1993 Project Abstract
FOR THE PERIOD ENDING JUNE 30, 1995
This project supported by MN Future Resources Fund

Title:	South Central Minnesota Groundwater Contamination Susceptibility - Continuation
Program Manager:	Henry W. Quade
Organization:	Mankato State University Water Resources Center
Legal Citation:	M.L. 93, Chpt. 172, Sect. 14, Subd. 11e
Approp. Amount	$290,000

STATEMENT OF OBJECTIVES

To develop regional groundwater potential susceptibility GIS coverages for South Central Minnesota utilizing existing data. This includes developing both an appropriate methodology for determining the susceptibility and for determining the level of confidence.

To incorporate municipal well water data into a data base and determine its value as a tool for aquifer water quality long term trend analysis.

RESULTS

The qualitative methods utilizing ARC/INFO GIS illustrate how existing water well driller data can be developed for a geologic sensitivity analysis. These methods were chosen as one way to define the three-dimensional configuration of confining materials in an economical and expedient manner. The use of ARC/INFO GIS AML provides a tool for quickly updating geologic sensitivity assessments as new data becomes available and may be used to produce many possible combinations for sensitivity ratings.

The level of confidence coverage is a representation of the uneven distribution and density of available well driller data. The level of confidence coverage can be used to establish confidence levels for specific areas on the geologic sensitivity coverage. In a period of budget limitations and time restrictions, the level of confidence coverage may be used as a guide to prioritize the location of new water well driller logs in areas where data is sparse.

The available municipal water quality data was not adequate to evaluate the water quality of the aquifer systems in south central Minnesota. At present, well monitoring is not required by the SDWA and MDH regulations; rather testing is required at the 'point of entry' to the public water supply system which is generally after treatment and may consist of blended water from two or more wells.

PROJECT RESULTS, USE AND DISSEMINATION

Results of this project have been presented at two series of workshops, fifteen in total, during the project period. The final workshops included round table discussion, and goals and benchmarks have been established for county work plans. The final report has been disseminated to state and federal agencies for review and comment.

July 1, 1995

LCMR Final Report - Detailed for Peer Review - Research

I. Project Title: W4-3 THE SOUTH CENTRAL MINNESOTA GROUNDWATER CONTAMINATION SUSCEPTIBILITY PROJECT - CONTINUATION
(A Regional Integration of Existing Data Utilizing GIS)

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A. Legal Citation: ML 93 Chpt. 172, Sect, 14, Subd. 11e

Total Biennial LCMR Budget: $290,000
Balance: 7/1/95 - $0

Appropriation Language as drafted 7/27/92: Subd. 11(e). This appropriation is from the future resources fund to the commissioner of natural resources for a contract with Mankato State University to couple surface hydrology, subsurface geology, and hydrogeology for environmental analysis to assess present environment conditions, establish benchmarks and develop regional priorities for South Central Minnesota.

B. LMIC Compatible Data Language: During the biennium ending June 30, 1995, the data collected by the projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted by the information policy office. Data review committees may be established to develop or comment on plans for data integration and distribution and shall submit semiannual status reports to the legislative commission on Minnesota resources on their findings. In addition, the data must be provided to and integrated with the Minnesota Land Management Information Center's geographic data bases with the integration costs borne by the activity receiving funding under this section.

II. Project Summary: The 13 counties of South Central Minnesota lie in an area that contains a great diversity of subsurface geologic environments from sedimentary bedrock units of the Hollandale Embayment in the east to the igneous and metamorphic bedrock of the Transcontinental Arch in the west. The overall goal of the South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS) is to develop a Geographic Information System (GIS) to generate integrated assessments for regions with vastly different environmental parameters based on subsurface geologic patterns, surface drainage and water quality. The resulting GIS analysis will be a tool that will help enable the counties to set reasonable goals and develop regional priorities for natural resources management in South Central Minnesota.

III. Statement of Objectives:

A. Develop regional potential geologic susceptibility GIS coverages.

B. Identify susceptible areas that may be at risk due to projected increases in population density, changes in aquifer use characteristics and changes in surface hydrology.

C. Incorporate municipal water quality data into the South Central Minnesota Groundwater Data Base.

IV. Research Objectives

A. Title of Objective: Develop Regional Geologic Potential Susceptibility GIS Coverages.

A.1. Activity: The point location for water wells and the geologic maps that were completed 1989-91 will be digitized using AutoCAD and converted into ARC/INFO coverages. The geologic maps include Bedrock Topography, Depth to Bedrock, Bedrock Structure, and Bedrock Geology for each of the 13 counties of South Central Minnesota. The geologic maps will be manipulated in ARC/INFO to produce regional cartographic GIS coverages for bedrock units that underlie South Central Minnesota.

A.1.a. Context within the project: The point digitized location for water wells will provide a base within ARC/INFO to which the water well log data base (1989-91) can be attached and used for GIS analysis. ARC/INFO coverages of the geologic maps will provide a means by which the geologic and hydrogeologic nature of the bedrock units, their areal distribution, orientation, and proximity to the land surface environment can be presented for evaluation in ARC/INFO GIS. The cartographic coverages for individual bedrock units will be essential to relate bedrock groundwater aquifers to surface hydrology.

A.1.b. Methods: The point location for water wells that correspond to water well driller's logs, located 1989-91 on to USGS 7.5 minute quadrangle maps, will be digitized using AutoCAD following USGS methodology. This has not been done by the Minnesota Geological Survey (MGS). The AutoCAD file will be converted to DXF format and then converted to ARC/INFO GIS coverages that will be compatible with MGS. Digitized point locations for water well logs, engineering logs, and other geologic logs will be acquired from the MGS and incorporated into the ARC/INFO GIS coverage.

More than 90 county based geologic maps that were completed (1989-91) were originally constructed at 1:62,500 scale. These maps will be digitized following USGS methodology using AutoCAD. Each map will be digitized into a separate AutoCAD layer, converted to DXF format, and then converted into ARC/INFO GIS coverages.

Individual ARC/INFO coverages will be created for each major bedrock unit that underlies South Central Minnesota. Each coverage will combine data contained in the ARC/INFO coverages created for the Bedrock Geology, Bedrock Topography, and Bedrock Structure maps. Individual bedrock structure maps that were constructed for key bedrock units (1989-91) will be modified, using average thickness data, to create structural coverages to fit the remaining bedrock units. Each coverage will include four parameters to describe the areal extent and physical orientation of an individual bedrock unit:

- The area where the bedrock unit is the eroded bedrock surface (Bedrock Geology Map)
- The topography of the eroded bedrock surface (Bedrock Topography Map)
- The area where the bedrock unit is overlain by upper bedrock units (Bedrock Geology Map)
- The structure at the top and bottom of the bedrock unit (Bedrock Structure Map)

A.1.c. Materials: Data contained on the geologic maps prepared during 1989-91 will be used to construct digital maps for use in ARC/INFO GIS analysis. Equipment in place includes a SUN SPARCstation 2GX, SUN SPARCstation IPC, Calcomp digitizing table, AutoCAD software and ARC/INFO software. Equipment needed includes a SUN SPARCstation 2GX workstation with AutoCAD and ARC/INFO expanded to multi users licensing, digitizer tablet and optical disk storage.

A.1.d. Budget: $108,000
Balance: $0

A.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Digitize water well locations	**********				
Prepare maps for digitizing	**********	**********			
Digitize maps using AutoCAD & convert into ARC/INFO		**********	**********		
Create ARC/INFO coverages for regional bedrock units			**********	**********	**********

A.2. Activity: We will delineate regional geologic potential susceptibility areas based on the general properties of geologic materials contained in glacial deposits from existing data. We will attach the water well log data base (1989-91) to the ARC/INFO coverage of water well locations. Through the use of ARC/INFO GIS analysis, potential geologic susceptibility maps will be developed for individual bedrock aquifers in South Central Minnesota.

A.2.a. Context within the project: ARC/INFO analysis will be used to delineate areas of coupling between surface and subsurface conditions which potentially affect groundwater susceptibility to surface contamination. The potential susceptibility maps will be constructed to address the variability of geologic settings throughout South Central Minnesota. These potential susceptibility maps will assist in determining benchmarks and in developing regional priorities for natural resources in South Central Minnesota.

A.2.b. Methods: The water well log data base, completed 1989-91, will be converted into ARC/INFO data files and attached to the ARC/INFO point coverage of water well locations developed in Activity A.1. Important stratigraphic data contained in engineering logs and geologic logs will be acquired from the Minnesota Geological Survey and incorporated into the water well log data base. The geologic portion of the water well log data base will be used to assess the presence and extent of high, low, and very low permeability units within the glacial deposits. This assessment will be used to construct an isometric map coverage of the general permeability for glacial deposits. A level of confidence (uncertainty) of the geologic potential susceptibility process will be determined for the 13 county region through analysis of the density and quality of the data points used to generate the map. The level of confidence will vary throughout the study area and be presented on an isometric map coverage in ARC/INFO. The general permeability map coverage for glacial deposits will be overlain and adjusted to fit the Depth to Bedrock map coverage (Activity A.1.) resulting in a potential susceptibility coverage that combines drift thickness with general permeability of the glacial deposits.

The geologic potential susceptibility assessment of individual bedrock aquifers will include the geologic map coverages developed in Activity A.1. and the general permeability assessment developed for overlying glacial deposits as GIS coverages. The geologic potential susceptibility assessment of each bedrock aquifer will include the structural and spatial relationship with overlying bedrock units and variables such as aquifer media, depth to aquifer, and impervious bedrock surfaces. Additional ARC/INFO coverages such as aquifer use characteristics, pumping rates, and general direction of groundwater flow, will be added to the GIS. Various combinations of the above coverages will be overlain, using ARC/INFO, to produce regional potential susceptibility maps. Available water quality data will be used to evaluate the potential susceptibility process.

A.2.c. Materials: Materials to be used include ARC/INFO coverages from Activity A.1., the South Central Minnesota Well Log Database (1989-91), the Minnesota Geological Survey County Well Index, and available water quality data. Equipment in place includes GIS system listed in activity A.1. and a Calcomp plotter. Other necessary equipment will include a laser writer printer.

A.2.d. Budget: $103,700
Balance $0

A.2.e. Timeline: 7/93 1/94 6/94 1/95 6/95

Convert water well log data base into ARC/INFO **********

Enter additional geologic data into ARC/INFO **********

Develop general permeability coverages for glacial deposits **********

Develop geologic potential susceptibility coverages **********

Analyze the susceptibility model **********

Produce geologic potential susceptibility maps **********

A. Status: This investigation has emphasized the study and definition of confining zones within the glacial drift for the 13 county region in south central Minnesota. A method of quantitative hydrogeologic mapping using ARC/INFO GIS, which resulted in an analysis of the geologic sensitivity for the glacial drift of the 13 county region, was demonstrated.

Three general hydrologic classes of geologic materials that have comparable hydrologic properties are distinguishable from the geologic portion of water well drillers' log records. Geologic materials with confining characteristics, permeable characteristics, and mixed permeable and confining characteristics were distinguished.

Most drillers' logs are of sufficient accuracy to warrant their use for preliminary analysis when more sophisticated data are not available or cannot be obtained due to budget limitations. The geologic data of water well driller logs are usually consistent when generalized geologic interpretations of drillers terminology is used to characterize the hydrogeologic properties of the geologic materials recorded in each log. Despite the variations in drillers' lithologic descriptions, this information is useful.

Hydrologic parameters were used to illustrate the hydraulic character of geologic material between the surface and an underlying aquifer. The distribution of confining materials within the glacial drift is expressed as products of depth, thickness, and areal variation.

One of three hydrologic class were assigned to each thickness interval recorded in water well driller logs; confining, permeable, or mixed. The hydrologic classes were used to characterize the hydrologic properties of geologic materials for each 10 foot thickness interval and an hydraulic conductivity rating was assigned to each 10-foot thickness interval based upon these properties. A series of nine 50-foot depth interval coverages, ranging from 0-50 feet to 400-450 feet, were constructed by combining the 10 foot thickness intervals into corresponding 50-foot depth interval.

All 50 foot depth interval coverages and their parameters were combined into one coverage for the entire glacial drift sequence. The depth to bedrock polygon coverage was used to control the union of 50 foot depth intervals into this final coverage. The final coverage contains the depth, thickness, and hydraulic character of geologic materials for each 10-foot thickness interval and can be used to produce many possible combinations of high to low sensitivity ratings.

Areas of high sensitivity may not represent the hydrologic character of geologic materials for the entire drift sequence. Water well drilling will stop when an adequate water supply is encountered and, therefore, geologic information for deeper sediments is not available for those well points. In areas where the drift deposits are thick and aquifer use is shallow, the AML program considered the unpenetrated drift interval devoid of material being mapped. Thus, areas of high geologic sensitivity in regions of thick drift deposits may indicate shallow aquifer use from the glacial drift.

The level of confidence coverage is a representation of the uneven distribution and density of available well driller data. The level of confidence coverage can be used to establish confidence levels for specific areas on the geologic sensitivity coverage. In a period of budget limitations and time restrictions, the level of confidence coverage may be used as a guide to prioritize the location of new water well driller logs in areas where data is sparse.

The quantitative methods utilizing ARC/INFO GIS illustrate how existing water well driller data can be developed for a geologic sensitivity analysis. These methods were chosen as one way to define the three-dimensional configuration of confining materials in an economical and expedient manner. The use of ARC/INFO GIS AML provides a tool for quickly updating geologic sensitivity assessments as new data becomes available and may be used to produce many possible combinations for sensitivity ratings.

The three bedrock units that combine to form the Cedar Valley-Maquoketa-Galena aquifer system are present in the eastern and southeastern portions of the 13 county region where they directly underlie the glacial drift. No bedrock of low permeability separate the aquifer system from the overlying glacial drift. For this reason, the geologic sensitivity assessment of the glacial drift is applied to the Cedar Valley-Maquoketa-Galena aquifer system without modification.

The St. Peter-Prairie du Chien-Jordan aquifer system is present throughout the eastern half of the 13 county region. These three bedrock units function as a single aquifer system because all three are sources of groundwater with no regional confining bed separating them. The St. Peter-Prairie du Chien-Jordan aquifer system is overlain by the Decorah shale in the eastern and southeastern portions of the 13 county region. The Decorah shale is a bedrock formation with confining characteristics and presents a barrier to the movement of groundwater. In areas where the Decorah shale has been removed by erosion the St. Peter, Prairie du Chien, and Jordan bedrock units directly underlie the glacial drift and form the bedrock surface.

The geologic sensitivity coverage for the St. Peter-Prairie du Chien-Jordan aquifer system was constructed by selecting the area containing these three bedrock units from the bedrock geology coverage and using it to clip the area

from the geologic sensitivity assessment of the glacial drift coverage. The areal distribution and thickness characteristics of the Decorah shale was used to modify the geologic sensitivity assessment of glacial drift in areas where the Decorah is present.

The Franconia-Ironton-Galesville aquifer system is present throughout the eastern half of the 13 county region. These three bedrock units function as a single aquifer system because all three are sources of groundwater with no regional confining bed separating them. The Franconia-Ironton-Galesville aquifer system is overlain by the St. Lawrence siltstone throughout most of the eastern half of the 13 county region. The St. Lawrence siltstone is a bedrock formation with confining characteristics and presents a barrier to the movement of groundwater. In areas where the St. Lawrence has been removed by erosion the Franconia and Ironton-Galesville bedrock units directly underlie the glacial drift and form the bedrock surface.

The geologic sensitivity coverage for the Franconia-Ironton-Galesville aquifer system was constructed by selecting the area containing these three bedrock units from the bedrock geology coverage and using it to clip the area from the geologic sensitivity assessment of the glacial drift coverage. The areal distribution and thickness characteristics of the St. Lawrence was used to modify the geologic sensitivity assessment of glacial drift in areas where the St. Lawrence is present.

Details of the methodology and procedures developed for this project, along with GIS plates showing results , are seen in the accompanying report titled: The South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS). 136 pp. + vi. + 10 plates, June 1995 (attached).

B. Title of Objective: Identify susceptible areas that may be at risk due to projected increases in population density, changes in aquifer use characteristics and changes in surface hydrology.

B.1. Activity: Identify additional surface areas that contribute surface water flow to, through and from the geologic potential susceptibility areas defined in Activity A.2.

B.1.a. Context within the project: To redefine the potential geologic susceptible areas based upon a combination of the potential geologic susceptibility (Activity A.2.) and its relationship to surface hydrology (LCMR 91-93). To include all areas (minor watershed, lakeshed, and ditchshed (LCMR 91-93)) that contribute surface water flow into potential geologic susceptible areas, and the nature of surface water movement to, through and from potential geologic susceptible areas by way of river, stream, county open ditch, and county tile ditch (LCMR 91-93). This is critical in determining the surface areas that may impact a potential geologic susceptible area.

B.1.b. Methods: Potential geologic susceptibility map coverages (Activity A.2.), National Wetlands Inventory, and surface hydrology map coverages (LCMR 91-93) which include minor watershed, lakeshed, ditchshed, county open ditch, and county tile ditch lines will be overlain to generate a potential surface source area coverage in ARC/INFO. These coverages will extend potential geologic susceptible areas to include minor watershed and subshed areas that

channel water to, through and from the related potential geologic susceptible area. Surface water storage areas will be identified by NWI and the nature of surface water movement will be defined by natural waterways, county open ditches, and county tile ditches (LCMR 91-93).

B.1.c. Materials: The materials include ARC/INFO coverages generated by Objective A., surface hydrology ARC/INFO coverages (1991-93), and NWI coverages. Existing equipment includes computer hardware and software as described in Activity A.1.c.

B.1.d. Budget: $20,300
Balance $0

B.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Potential surface source coverage			**********		

B.2. Activity: Hold multi-county workshops to train county water planning technical personnel on the use and interpretation of the South Central Minnesota Atlases, GIS and data bases, and to assist counties in setting regional priorities and determining benchmarks.

B.2.a. Context Within the Project: To provide a forum for counties to be informed active participants in the setting of priorities for groundwater protection based on reasonable and reliable benchmarks.

B.2.b. Methods: Two sets of workshops will be held to inform and train county personnel. The first set of workshops to be held in 1994 will train county personnel in the use of existing data: geologic atlases (89-91), surface hydrology atlases (91-93), and computer regional data bases (89-93). The second set of workshops, to be held in 1995, will train the county personnel in the use of the potential geologic susceptibility maps developed in Objective A, the potential surface source maps developed in Objective B, and the groundwater quality coverage in Objective C. County water planners and Water Resources Center staff will then set reasonable priorities and establish benchmarks for the 13 county region of South Central Minnesota.

B.2.c. Materials: Geologic Atlases and Data Base (1989-91), Surface Water Atlases, GIS and Data Base (1991-93), GIS coverages generated from Objective A, Activity B.1., and Objective C, will be used for this activity. The GIS system for analysis is in place as described in Activity A.1. IBM Corporation is providing Mankato State University with an off campus technology exchange training center (AS/400), 12 work stations, conference room, networking, etc.) and this center will be used for some of these workshops.

B.2.d. Budget: $20,300
Balance $0

B.2.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
First workshops		**********			
Second Workshops					****

B. Status: In the 13 county region, potential areas of rapid recharge to the groundwater will be high geologic sensitive areas where the geologic materials have high hydraulic conductivities or in areas where glacial drift is thin and overlies a bedrock aquifer or absent and a bedrock aquifer is exposed at the surface. The high geologic sensitivity areas define regions of high hydraulic conductivity. Water within a high geologic sensitive area represents water that is available for potential rapid recharge of an underlying aquifer or aquifer system. Water becomes available for rapid groundwater recharge as it enters a geologic sensitive area. Generally sources for recharge may be precipitation, overland flow, stream flow, or subsurface flow.

Land area that contributes surface runoff to a common downstream outlet are delineated as watersheds. In Minnesota, a hierarchical system of minor watersheds are connected by surface flow which define major river watersheds. Surface areas which contribute runoff to a region are identified by determining the drainage network upstream and corresponding minor watersheds. Any surface flow which enters a geologic sensitive areas is potential recharge for that area. The minor watersheds providing surface runoff to the surface flow are identified as contributing potential surface source areas. Complete methodology for determining potential surface source areas is contained in Appendix F. Contributing surface source areas for geologic sensitive regions are shown in PLATE IX and PLATE X.

The relationship of the contributing surface source areas to the geologic sensitive areas show an extended region of sensitivity based on the potential for surface flow to recharge groundwater.

Introduction

The 13 counties of south central Minnesota have ARCVIEW GIS systems in place and are presently using ARC/INFO GIS data provided by the MSU Water Resources Center. Data generated by this study will be provided to the 13 counties for use in ARCVIEW.

Thirteen individual county workshops were held in the spring of 1994 for the water planners, and county commissioners. Also in attendance were sheriff's departments (911 and emergency preparedness), county data personnel, regional and state agency personnel, SCS, SWCD, County Water Planning Advisory Committee members and Extension personnel. The 1994 workshops dealt with training on the uses, both hard copy and electronic, of the geologic and surface water hydrology atlases and data bases. The surface hydrology ARC/INFO coverages have been prepared for each individual county and downloaded on the county PC computers for use with ARC View.

Two workshops were held in June, 1995, for the water planners of the 13 counties of South Central Minnesota. Also participating were agency representatives from MDNR - Waters (St. Paul & local), BWSR and MGS. The purpose of the workshop was to introduce the water planners to the newly developed regional groundwater susceptibility methodology and results, and based on these results to set goals and benchmarks for groundwater protection. Results of the goals/benchmarks discussion are summarized below and will be included in the 13 county water plan updates.

Goals

A. Regional Groundwater Susceptibility

1. A goal of the 13 counties will be to complete the MDNR Level I (soils based) assessment for all 13 counties. The MDNR will provide the soil rating tables and the MSU Water Resources Center will put them into the ARC/INFO soils layer being developed during 95-97. We will be comparing the results of the Level I methodology to our methodology. It should be noted that the University of Minnesota Geology and Geophysics Department has compared MDNR Level I to Level III and found that Level I achieved 80 percent of Level III.

2. A goal of the 13 counties will be to request and encourage the MDNR to do a regional quaternary mapping study of our 13 counties. This mapping project develops aggregate patterns based on land forms and would help in the interpretation of our findings. Portions of two of our western counties are already being mapped.

B. Water Well Data

1. A goal of the 13 counties will be to update the private and public well data which will help increase our confidence levels in the susceptibility mapping. The lack of confidence, as we have defined confidence, is based on limited data points. The 13 county data base, and by pedigree the MGS County Well Index (CWI), has the wells up to 1990. However, wells since 1990 have not been located. MGS has informed the 13 counties that only limited stratigraphic and water quality data will be in the new MGS water well data base (Fox Pro). Our goal is to be a regional pilot group for locating and for data entry on all added wells. We feel we cannot wait for the state.

2. A goal of the 13 counties is to get all municipal water supply wells located so that we can greatly increase our urban water quality data base. We encourage municipalities and the state to test not only the water at the point of entry to public water supply, but also the source aquifers at the same time. This would create an aquifer water quality data base over time which is lacking at present.

Benchmarks

The 13 counties being predominantly rural realize that there is a limit as to the number of wells per section that will ever be available for utilization in our methodology. However, by adding the wells from 1990 to present and by developing a process to continue this into the future, we should be able to greatly increase our confidence. The confidence map developed in this project becomes a benchmark in time and our goal is to decrease the amount of red (lowest confidence) as shown in PLATE V.

Limitations Of Methodology

Two major concerns were identified by the 13 county water planners with this methodology for quantifying susceptibility.

1. Some of the areas which show low sensitivity are critical in that although there is sufficient clay stratigraphy or aquitards to protect them they are the only source of groundwater in that region. There is no alternative deeper source. These areas deserve additional concern and protection.

2. In the western part of the 13 counties many areas are turning to rural water suppliers rather than drilling deeper. Research is needed as to just how many deep wells are going in and what the key decision parameters are or should be in determining further drilling or use of rural water supply systems.

Details of the methodology and procedures developed for this project, along with GIS plates showing results , are seen in the accompanying report titled: The South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS). 136 pp. + vi. + 10 plates, June 1995 (attached).

C. Title of Objective: Incorporate municipal water quality data into the South Central Minnesota Groundwater Data Base.

C.1. Activity: Inventory and match available municipal water quality data to water well data base (1989-91) and individual aquifers.

C.1.a. Context with the project: Municipal water quality data matched to individual aquifers will indicate aquifer water quality and will provide a method to identify contaminants within the aquifer. The ARC/INFO water quality data coverages will be used in Activity B.2. to assist in setting benchmarks and regional priorities. This will provide a base for future groundwater quality monitoring and allow trend analysis of groundwater contamination in South Central Minnesota.

C.1.b. Methods: Water quality data will be acquired from the Minnesota Department of Health. and entered into the water well data base. The Minnesota Department of Health municipal water well records with water quality data prior to 1989 are on file at the Water Resources Center and will be added to the water well data base. More recent municipal water quality well data will be obtained from MDH and also added to the data base. The water quality water well data will be converted into ARC/INFO and attached to the water well location coverage (Activity A.1.) The water quality of each aquifer will be identified by using ARC/INFO analysis resulting in water quality coverages for individual aquifers. Water quality coverages will indicate the levels of chemical and biological contamination and will allow trend analysis of contaminants if historic water quality data is available. The water quality coverages will become more accurate as water quality monitoring continues and future data becomes available.

C.1.c. Materials: Materials include Minnesota Department of Health municipal water well records prior to 1989 which have been collected by the Water Resources Center, and Minnesota Department of Health municipal water well records since 1989. The GIS that is in place is described in Activity A.1.

C.1.d. Budget: $37,700
Balance $0

C.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Collect and enter water quality data	**********	**********	**********		
Convert to ARC/INFO		**********	**********		
Create water quality coverages			**********	**********	

C. Status: The municipal well water quality records contained varying amounts of data and information. Many of the records entered into the municipal well data base had a sample date but no water quality data. The ability to analyze data is limited by the availability of measurable water quality results and the number of located municipal water wells. The ability to compare data and predict trends are limited by changes in quantitative methodology and detection limits of the water quality parameters.

The available municipal water quality data was not adequate to evaluate the water quality of the aquifer systems in south central Minnesota. At the present, well monitoring is not required by the SDWA regulations; rather testing is required at the 'point of entry' to the public water supply system which is generally after treatment and may consist of blended water from two or more wells.

Details of the methodology and procedures developed for this project, along with GIS plates showing results , are seen in the accompanying report titled: The South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS). 136 pp. + vi. + 10 plates, June 1995 (attached).

V. Evaluation: This project can be evaluated by its ability to: 1.) Identify regions of geologic potential susceptibility for individual aquifers to surface contaminants utilizing existing data. 2.) Determine benchmarks and regional priorities for natural resources in South Central Minnesota, and 3.) Utilize municipal water well quality data to both establish trends in water quality and to establish a relationship between groundwater quality and our potential susceptibility determination.

In the long term, the project should be evaluated by the ability to introduce new data into the GIS and update susceptibility assessments; for example to develop and implement land management practices designed to improve the groundwater quality, and the ability to determine if management practices are having an affect on the quality of groundwater over time.

VI. Context within field: This project will integrate the work produced by two previous LCMR projects, developed at the Water Resources Center, Mankato State University, over several years: The South Central Minnesota County Groundwater Atlases and Data Base (1989-91) and the South Central Minnesota Surface Water Hydrology Atlases and Data Base (1991-93). The project will provide regional potential geologic susceptibility assessments.

To date groundwater susceptibility mapping does not address the influence of surface hydrology but rather looks at susceptibility strictly from a vertical perspective (geologic column). This study is unique in that it considers expanding the concept of regional susceptibility to include those areas which contribute drainage to a susceptible area.

VII. Benefits: The South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS) will generate an alternative regional groundwater susceptibility methodology. The susceptibility assessment methods will explore a relationship between groundwater quality and the horizontal movement of surficial water to and from potential geologic susceptible areas. In South Central Minnesota, county and judicial ditch and tile systems, developed during the last 100 years, have had a dramatic impact on surface water movement. This project has the advantage of utilizing ARC/INFO GIS coverages for both hydrogeology and surface hydrology to determine the total potential surface area that contributes water to potential geologic susceptible areas.

This research project will benefit each of the 13 county water planning committees as well as the natural resources and planning agencies of the State of Minnesota. The results of this project will provide essential and needed insight for developing comprehensive county water plan annual updates as well as providing a first step in developing a methodology for the State of Minnesota to combine hydrogeology and surface hydrology into a meaningful and holistic groundwater susceptibility assessment. It will provide a means by which we can develop reasonable and achievable county and regional benchmarks and priorities in a cost effective way.

The data collected 1991-1993 and its conversion to ARC/INFO 1993-1994 has been requested by the US Fish &Wildlife Service & US Geological Survey and sent, in both hard and electronic format, to Vice President Al Gore's Mississippi River Flood Plain select team in Sioux Falls, South Dakota.

VIII. Dissemination: Results from this project will be presented to multi-county workshops utilizing Mankato State University's new Technology Exchange Center. These workshops will be geared for county water planners as well as regional and state agency personnel. Most important is that these workshops will not only inform and train county water planners in the use of susceptibility maps but will also provide the opportunity for county personnel and Water Resources Center staff to work closely together to develop reasonable priorities and establish benchmarks.

Documentation of the methodologies developed for this research project will be distributed to local, state, and national water planners. ARC/INFO GIS data will be provided to the Minnesota land management information center's geographic data bases. Data will be made available to the MDNR, USGS, MDOH, MGS and MPCA through LMIC.

IX. Time: To be completed in two years (1993-95).

X. Cooperation:

1. John Rongstad and Cis Berg
   Staff, Cartography and GIS, M.S.U. Water Resources Center. These two staff members of Mankato State University's Water Resources Center have had extensive experience during the past four years developing the 13 county geologic atlases and the 13 county surface hydrology atlases. They will be involved in all three objectives full time.

2. The 13 counties of South Central Minnesota County Comprehensive Water Planning Project Joint Powers. The South Central Minnesota Groundwater Contamination Susceptibility Project has a resolution of support passed by our Joint Powers Board ($91,000). The 13 county water planning technical committee will be active participants in Objective B and were instrumental in proposal development..

3. Mankato State University and IBM Corporation.
   The new M.S.U. Technology Exchange Center with start up funding and computer networking provided by I.B.M. and M.S.U. will provide the ideal environment for dissemination (Objective B) as well as an interactive forum for the counties/state and the Water Resources Center project..

XI. Reporting Requirements: Semiannual status reports will be submitted not later than January 1, 1994; July 1, 1994; January 1, 1995; and a final status report by June 30, 1995.

XII. Literature Cited:

Aller, L., T. Bennett, J.H. Leher, and R.J. Petty. 1985. DRASTIC: A Standardized System for Evaluating Groundwater Pollution Using Hydrogeologic Settings: U.S. Environmental Protection Agency/600/2-85/018, 163 pp.

Geier, Theodore W., and James A. Perry. 1992. Guide to Groundwater Sensitivity Rating Techniques: Minnesota Water Resources Research Center Special Report No. 22. University of Minnesota, St. Paul, MN. 87 pp.

Minnesota Department of Natural Resources. 1991. Criteria and Guidelines for Assessing Geologic Sensitivity of Groundwater Resources in Minnesota. Division of Waters. 122 pp.

Porcher, Eric. 1988. Groundwater Contaminaton Susceptibility in Minnesota: Minnesota Pollution Control Agency. 31 pp.

Setterholm, Dale R., et. al. 1991. Geologic Factors Affecting the Sensitivity of the Prairie Du Chien - Jordan Aquifer. Open-file Report 91-5. Minnesota Geological Survey. 29 pp.

Literature Review

Geier and Perry (1992) report in The Guide to Groundwater Sensitivity Rating Techniques that large scale sensitivity ranking methods such as DRASTIC (1985) and Minnesota Sensitivity Rating Method (1991) are well suited for GIS applications. The relationship of aquifer sensitivity to the nature and thickness of geologic materials which overlie the aquifer is examined by Setterholm, et. al. (1991). The study involves the use of GIS to create maps from goelogical data for further use in sensitivity assessments.

The DRASTIC (1985) methodology uses existing hydrogeologic, soil, and topographic data to produce a relative ranking of geologic sensitivity among geographic areas. The weighted index requires seven hydrogeologic factors and incorporates agricultural and non-agricultural land use into the rating system. Modifications of DRASTIC may be appropriate for evaluating geologic sensitivity.

The Minnesota Sensitivity Rating Method (1991) evaluates geologic sensitivity by assessing the properties of sediments overlying groundwater. Groundwater susceptibility is based on the vertical permeability of the geologic materials. Lateral movement of groundwater, contaminant properties, and land use information are not included in this methodology.

1993 Project Abstract
FOR THE PERIOD ENDING JUNE 30, 1995
This project supported by MN Future Resources Fund

Title:	South Central Minnesota Groundwater Contamination Susceptibility - Continuation
Program Manager:	Henry W. Quade
Organization:	Mankato State University Water Resources Center
Legal Citation:	M.L. 93, Chpt. 172, Sect. 14, Subd. 11e
Approp. Amount	$290,000

STATEMENT OF OBJECTIVES

To develop regional groundwater potential susceptibility GIS coverages for South Central Minnesota utilizing existing data. This includes developing both an appropriate methodology for determining the susceptibility and for determining the level of confidence.

To incorporate municipal well water data into a data base and determine its value as a tool for aquifer water quality long term trend analysis.

RESULTS

The qualitative methods utilizing ARC/INFO GIS illustrate how existing water well driller data can be developed for a geologic sensitivity analysis. These methods were chosen as one way to define the three-dimensional configuration of confining materials in an economical and expedient manner. The use of ARC/INFO GIS AML provides a tool for quickly updating geologic sensitivity assessments as new data becomes available and may be used to produce many possible combinations for sensitivity ratings.

The level of confidence coverage is a representation of the uneven distribution and density of available well driller data. The level of confidence coverage can be used to establish confidence levels for specific areas on the geologic sensitivity coverage. In a period of budget limitations and time restrictions, the level of confidence coverage may be used as a guide to prioritize the location of new water well driller logs in areas where data is sparse.

The available municipal water quality data was not adequate to evaluate the water quality of the aquifer systems in south central Minnesota. At present, well monitoring is not required by the SDWA and MDH regulations; rather testing is required at the 'point of entry' to the public water supply system which is generally after treatment and may consist of blended water from two or more wells.

PROJECT RESULTS, USE AND DISSEMINATION

Results of this project have been presented at two series of workshops, fifteen in total, during the project period. The final workshops included round table discussion, and goals and benchmarks have been established for county work plans. The final report has been disseminated to state and federal agencies for review and comment.

July 1, 1995

LCMR Final Report - Summary - Research

I. Project Title: W4-3 THE SOUTH CENTRAL MINNESOTA GROUNDWATER CONTAMINATION SUSCEPTIBILITY PROJECT - CONTINUATION
(A Regional Integration of Existing Data Utilizing GIS)

Program Manager:	Henry W. Quade
Agency Affiliation:	Mankato State University
Address:	Water Resources Center Box 70
	M.S.U. Box 8400
	Mankato, MN 56002-8400
Phone:	(507)389-5492

A. Legal Citation: ML 93 Chpt. 172, Sect, 14, Subd. 11e

Total Biennial LCMR Budget: $290,000
Balance: 7/1/95 - $0

Appropriation Language as drafted 7/27/92: Subd. 11(e). This appropriation is from the future resources fund to the commissioner of natural resources for a contract with Mankato State University to couple surface hydrology, subsurface geology, and hydrogeology for environmental analysis to assess present environment conditions, establish benchmarks and develop regional priorities for South Central Minnesota.

B. LMIC Compatible Data Language: During the biennium ending June 30, 1995, the data collected by the projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted by the information policy office. Data review committees may be established to develop or comment on plans for data integration and distribution and shall submit semiannual status reports to the legislative commission on Minnesota resources on their findings. In addition, the data must be provided to and integrated with the Minnesota Land Management Information Center's geographic data bases with the integration costs borne by the activity receiving funding under this section.

II. Project Summary: The 13 counties of South Central Minnesota lie in an area that contains a great diversity of subsurface geologic environments from sedimentary bedrock units of the Hollandale Embayment in the east to the igneous and metamorphic bedrock of the Transcontinental Arch in the west. The overall goal of the South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS) is to develop a Geographic Information System (GIS) to generate integrated assessments for regions with vastly different environmental parameters based on subsurface geologic patterns, surface drainage and water quality. The resulting GIS analysis will be a tool that will help enable the counties to set reasonable goals and develop regional priorities for natural resources management in South Central Minnesota.

III. Statement of Objectives:

A. Develop regional potential geologic susceptibility GIS coverages.

B. Identify susceptible areas that may be at risk due to projected increases in population density, changes in aquifer use characteristics and changes in surface hydrology.

C. Incorporate municipal water quality data into the South Central Minnesota Groundwater Data Base.

IV. Research Objectives

A. Title of Objective: Develop Regional Geologic Potential Susceptibility GIS Coverages.

A.1. Activity: The point location for water wells and the geologic maps that were completed 1989-91 will be digitized using AutoCAD and converted into ARC/INFO coverages. The geologic maps include Bedrock Topography, Depth to Bedrock, Bedrock Structure, and Bedrock Geology for each of the 13 counties of South Central Minnesota. The geologic maps will be manipulated in ARC/INFO to produce regional cartographic GIS coverages for bedrock units that underlie South Central Minnesota.

A.1.a. Context within the project: The point digitized location for water wells will provide a base within ARC/INFO to which the water well log data base (1989-91) can be attached and used for GIS analysis. ARC/INFO coverages of the geologic maps will provide a means by which the geologic and hydrogeologic nature of the bedrock units, their areal distribution, orientation, and proximity to the land surface environment can be presented for evaluation in ARC/INFO GIS. The cartographic coverages for individual bedrock units will be essential to relate bedrock groundwater aquifers to surface hydrology.

A.1.b. Methods: The point location for water wells that correspond to water well driller's logs, located 1989-91 on to USGS 7.5 minute quadrangle maps, will be digitized using AutoCAD following USGS methodology. This has not been done by the Minnesota Geological Survey (MGS). The AutoCAD file will be converted to DXF format and then converted to ARC/INFO GIS coverages that will be compatible with MGS. Digitized point locations for water well logs, engineering logs, and other geologic logs will be acquired from the MGS.and incorporated into the ARC/INFO GIS coverage.

More than 90 county based geologic maps that were completed (1989-91) were originally constructed at 1:62,500 scale. These maps will be digitized following USGS methodology using AutoCAD. Each map will be digitized into a separate AutoCAD layer, converted to DXF format, and then converted into ARC/INFO GIS coverages.

Individual ARC/INFO coverages will be created for each major bedrock unit that underlies South Central Minnesota. Each coverage will combine data contained in the ARC/INFO coverages created for the Bedrock Geology, Bedrock Topography, and Bedrock Structure maps. Individual bedrock structure maps that were constructed for key bedrock units (1989-91) will be modified, using average thickness data, to create structural coverages to fit the remaining bedrock units. Each coverage will include four parameters to describe the areal extent and physical orientation of an individual bedrock unit:

A.1.c. Materials: Data contained on the geologic maps prepared during 1989-91 will be used to construct digital maps for use in ARC/INFO GIS analysis. Equipment in place includes a SUN SPARCstation 2GX, SUN SPARCstation IPC, Calcomp digitizing table, AutoCAD software and ARC/INFO software. Equipment needed includes a SUN SPARCstation 2GX workstation with AutoCAD and ARC/INFO expanded to multi users licensing, digitizer tablet and optical disk storage.

A.1.d. Budget: $108,000
Balance: $0

A.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Digitize water well locations	**********				
Prepare maps for digitizing	**********	**********			
Digitize maps using AutoCAD & convert into ARC/INFO		**********	**********		
Create ARC/INFO coverages for regional bedrock units			**********	**********	**********

A.2. Activity: We will delineate regional geologic potential susceptibility areas based on the general properties of geologic materials contained in glacial deposits from existing data. We will attach the water well log data base (1989-91) to the ARC/INFO coverage of water well locations. Through the use of ARC/INFO GIS analysis, potential geologic susceptibility maps will be developed for individual bedrock aquifers in South Central Minnesota.

A.2.a. Context within the project: ARC/INFO analysis will be used to delineate areas of coupling between surface and subsurface conditions which potentially affect groundwater susceptibility to surface contamination. The potential susceptibility maps will be constructed to address the variability of geologic settings throughout South Central Minnesota. These potential susceptibility maps will assist in determining benchmarks and in developing regional priorities for natural resources in South Central Minnesota.

A.2.b. Methods: The water well log data base, completed 1989-91, will be converted into ARC/INFO data files and attached to the ARC/INFO point coverage of water well locations developed in Activity A.1. Important stratigraphic data contained in engineering logs and geologic logs will be acquired from the Minnesota Geological Survey and incorporated into the water well log data base. The geologic portion of the water well log data base will be used to assess the presence and extent of high, low, and very low permeability units within the glacial deposits. This assessment will be used to construct an isometric map coverage of the general permeability for glacial deposits. A level of confidence (uncertainty) of the geologic potential susceptibility process will be determined for the 13 county region through analysis of the density and quality of the data points used to generate the map. The level of confidence will vary throughout the study area and be presented on an isometric map coverage in ARC/INFO. The general permeability map coverage for glacial deposits will be overlain and adjusted to fit the Depth to Bedrock map coverage (Activity A.1.) resulting in a potential susceptibility coverage that combines drift thickness with general permeability of the glacial deposits.

A.2.c. Materials: Materials to be used include ARC/INFO coverages from Activity A.1., the South Central Minnesota Well Log Database (1989-91), the Minnesota Geological Survey County Well Index, and available water quality data. Equipment in place includes GIS system listed in activity A.1. and a Calcomp plotter. Other necessary equipment will include a laser writer printer.

A.2.d. Budget: $103,700
Balance $0

A.2.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Convert water well log data base into ARC/INFO	**********	**********			
Enter additional geologic data into ARC/INFO		**********	**********		
Develop general permeability coverages for glacial deposits	**********	**********			
Develop geologic potential susceptibility coverages			**********	**********	
Analyze the susceptibility model				**********	**********
Produce geologic potential susceptibility maps					**********

A. Status: This investigation has emphasized the study and definition of confining zones within the glacial drift for the 13 county region in south central Minnesota. A method of quantitative hydrogeologic mapping using ARC/INFO GIS, which resulted in an analysis of the geologic sensitivity for the glacial drift of the 13 county region, was demonstrated.

Three general hydrologic classes of geologic materials that have comparable hydrologic properties are distinguishable from the geologic portion of water well drillers' log records. Geologic materials with confining characteristics, permeable characteristics, and mixed permeable and confining characteristics were distinguished.

Most drillers' logs are of sufficient accuracy to warrant their use for preliminary analysis when more sophisticated data are not available or cannot be obtained due to budget limitations. The geologic data of water well driller logs are usually consistent when generalized geologic interpretations of drillers terminology is used to characterize the hydrogeologic properties of the geologic materials recorded in each log. Despite the variations in drillers' lithologic descriptions, this information is useful.

Hydrologic parameters were used to illustrate the hydraulic character of geologic material between the surface and an underlying aquifer. The distribution of confining materials within the glacial drift is expressed as products of depth, thickness, and areal variation.

One of three hydrologic class were assigned to each thickness interval recorded in water well driller logs; confining, permeable, or mixed. The hydrologic classes were used to characterize the hydrologic properties of geologic materials for each 10 foot thickness interval and an hydraulic conductivity rating was assigned to each 10-foot thickness interval based upon these properties. A series of nine 50-foot depth interval coverages, ranging from 0-50 feet to 400-450 feet, were constructed by combining the 10 foot thickness intervals into corresponding 50-foot depth interval.

All 50 foot depth interval coverages and their parameters were combined into one coverage for the entire glacial drift sequence. The depth to bedrock polygon coverage was used to control the union of 50 foot depth intervals into this final coverage. The final coverage contains the depth, thickness, and hydraulic character of geologic materials for each 10-foot thickness intervals and can be used to produce many possible combinations of high to low sensitivity ratings.

Areas of high sensitivity may not represent the hydrologic character of geologic materials for the entire drift sequence. Water well drilling will stop when an adequate water supply is encountered and, therefore, geologic information for deeper sediments is not available for those well points. In areas where the drift deposits are thick and aquifer use is shallow, the AML program considered the unpenetrated drift interval devoid of material being mapped. Thus, areas of high geologic sensitivity in regions of thick drift deposits may indicate shallow aquifer use from the glacial drift.

The level of confidence coverage is a representation of the uneven distribution and density of available well driller data. The level of confidence coverage can be used to establish confidence levels for specific areas on the geologic sensitivity coverage. In a period of budget limitations and time restrictions, the level of confidence coverage may be used as a guide to prioritize the location of new water well driller logs in areas where data is sparse.

The quantitative methods utilizing ARC/INFO GIS illustrate how existing water well driller data can be developed for a geologic sensitivity analysis. These methods were chosen as one way to define the three-dimensional

configuration of confining materials in an economical and expedient manner. The use of ARC/INFO GIS AML provides a tool for quickly updating geologic sensitivity assessments as new data becomes available and may be used to produce many possible combinations for sensitivity ratings.

The three bedrock units that combine to form the Cedar Valley-Maquoketa-Galena aquifer system are present in the eastern and southeastern portions of the 13 county region where they directly underlie the glacial drift. No bedrock of low permeability separate the aquifer system from the overlying glacial drift. For this reason, the geologic sensitivity assessment of the glacial drift is applied to the Cedar Valley-Maquoketa-Galena aquifer system without modification.

The St. Peter-Prairie du Chien-Jordan aquifer system is present throughout the eastern half of the 13 county region. These three bedrock units function as a single aquifer system because all three are sources of groundwater with no regional confining bed separating them. The St. Peter-Prairie du Chien-Jordan aquifer system is overlain by the Decorah shale in the eastern and southeastern portions of the 13 county region. The Decorah shale is a bedrock formation with confining characteristics and presents a barrier to the movement of groundwater. In areas where the Decorah shale has been removed by erosion the St. Peter, Prairie du Chien, and Jordan bedrock units directly underlie the glacial drift and form the bedrock surface.

The geologic sensitivity coverage for the St. Peter-Prairie du Chien-Jordan aquifer system was constructed by selecting the area containing these three bedrock units from the bedrock geology coverage and using it to clip the area from the geologic sensitivity assessment of the glacial drift coverage. The areal distribution and thickness characteristics of the Decorah shale was used to modify the geologic sensitivity assessment of glacial drift in areas where the Decorah is present.

The Franconia-Ironton-Galesville aquifer system is present throughout the eastern half of the 13 county region. These three bedrock units function as a single aquifer system because all three are sources of groundwater with no regional confining bed separating them. The Franconia-Ironton-Galesville aquifer system is overlain by the St. Lawrence siltstone throughout most of the eastern half of the 13 county region. The St. Lawrence siltstone is a bedrock formation with confining characteristics and presents a barrier to the movement of groundwater. In areas where the St. Lawrence has been removed by erosion the Franconia and Ironton-Galesville bedrock units directly underlie the glacial drift and form the bedrock surface.

The geologic sensitivity coverage for the Franconia-Ironton-Galesville aquifer system was constructed by selecting the area containing these three bedrock units from the bedrock geology coverage and using it to clip the area from the geologic sensitivity assessment of the glacial drift coverage. The areal distribution and thickness characteristics of the St. Lawrence was used to modify the geologic sensitivity assessment of glacial drift in areas where the St. Lawrence is present.

Details of the methodology and procedures developed for this project, along with GIS plates showing results , are seen in the accompanying report titled: The South Central Minnesota Groundwater Contamination Susceptibility

Project - Continuation (A Regional Integration of Existing Data Utilizing GIS). 136 pp. + vi. + 10 plates, June 1995.

B. Title of Objective: Identify susceptible areas that may be at risk due to projected increases in population density, changes in aquifer use characteristics and changes in surface hydrology.

B.1. Activity: Identify additional surface areas that contribute surface water flow to, through and from the geologic potential susceptibility areas defined in Activity A.2.

B.1.a. Context within the project: To redefine the potential geologic susceptible areas based upon a combination of the potential geologic susceptibility (Activity A.2.) and its relationship to surface hydrology (LCMR 91-93). To include all areas (minor watershed, lakeshed, and ditchshed (LCMR 91-93)) that contribute surface water flow into potential geologic susceptible areas, and the nature of surface water movement to, through and from potential geologic susceptible areas by way of river, stream, county open ditch, and county tile ditch (LCMR 91-93). This is critical in determining the surface areas that may impact a potential geologic susceptible area.

B.1.b. Methods: Potential geologic susceptibility map coverages (Activity A.2.), National Wetlands Inventory, and surface hydrology map coverages (LCMR 91-93) which include minor watershed, lakeshed, ditchshed, county open ditch, and county tile ditch lines will be overlain to generate a potential surface source area coverage in ARC/INFO. These coverages will extend potential geologic susceptible areas to include minor watershed and subshed areas that channel water to, through and from the related potential geologic susceptible area. Surface water storage areas will be identified by NWI and the nature of surface water movement will be defined by natural waterways, county open ditches, and county tile ditches (LCMR 91-93).

B.1.c. Materials: The materials include ARC/INFO coverages generated by Objective A., surface hydrology ARC/INFO coverages (1991-93), and NWI coverages. Existing equipment includes computer hardware and software as described in Activity A.1.c.

B.1.d. Budget: $20,300
Balance $0

B.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Potential surface source coverage			**********		

B.2. Activity: Hold multi-county workshops to train county water planning technical personnel on the use and interpretation of the South Central Minnesota Atlases, GIS and data bases, and to assist counties in setting regional priorities and determining benchmarks.

B.2.a. Context Within the Project: To provide a forum for counties to be informed active participants in the setting of priorities for groundwater protection based on reasonable and reliable benchmarks.

B.2.b. Methods: Two sets of workshops will be held to inform and train county personnel. The first set of workshops to be held in 1994 will train county personnel in the use of existing data: geologic atlases (89-91), surface hydrology atlases (91-93), and computer regional data bases (89-93). The second set of workshops, to be held in 1995, will train the county personnel in the use of the potential geologic susceptibility maps developed in Objective A, the potential surface source maps developed in Objective B, and the groundwater quality coverage in Objective C. County water planners and Water Resources Center staff will then set reasonable priorities and establish benchmarks for the 13 county region of South Central Minnesota.

B.2.c. Materials: Geologic Atlases and Data Base (1989-91), Surface Water Atlases, GIS and Data Base (1991-93), GIS coverages generated from Objective A, Activity B.1., and Objective C, will be used for this activity. The GIS system for analysis is in place as described in Activity A.1. IBM Corporation is providing Mankato State University with an off campus technology exchange training center (AS/400), 12 work stations, conference room, networking, etc.) and this center will be used for some of these workshops.

B.2.d. Budget: $20,300
Balance $0

B.2.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
First workshops		**********			
Second Workshops					****

B. Status: In the 13 county region, potential areas of rapid recharge to the groundwater will be high geologic sensitive areas where the geologic materials have high hydraulic conductivities or in areas where glacial drift is thin and overlies a bedrock aquifer or absent and a bedrock aquifer is exposed at the surface. The high geologic sensitivity areas define regions of high hydraulic conductivity. Water within a high geologic sensitive area represents water that is available for potential rapid recharge of an underlying aquifer or aquifer system. Water becomes available for rapid groundwater recharge as it enters a geologic sensitive area. Generally sources for recharge may be precipitation, overland flow, stream flow, or subsurface flow.

Land area that contributes surface runoff to a common downstream outlet are delineated as watersheds. In Minnesota, a hierarchical system of minor watersheds are connected by surface flow which define major river watersheds. Surface areas which contribute runoff to a region are identified by determining the drainage network upstream and corresponding minor watersheds. Any surface flow which enters a geologic sensitive areas is potential recharge for that area. The minor watersheds providing surface runoff to the surface flow are identified as contributing potential surface source areas. Complete methodology for determining potential surface source areas is contained in Appendix F. Contributing surface source areas for geologic sensitive regions are shown in PLATE IX and PLATE X.

The relationship of the contributing surface source areas to the geologic sensitive areas show an extended region of sensitivity based on the potential for surface flow to recharge groundwater.

Introduction

The 13 counties of south central Minnesota have ARCVIEW GIS systems in place and are presently using ARC/INFO GIS data provided by the MSU Water Resources Center. Data generated by this study will be provided to the 13 counties for use in ARCVIEW.

Thirteen individual county workshops were held in the spring of 1994 for the water planners, and county commissioners. Also in attendance were sheriff's departments (911 and emergency preparedness), county data personnel, regional and state agency personnel, SCS, SWCD, County Water Planning Advisory Committee members and Extension personnel. The 1994 workshops dealt with training on the uses, both hard copy and electronic, of the geologic and surface water hydrology atlases and data bases. The surface hydrology ARC/INFO coverages have been prepared for each individual county and downloaded on the county PC computers for use with ARC View.

Two workshops were held in June, 1995, for the water planners of the 13 counties of South Central Minnesota. Also participating were agency representatives from MDNR - Waters (St. Paul & local), BWSR and MGS. The purpose of the workshop was to introduce the water planners to the newly developed regional groundwater susceptibility methodology and results, and based on these results to set goals and benchmarks for groundwater protection. Results of the goals/benchmarks discussion are summarized below and will be included in the 13 county water plan updates.

Goals

A. Regional Groundwater Susceptibility

1. A goal of the 13 counties will be to complete the MDNR Level I (soils based) assessment for all 13 counties. The MDNR will provide the soil rating tables and the MSU Water Resources Center will put them into the ARC/INFO soils layer being developed during 95-97. We will be comparing the results of the Level I methodology to our methodology. It should be noted that the University of Minnesota Geology and Geophysics Department has compared MDNR Level I to Level III and found that Level I achieved 80 percent of Level III.

2. A goal of the 13 counties will be to request and encourage the MDNR to do a regional quaternary mapping study of our 13 counties. This mapping project develops aggregate patterns based on land forms and would help in the interpretation of our findings. Portions of two of our western counties are already being mapped.

B. Water Well Data

1. A goal of the 13 counties will be to update the private and public well data which will help increase our confidence levels in the susceptibility mapping. The lack of confidence, as we have defined confidence, is based on limited data points. The 13 county data base, and by pedigree the MGS County Well Index (CWI), has the wells up to 1990. However, wells since 1990 have not been located. MGS has informed the 13 counties that only limited stratigraphic and water quality data will be in the new MGS water well data base (Fox Pro).

Our goal is to be a regional pilot group for locating and for data entry on all added wells. We feel we cannot wait for the state.

2. A goal of the 13 counties is to get all municipal water supply wells located so that we can greatly increase our urban water quality data base. We encourage municipalities and the state to test not only the water at the point of entry to public water supply, but also the source aquifers at the same time. This would create an aquifer water quality data base over time which is lacking at present.

Benchmarks

The 13 counties being predominantly rural realize that there is a limit as to the number of wells per section that will ever be available for utilization in our methodology. However, by adding the wells from 1990 to present and by developing a process to continue this into the future, we should be able to greatly increase our confidence. The confidence map developed in this project becomes a benchmark in time and our goal is to decrease the amount of red (lowest confidence) as shown in PLATE V.

Limitations Of Methodology

Two major concerns were identified by the 13 county water planners with this methodology for quantifying susceptibility.

1. Some of the areas which show low sensitivity are critical in that although there is sufficient clay stratigraphy or aquitards to protect them they are the only source of groundwater in that region. There is no alternative deeper source. These areas deserve additional concern and protection.

2. In the western part of the 13 counties many areas are turning to rural water suppliers rather than drilling deeper. Research is needed as to just how many deep wells are going in and what the key decision parameters are or should be in determining further drilling or use of rural water supply systems.

Details of the methodology and procedures developed for this project, along with GIS plates showing results , are seen in the accompanying report titled: The South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS). 136 pp. + vi. + 10 plates, June 1995.

C. **Title of Objective:** Incorporate municipal water quality data into the South Central Minnesota Groundwater Data Base.

C.1. Activity: Inventory and match available municipal water quality data to water well data base (1989-91) and individual aquifers.

C.1.a. Context with the project: Municipal water quality data matched to individual aquifers will indicate aquifer water quality and will provide a method to identify contaminants within the aquifer. The ARC/INFO water quality data coverages will be used in Activity B.2. to assist in setting benchmarks and regional priorities. This will provide a base for future groundwater quality monitoring and allow trend analysis of groundwater contamination in South Central Minnesota.

C.1.b. Methods: Water quality data will be acquired from the Minnesota Department of Health. and entered into the water well data base. The Minnesota Department of Health municipal water well records with water quality data prior to 1989 are on file at the Water Resources Center and will be added to the water well data base. More recent municipal water quality well data will be obtained from MDH and also added to the data base. The water quality water well data will be converted into ARC/INFO and attached to the water well location coverage (Activity A.1.) The water quality of each aquifer will be identified by using ARC/INFO analysis resulting in water quality coverages for individual aquifers. Water quality coverages will indicate the levels of chemical and biological contamination and will allow trend analysis of contaminants if historic water quality data is available. The water quality coverages will become more accurate as water quality monitoring continues and future data becomes available.

C.1.c. Materials: Materials include Minnesota Department of Health municipal water well records prior to 1989 which have been collected by the Water Resources Center, and Minnesota Department of Health municipal water well records since 1989. The GIS that is in place is described in Activity A.1.

C.1.d. Budget: $37,700
Balance $0

C.1.e. Timeline:

	7/93	1/94	6/94	1/95	6/95
Collect and enter water quality data	**********				
Convert to ARC/INFO		**********			
Create water quality coverages			**********		

C. Status: The municipal well water quality records contained varying amounts of data and information. Many of the records entered into the municipal well data base had a sample date but no water quality data. The ability to analyze data is limited by the availability of measurable water quality results and the number of located municipal water wells. The ability to compare data and predict trends are limited by changes in quantitative methodology and detection limits of the water quality parameters.

The available municipal water quality data was not adequate to evaluate the water quality of the aquifer systems in south central Minnesota. At the present, well monitoring is not required by the SDWA regulations; rather testing is required at the 'point of entry' to the public water supply system which is generally after treatment and may consist of blended water from two or more wells.

Details of the methodology and procedures developed for this project, along with GIS plates showing results , are seen in the accompanying report titled: The South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS). 136 pp. + vi. + 10 plates, June 1995.

V. Evaluation: This project can be evaluated by its ability to: 1.) Identify regions of geologic potential susceptibility for individual aquifers to surface contaminants utilizing existing data. 2.) Determine benchmarks and regional priorities for natural resources in South Central Minnesota, and 3.) Utilize municipal water well quality data to both establish trends in water quality and to establish a relationship between groundwater quality and our potential susceptibility determination.

In the long term, the project should be evaluated by the ability to introduce new data into the GIS and update susceptibility assessments; for example to develop and implement land management practices designed to improve the groundwater quality, and the ability to determine if management practices are having an affect on the quality of groundwater over time.

VI. Context within field: This project will integrate the work produced by two previous LCMR projects, developed at the Water Resources Center, Mankato State University, over several years: The South Central Minnesota County Groundwater Atlases and Data Base (1989-91) and the South Central Minnesota Surface Water Hydrology Atlases and Data Base (1991-93). The project will provide regional potential geologic susceptibility assessments.

To date groundwater susceptibility mapping does not address the influence of surface hydrology but rather looks at susceptibility strictly from a vertical perspective (geologic column). This study is unique in that it considers expanding the concept of regional susceptibility to include those areas which contribute drainage to a susceptible area.

VII. Benefits: The South Central Minnesota Groundwater Contamination Susceptibility Project - Continuation (A Regional Integration of Existing Data Utilizing GIS) will generate an alternative regional groundwater susceptibility methodology. The susceptibility assessment methods will explore a relationship between groundwater quality and the horizontal movement of surficial water to and from potential geologic susceptible areas. In South Central Minnesota, county and judicial ditch and tile systems, developed during the last 100 years, have had a dramatic impact on surface water movement. This project has the advantage of utilizing ARC/INFO GIS coverages for both hydrogeology and surface hydrology to determine the total potential surface area that contributes water to potential geologic susceptible areas.

This research project will benefit each of the 13 county water planning committees as well as the natural resources and planning agencies of the State of Minnesota. The results of this project will provide essential and needed insight for developing comprehensive county water plan annual updates as well as providing a first step in developing a methodology for the State of Minnesota to combine hydrogeology and surface hydrology into a meaningful and holistic groundwater susceptibility assessment. It will provide a means by which we can develop reasonable and achievable county and regional benchmarks and priorities in a cost effective way.

The data collected 1991-1993 and its conversion to ARC/INFO 1993-1994 has been requested by the US Fish &Wildlife Service & US Geological Survey and sent, in both hard and electronic format, to Vice President Al Gore's Mississippi River Flood Plain select team in Sioux Falls, South Dakota.

VIII. Dissemination: Results from this project will be presented to multi-county workshops utilizing Mankato State University's new Technology Exchange Center. These workshops will be geared for county water planners as well as regional and state agency personnel. Most important is that these workshops will not only inform and train county

water planners in the use of susceptibility maps but will also provide the opportunity for county personnel and Water Resources Center staff to work closely together to develop reasonable priorities and establish benchmarks.

Documentation of the methodologies developed for this research project will be distributed to local, state, and national water planners. ARC/INFO GIS data will be provided to the Minnesota land management information center's geographic data bases. Data will be made available to the MDNR, USGS, MDOH, MGS and MPCA through LMIC.

IX. Time: To be completed in two years (1993-95).

X. Cooperation:

1. John Rongstad and Cis Berg
   Staff, Cartography and GIS, M.S.U. Water Resources Center. These two staff members of Mankato State University's Water Resources Center have had extensive experience during the past four years developing the 13 county geologic atlases and the 13 county surface hydrology atlases. They will be involved in all three objectives full time.

2. The 13 counties of South Central Minnesota County Comprehensive Water Planning Project Joint Powers. The South Central Minnesota Groundwater Contamination Susceptibility Project has a resolution of support passed by our Joint Powers Board ($91,000). The 13 county water planning technical committee will be active participants in Objective B and were instrumental in proposal development..

3. Mankato State University and IBM Corporation.

XI. Reporting Requirements: Semiannual status reports will be submitted not later than January 1, 1994; July 1, 1994; January 1, 1995; and a final status report by June 30, 1995.

XII. Literature Cited:

Aller, L., T. Bennett, J.H. Leher, and R.J. Petty. 1985. DRASTIC: A Standardized System for Evaluating Groundwater Pollution Using Hydrogeologic Settings: U.S. Environmental Protection Agency/600/2-85/018, 163 pp.

Geier, Theodore W., and James A. Perry. 1992. Guide to Groundwater Sensitivity Rating Techniques: Minnesota Water Resources Research Center Special Report No. 22. University of Minnesota, St. Paul, MN. 87 pp.

Minnesota Department of Natural Resources. 1991. Criteria and Guidelines for Assessing Geologic Sensitivity of Groundwater Resources in Minnesota. Division of Waters. 122 pp.

Porcher, Eric. 1988. Groundwater Contaminaton Susceptibility in Minnesota: Minnesota Pollution Control Agency. 31 pp.

Setterholm, Dale R., et. al. 1991. Geologic Factors Affecting the Sensitivity of the Prairie Du Chien - Jordan Aquifer. Open-file Report 91-5. Minnesota Geological Survey. 29 pp.

Literature Review

Geier and Perry (1992) report in The Guide to Groundwater Sensitivity Rating Techniques that large scale sensitivity ranking methods such as DRASTIC (1985) and Minnesota Sensitivity Rating Method (1991) are well suited for GIS applications. The relationship of aquifer sensitivity to the nature and thickness of geologic materials which overlie the aquifer is examined by Setterholm, et. al. (1991). The study involves the use of GIS to create maps from goelogical data for further use in sensitivity assessments.

The DRASTIC (1985) methodology uses existing hydrogeologic, soil, and topographic data to produce a relative ranking of geologic sensitivity among geographic areas. The weighted index requires seven hydrogeologic factors and incorporates agricultural and non-agricultural land use into the rating system. Modifications of DRASTIC may be appropriate for evaluating geologic sensitivity.

The Minnesota Sensitivity Rating Method (1991) evaluates geologic sensitivity by assessing the properties of sediments overlying groundwater. Groundwater susceptibility is based on the vertical permeability of the geologic materials. Lateral movement of groundwater, contaminant properties, and land use information are not included in this methodology.