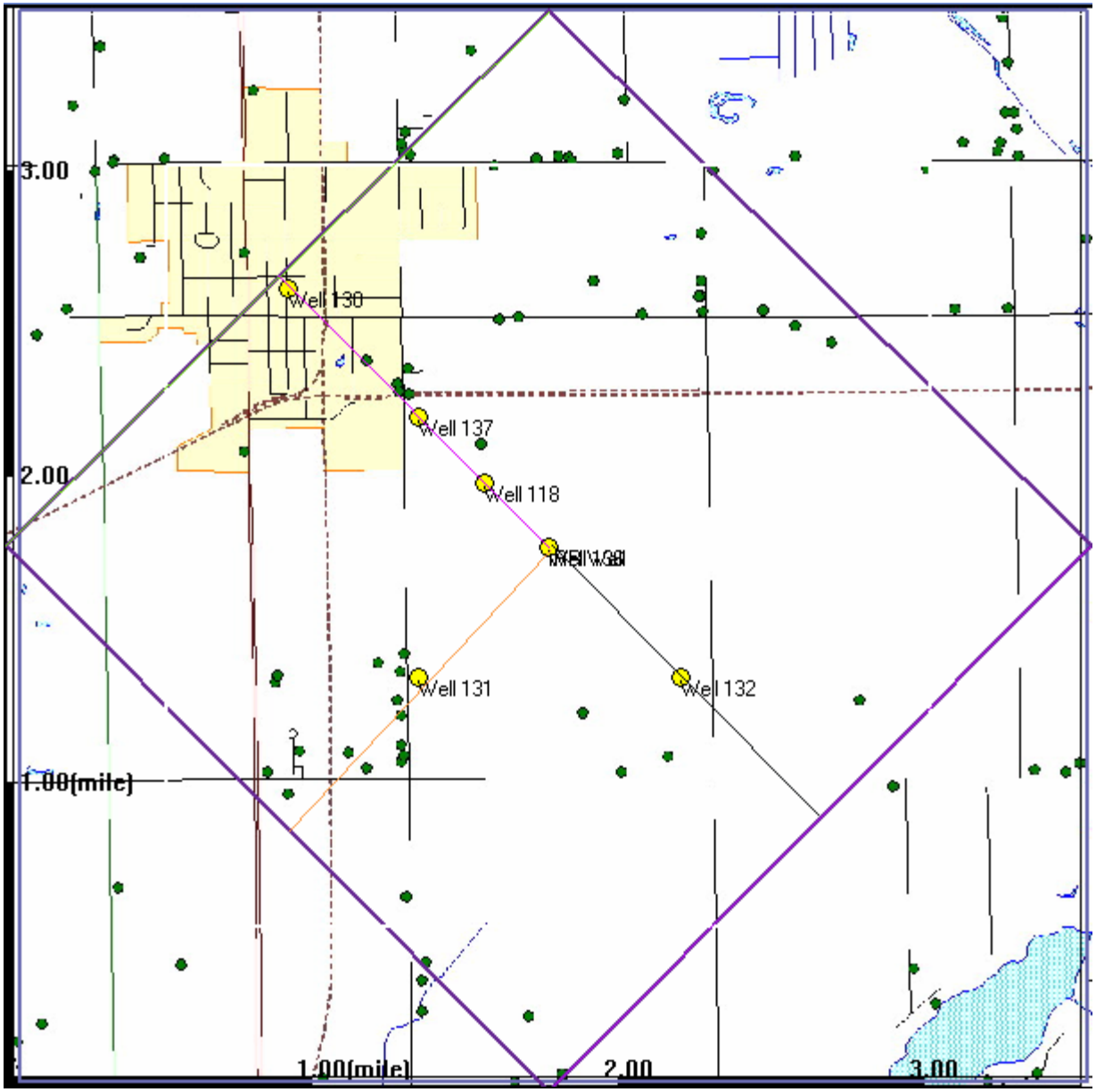

3.00
2.00
1.00(mile)
Well 130
Well 137
Well 118
Well 131
Well 132
1.00(mile)
2.00
3.00

Table 1: Drawdown at MW located 500m from the pumping well (1000 GPM)

Unconfined Aquifer (K=141 ft/day)					
Recharge 4 in/yr			Recharge 9 in/yr		
dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr	dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr
5.926	3.297	0.326	4.485	2.004	-0.924

Unconfined Aquifer (K=300 ft/day)					
Recharge 4 in/yr			Recharge 9 in/yr		
dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr	dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr
2.777	2.085	0.053	2.729	2.061	0.05

Confined Aquifer (K=141 ft/day)					
Recharge 4 in/yr			Recharge 9 in/yr		
dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr	dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr
5.958	3.306	0.328	5.743	3.243	0.308

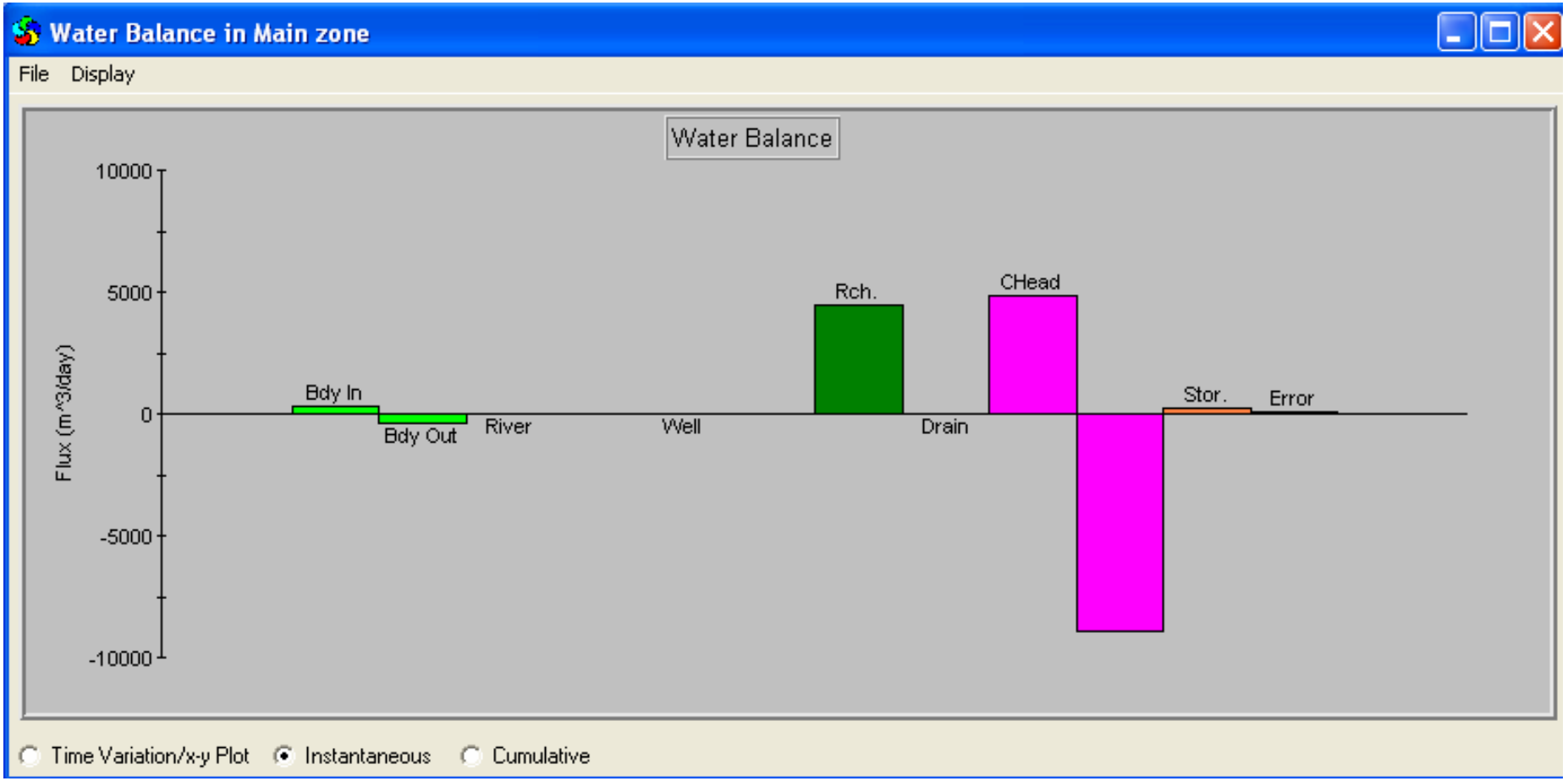
*Aquifer thickness is 84ft

Confined Aquifer (K=300 ft/day)					
Recharge 4 in/yr			Recharge 9 in/yr		
dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr	dd at Steady State	dd at 90 days pumping	dd at 90 days pumping w/recovery for total time of 1 yr
2.776	2.085	0.053	2.729	2.061	0.05

Mass Balance for Unconfined Case

with 4in/yr of Recharge and K=300 ft/day

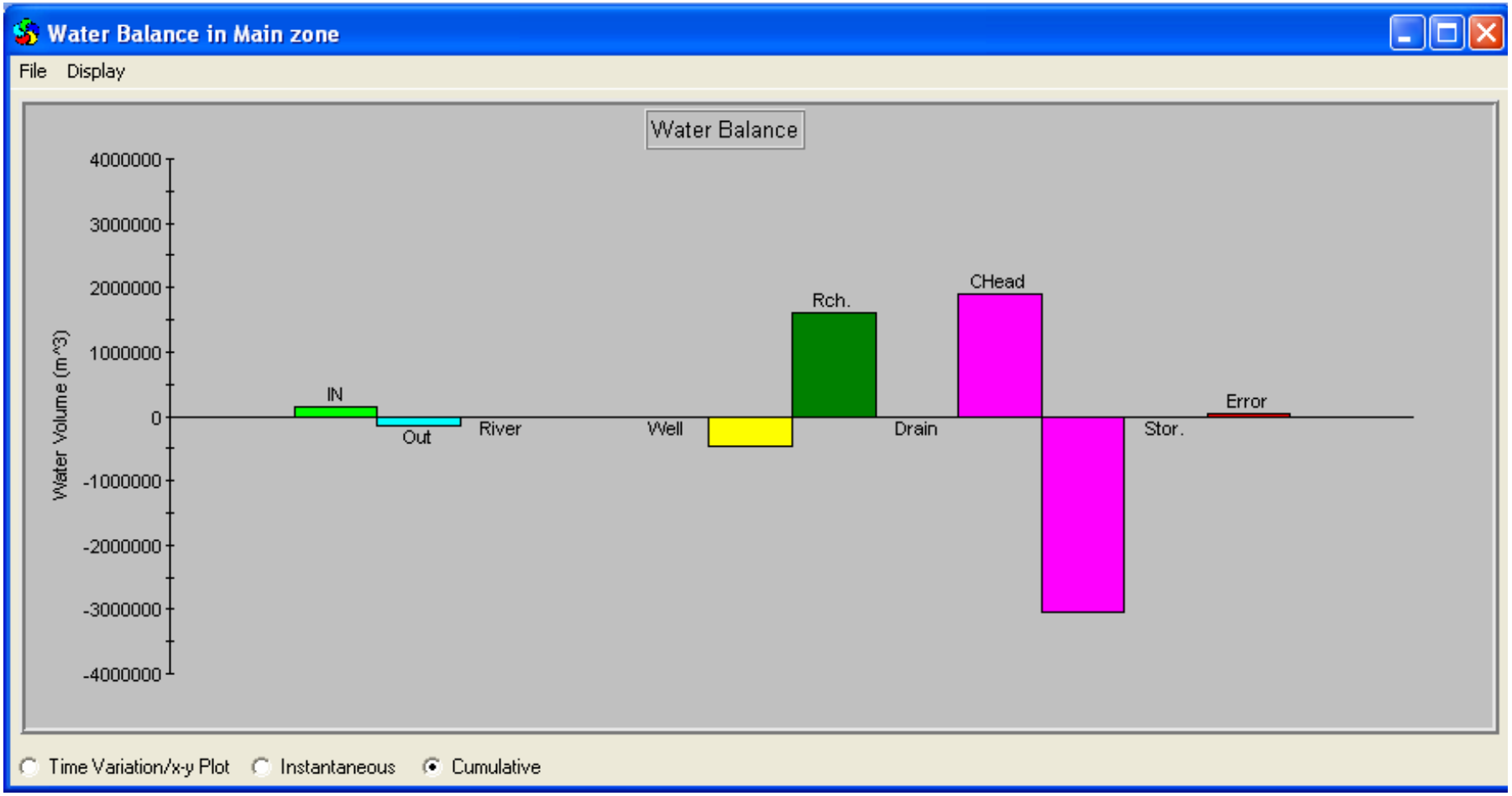
instantaneous



Mass Balance for Unconfined Case

with 4in/yr of Recharge and K=300 ft/day

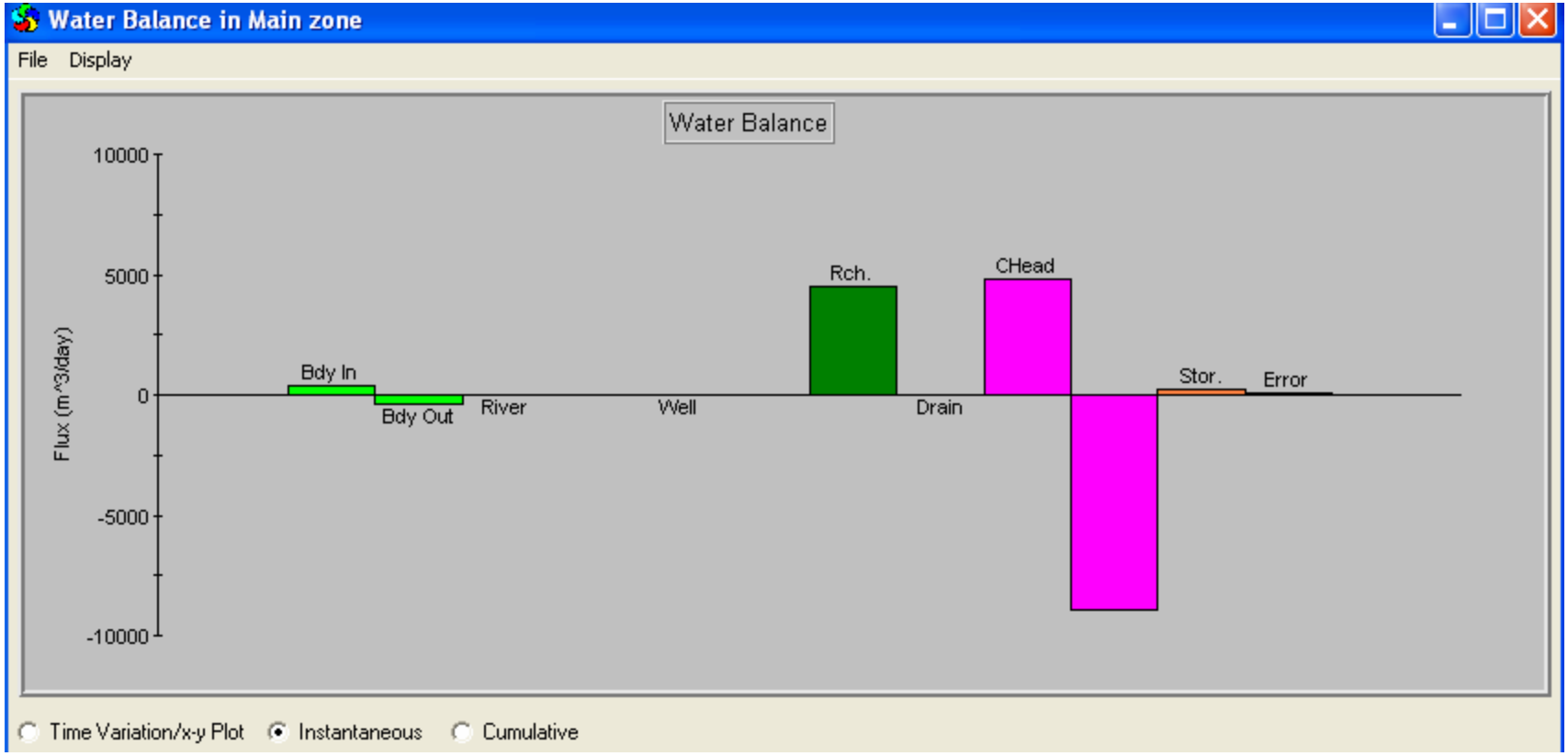
cumulative



Mass Balance for Confined Case

with 4in/yr of Recharge and K=300 ft/day

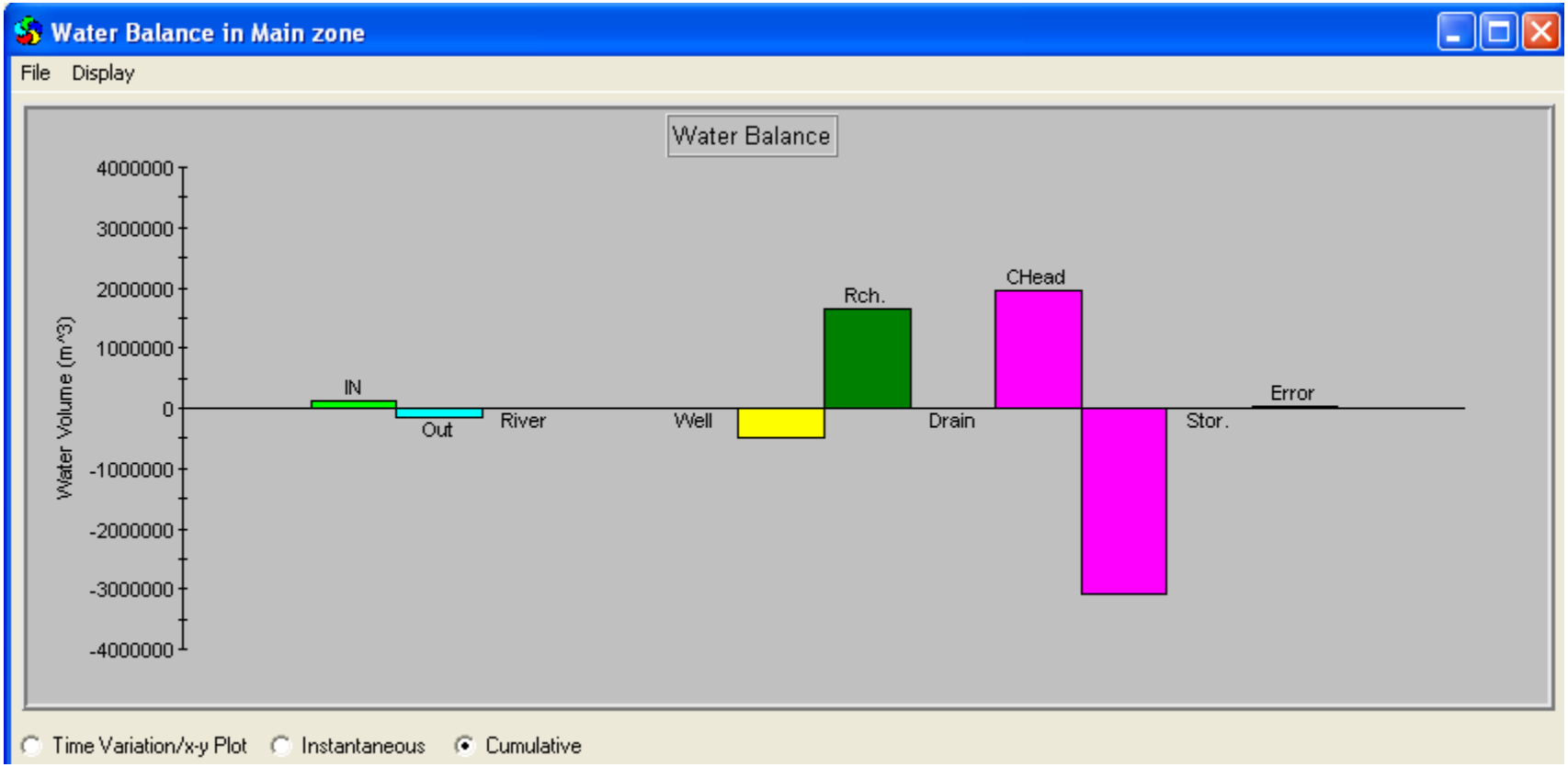
instantaneous

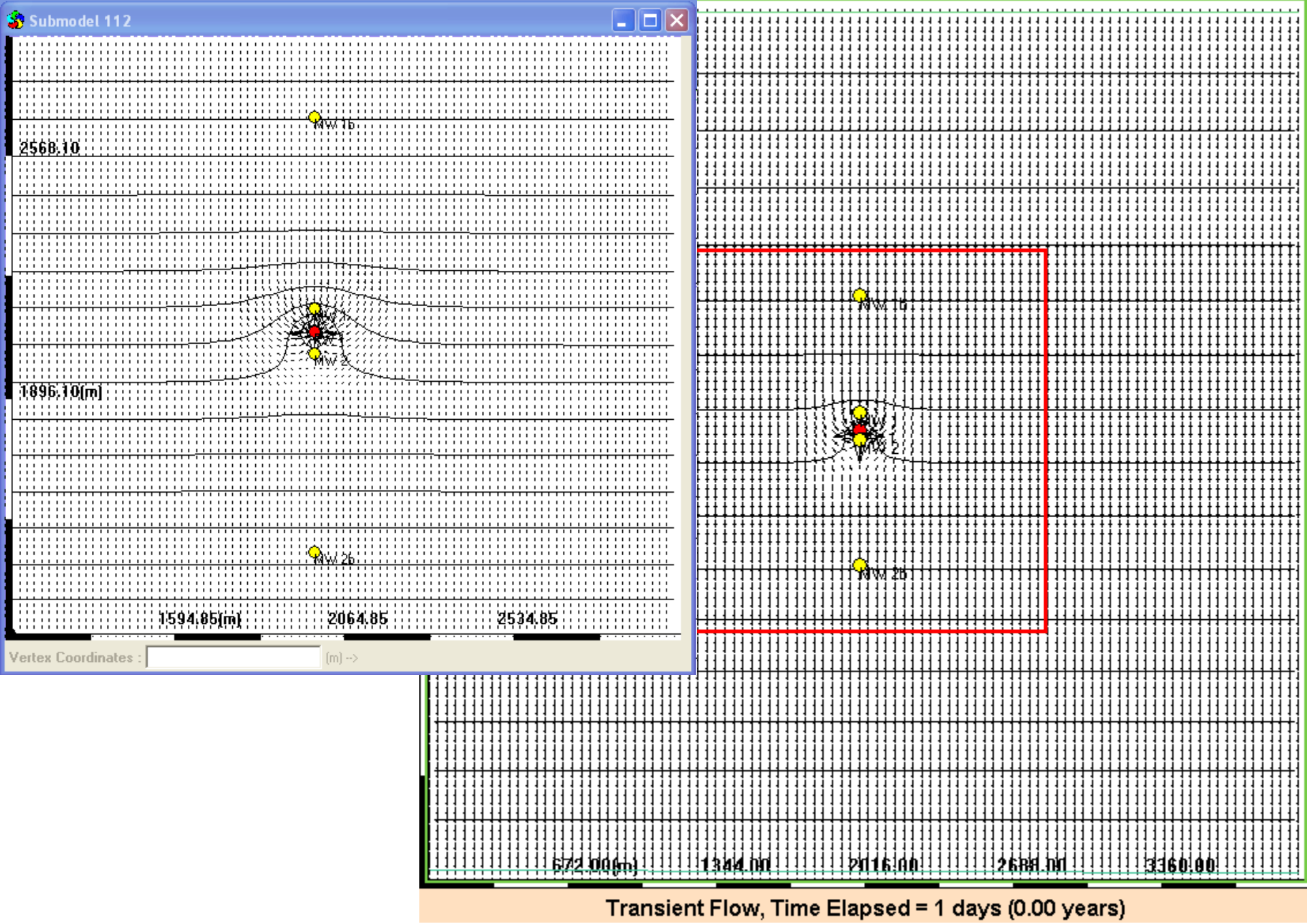


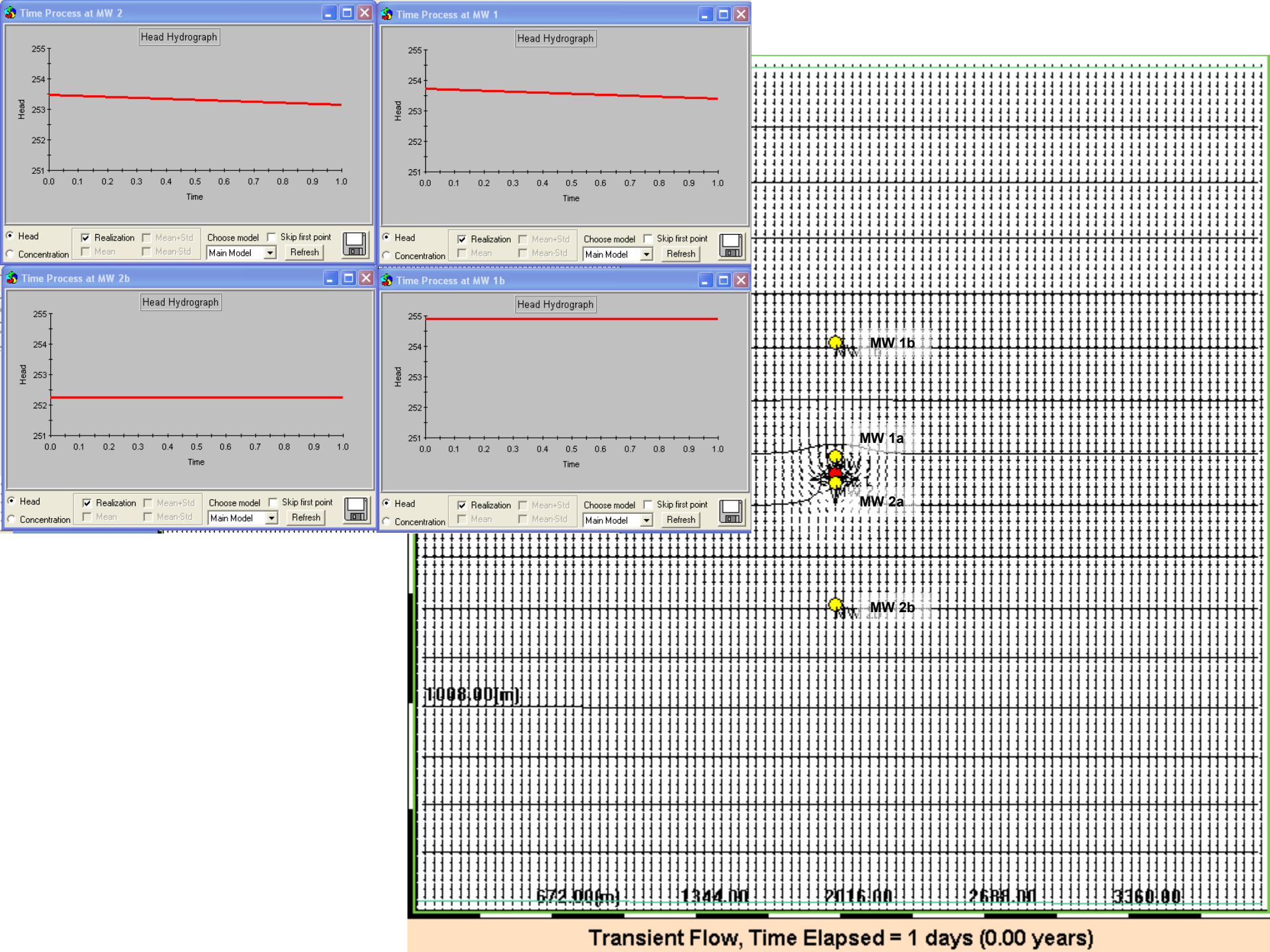
Mass Balance for Confined Case

with 4in/yr of Recharge and K=300 ft/day

cumulative



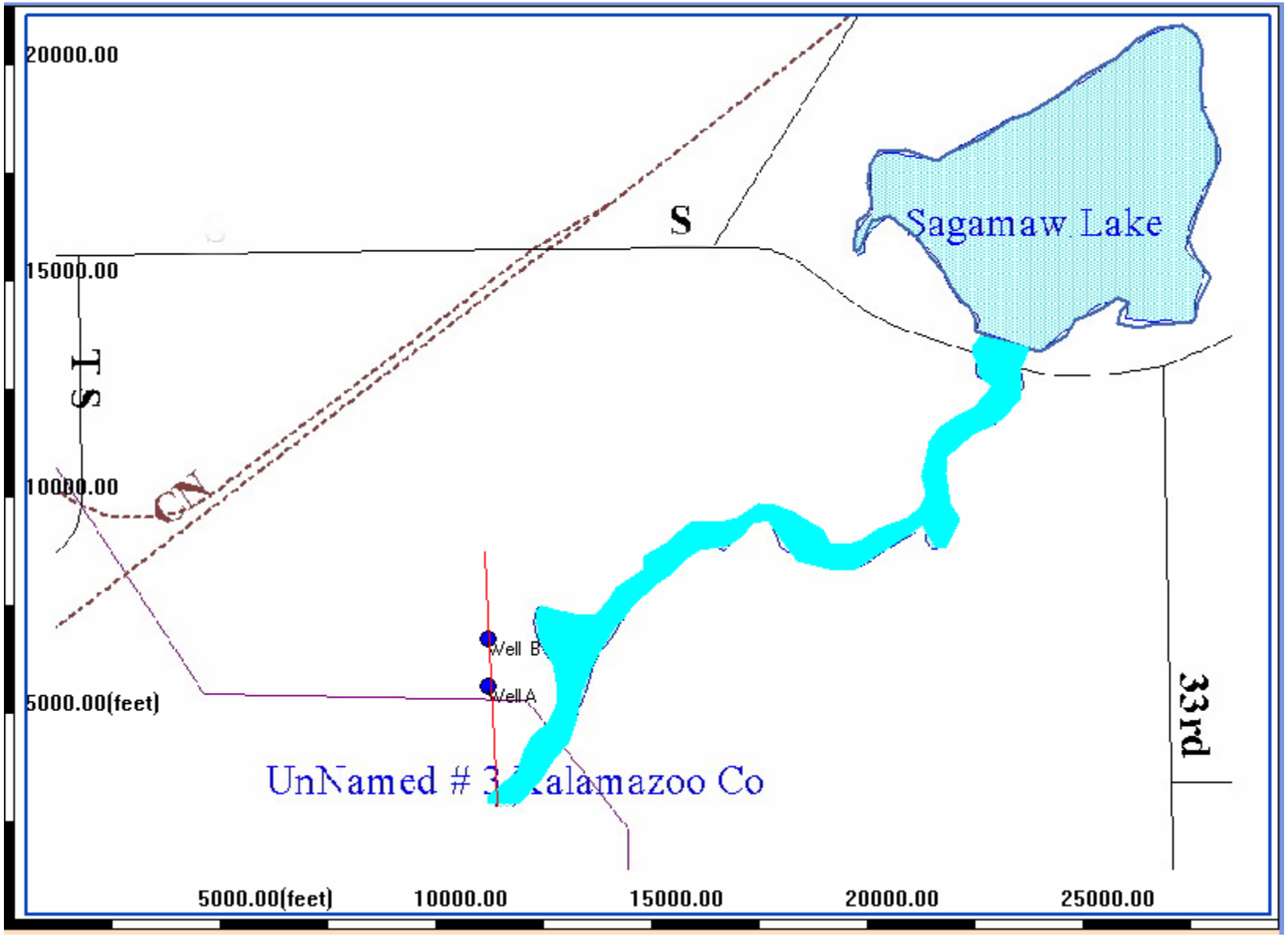

Submodel 112
MW 1b
2568.10
MW 2
1896.10(m)
MW 2b
1594.85(m)
2064.85
2534.85
Vertex Coordinates :
(m) -->
MW 1b
MW 2
MW 2b
672.00(m)
1344.00
2016.00
2688.00
3360.00
Transient Flow, Time Elapsed = 1 days (0.00 years)


Time Process at MW 2
Head Hydrograph
Head
Time
Head
Concentration
Realization
Mean
Mean+Std
Mean-Std
Choose model
Main Model
Skip first point
Refresh
Time Process at MW 1
Head Hydrograph
Head
Time
Head
Concentration
Realization
Mean
Mean+Std
Mean-Std
Choose model
Main Model
Skip first point
Refresh
Time Process at MW 2b
Head Hydrograph
Head
Time
Head
Concentration
Realization
Mean
Mean+Std
Mean-Std
Choose model
Main Model
Skip first point
Refresh
Time Process at MW 1b
Head Hydrograph
Head
Time
Head
Concentration
Realization
Mean
Mean+Std
Mean-Std
Choose model
Main Model
Skip first point
Refresh
MW 1b
MW 1a
MW 2a
MW 2b
1008.00[m]
672.00[m]
1344.00
2016.00
2688.00
3360.00
Transient Flow, Time Elapsed = 1 days (0.00 years)

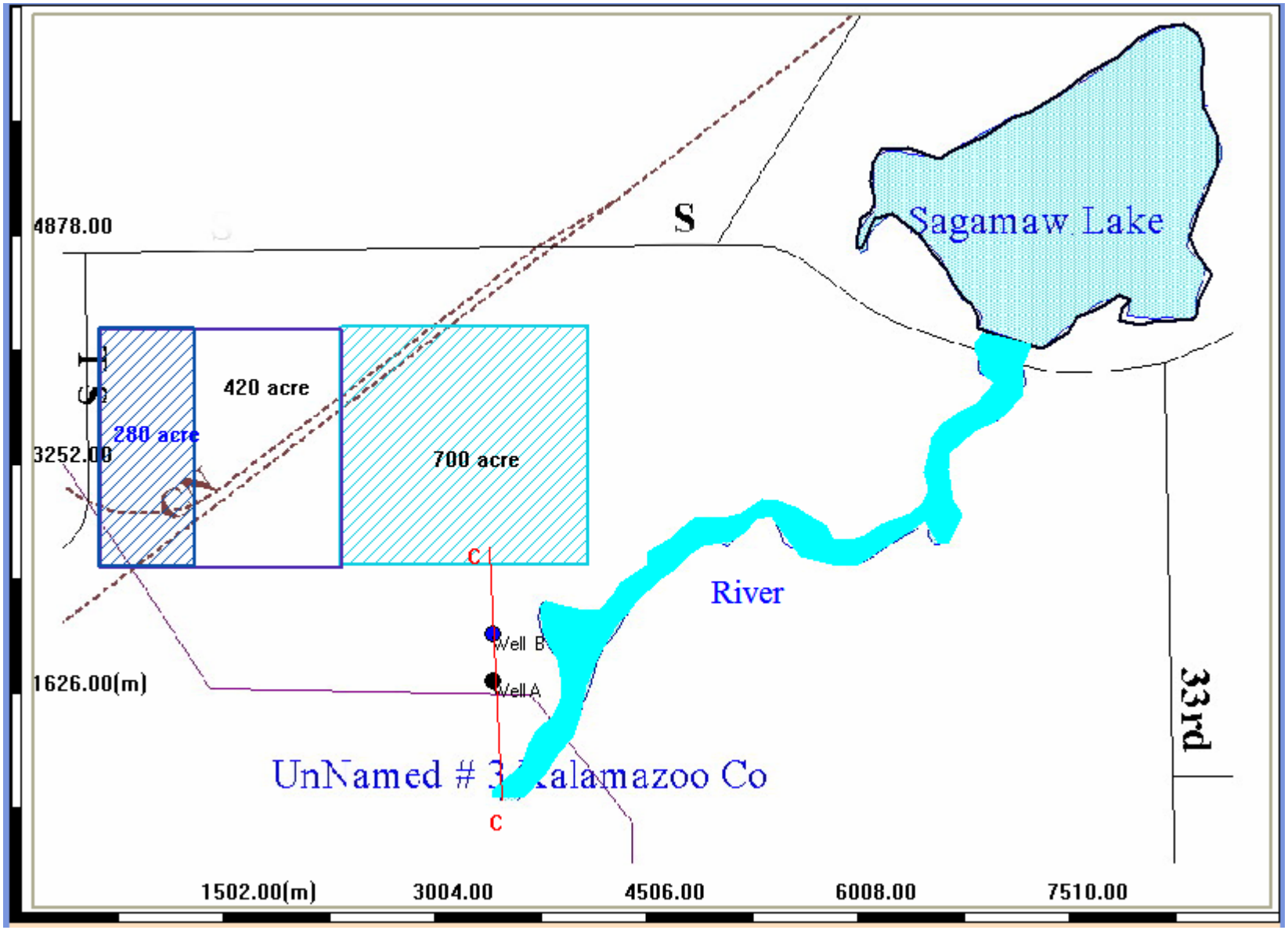
Use of water harvesting technique to enhance aquifer recharge and associated water supply

July 29, 2004

Modeling domain



No-flow boundary



No-flow boundary

No-flow boundary

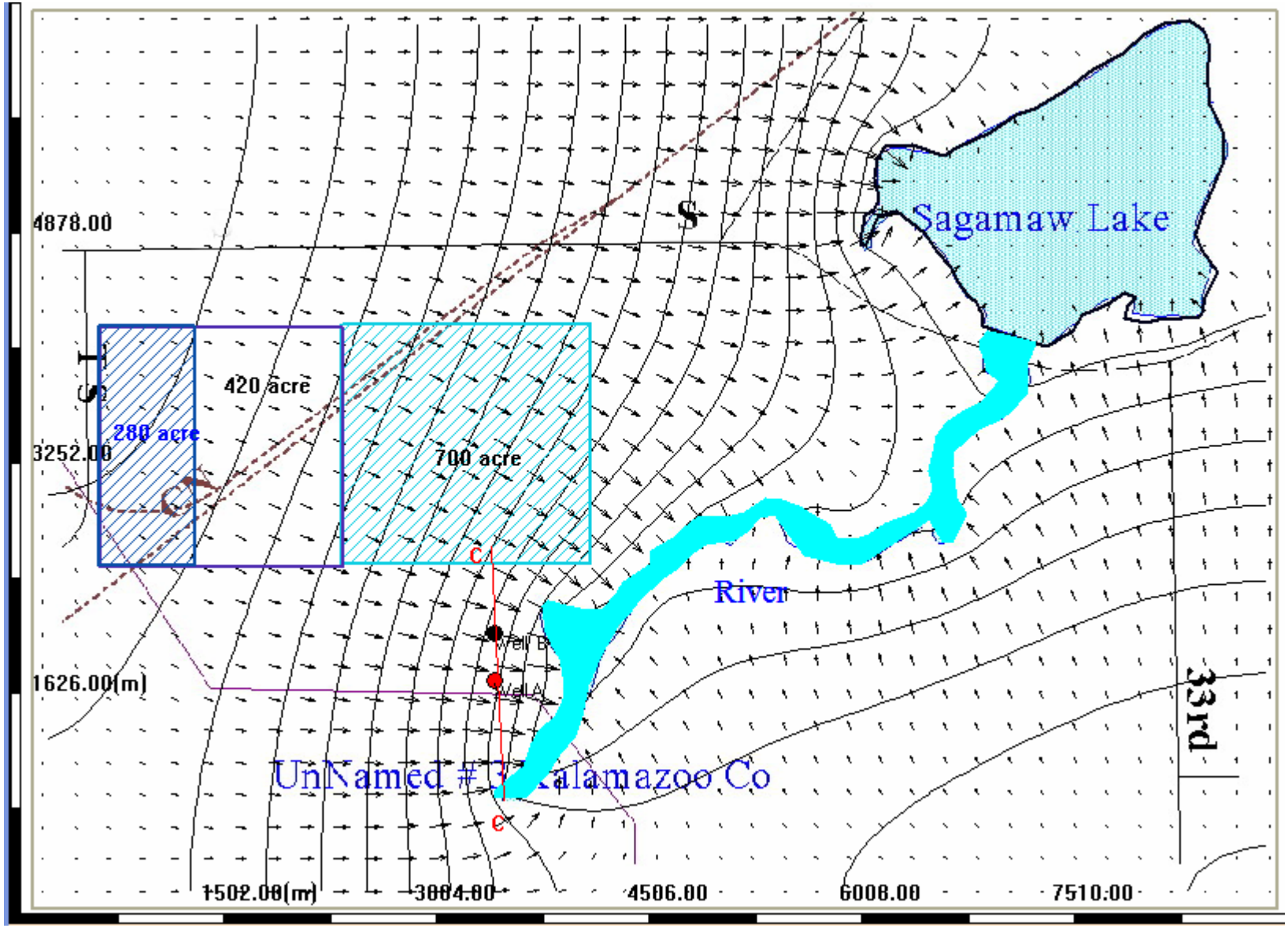
No-flow boundary

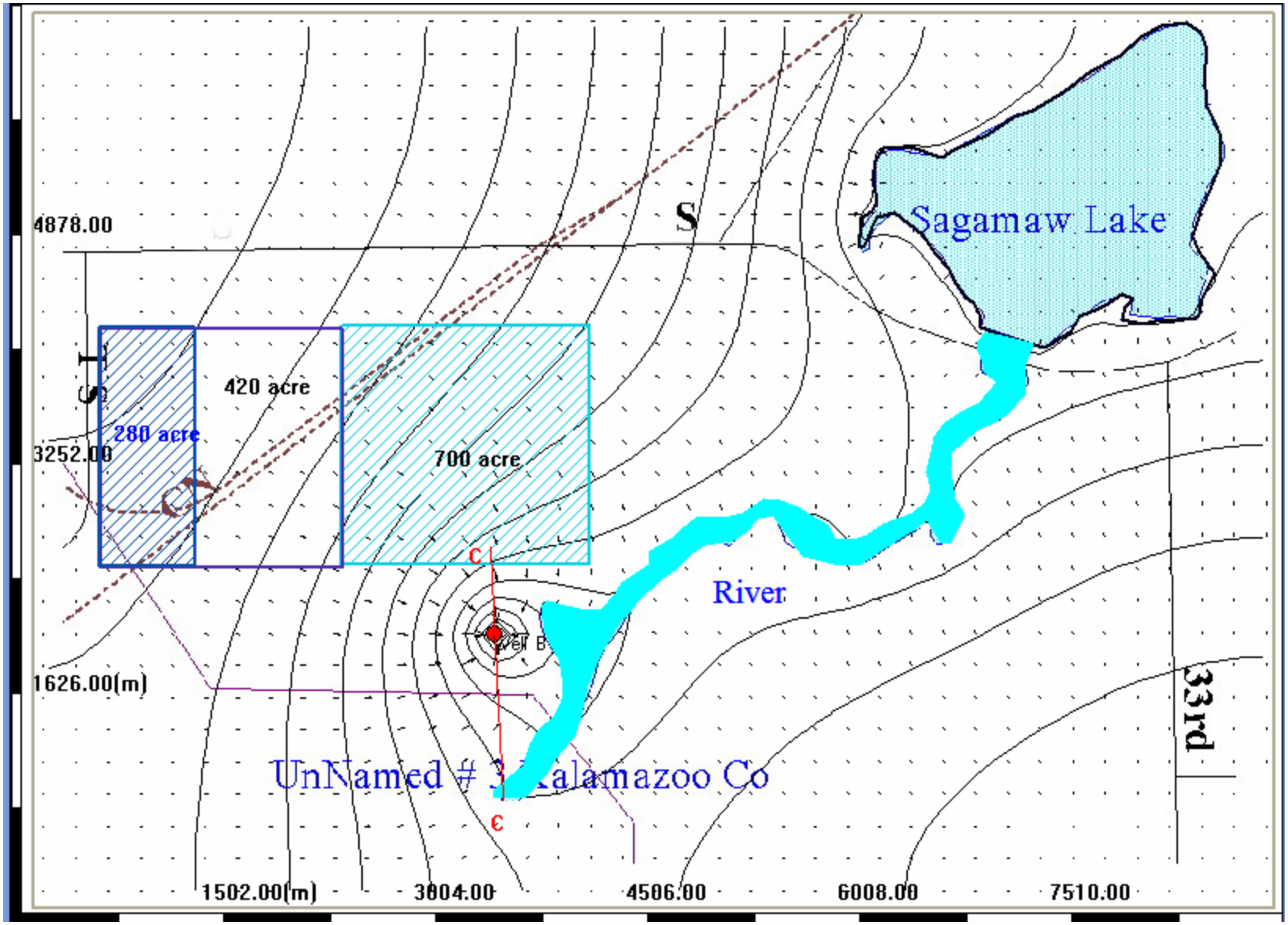
Physical parameters	Value (unit)
Ground Surface elevation	+32 (ft)
Aquifer top elevation (unconfined)	+32 (ft)
Aquifer bottom elevation	-164 (ft)
Hydraulic conductivity K_x	32(ft/day)
Ratio of anisotropy in horizontal direction K_x / K_y	1 (-)
Effective recharge	5 (in/year)
Specific yield	0.1 (-)

Lake parameters	Value (unit)
Water Elevation	0.00(ft)
Leakance	5 (1/day)
Bottom elevation	-98 (ft)
Area	1.118 (E+10) (ft^2)

River parameters	Value (unit)
Elevation	0.32 (ft)
Leakance	0.01 (1/day)
Width, Length	Given (basemap)

Pumping well parameters	Value (unit)
Top screen Elevation	-32 (ft)
Top screen Elevation	-98 (ft)
Well A Pumping rate	-1000 (gpm)
Well B Pumping rate	-1000 (gpm)
Pumping duration	90 (days)


4878.00
3252.00
1626.00(m)
1502.08(m)
3004.00
4506.00
6008.00
7510.00
420 acre
280 acre
700 acre
Sagamaw Lake
River
33rd
Well B
Well A
UnNamed #3 Kalamazoo Co



Transient case at the end of 30 days

Sensitivity analysis for different recharge rates

Water balance for whole modeling domain

	Case 1 No additional recharge		Case 2 700 acre field with additional 2in/yr recharge		Case 3 700 acre field with additional 4in/yr recharge	
	Steady state regional recharge 5 in/yr	after 30 days pumping with 1000 gpm	Steady state	after 30 days pumping with 1000 gpm	Steady state	after 30 days pumping with 1000 gpm
Recharge	18000(m^3/day)	18000	18200	18200	18700	18700
Lake	-6500	-6000	-6500	-5700	-6500	-6000
River	-11500	-6500	-11700	-7000	-12200	-7200
Pumping well	0	-5500	0	-5500	0	-5500

Sensitivity analysis for different recharge rates

Water balance for whole modeling domain

	Case 1 No additional recharge		Case 2 280 acre field with additional 2in/yr recharge		Case 3 280 acre field with additional 4in/yr recharge	
	Steady state regional recharge 5 in/yr	after 30 days pumping with 1000 gpm	Steady state	after 30 days pumping with 1000 gpm	Steady state	after 30 days pumping with 1000 gpm
Recharge	18000(m^3/day)	18000	18100	18100	18500	18500
Lake	-6500	-6000	-6500	-5800	-6500	-5800
River	-11500	-6500	-11600	-6800	-12000	-7200
Pumping well	0	-5500	0	-5500	0	-5500

Modeling domain

x direction $2.9527559 \cdot 10^4 \cdot \text{ft} = 5.592\text{mi}$

y direction $2.1325459 \cdot 10^4 \cdot \text{ft} = 4.039\text{mi}$

$1 \cdot \text{acre} = 4.047 \times 10^3\ \text{m}^2$

$1 \cdot \text{acre} = 4.356 \times 10^4\ \text{ft}^2$

Pumping rate 1000 gpm:

$$1000 \cdot \frac{\text{gal}}{\text{min}} = 5.451 \times 10^3\ \text{m}^3 \cdot \text{day}^{-1}$$

$$1000 \cdot \frac{\text{gal}}{\text{min}} \cdot 30 \cdot \text{day} = 1.635 \times 10^5\ \text{m}^3$$

$$700 \cdot \text{acre} \cdot 2 \cdot \frac{\text{in}}{\text{yr}} \cdot 1\text{yr} = 1.439 \times 10^5\ \text{m}^3$$

$$700 \cdot \text{acre} \cdot 4 \cdot \frac{\text{in}}{\text{yr}} \cdot 1\text{yr} = 2.878 \times 10^5\ \text{m}^3$$

$$280 \cdot \text{acre} \cdot 2 \cdot \frac{\text{in}}{\text{yr}} \cdot 1\text{yr} = 5.756 \times 10^4\ \text{m}^3$$

$$280 \cdot \text{acre} \cdot 4 \cdot \frac{\text{in}}{\text{yr}} \cdot 1\text{yr} = 1.151 \times 10^5\ \text{m}^3$$

For one year

$$\frac{1.635 \times 10^5\ \text{m}^3}{2 \cdot \text{in}} = 795.31\text{acre}$$

$$\frac{1.635 \times 10^5\ \text{m}^3}{4 \cdot \text{in}} = 397.655\text{acre}$$

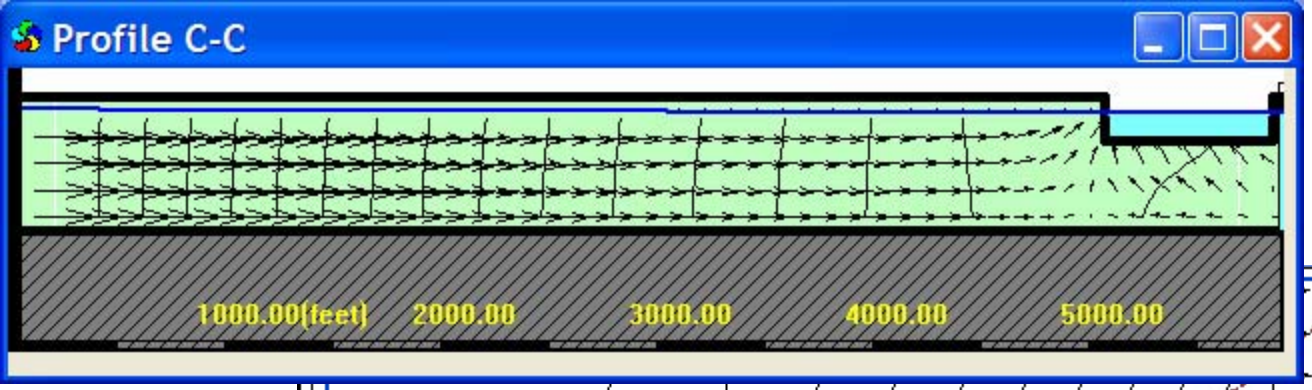
$$600 \cdot \frac{\text{gal}}{\text{min}} \cdot 30 \cdot \text{day} = 9.812 \times 10^4\ \text{m}^3$$

$$900 \cdot \frac{\text{gal}}{\text{min}} \cdot 30 \cdot \text{day} = 1.472 \times 10^5\ \text{m}^3$$

$$\frac{9.812 \times 10^4 \cdot \text{m}^3}{40 \cdot \text{acre}} = 23.864\text{in}$$

$$\frac{1.472 \times 10^5 \cdot \text{m}^3}{40 \cdot \text{acre}} = 35.801\text{in}$$

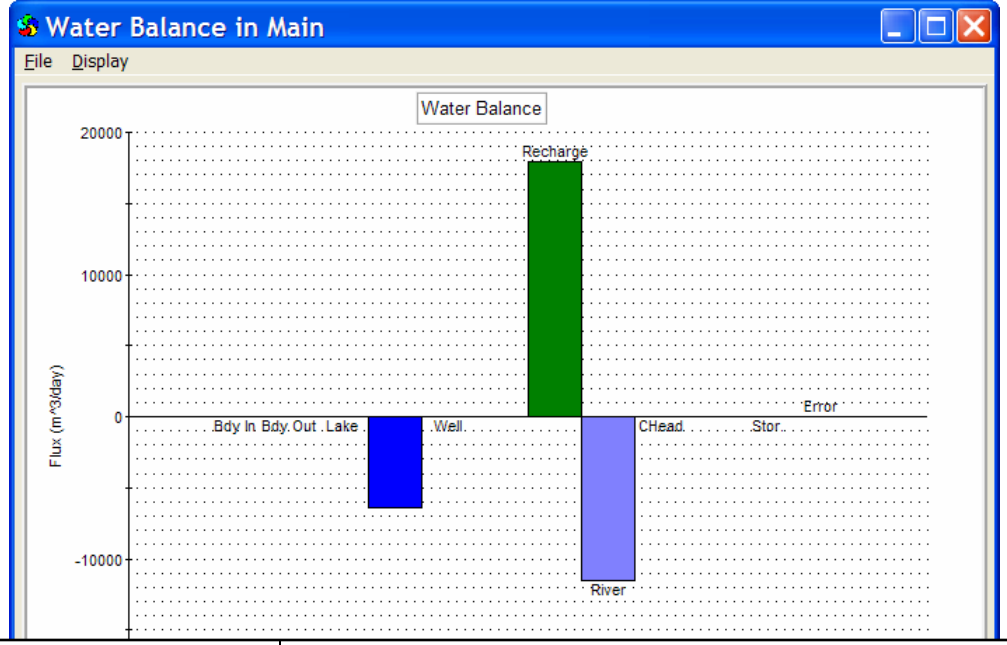
END



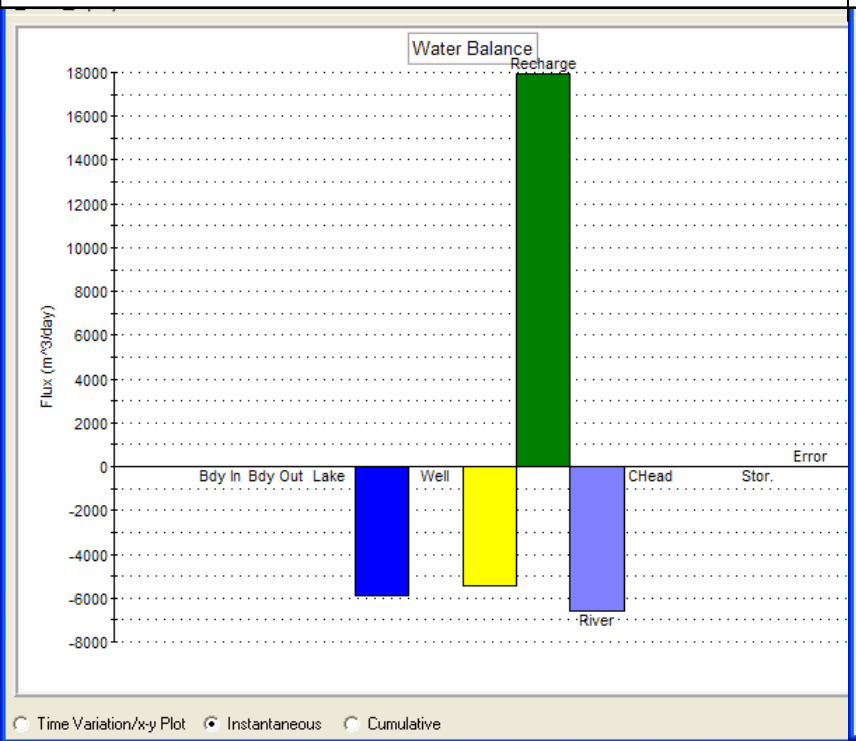
Head contour map for steady state condition

- Unconfined Aquifer
- Constant aquifer thickness
- Constant recharge
- No-flow boundaries from all sides

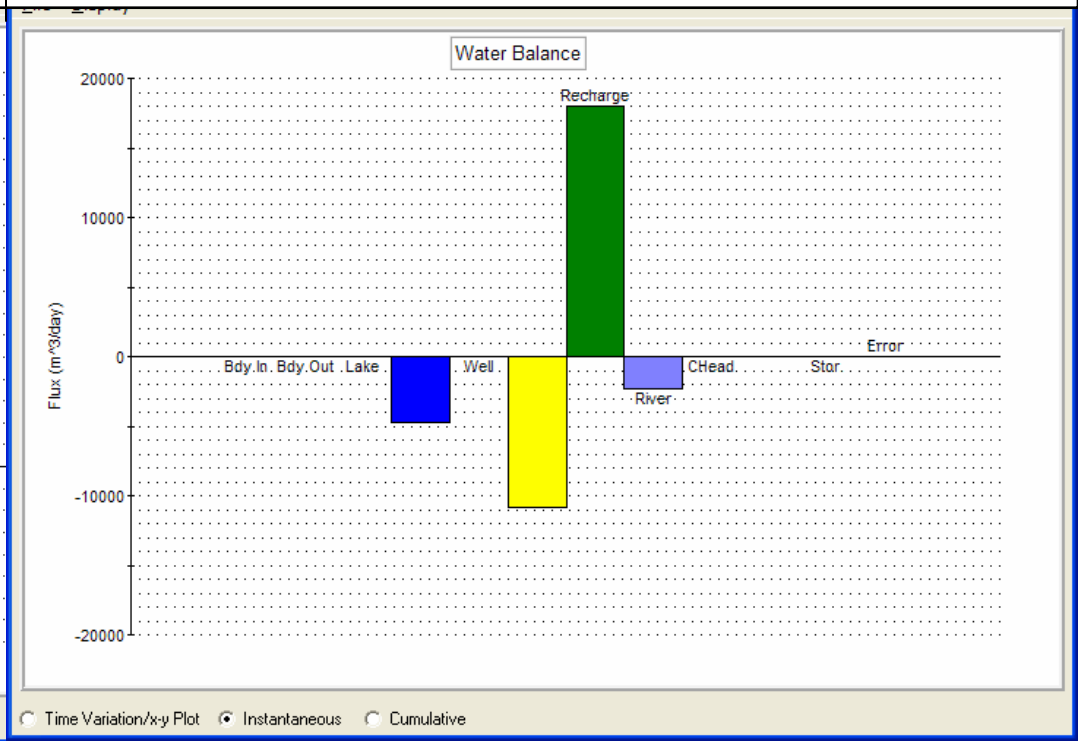
Water balance for the main modeling domain. Steady state condition no pumping wells

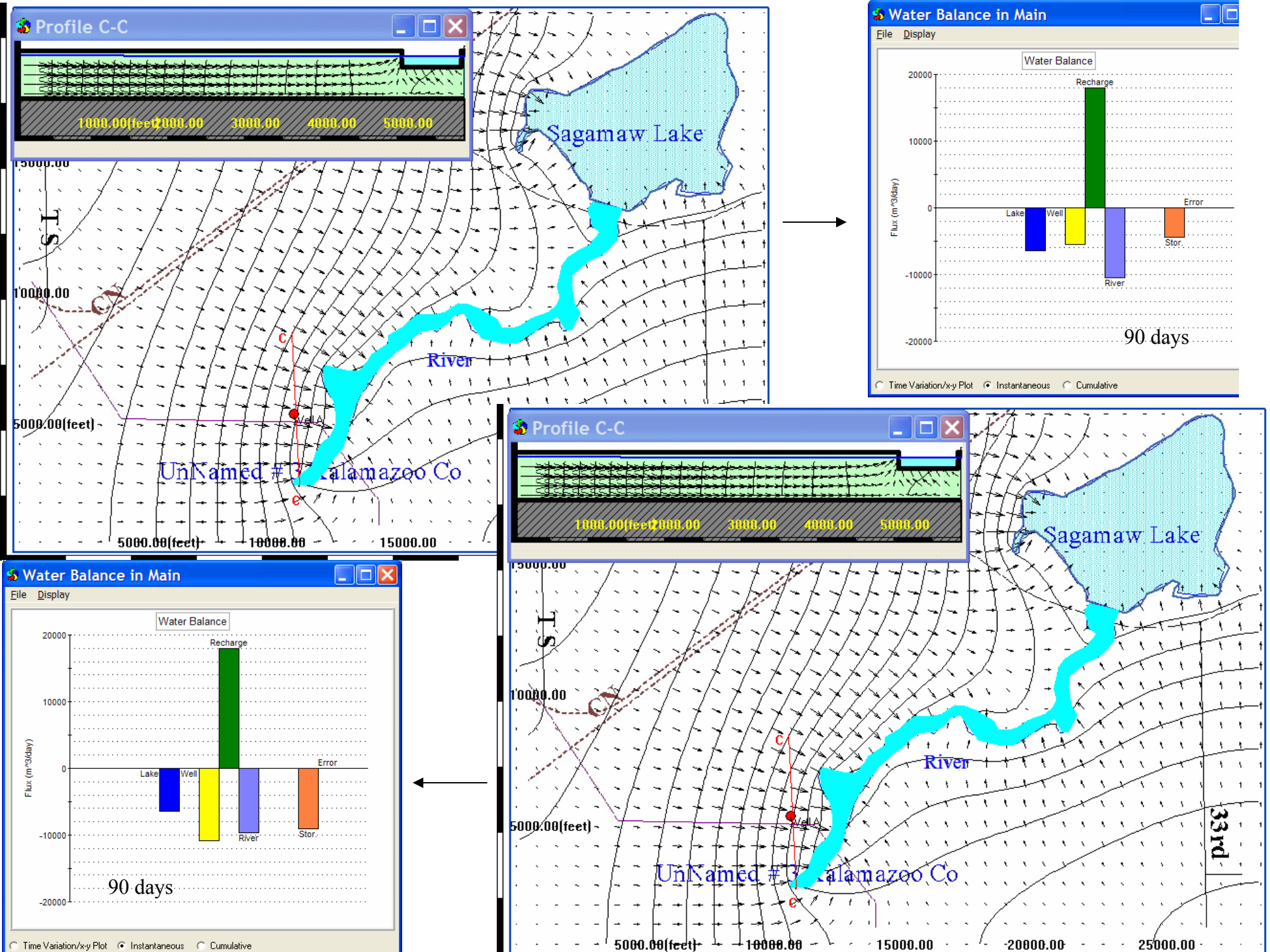


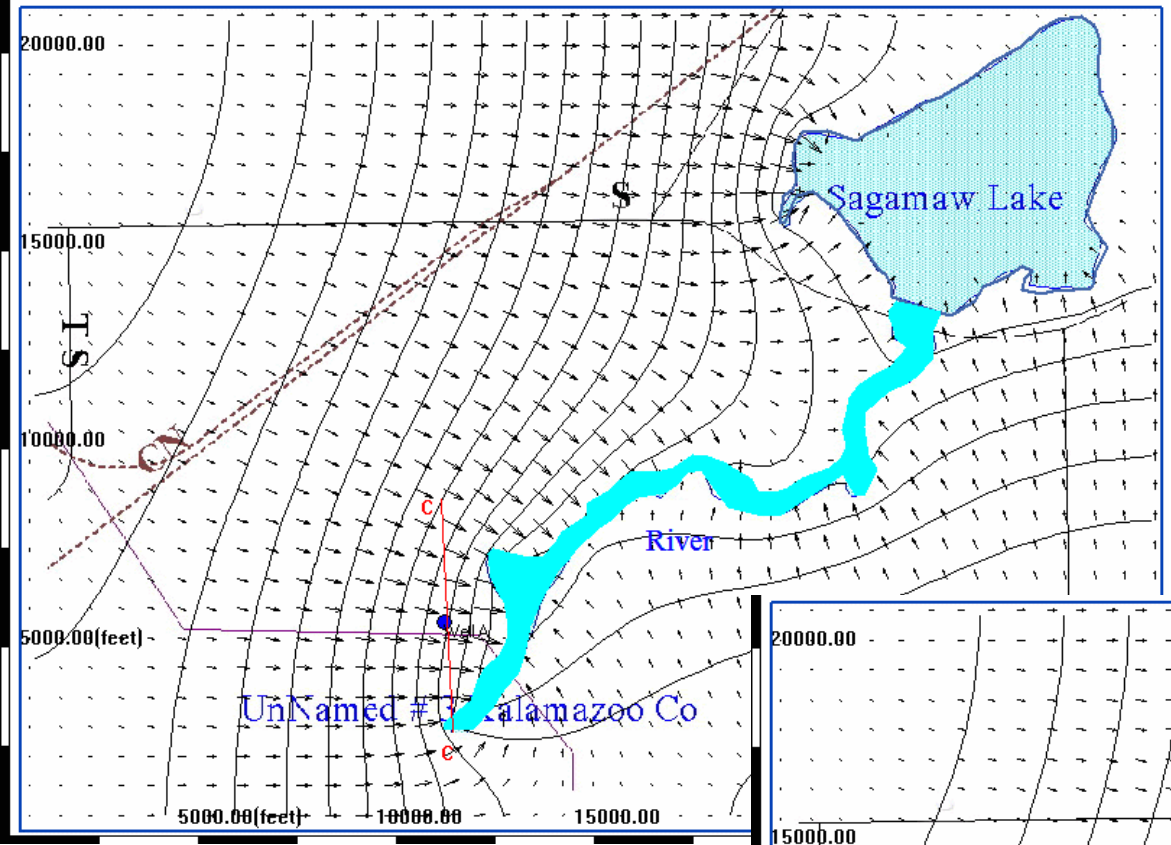
Steady state condition with one pumping wells

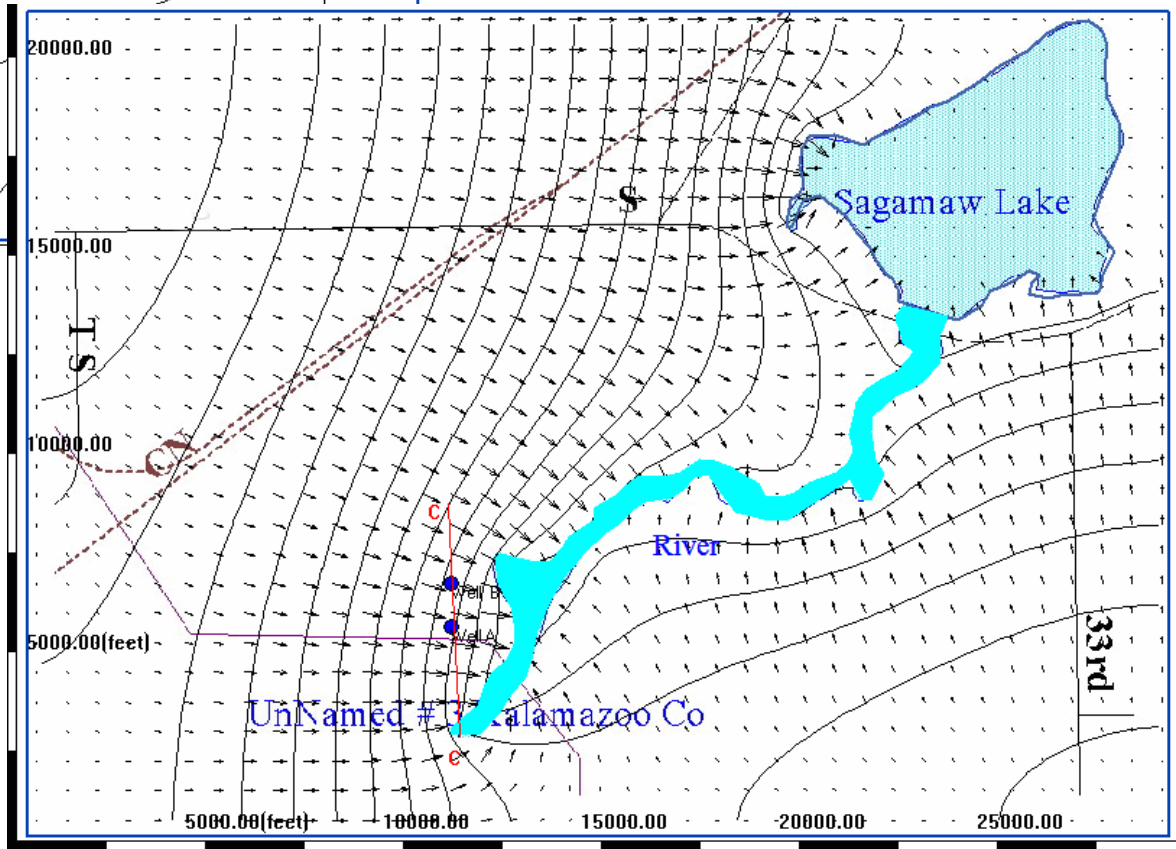


Steady state condition with two pumping wells



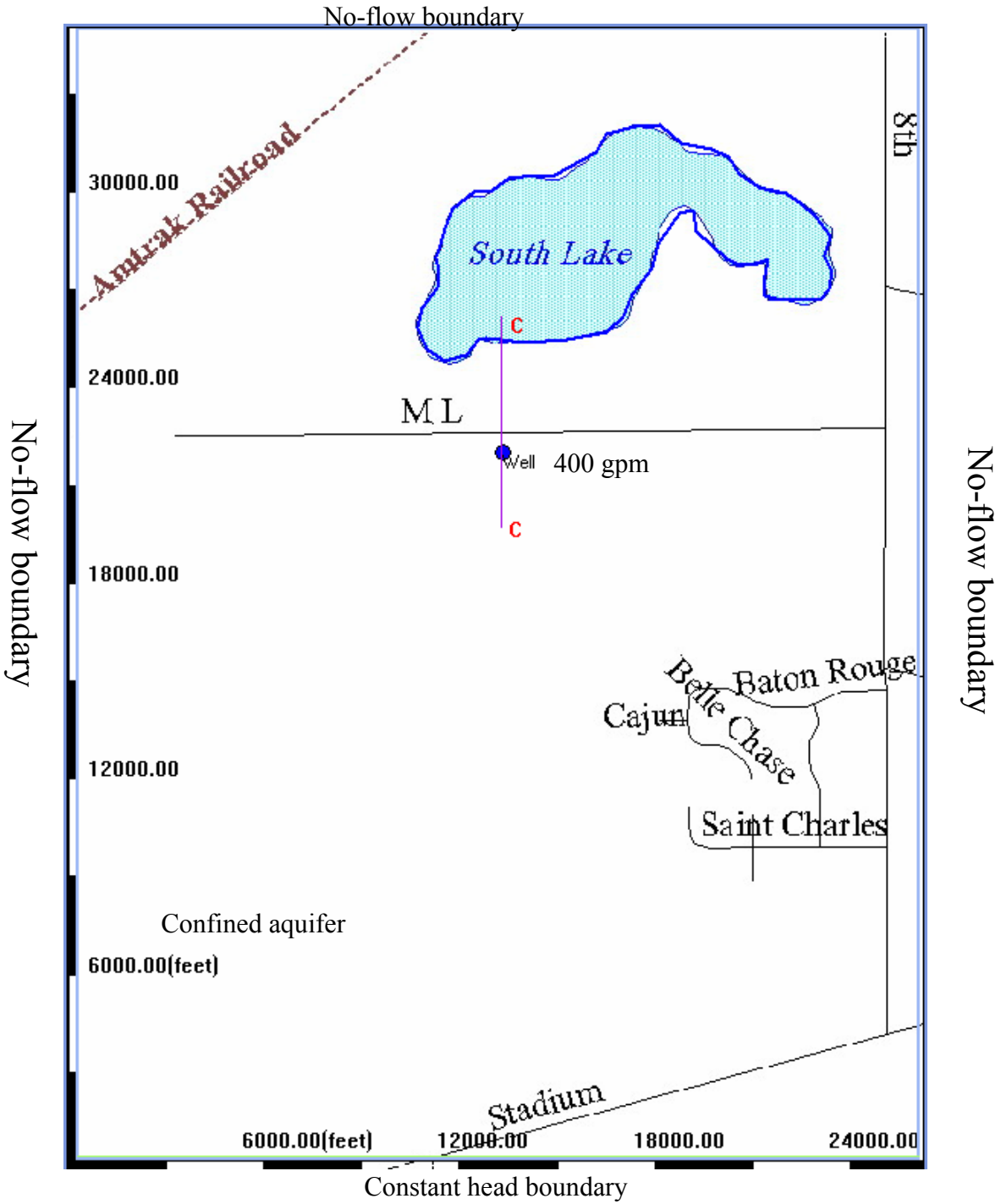

Profile C-C
1000.00(feet)2000.00
3000.00
4000.00
5000.00
Sagamaw Lake
River
UnNamed #3 Kalamazoo Co
5000.00(feet)
10000.00
15000.00
Water Balance in Main
File
Display
Water Balance
Recharge
Lake
Well
River
Stor
Error
Flux (m^3/day)
90 days
Time Variation/x-y Plot
Instantaneous
Cumulative
Profile C-C
1000.00(feet)2000.00
3000.00
4000.00
5000.00
Sagamaw Lake
River
UnNamed #3 Kalamazoo Co
5000.00(feet)
10000.00
15000.00
20000.00
25000.00
33rd
Water Balance in Main
File
Display
Water Balance
Recharge
Lake
Well
River
Stor
Error
Flux (m^3/day)
90 days
Time Variation/x-y Plot
Instantaneous
Cumulative


20000.00
15000.00
10000.00
5000.00(feet)
S
LS
CV
Sagamaw Lake
River
c
c
Well A
UnNamed #3 Kalamazoo Co
5000.00(feet)
10000.00
15000.00


20000.00
15000.00
10000.00
5000.00(feet)
S
LS
CV
Sagamaw Lake
River
c
Well B
Well A
c
UnNamed #3 Kalamazoo Co
33rd
5000.00(feet)
10000.00
15000.00
20000.00
25000.00

Pumping near a lake

- Lakes are one of the water surface bodies that can interact with aquifers.
- Depending on connection of lake to aquifer and other stresses, lake can gain or loose water to the aquifer.
- In this example we illustrate impact of pumping near a lake and its influence on steady state ground water flow.



Modeling domain

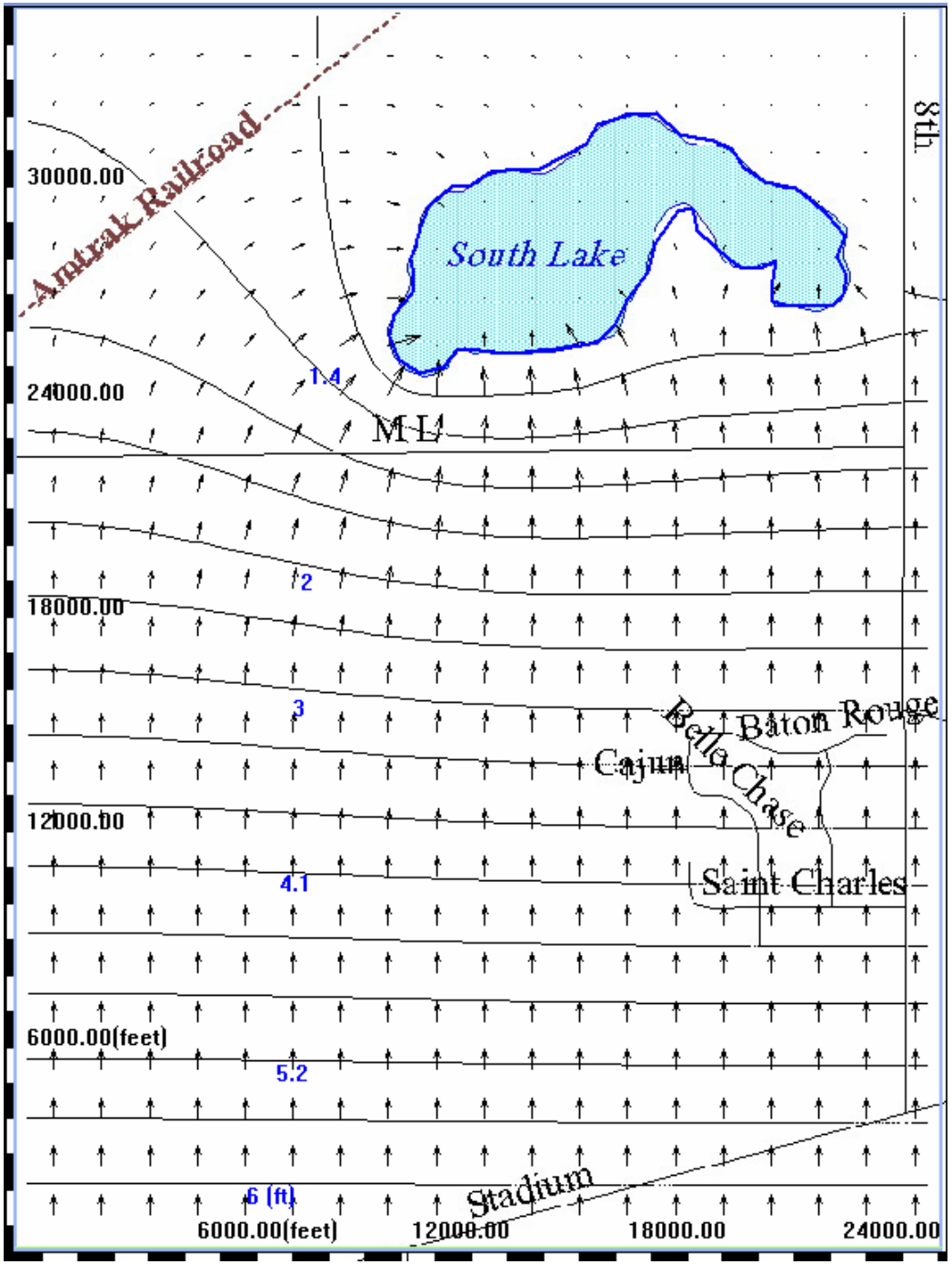
Physical parameters of aquifer

Physical parameters	Value (unit)
Ground Surface elevation	+32 (ft)
Aquifer top elevation (confined)	-32 (ft)
Aquifer bottom elevation	-164 (ft)
Hydraulic conductivity K_x	164(ft/day)
Ratio of anisotropy in horizontal direction K_x / K_y	1 (-)
Specific storage	3.048e-6 (1/ft)

Lake parameters	Value (unit)
Water Elevation	0.00(ft)
Leakance	5 (1/day)
Bottom elevation	-98 (ft)
Area	4.894(E07) (ft^2)

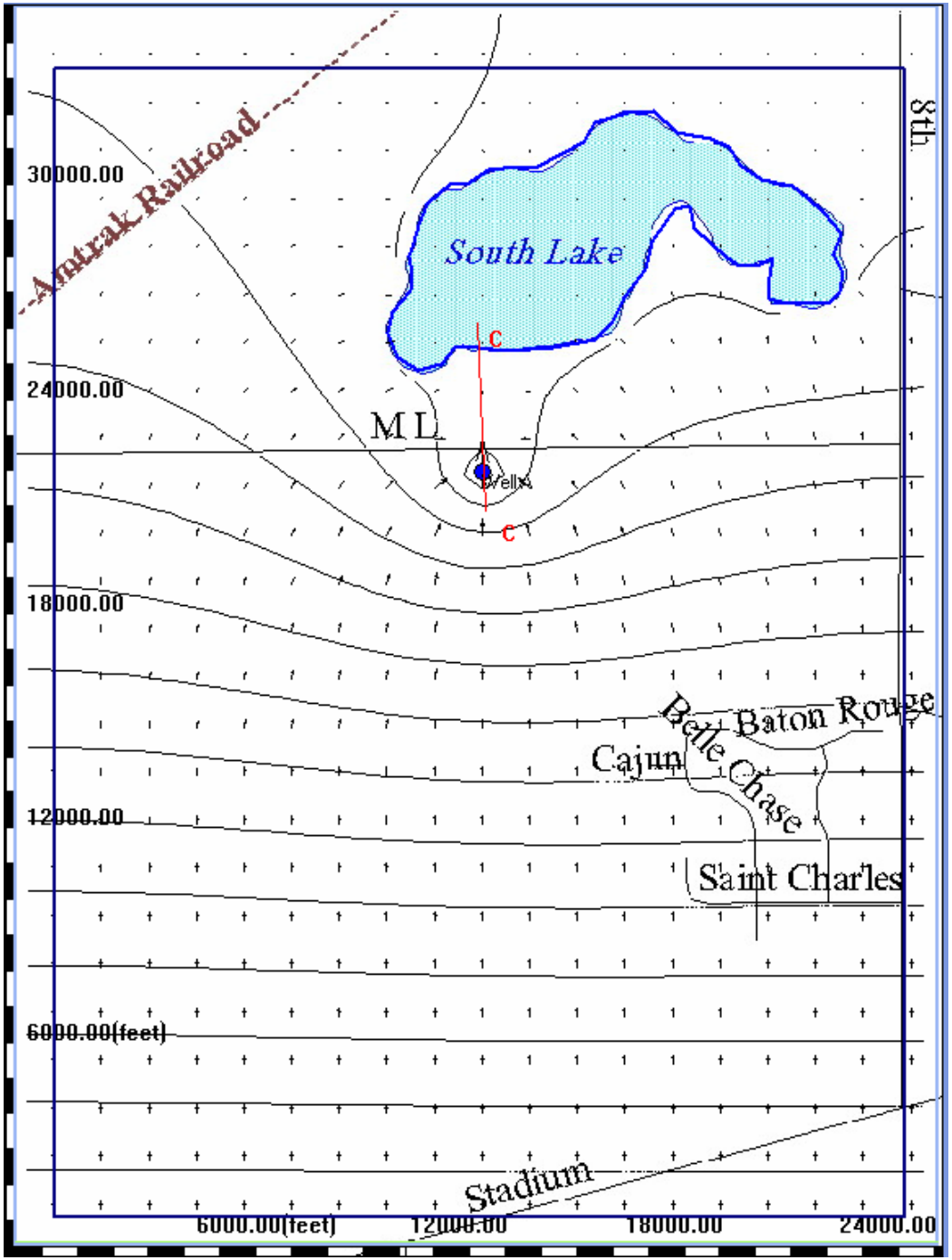
Parameters for pumping wells

Pumping well parameters	Value (unit)
Top screen Elevation	-76 (ft)
Top screen Elevation	-120 (ft)
Well A Pumping rate	-400 (gpm)
Well B Pumping rate	-500 (gpm)

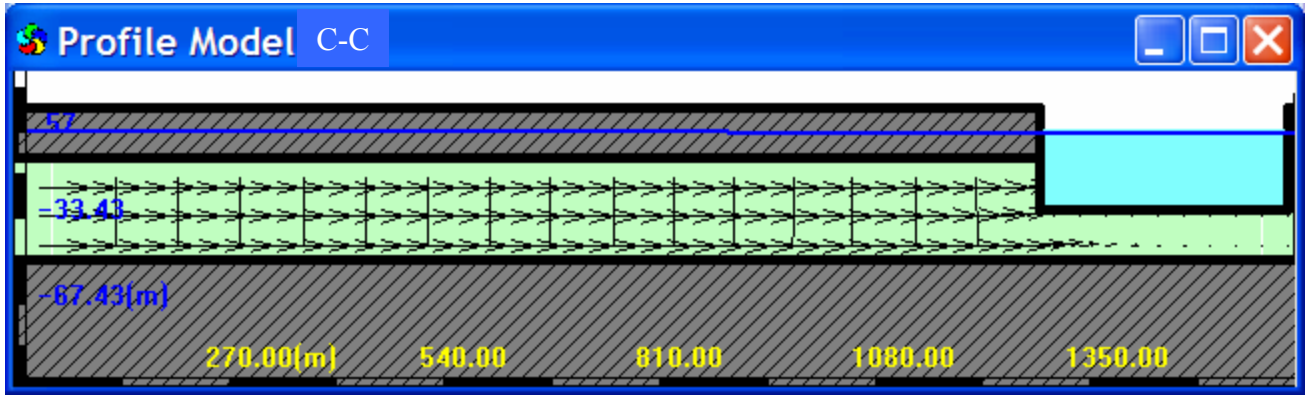


Steady state ground water flow prior to pumping

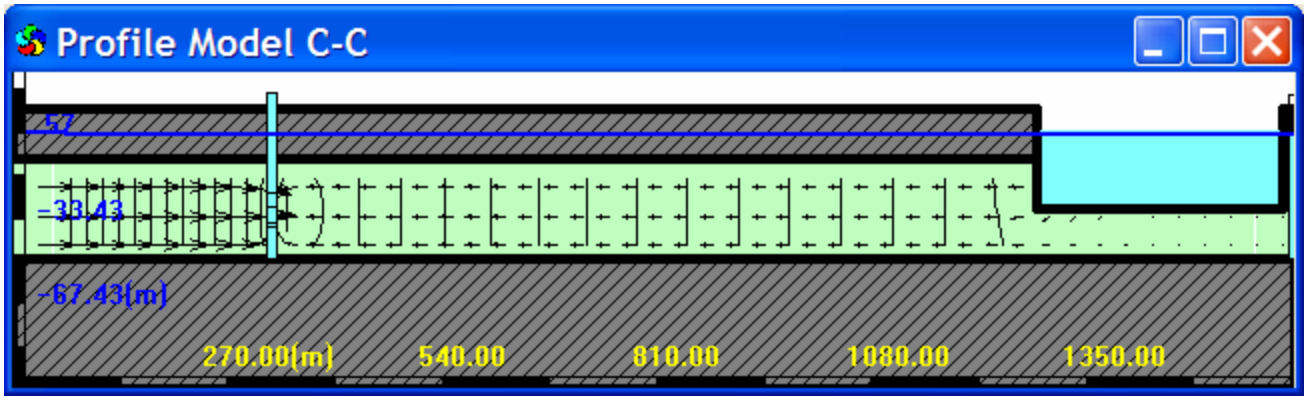
Steady state ground water flow after pumping

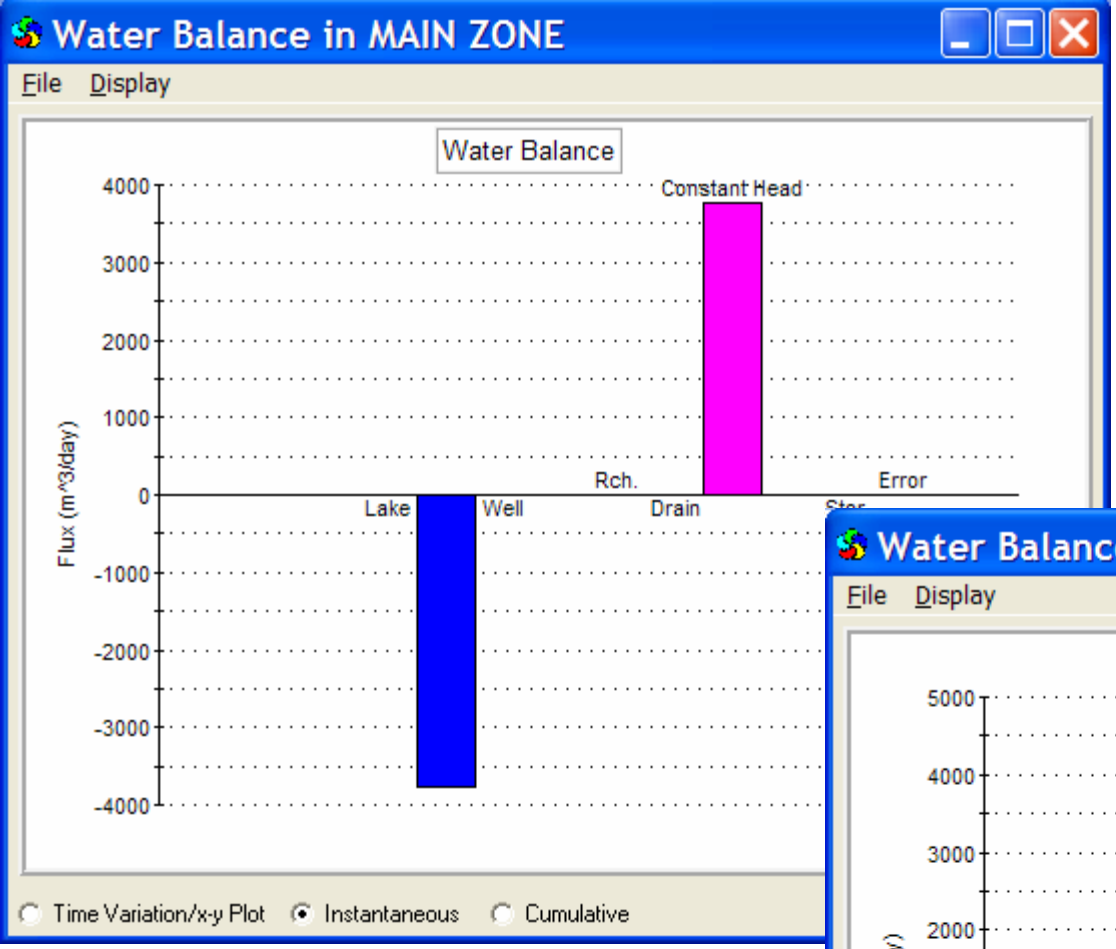


Flow cross section prior to pumping



Flow cross section after pumping

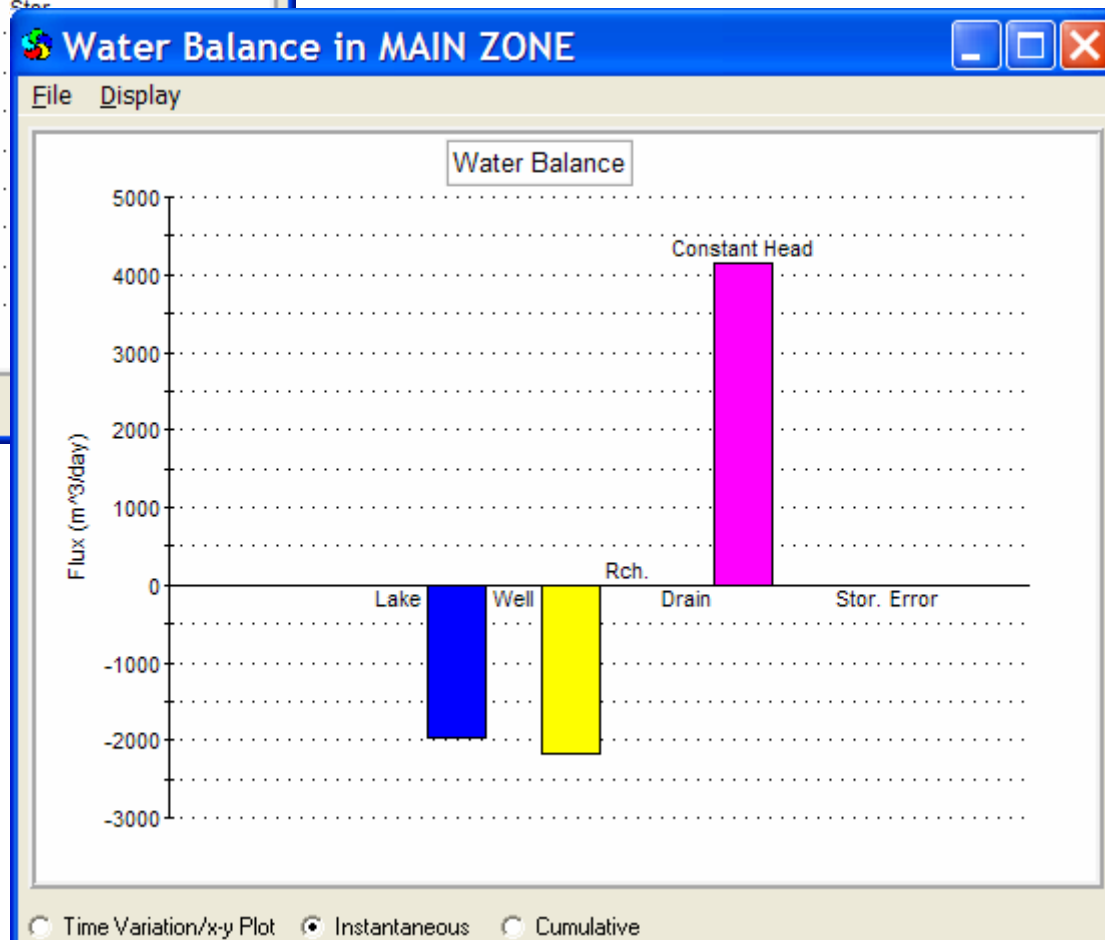




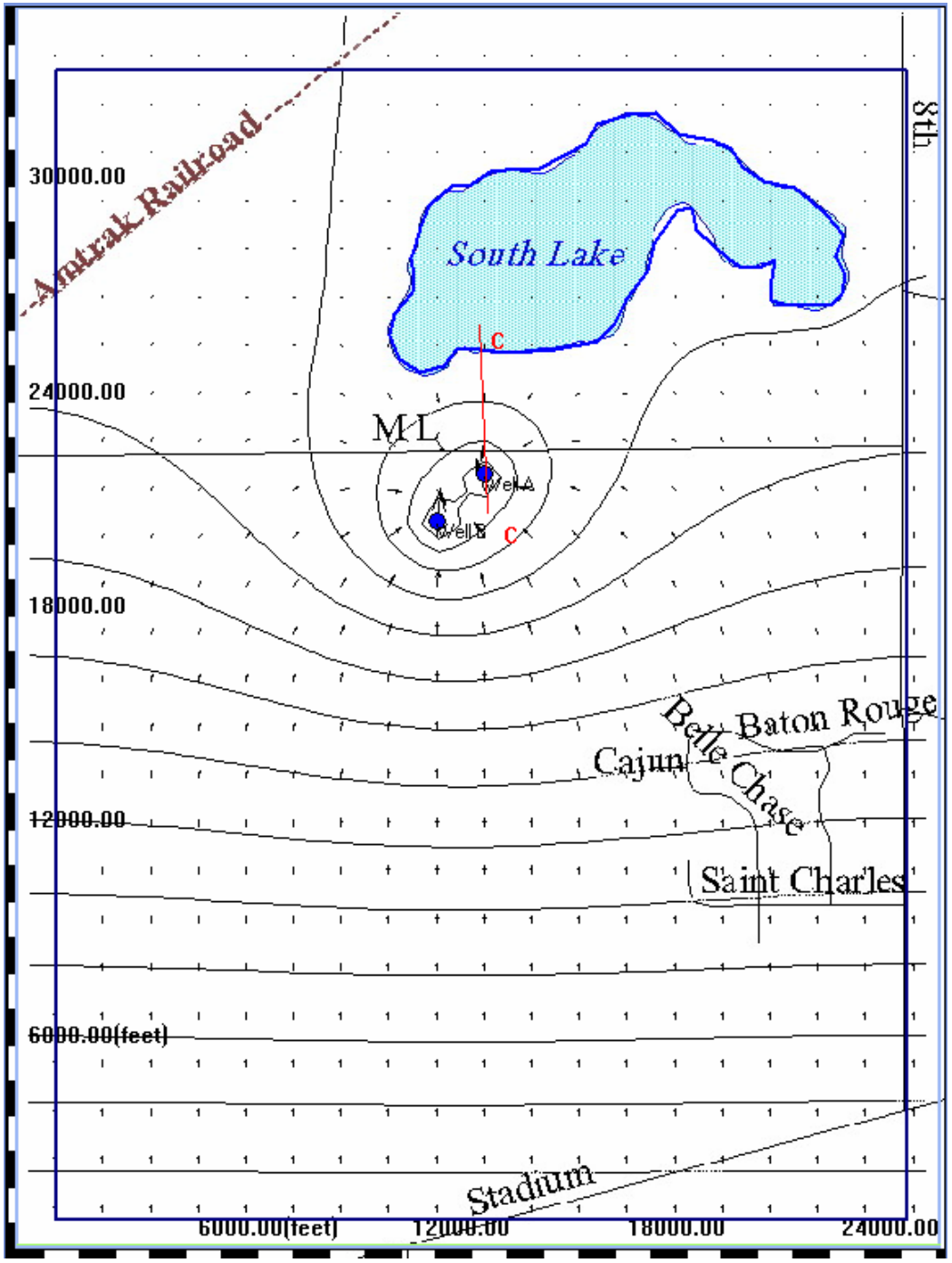
Steady state condition

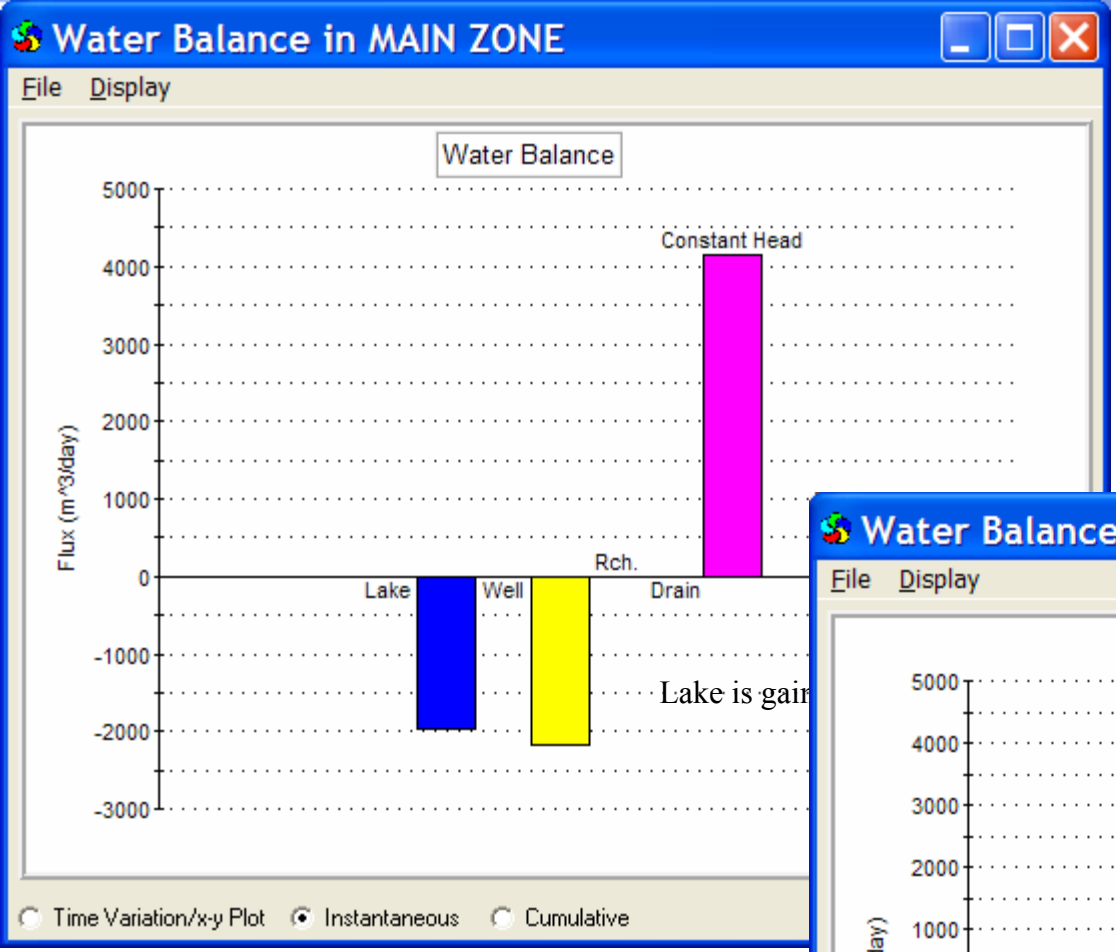
Water balance for whole modeling domain prior to pumping.

Water balance for whole modeling domain after pumping. Surface water level in the lake drops by 3.031 in.



Steady state ground water flow with **two** pumping wells

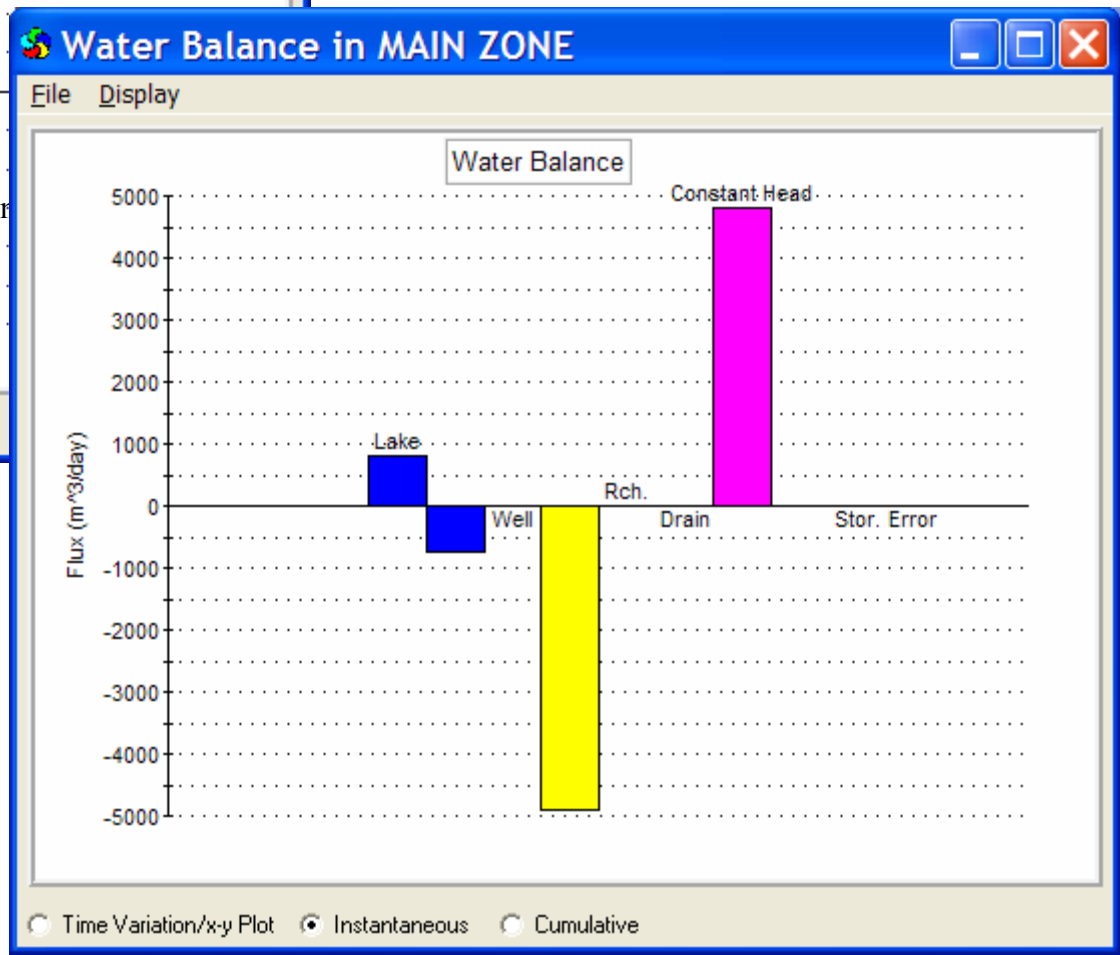


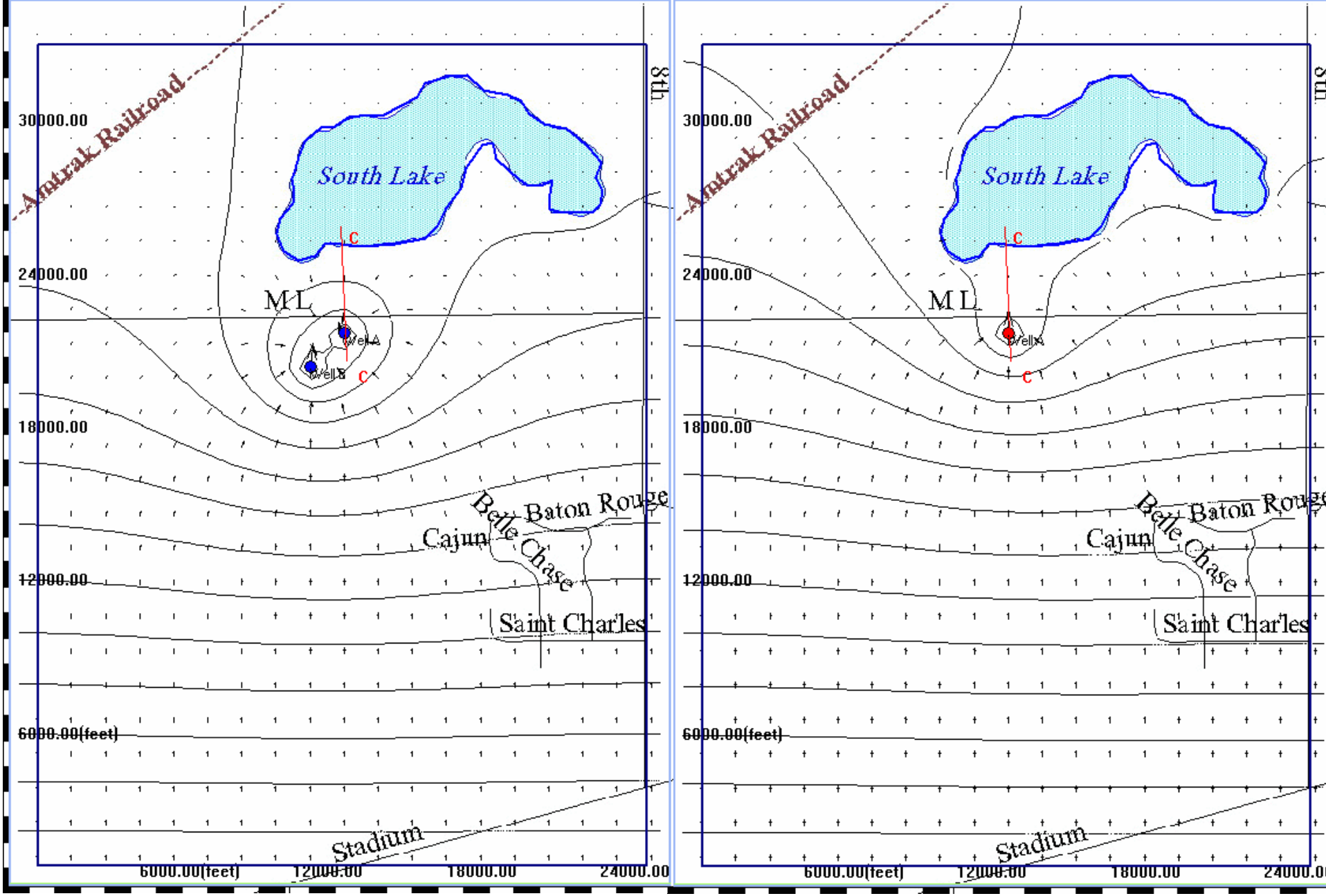


Water balance for whole modeling domain with **one** pumping well

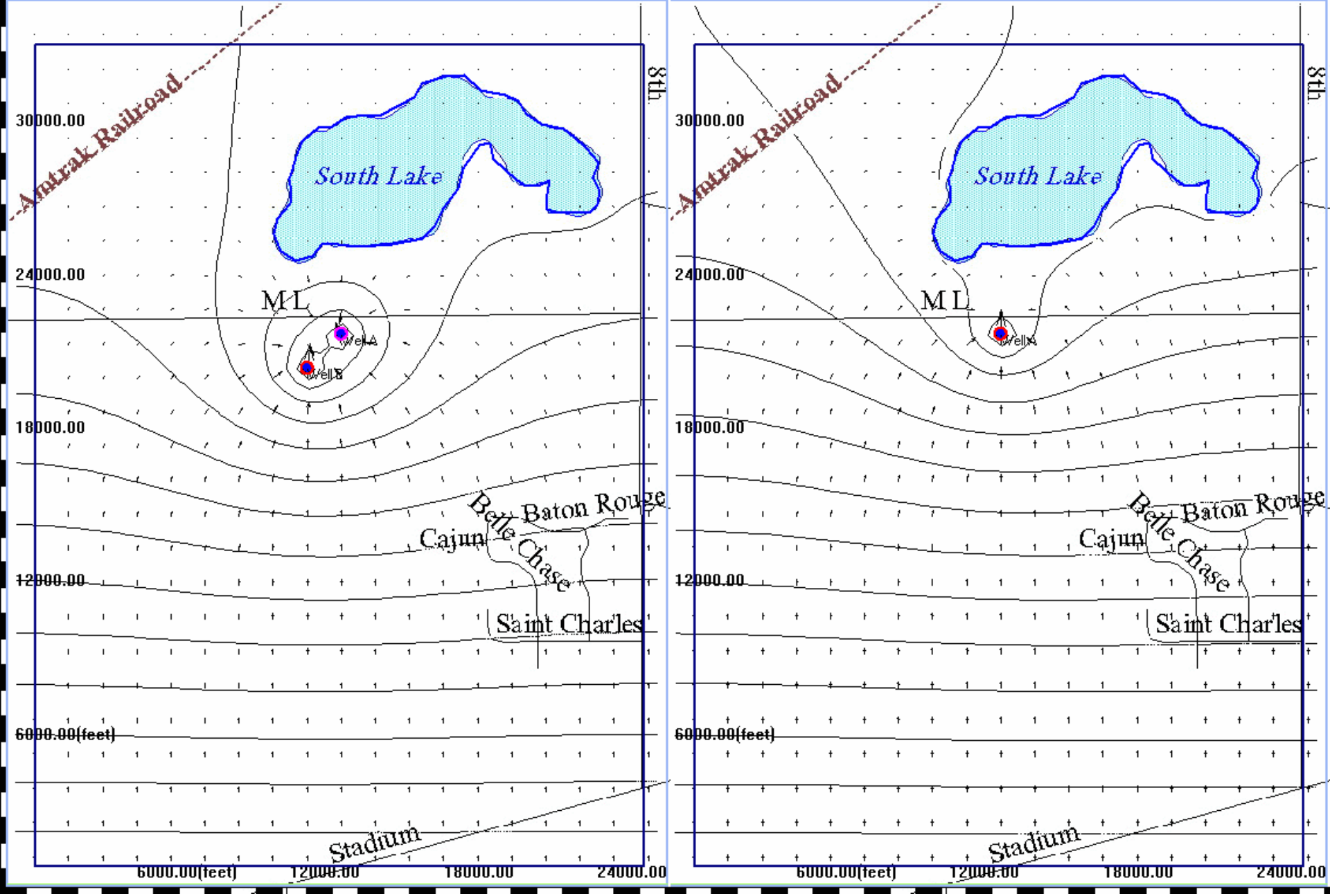
Lake is gain

Water balance for whole modeling domain with **two** pumping well





Transient head for 30 days



WHPA for 30 years

Use of Spatial Data and GIS in Evaluating Manure Application Risk Index (MARI)

Basic Information

Title:	Use of Spatial Data and GIS in Evaluating Manure Application Risk Index (MARI)
Project Number:	2004MI50B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	Eighth
Research Category:	Not Applicable
Focus Category:	Water Quality, Nutrients, Agriculture
Descriptors:	Water Quality; Animal Manure; Nutrients; Risk Index; GIS; Non-point Source Pollution; Modeling.
Principal Investigators:	Da Ouyang, Carrie Laboski

Publication

Project Number: **Start:** 03/01/04 (actual)
FY 2004 Federal Funds: $15,000 **End:** 02/28/05 (actual)
FY 2004 Non-Federal Funds: $15,100

Title: Use of Spatial Data and GIS in Evaluating Manure Application Risk Index (MARI)

Principal Investigators: Da Ouyang, Institute of Water Research, Michigan State University; Carrie Laboski, Department of Crop and Soil Sciences, Michigan State University.

Project Type: Research
Focus Categories: WQL, NU, AG
Congressional District: Eighth
Keywords: Water Quality; Animal Manure; Nutrients; Risk Index; GIS; Non-point Source Pollution; Modeling.

Abstract:
Proper manure management is essential to the profitability of livestock producers, and must also address environmental concerns about nutrients, microorganisms, and organic matter from manure/sediment potentially polluting water resources. The Manure Application Risk Index (MARI), as developed by NRCS specialists, is used by farmers and agency personnel to evaluate fields for winter spreading of manure in an environmentally responsible manner. The MARI is based on 12 weighted field factors, including soil groups, soil test P value, concentrated water flow, vegetative buffer width, and manure application rates and methods. The MARI is used in Michigan as a part of the state-recognized Generally Accepted Agricultural Management Practices (GAAMP). It has the potential for use throughout the region to assist livestock operators in evaluating areas to determine whether the level of environmental risk associated with manure applications is acceptable or unacceptable. However, wider use of the MARI approach requires additional, broad-scale field verification of its usefulness in various soil types, landscapes, and manure management systems to facilitate its application throughout the Midwestern region. This study uses spatial data and GIS technology in assess the manure application risk index in Sycamore Creek Watershed in Michigan. Potentially risk areas are identified in the watershed where precaution has to be made when spreading manure, particularly in the water season.
Keywords: Water Quality; Animal Manure; Nutrients; Risk Index; GIS; Non-point Source Pollution; Modeling.

Introduction:
The environmental risk of manure applications is greatest when applications are made on frozen, snow-covered, or saturated soils during winter months. However, daily hauling and application of manure is a common practice. In much of Wisconsin, for example, daily hauling is the most common means of application, and over 70 percent of Michigan livestock operators, as estimated by NRCS staff, use daily hauling for manure management. The comparative cost differential between daily hauling and liquid manure 8-month storage is significant and varies according to the scale of operations: six times

greater cost per cow for long-term storage in a 60-cow operation, five times greater for 120-cow operations, and three times greater for 250-cow operations.

Manure storage facilities can also be difficult to manage in terms of environmental risk. And even in using liquid-manure holding facilities, the need to apply manure on potentially frozen ground during the winter and/or spring under various climate conditions may still arise. However, these practices have in many cases resulted in runoff with excessive concentrations of manure causing environmental damage to water resources. As a result, many Midwestern legislatures have prohibited manure applications when frozen ground is likely.

In Michigan, the Manure Application Risk Index was developed to evaluate fields and determine whether manure applications are safe and appropriate throughout the year on those fields. Management practices such as appropriate setbacks and rates of application with consideration of climatic conditions, i.e. snow, predicted rainfall, etc., are incorporated in the risk analysis/index.

Proper manure management is essential to the profitability of livestock producers, and must also address environmental concerns about nutrients, microorganisms, and organic matter from manure/sediment potentially polluting water resources. The Manure Application Risk Index (MARI), as developed by NRCS specialists, is used by farmers and agency personnel to evaluate fields for winter spreading of manure in an environmentally responsible manner. The MARI is based on 12 weighted field factors, including soil groups, soil test P value, concentrated water flow, vegetative buffer width, and manure application rates and methods. Daily hauling of manure remains a common practice in the Midwestern region as an economically viable method for winter manure application. In addition, the cost impacts of alternative manure management options are significantly higher. Liquid manure management 8-month storage systems, for example, are 3-6 times more costly depending on operation size.

Methods:

The project approach is to use GIS technology such as using DEM to calculate slopes and other GIS data layers such as Soil Survey Geographic Database (SSURGO) in processing some input data that are required by MARI. The MARI is based on 12 weighted field factors, including soil groups, soil test P value, concentrated water flow, vegetative buffer width, and manure application rates and methods. Soil testing phosphorus data were provided by the MSU Soil Testing Lab. The GIS layers including digital elevation model (DEM), soil management group, nitrogen leaching index for soil hydrologic group were used to perform an analysis of MARI for the selected watershed. Weighting factors for the 12 MARI factors were used in the assessment.

Table 1. The weighting factors for the 12 MARI parameters:

Field Feature Factors	Very Low (1)	Low (2)	Medium (4)	High (8)

1. Soil Hydrologic Group (1.0)	A	B	C	D
2. Soil Management Group (1.0)	5.0	2.5-4.0	1.5	0-1.0
3. Percent Slope (1.0)	0-1.9	2-3.0	3.1-6	>6
4. Soil Test P Value (lbs/ac) (1.5)	Medium (<79)	High (80-149)	Very High (150-300)	Excessive (>300)
5. Concentrated Water Flow or Surface Inlet Discharge (1.5)	Ponds in flat field or no runoff	Few No direct flow offsite into surface water	Some Enters surface water through a designed buffer	Many Ephemeral channels discharges directly into surface water, no buffer
6. Nitrogen Leaching Index for Soil Hydrologic Group (1.5)	N/A	Low	Medium	High
7. Residue/Cover or Perennial Cover (1.0)	> 40% residue good perennial grass alfalfa or cover crop	30-39% residue fair perennial grass legume, small grain	10-29% residue poor grass legume	<10% residue fall tillage or no cover
8. Surface Water Setback (1.0)	> 300 ft. to edge of stream	150-299 ft. to edge of stream	<150 ft. incorporates manure	<150 ft. surface applies manure does not incorporate
9. Vegetative Buffer Width (1.5)	>100 ft. or if not applicable to the site	66-99 ft.	20-65 ft.	<20 ft.
10. Manure Application Rate (P_2O_5 lbs/ac) (1.0)	< 30	30-60	61-99	>100
11. Manure N Application Rate (lbs/ac) (1.0)	<60	61-130	131-200	>200
12. Manure Application Method (1.0)	Injected	Surface applied and incorporated within 48 hr.	Surface applied and incorporated within 3	Surface applied and unincorporated for at least 3

			months	months.

We used the spatial data to created several GIS layer in grids and then calculated the composite layer by applying those weighting factors. Specifically, the following ratings are used in grid creation and calculations:

For Soil Hydrologic Groups, we rated it as follows:
A = 1 (very low)
B = 2 (low)
C = 3 (medium)
D = 8 (high)

For Soil Management Group:
5.0 = 1 (very low)
2.5-4.0 = 2 (low)
1.5 = 4 (medium)

For Percent Slope:
<2% = 1 (very low)
2-3% = 2 (low)
3-6% = 4 (medium)
>6% = 8 (high)

For Soil Test P value, we used a constant of 2 (low) based on the soil testing P values provided by the MSU Soil Testing Lab.

For Concentrated Water Flow, we used a constant of 8 (high) which is Discharges directly to surface water.

For Nitrogen Leaching Index for Hydrologic Groups, we rated Group C = 2 (low), Groups A & B = 4 (medium).
For Residue/Cover Crops, we used a constant of 4 (medium) for the study watershed.

For Surface Water Setback, we used a constant of 8 (high) for the study watershed.

For Vegetative Buffer Width, we used a constant of 8 (high) which is less than 20 ft. wide for fields within 100 ft. of surface water.

For Manure Application Rate of P2O5, we used a constant of 8 (high) which is greater than 100 lbs/ac applied.

For Manure Application Rate N, we used a constant of 8 (high) which is greater than 200 lb/ac applied.

For Manure Application Method, we used a constant of 8 (high) which is surface applied and not incorporated for at least 3 months.

MARI index can be calculated using the following equation:

MARI = (factor 1) + (factor 2) + (factor 3) + (factor 4) x 1.5 + (factor 5) x 1.5 + (factor 6) x 1.5 + (factor 7) + (factor 8) + (factor 9) x 1.5 + (factor 10) + (factor 11) + (factor 12)

Results and Discussion:
By calculating the composite grid layer based on the spatial data layers and assumed the constants for other factors, we have generated the MARI grids (see figure 1).

The MARI map demonstrates the potentially high risk areas where precaution is needed when manure is applied. It has the potential for use in the watershed to assist livestock operators in evaluating areas to determine whether the level of environmental risk associated with manure applications is acceptable or unacceptable. However, wider use of the MARI approach requires additional, broad-scale field verification of its usefulness in various soil types, landscapes, and manure management systems to facilitate its application throughout the Midwestern region.

Field vulnerability for manure loss is rated based on the composite MARI ratings. The following table shows how the MARI is rated.

Table 2. Field Vulnerability for Manure Loss

Manure Application Risk Index for a filed	**Generalized Interpretation of Manure Application Risk Index**
<19	"VERY LOW" potential for manure movement from the field. If manure is managed, there is a low probability of an adverse impact to surface water. These fields have good potential for winter spreading.
19-37	"LOW" potential for manure movement from the field. The chance of organic material and nutrients getting into surface water exists. Buffers, setbacks, lower manure rates, cover crops, and crop residue practices alone or in combination may reduce impact. These fields have good potential for winter spreading.
38-75	"MEDIUM" potential for manure movement from the field. The chance of organic material and nutrients getting to surface water is likely. Buffers, setbacks, lower manure rates, cover crops, crop residues, etc. in combination may reduce impact. These fields have limited potential for winter spreading and only a partial area of the field may be acceptable.
> 75	"HIGH" potential for manure movement from the field and an adverse impact on surface water. Winter Spreading should not be done on these fields.

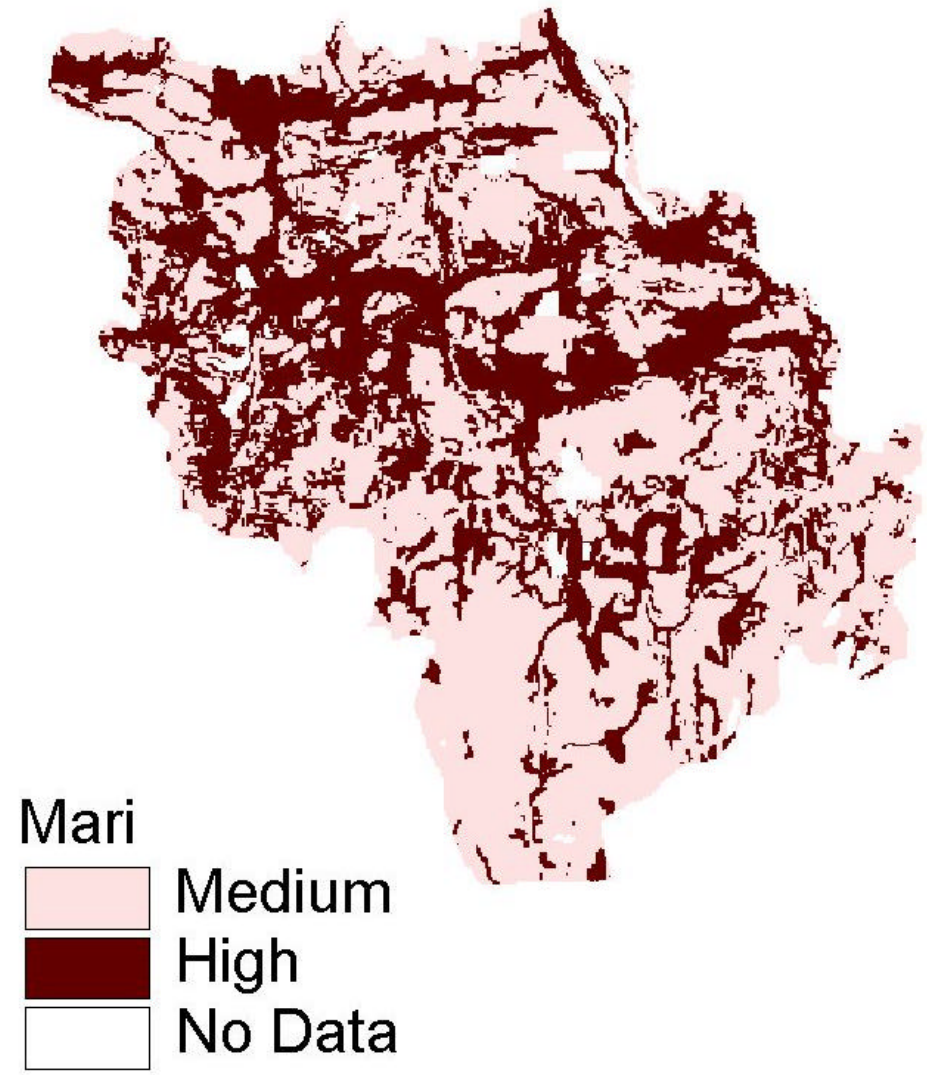
As shown on the map, most areas fall in the categories of Medium and High risk in the study watershed. There may be a limited potential for winter spreading of manure in the fields.

The MARI is used in Michigan as a part of the state-recognized Generally Accepted Agricultural Management Practices (GAAMP). The long-term impact of this project is a more economically-viable and environmentally-sustainable agricultural system. The

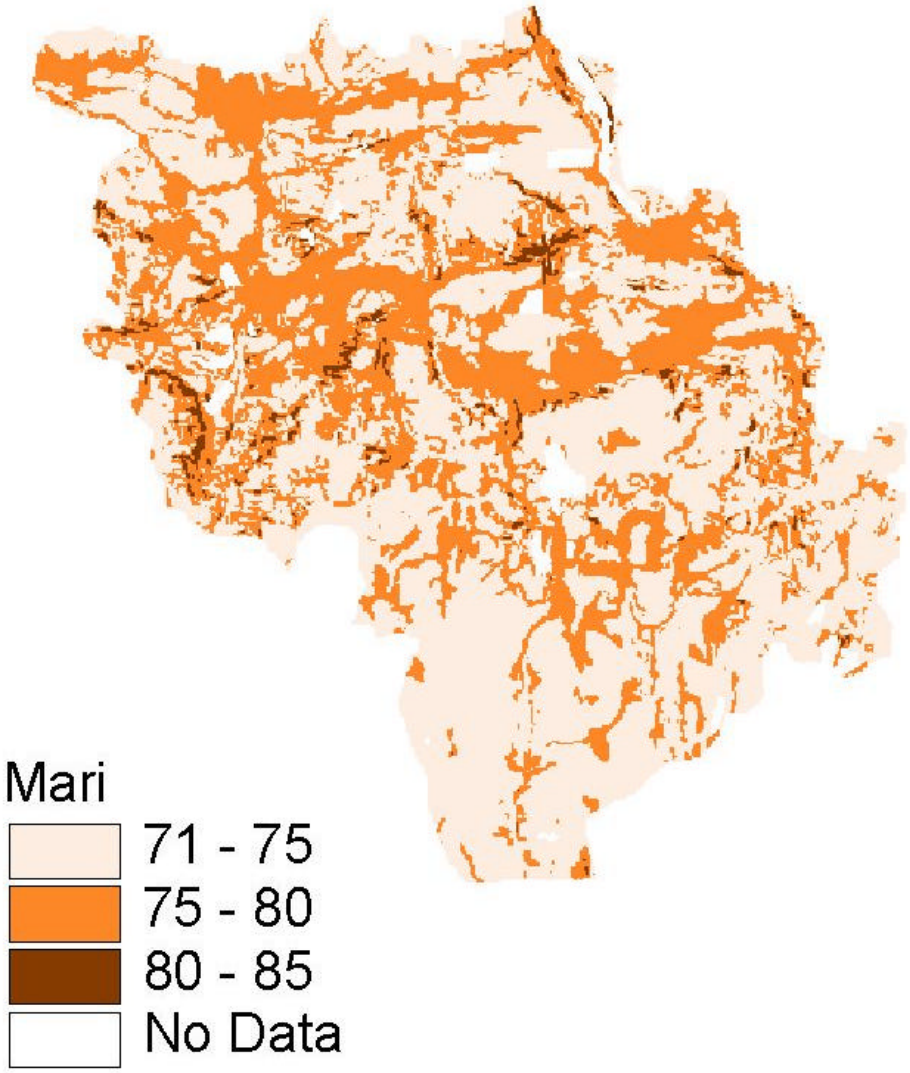
Manure Application Risk Index (MARI) identifies areas that may safely receive manure applications under specified weather conditions and during which seasons. This index enables operators to make informed decisions about their manure management systems and avoid potentially heavy capital costs where expensive storage systems are not necessary. Use of this index at the landscape level will result in long-term environmental benefits, specifically, protecting valuable water resources. Finally, more effective manure application techniques based on scientific knowledge of transport, runoff, and concentrations of potential nutrient loadings will increase the public's confidence in the ability of agricultural/ livestock operators to practice responsible stewardship of productive agricultural lands and precious water resources.

Other layers that were created for MARI are included in the Appendix.

Manure Application Risk Index (MARI) in
Sycamore Creek Watershed



Manure Application Risk Index (MARI) in
Sycamore Creek Watershed



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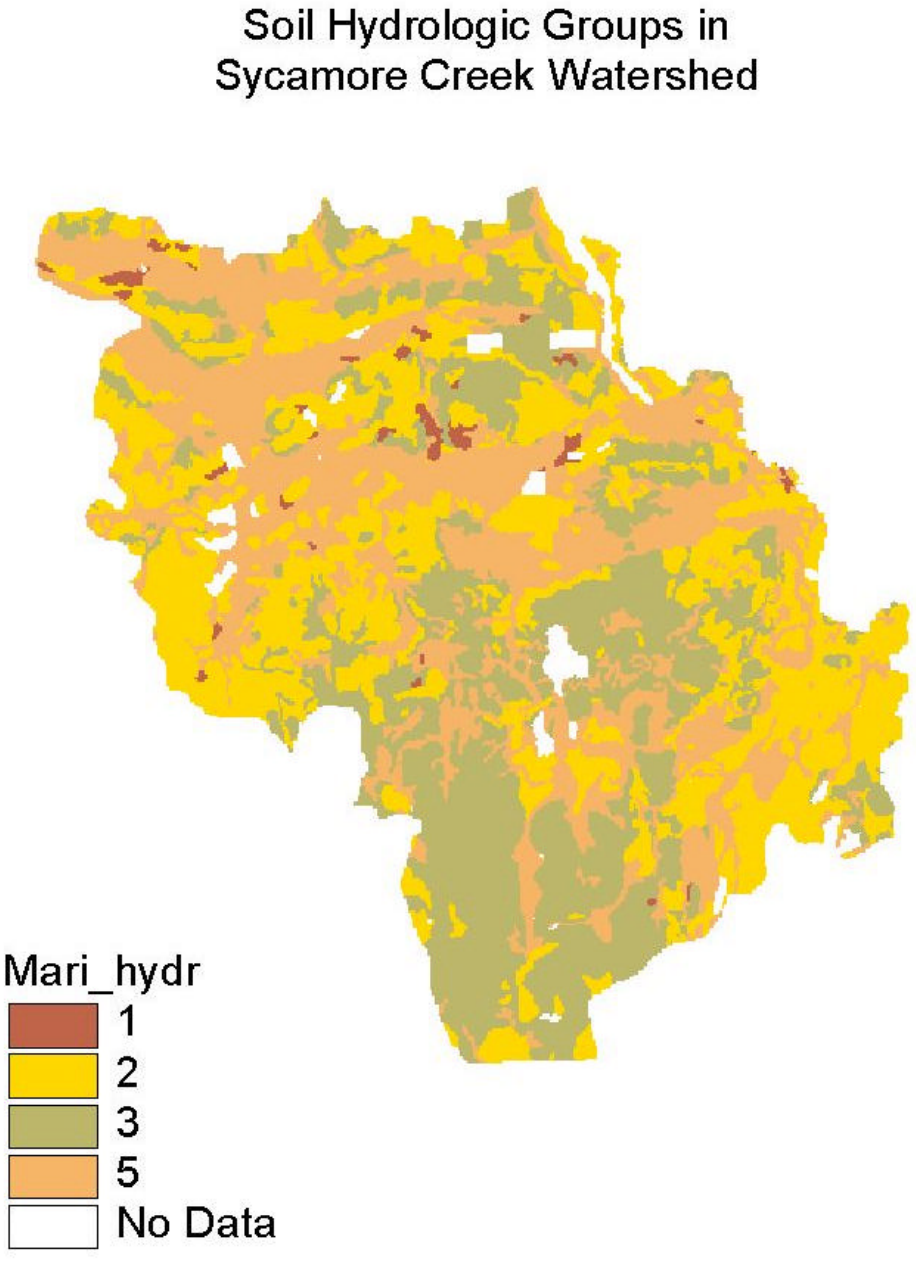
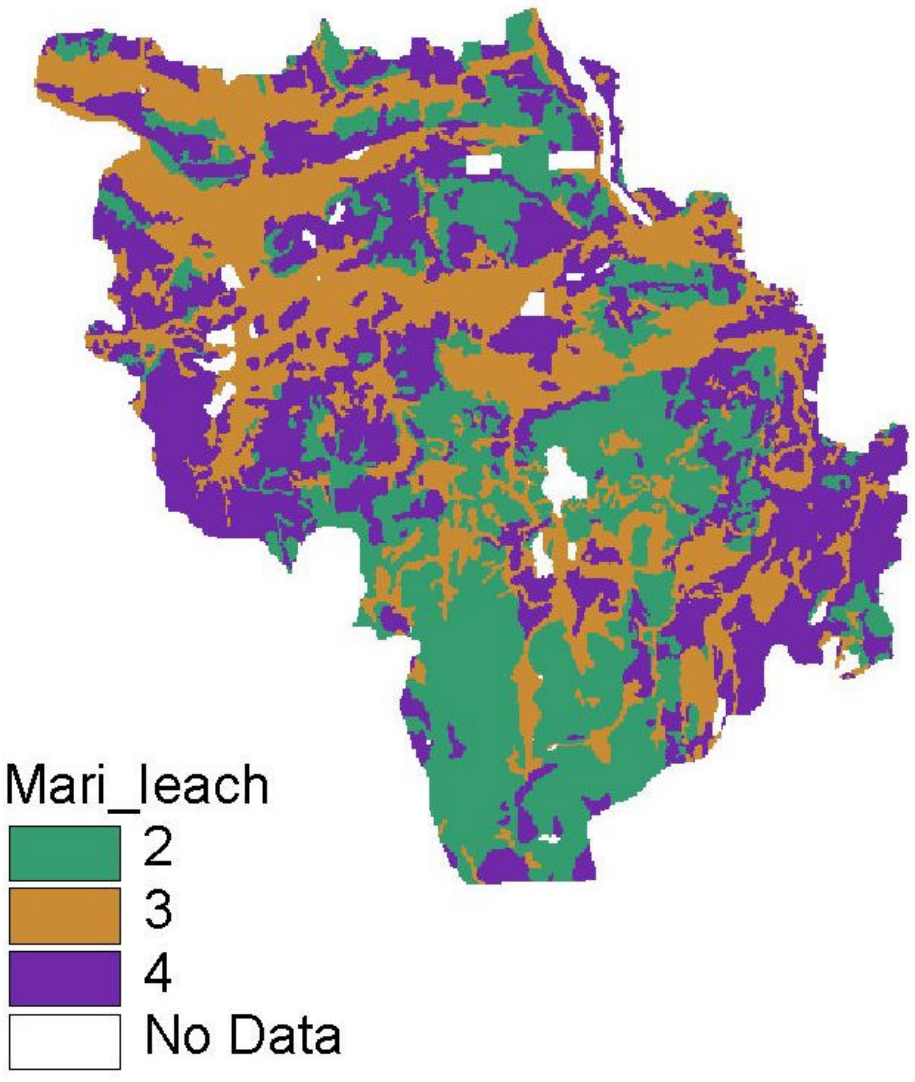
R. C. Williams, 2002. Stony Creek Watershed Plan – Environmental Assessment. NRCS, USDA, MI.

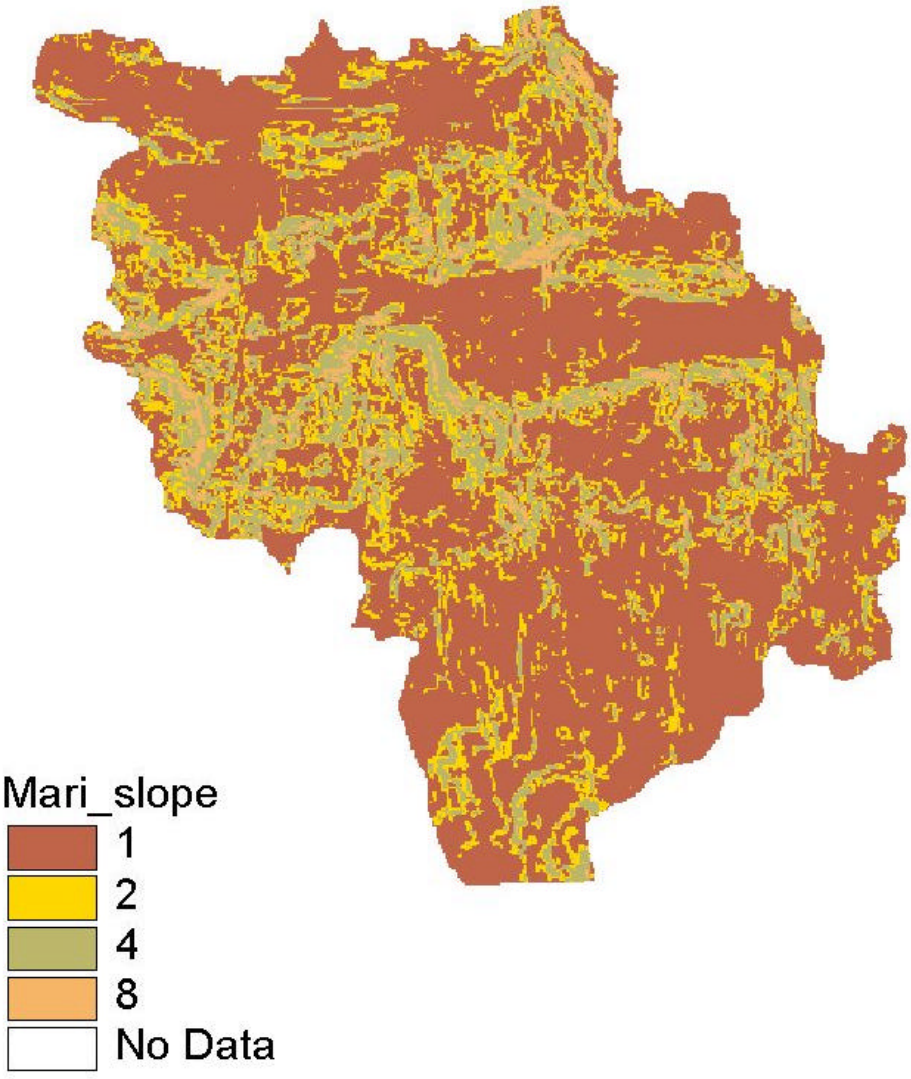
Appendix


Soil Hydrologic Groups in
Sycamore Creek Watershed
Mari_hydr
1
2
3
5
No Data

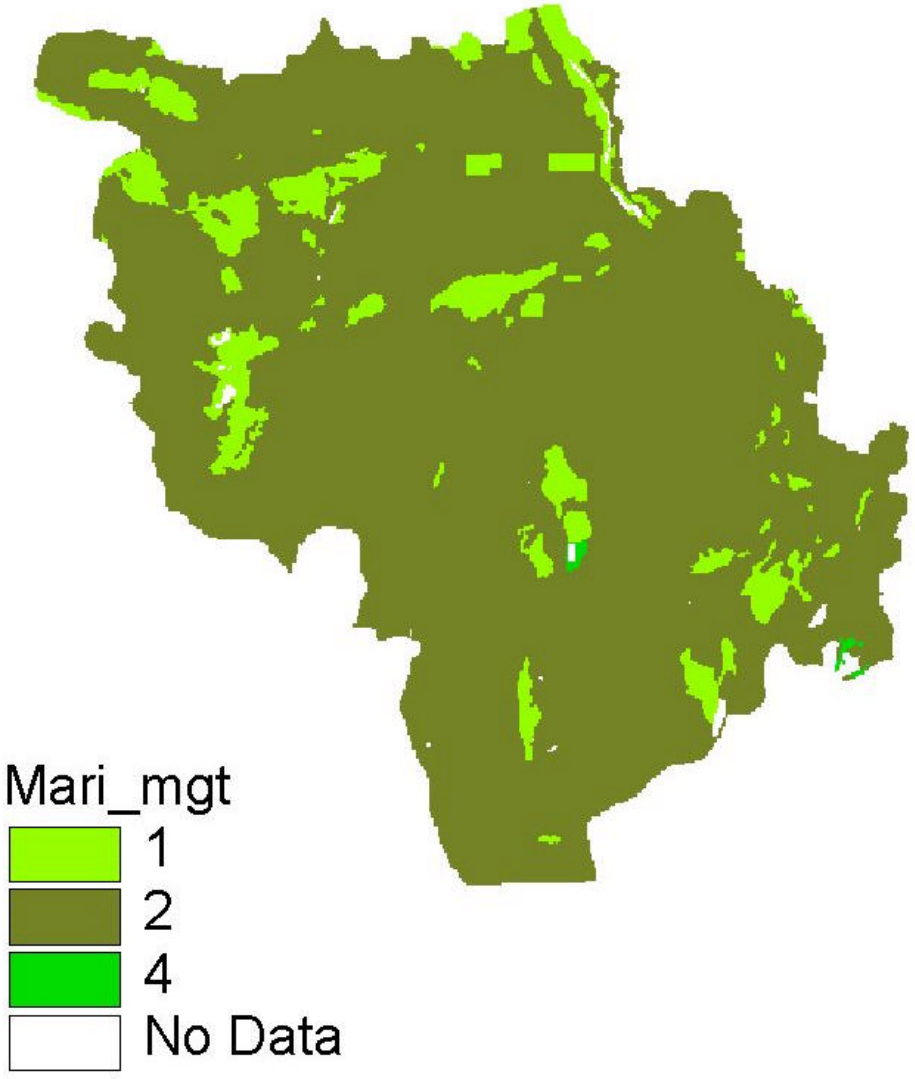
Nitrogen Leaching Index for Hydrologic Groups in Sycamore Creek Watershed



MARI Rating on Slopes in
Sycamore Creek Watershed



Soil Management Groups in
Sycamore Creek Watershed



Sediment transport modeling using high resolution LIDAR-derived DEMs

Basic Information

Title:	Sediment transport modeling using high resolution LIDAR-derived DEMs
Project Number:	2004MI52B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	Eighth
Research Category:	Not Applicable
Focus Category:	Methods, Non Point Pollution, Sediments
Descriptors:	Scale, DEM, hydrologic model, accuracy, LIDAR
Principal Investigators:	A. M. Shortridge, Yi Shi

Publication

1. C. P. Barber and A. M. Shortridge (2005a) Terrain representation, scale, and hydrologic modeling: does LiDAR make a difference? Invited Submission to Computers and Geographic Information Science, May 1, 2005.
2. C. P. Barber and A. M. Shortridge (2005b) Terrain representation, scale, and hydrologic modeling: does LiDAR make a difference? Autocarto 2005. Las Vegas, Nevada, March 21-23.
3. C. P. Barber and A. M. Shortridge (2004) Light Detection and Ranging (LiDAR) Derived Elevation Data for Surface Hydrology Applications. Institute of Water Research Technical Report IWR-1(2004), Michigan State University, East Lansing, Michigan. http://www.hydra.iwr.msu.edu/iwr/publications/index.asp

Project Number: 2004MI52B
FY 2004 Federal Funds: $15,000
FY 2004 Non-Federal Funds: $30,879

Start Date: 03/01/04 (actual)
End Date: 02/28/05 (actual)

Title: Sediment transport modeling using high resolution LIDAR-derived DEMs
Investigator(s): Ashton Shortridge, Assistant Professor, Michigan State University
Co PI: Yi Shi, Research Assistant, Michigan State University
Focus Category: Methods, Non Point Pollution, Sediments
Descriptors: Scale, DEM, hydrologic model, accuracy, LIDAR
Congressional District: Eighth

Background

In the past few years high resolution, remotely sensed radar and laser-derived digital elevation models (DEMs) have moved from a promising technology to a primary means of base data development. The Shuttle Radar Topography Mission (SRTM), flown in early 2000, has yielded terrain data across much of the globe NASA (2005). Far higher resolution data (sub 3 meter horizontal resolution) has been collected from laser sensors collecting data via LIDAR (light detection and ranging) mounted in aircraft (Sapeta, 2000); some of this data is publically available via the internet. Due to its high spatial resolution, relatively inexpensive production cost, and rapid processing, it is anticipated that much or all of the United States will be covered by high resolution DEMs derived from this technology within a decade (see e.g. FEMA, 2005).

Digital elevation models are a primary input source for developing and parameterizing a range of hydrologic modeling applications (Hutchinson & Gallant, 1999; Moore et al., 1991). The implications for modeling erosion and sediment load are profound, since the spatial resolution of this data is an order of magnitude finer than the best available for much of the country, including Michigan. In theory, this should lead to tremendous improvements in our ability to determine key spatial hydrological parameters like flow vectors, which in turn should enable a high degree of precision in specifying the dynamics of transport in surface water flow.

However, important questions remain. No DEM is without error, and it is not straightforward to translate a data quality report into a clear understanding of how data error will affect a given application (Heuvelink et al., 1989). Studies into specific DEM products have revealed numerous problems (eg. Bolstad & Stowe, 1994), and terrain derivative datasets critical for surface hydrology applications are known to be highly sensitive to scale factors and error (Garbrecht & Starks, 1995; Zhang & Montgomery, 1994). How well do LIDAR-derived DEMs depict terrain derivatives important for water-related applications? Are these products truly “bare-earth”, meaning that they depict the way that water flows across it, or are they affected by vegetation and human constructions? Perhaps most importantly, will the low relief typical of Michigan watersheds confound sediment transport modeling applications, even employing high resolution, high accuracy DEMs? Recent research has begun to consider these questions (Raber, 2003), but clear answers have not emerged.

Project Objectives
In light of these important questions, we proposed to conduct a comparative study to evaluate the utility of LiDAR-derived DEMs for hydrologic modeling applications. Specifically, we wished to accomplish the following objectives:

1. Review recent literature on LiDAR DEM generation and quality
2. Identify and obtain high-resolution (sub-5 meter) LiDAR DEM data
3. Conduct a GIS-based hydrologic study and compare results using LiDAR and conventional medium-resolution products
4. Evaluate spatial resolution effects & production artifacts
5. Communicate findings via:
    1. a web presence
    2. major conference
    3. paper in an appropriate journal

Personnel
Dr. Ashton Shortridge, an assistant professor in the Department of Geography, wrote the original proposal, served as principal investigator. Mr. Chris Barber, a graduate student in the Forestry Department, worked as a graduate research assistant on this grant. Institute of Water Research staff and scientists supplied critical space, equipment, support, and suggestions.

Accomplishments
1. *Literature Review*
LiDAR DEM research is highly multidisciplinary, and results appear in diverse outlets. The first few months of the project were spent developing a bibliography of relevant work from this body of work, and preparing a technical report on results to date, along with some preliminary findings. This technical report, published in the Institute of Water Research series as WR-1 2004, is entitled, *Light Detection and Ranging (LiDAR) - Derived Elevation Data for Surface Hydrology Applications*. The report is available online.

2. *Obtaining high resolution LiDAR DEM data*
We had originally intended to identify a study area in Michigan with LiDAR and conventional sources. While considerable LiDAR data exists for the state, most of it is for areas immediately adjacent to the Great Lakes. Since the focus of this project is on watershed modeling, this was not adequate for our needs. We looked elsewhere and identified three free, publically available sources:

1. Puget Sound, Washington (from USGS, 2005)
2. North Carolina (North Carolina, 2005)
3. Louisiana (CADGIS, 2005)

We evaluated all three and settled on two watersheds in eastern North Carolina for subsequent research. These study regions were chosen due to their similarity to topography in Michigan. USGS 7.5”-series DEM data were obtained for these watersheds in addition to the LiDAR data. Details about the study region and the available data are included in the papers.

3. *Comparative GIS-based hydrological modeling study*
We conducted an intensive analysis on elevation data for the two watershed study regions in North Carolina. This work involved the calculation of many critical hydrologic parameters, like slope, flow direction, upstream contributing area, and basin delineation. Full results are reported in Barber & Shortridge (2005a).

4. *Evaluate spatial resolution effects & production artifacts*
This became the primary focus of the research. We found that, in comparison with conventional medium resolution DEM products, LiDAR data methods produced strikingly different results for certain hydrologic operations, such as basin delineation, in areas of low relief. Cell resolution alone did not explain this effect. Other operations were much more robust to the source of elevation or the resolution. A higher relief watershed showed only moderate sensitivity to basin delineation, indicating that these effects are very much dependent on the geography of the region in question. At the same time, postprocessing conducted by the producers of the North Carolina DEM data appeared to have successfully resolved potential artifacts like bridges and culverts. Full results are reported in Barber & Shortridge (2005a).

5. *Communicate findings*
We presented two brown-bag luncheon presentations at the Institute of Water Research on the campus of Michigan State University. The first of these, held in fall 2004, provided a review of the sources, production, strengths, and potential weaknesses of LiDAR-derived digital elevation data. The second of these, held in spring of 2005, documented our findings.

We published a technical report (Barber & Shortridge, 2004) that provided a review of LiDAR-based DEM data production methods, data characteristics, and applications. The report also indicated the potential of LiDAR data for hydrologic applications, but identified potential pitfalls to its use.

An abstract submitted to Autocarto 2005, a longstanding, prestigious international conference in geographic information science with a selective peer reviewed application process, was accepted for a full paper. We wrote the paper, which was published in the conference proceedings (Barber & Shortridge, 2005b). Chris Barber presented the paper in Las Vegas at the conference in March of 2005. Ours was one of a subset of papers from that conference that were invited for submission to a special issue of Computers and Geographic Information Science (CaGIS), an international journal with high standing in the field (Barber & Shortridge, 2005a). This manuscript, reworked extensively after the conference, is currently (late May, 2005) under review.

Opportunities and Challenges
There is no such thing as a standard LiDAR DEM. The final product is the result of a series of processing decisions, and its quality is a function of many factors. The Louisiana product mentioned previously in this report is subject to 'damming' artifacts, as it is essentially a straightforward surface model. Features such as bridges and culverts were not accounted for in postprocessing. As a result, standard hydrologic operations such as calculating flow directions can produce substantial 'ponded' areas. In contrast, the North Carolina product was edited with the use of USGS stream line data to remove such

features. This data was not subject to damming artifacts. Information about postprocessing decisions should be vital components of metadata for LiDAR DEMs; how to incorporate this seamlessly in spatial analysis such as hydrologic modeling applications remains an important research question.

We never quite got around to running a sediment transport model on these data. We decided against this because analyzing the sensitivity of terrain and derivatives like slope seemed most important. The addition of more variables for the sediment model (e.g. soil information) would have obscured the role of the topographic inputs and the sensitivity of elevation to resolution. The manuscript under review at CaGIS covers this material in detail; we have a much better understanding now of the role of these factors. One clear next step is to implement the RUSLE-based sediment model in a comparative analysis.

A profound issue for the production and dissemination of national elevation data was identified in this study. This issue concerns the USGS National Elevation Data (NED) product, which combines data from different sources to produce the seamless product (USGS, 2005). In this research, we found substantial discrepancies in basin delineation for the low-lying topography of the Neuse watershed. **These discrepancies appeared to be related to the source of the elevation data**, and were not moderated by resampling to 30 meters. The effect of data conflation in NED on sensitive derivatives like basin delineation is unclear but potentially significant. We advise researchers to consider the NED metadata carefully to determine if multiple sources have been mosaicked for their study regions, and suggest that further study is warranted on this issue.

Output

C. P. Barber and A. M. Shortridge (2005a) *Terrain representation, scale, and hydrologic modeling: does LiDAR make a difference? Invited Submission to* Computers and Geographic Information Science, *May 1, 2005*.

C. P. Barber and A. M. Shortridge (2005b) *Terrain representation, scale, and hydrologic modeling: does LiDAR make a difference?* Autocarto 2005. Las Vegas, Nevada, March 21-23.

C. P. Barber and A. M. Shortridge (2004) *Light Detection and Ranging (LiDAR) – Derived Elevation Data for Surface Hydrology Applications*. Institute of Water Research Technical Report IWR-1(2004), Michigan State University, East Lansing, Michigan. http://www.hydra.iwr.msu.edu/iwr/publications/index.asp

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Information Transfer Program

Information Dissemination and Technology Transfer Training Programs

Basic Information

Title:	Information Dissemination and Technology Transfer Training Programs
Project Number:	2004MI45B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	Eighth
Research Category:	Not Applicable
Focus Category:	Education, Groundwater, Water Quality
Descriptors:	Water Quality; Watershed Management; Macroinvertebrates; Volunteer Monitoring; GIS
Principal Investigators:	Lois G Wolfson

Publication

1. Bruhn, L. and L. Wolfson. In prep. Citizens Monitoring Bacteria: A Training Manual for Monitoring E. coli. Michigan State University, East Lansing, MI. 40 pp.
2. Kline-Robach, Ruth. 2005. An Integrated Approach to Stormwater Management at Michigan State University. CSREES National Water Quality Conference, La Jolla, CA.
3. Iles, J., L. Wolfson, OBrien, E., B. Luikkonen, K. Stepenuck, L. Seigley, and L. Crighton. 2005. Bacteria Monitoring in the Upper Midwest: Developing Consistent Training and Monitoring Methods (poster). 2005. USDA CSREES National Water Quality Conference, La Jolla, CA.
4. Wandell, H., L. Wolfson, and J. Herbert. 2004. Protecting Michigans Vanishing Native Lakeshore. MSU Extension Bulletin (unnumbered). Michigan State University, East Lansing, MI. 2 pp.
5. Asher, J., O. Da, S. Yi. 2004 (revised). Digital Watershed (http://www.iwr.msu.edu/dw/)

Project Number: 2004MI45B
FY 2004 Federal Funds: $20,000
FY 2004 Non-Federal Funds: $40,571

Start: 03/01/04 (actual)
End: 02/28/05 (actual)

Title: Information Dissemination and Technology Transfer Training Programs
Investigators: Lois G. Wolfson, Institute of Water Research, Michigan State University
Focus Categories: EDU, GW, SW, WQL
Congressional District: Eighth
Descriptors: Water Quality; Watershed Management; Macroinvertebrates; Volunteer Monitoring; GIS

Problem and Research Objective:
Science-based accurate information is essential in the development and implementation of an effective information dissemination program. It must be current, reliable and readily transferable to a wide audience in formats that are easily understood. In order to help protect, manage, and/or rehabilitate the water resources in the state, the Institute of Water Research has developed and expanded upon its information dissemination and training program addressing real-world problems and providing timely information to scientists, decision makers, farmers, riparians and other interested citizens throughout the state.

The objectives are to develop and present educational programs designed to increase the public's awareness and appreciation of the water quality and quantity problems in Michigan and to stress the economic trade-offs required to solve water related problems. These programs are offered in the form of conferences, training workshops, demonstrations, computer models and decision support systems, web-based programs, and printed material.

Methodology:
Methods used to meet the objectives are to: (1) sponsor state of the art conferences and workshops that deal with pressing water related issues; (2) prepare lecture/demonstrations, audio-visual materials; and power point presentations (3) develop training sessions and workshops to assess trends in water quality; (4) present web based programs that provide users with information and other data needed for decision making; (5) compile, interpret, and distribute water related information as well as directing users to appropriate sources of expertise and information; and (6) cooperate with the Michigan State University Extension Service to make water related information available through the county cooperative extension agents.

Principal Findings and Significance:
The dissemination portion has involved a number of technology transfer mechanisms such as seminars, workshops, and conferences; web based information systems, data and virtual courses; and pamphlets, exhibits and demonstrations. Each program is designed to make the latest information available to the appropriate user groups. Local, state, and federal agency personnel as well as students, staff, and others are given the opportunity to hear and interact with outstanding researchers and have access to a variety of written materials and multi-media presentations. Participants have been able to use the information gained from these programs in their decision-making processes concerning water resources.

Publications, Web-based Programs, and Posters (2004-2005):

Bruhn, L. and L. Wolfson. In prep. Citizens Monitoring Bacteria: A Training Manual for Monitoring *E. coli*. Michigan State University, East Lansing, MI. 40 pp.

Kline-Robach, Ruth. 2005. An Integrated Approach to Stormwater Management at Michigan State University. CSREES National Water Quality Conference, La Jolla, CA.

Iles, J., L. Wolfson, O'Brien, E., B. Luikkonen, K. Stepenuck, L. Seigley, and L. Crighton. 2005. Bacteria Monitoring in the Upper Midwest: Developing Consistent Training and Monitoring Methods (poster). 2005. USDA CSREES National Water Quality Conference, La Jolla, CA.

Wandell, H., L. Wolfson, and J. Herbert. 2004. Protecting Michigan's Vanishing Native Lakeshore. MSU Extension Bulletin (unnumbered). Michigan State University, East Lansing, MI. 2 pp.

Asher, J., O. Da, S. Yi. 2004 (revised). Digital Watershed (http://www.iwr.msu.edu/dw/)

Project Relevance

Michigan is fortunate to have an abundant and widespread supply of water due in large part to its geographical location within the Upper Great Lakes Region. Although relatively plentiful, the high demand on and use of the water resources in the state often result in both water quantity and water quality problems. As activities within the state continue to increase, the state's water resources continue to be at risk.

As impacts on water quality become more widespread, the need for action at the watershed level becomes more apparent. The movement of pollutants across a watershed is not constrained by political boundaries, and activities in one political jurisdiction may lead to water degradation in another. The difficulty in assessing impacts from erosion, nonpoint source pollution or shoreline development lies not only in the magnitude of the data collection efforts, but in the proper analysis and interpretation of the data needed for assessing the problem.

In order to stay informed about water quality changes over time, and to determine if efforts being made to reduce pollutants are proving effective, an education, monitoring, and evaluation program is appropriate. An effective information dissemination and training program facilitates the transfer of information needed to protect the water resources in the state, and helps to inform scientists, legislators, and citizens of the most recent information available. For further effectiveness, agency personnel, riparians, educators and others interested in protecting their water resources or in teaching others about it must understand the importance of collecting and/or analyzing information at the watershed level to ensure that reliable and appropriate information is being used to make sound decisions for water quality protection.

Project Objectives

The Institute of Water Research has a long history of providing effective information dissemination and training programs. These programs have involved close cooperation with other groups and organizations within the University and the state in order to enhance their effectiveness. Partnering with other groups has become a critical component for successful

programming and delivery. Because educational levels and prior knowledge in the subject area are so varied, a number of transfer mechanisms are necessary. With the increasing use of web-based programs, the Institute has put much of its resources into providing access to data, papers, models, programs, and other types of information that can be successfully accessed and utilized on the web. Other traditional methods such as conferences, workshops, written publications, and self-contained computer programs are utilized for both lay audiences and professional groups throughout the state. Training sessions are also offered to provide hands-on experience for a number of diverse audiences.

The following objectives relate to information dissemination programs arising from water-related activities at the Institute of Water Research.

1. Utilize the dissemination potential of the web by developing educational modules; interactive models; and virtual reality courses.

2. Develop and present educational programs such as conferences, seminars, and training workshops designed to increase the public's awareness and appreciation of the water quality problems in the state and to stress the economic trade-offs required to solve any problem.

3. Prepare lecture/demonstrations for presentations to college classes, secondary and elementary schools, and private groups on such topics as watershed management, wastewater treatment, wetland and lake ecology, water conservation, and groundwater contamination.

4. Cooperate with the Michigan State University Extension to make water-related information available through the cooperative extension network.

Program Results

Since the Institute of Water Research Information Dissemination and Technology Transfer Program began in the early 1970s, it has been responsive to the informational needs of a wide variety of user groups. Many modes of information exchange have been used to further this program and provide the latest research information to user groups. The following programs were developed and delivered for fiscal year 2004-2005.

Conferences

The Great Lakes are continuously faced with a multitude of threats that can degrade both their water quality and recreational potential. The IWR cosponsored its annual Great Lakes conference, titled: *The Great Lakes: Assessing Ecosystem Health through Partnerships* during Agriculture and Natural Resources Week (ANR Week) at MSU. As implied in the title, the conference focused on current research and activities of agencies, Universities and organizations working on various Great Lakes issues such as mercury and PCB contamination; invasive species; and the Great Lakes restoration strategy. The Office of the Great Lakes, Michigan Department of Environmental Quality, was a cosponsor as was Michigan Sea Grant and MSU's Department of Fisheries and Wildlife. Approximately 200 people, including state and local agency personnel, researchers and educators, environmental organizations, and interested citizens attended the event. Overall evaluations ranked the conference between very good and

excellent.

Volunteer Monitoring
Institute staff personnel were involved in several Volunteer Monitoring programs this fiscal year. One involved an in-depth training for adult volunteers on stream monitoring in the southwestern part of the state. Topics for the sessions focused on physical, chemical, and biological parameters and included both lecture and hands-on activities. A second program focused on sampling and analysis of *E. coli* in streams. Funding from another source was obtained for this project, and IWR staff coordinated the technology transfer program with this project.

Lake and Stream Leader's Institute
To develop a core of local water/land resource leaders who will promote lake, stream and watershed management partnerships with state natural resource agencies and encourage and instruct other citizens in resource management, a Lake and Stream Leader's Institute was developed by the Water Quality team in Extension. IWR staff played a significant role in both the development and implementation of this program. This past fiscal year was an advanced training for alumni from the first year's class. Also, a curriculum was developed for a new class in 2005. Responsibilities of the IWR staff members for the alumni session included leading hands-on sessions on macroinvertebrate identification; phosphorus analysis; and general lake ecology. Other involvement included helping with logistics and serving on the advisory committee. Funds from other sources were utilized in this program.

Internet-Based Programs
IWR staff continued to expand on its Watershed Mapping program, both in Michigan (www.iwr.msu.edu/water) and US wide (www.iwr.msu.edu/dw) to make data more available as well as comprehensive. This year staff worked with Purdue University and incorporated a hydrologic model into the program that allows users to delineate a watershed and determine surrounding land uses. Additionally, the program was linked to the Terra Server to enable access of digital orthoquad photographs in any area of the continental United States.

Campus Storm Water Management Education and Outreach
This fiscal year IWR staff in coordinator with the campus-wide MSU-WATER (Watershed Action through Education and Research) developed a program involving both MSU students and elementary school children. The MSU students served as mentors and taught the elementary school students about water quality and pollution in the river that flows through campus. They then helped the children paint pictures and messages about what they learned on trash barrels. The painted trash barrels were then placed along walkways near the river to highlight the river and its vulnerability to pollution. To further increase awareness, faculty and students set up a live fish display during two football Saturdays to show visitors the wide variety of fish that inhabit the river. The event included a demonstration of fish seining (netting), the live fish display and other river organisms, including aquatic insects and crustaceans. IWR staff helped with the event and answered questions from participants.

Lakescaping Demonstration and Training
Following a planning and implementation phase, a 120-foot shoreline along a small pond was planted with a variety of vegetation. The shoreline was divided into two segments to help illustrate good and poor practices with regards to erosion control, wildlife habitat enhancement, and water quality. A photo history of the site development was maintained, and a web page

showing the entire process and results is being developed.

Exhibits and Demonstrations
IWR staff members took part in various programs hosted by other University units or outside agencies. The IWR participated in the Michigan Science Olympiad by serving as the State Supervisor for Water Quality in the state finals. This annual event included 48 junior high and high schools who competed in a variety of science related events. Winners of the event continued to the national finals.

In late July, MSU's Ag Expo, an agricultural oriented exposition was held. Approximately 35,000 people attended the event. Each year the Institute features an educational exhibit. The IWR this year again highlighted its web-based programs, "Understanding Your Watershed" and "EZ mapper." Color printers were available for participants to download a rectified aerial photograph of their property along with several data layers such as rivers, streams, elevation, or watershed area. The IWR coordinated efforts with the MSU Land Policy Program. Approximately 500 people visited the tent over the three day event.

The IWR again participated in the Children's Water Festival, an event that brings together nearly 1000 elementary school children from across the tri-county area to be introduced to a variety of natural resources and science-related topics. The IWR led two topic areas. One featured aquatic macroinvertebrates and their role as water quality indicators. The other focused on aquifer vulnerability and used ice cream, dyes, and candy to depict aquifers and contaminants. Six classes for each topic were held with 30 to 40 students per class.

Lectures and Seminars
The Institute staff gave numerous presentations throughout the year on issues such as nonpoint source pollution, wellhead protection, indicator species for water quality testing, watershed management plans, and exotic species introduction. Staff gave class lectures in the Departments of Fisheries and Wildlife, Community, Agriculture, Recreation and Resources, Journalism, and Zoology. Audience or class participation ranges from approximately 25 to over 100 for each presentation.

Personnel and Facilities
The Institute of Water Research maintains such facilities and equipment as the latest software packages for desktop publishing, GIS, video editing and photographic equipment to support its Information Dissemination Program. It also has microcomputers, three Sun Sparc-20 work station, a graphic plotter, scanner, color printer, and digital camera to enhance its educational programs. For field demonstrations and research related opportunities the Institute also has a Data Sonde mini-probe for measuring chemical parameters in lakes. The Institute's technology transfer program is under the direction of Principal Investigator Dr. Lois Wolfson, with several Institute personnel contributing to the project, including Dr. Jon Bartholic, Ruth Kline-Robach, and Jeremiah Asher.

Student Support

None

Notable Awards and Achievements

Wise management of our ground water resources requires scientific understanding of the states aquifers (underground water resources) and integrated information about the location, availability, and sustainability of these resources. Citizens, natural resource organizations, the state legislature, and government are requesting information as they develop improved ground water strategies for the state.

Act 148 (Public Acts of 2003) required the Michigan Department of Environmental Quality (MDEQ) to ... collect and compile groundwater data into a statewide groundwater inventory and map by August, 2005. MDEQ assembled and funded with $1 million dollars the USGS MSU team to conduct this challenging project.

MSUs project team is an innovative and highly synergistic cross-collaborative activity involving MSUs Institute of Water Research, the Remote Sensing & GIS Research and Outreach Services Group in the Department of Geography, and the Department of Biosystems and Agricultural Engineering, in partnership with the USGS Water Science Center in Lansing. The group is now putting the finishing touches on this historic statewide groundwater mapping effort that includes several associated products essential to the states ability to wisely manage this resource. The scores of GIS maps and scanned ground water reports and products have been compiled and will be delivered to MDEQ by August and made available to the public through an MSU website (gwmap.rsgis.msu.edu).

Publications from Prior Projects

1. 2002MI1B ("Natural Resources Integrated Information System") - Articles in Refereed Scientific Journals - Nelson, S.A.C., P.A. Soranno, K.S. Cheruvelil, S.A. Batzli and D.L. Skole. 2003. Regional assessment of lake water clarity using satellite remote sensing, Journal of Limnology.
2. 2002MIB ("Natural Resources Integrated Information System") - Articles in Refereed Scientific Journals - Cheruvelil, K.S., N.A. Nate, P.A. Soranno, M.T. Bremigan 2003. A field-test of the unimodal relationship between fish growth and macrophyte cover in lakes, Submitted to Ecological Applications
3. 2002MIB ("Natural Resources Integrated Information System") - Articles in Refereed Scientific Journals - Nelson, S.A.C., K.S. Cheruvelil, and P.A. Soranno. 2003. Remote sensing of freshwater macrophytes and the influence of lake characteristics. Submitted to Aquatic Botany