



CRITICAL ISSUES WEBINAR

Co-Sponsors: AASG | AIPG | ASBOG | EEGS | GSA | SEG | SEPM

Geologic Mapping to Empower Communities

Examples from the Great Lakes

December 6th, 1:30 PM EST

<http://bit.ly/AGI-GreatLakesMapping-Webinar>

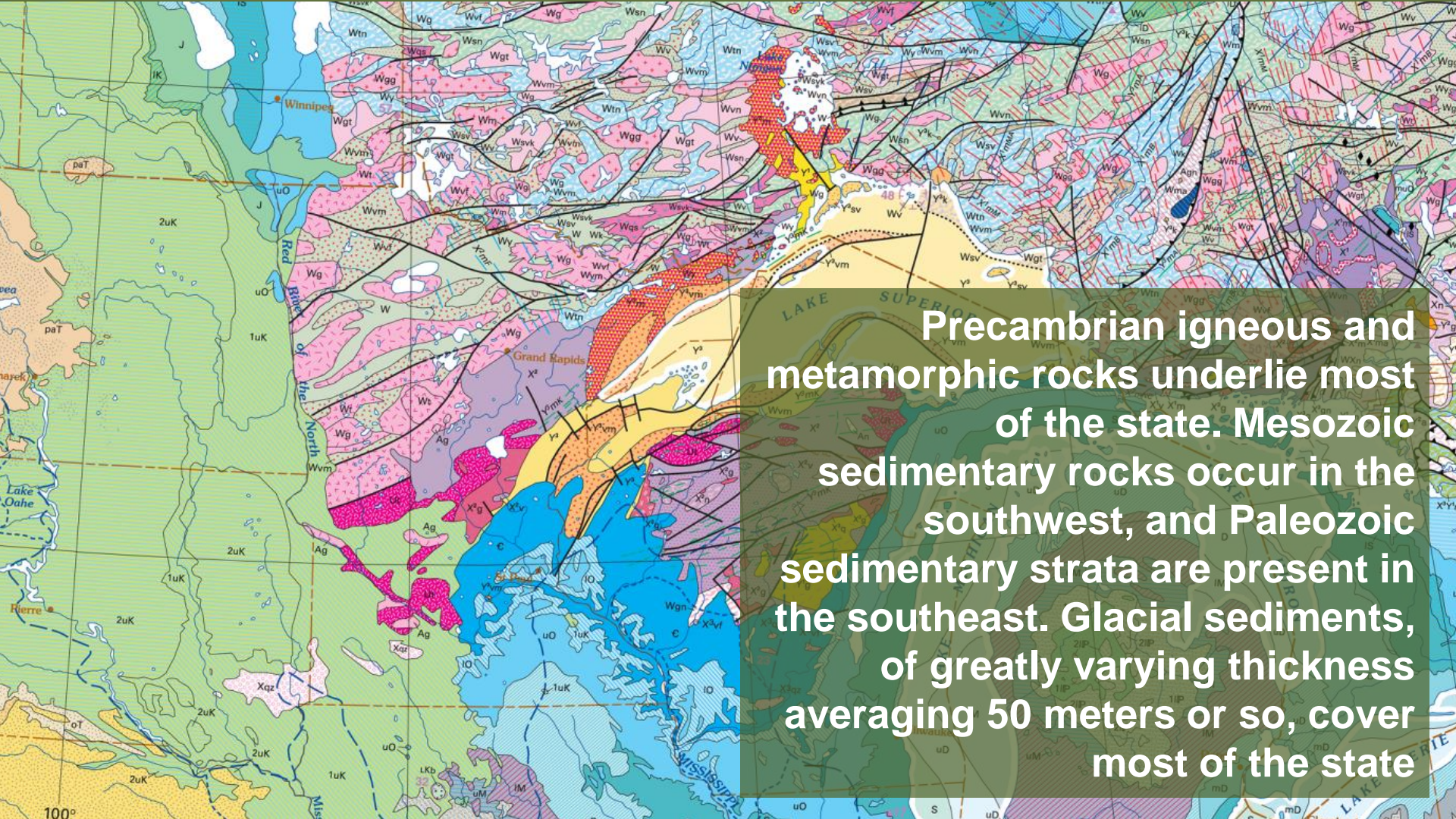
Harvey Thorleifson, Director,
Minnesota Geological Survey

Status of geological mapping needed for groundwater protection in Minnesota





Minnesota is located between the Dakotas and Wisconsin, north of Iowa, and south of Manitoba and Ontario. Two thirds of our five million residents live in the Twin Cities. Agriculture is prevalent in the south and west, and the Iron Range in the north supplies iron ore to the US through our Great Lakes ports



Precambrian igneous and metamorphic rocks underlie most of the state. Mesozoic sedimentary rocks occur in the southwest, and Paleozoic sedimentary strata are present in the southeast. Glacial sediments, of greatly varying thickness averaging 50 meters or so, cover most of the state

Permitted high capacity wells

We are known for our lakes and rivers, and the majority of our drinking water comes from wells. Recently, Minnesotans have become concerned about groundwater contamination, and over-pumping. A 2007 Minneapolis Star Tribune editorial, for example, called for steps to restore confidence in our drinking water, including enhanced funding to the state geological survey

Restore confidence in local drinking water

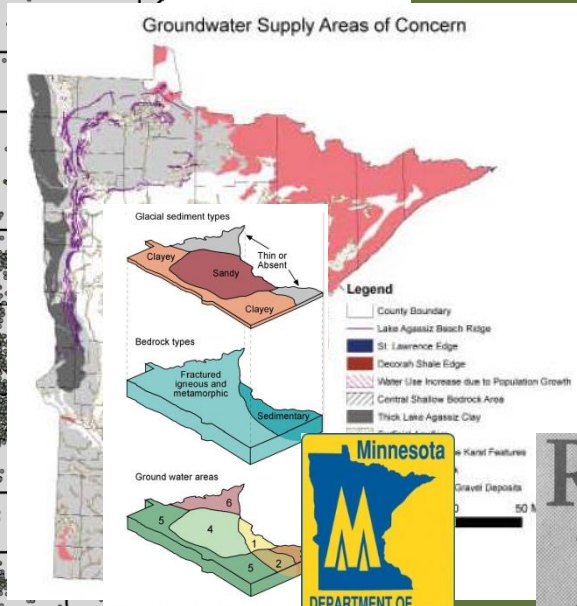
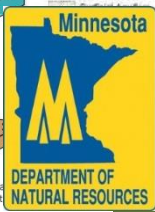


FIGURE 1. General availability of ground-water resources depends on the type of sediment rock beneath the land surface.



40 0 40 80 Miles

Minnesota DNR

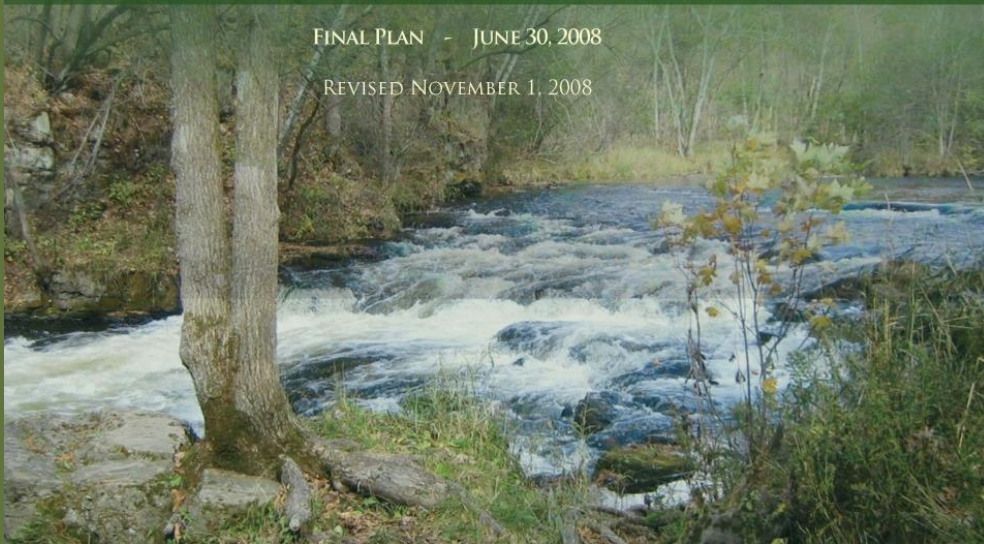
MINNESOTA

STATEWIDE CONSERVATION AND PRESERVATION PLAN



FINAL PLAN - JUNE 30, 2008

REVISED NOVEMBER 1, 2008

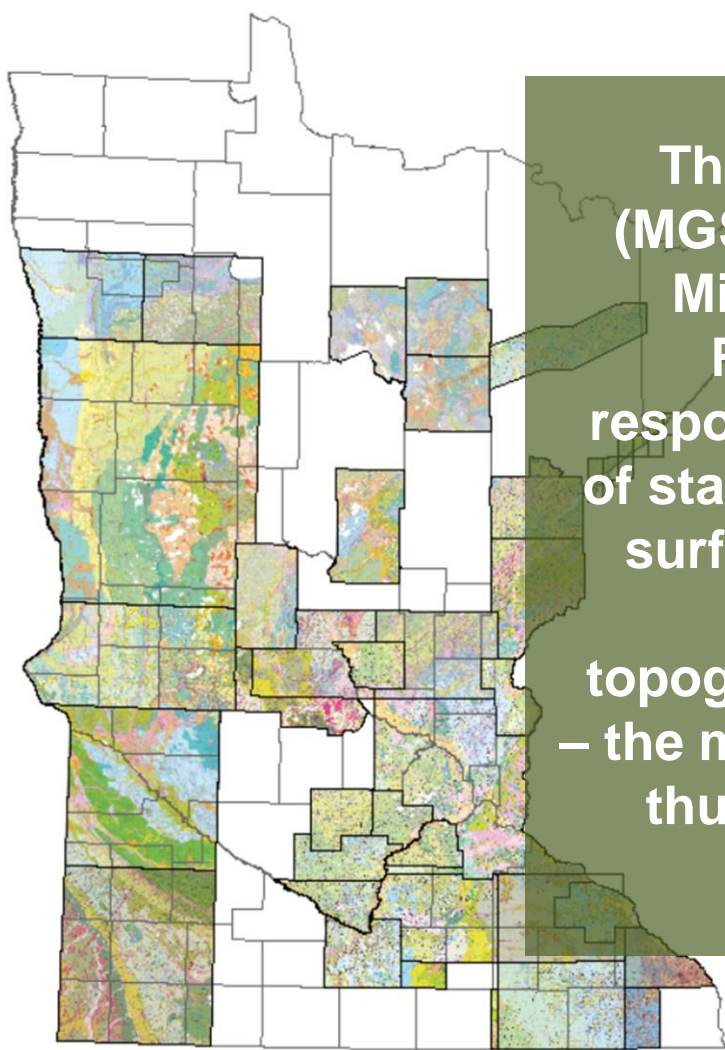


A 2008 assessment of our environment and natural resources specified, as one of many recommendations, that statewide, consistent, multi-layered geological mapping would be required, to empower the people of the state to plan and protect their water resources

MINNESOTA WATER SUSTAINABILITY FRAMEWORK



A 2011 water sustainability framework that was commissioned by the Legislature then advocated that one of several measures of our progress in caring for our groundwater should be the rate of completion of county geologic atlases; a doubling of the pace of geological mapping was recommended



The Minnesota Geological Survey (MGS) therefore is working with the Minnesota Department of Natural Resources (DNR) to fulfill these responsibilities, through completion of statewide 1:100,000 and 1:500,000 surficial geology, bedrock geology, subsurface geology, bedrock topography, and sediment thickness – the mapping is comprehensive, and thus applicable to water and other applications



We concurrently are undertaking funded basic research that is needed to optimize our mapping, with an emphasis on enhanced hydrogeological characterization of sediment and rock strata



**ENVIRONMENT
AND NATURAL RESOURCES
TRUST FUND**

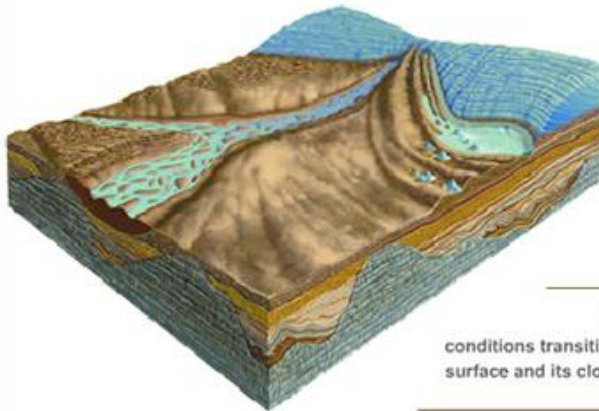
**CLEAN
WATER
LAND &
LEGACY
AMENDMENT**

Crucial to our work is support from the Environment and Natural Resources Trust Fund, established by voter approval in 1988. In addition, in 2008, the people of Minnesota voted for a tax increase – the Clean Water, Land, and Legacy Amendment. The resulting program also supports our work

Groundwater & Drinking Water
PROTECTION
Locally Led Projects to Protect Groundwater



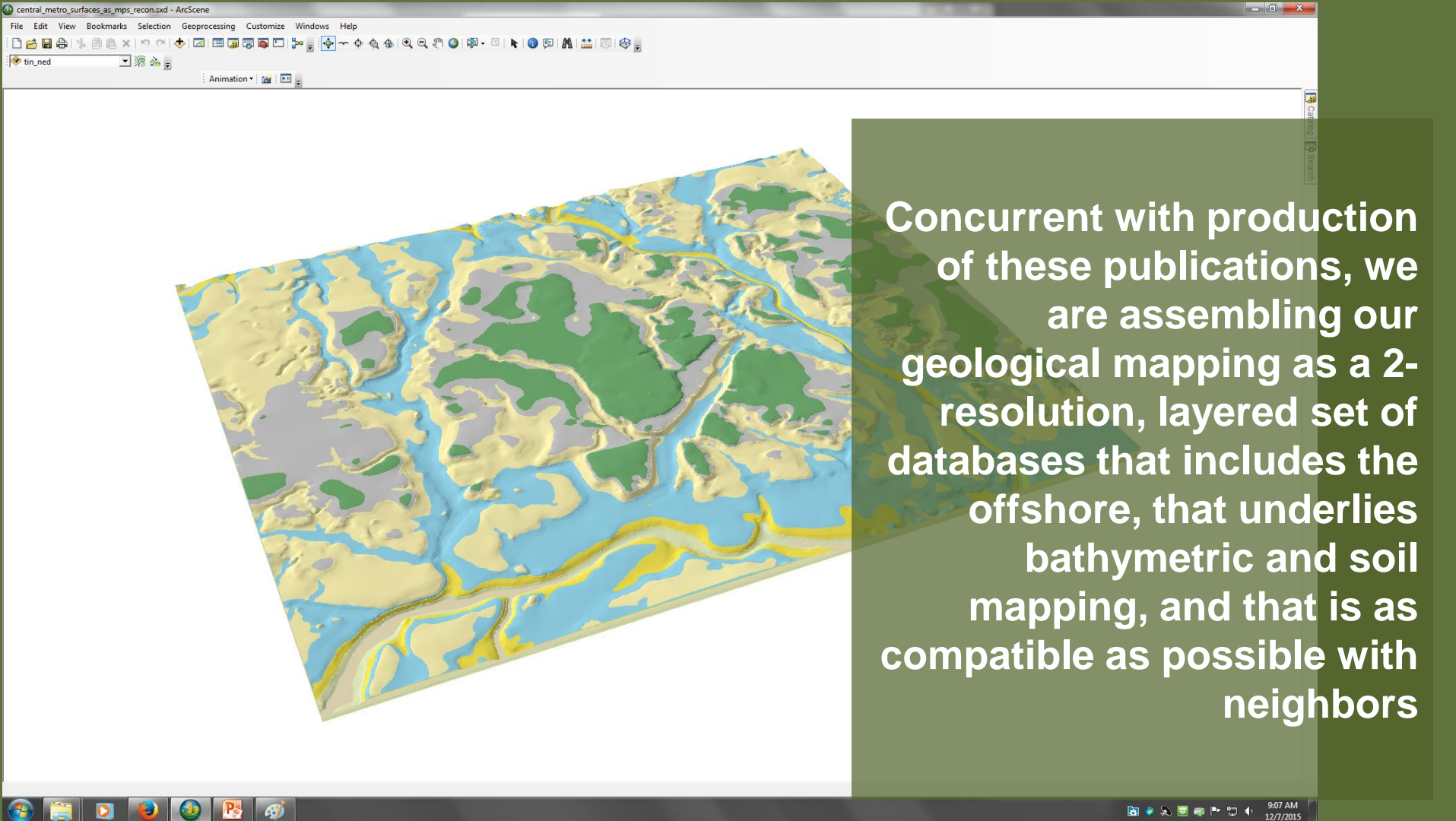
Our geological mapping thus is being very strongly supported by the Minnesota Legislature, with crucial roles also being played by programs such as the USGS Great Lakes Geological Mapping Coalition



**GREAT LAKES
GEOLOGICAL MAPPING COALITION**

**...to address critical water resource,
environmental, and landuse issues**

The block diagram showing generalized Ice-Age conditions transitions to a block diagram showing the modern land surface and its close ties to the underlying geological deposits.



Concurrent with production of these publications, we are assembling our geological mapping as a 2-resolution, layered set of databases that includes the offshore, that underlies bathymetric and soil mapping, and that is as compatible as possible with neighbors

QUATERNARY LITHOSTRATIGRAPHIC UNITS OF MINNESOTA

Mark D. Johnson

*Department of Earth Sciences
University of Gothenburg, Sweden*

Angela S. Gowan

Minnesota Geological Survey

Howard C. Hobbs

Minnesota Geological Survey

Alan R. Knaeble

Minnesota Geological Survey

Roberta S. Adams

*Minnesota Geological Survey**

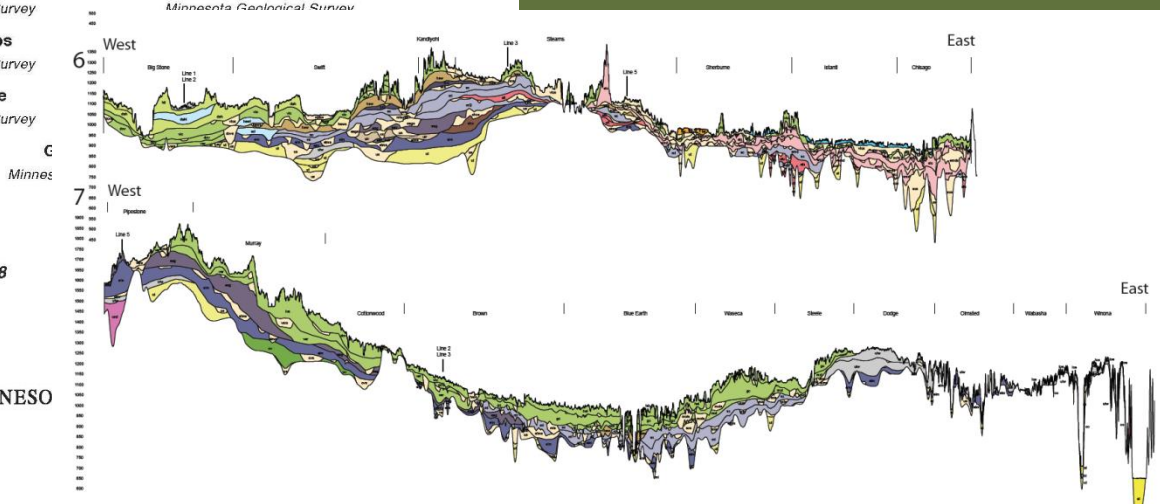
Kenneth L. Harris

Minnesota Geological Survey

Report of Investigations 68
ISSN 0076-9177

UNIVERSITY OF MINNESOTA
Saint Paul — 2016

With support from the Great Lakes Coalition, we have made major strides in reconciling our Quaternary stratigraphic naming. In addition to a naming guide, it was necessary to construct several statewide cross-sections to fulfil this objective



Pollution Sensitivity of Near-Surface Materials

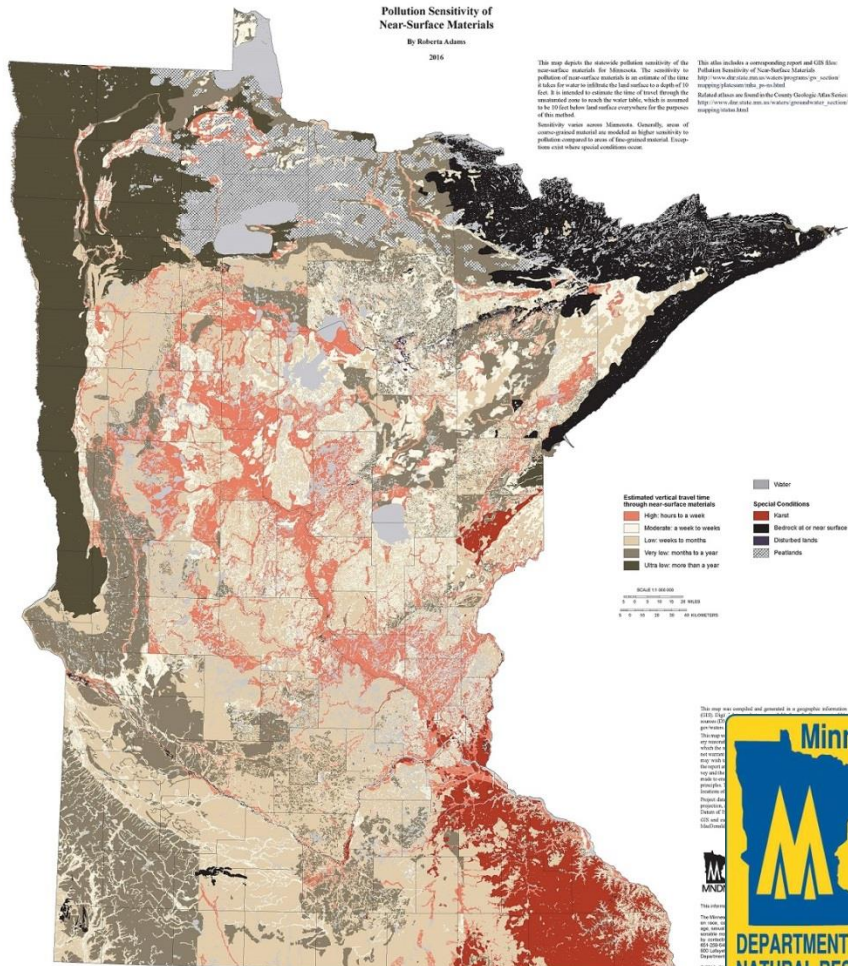
By Roberts Adams

2016

This map depicts the materials pollution sensitivity of the near-surface materials for Minnesota. The sensitivity to pollution of near-surface materials is an estimate of the time it takes for water to infiltrate the land surface to a depth of 10 feet. It is intended to estimate the time of travel through the unsaturated zone to reach the water table, which is assumed to be 10 feet below land surface everywhere for the purposes of this method.

Sensitivity varies across Minnesota. Generally, areas of unconsolidated material are modeled as higher sensitivity to pollution compared to areas of fine-grained material. Exceptions exist where special conditions occur.

This atlas includes a corresponding report and GIS files: Pollution Sensitivity of Near-Surface Materials
[http://www.dnr.state.mn.us/waters/pubs/pubs_pp_section_mapping.html](http://www.dnr.state.mn.us/waters/pubs/pubs_pp_section_mapping/pubs/pp_section_mapping.html) (pdf)
Related atlases are found in the County Geology Atlas Series: [http://www.dnr.state.mn.us/waters/pubs/water_section_mapping.html](http://www.dnr.state.mn.us/waters/pubs/water_section_mapping/water_section_mapping.html)



Estimated vertical travel time through near-surface materials

- High: hours to a week
- Moderate: a week to months
- Low: weeks to months
- Very low: months to a year
- Ultra low: more than a year

Special Conditions

- Forest
- Disturb of or near surface
- Disturbed lands
- Peatlands

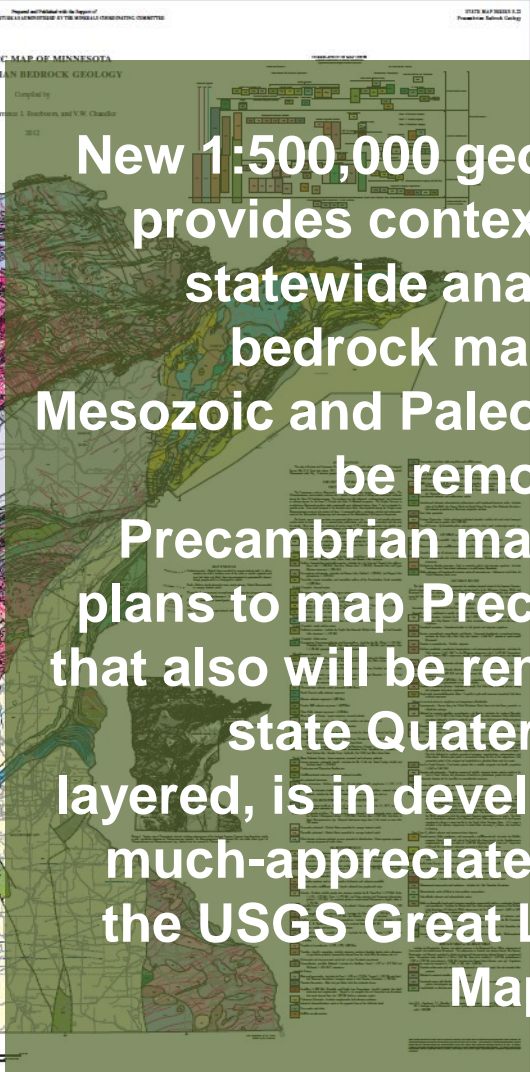
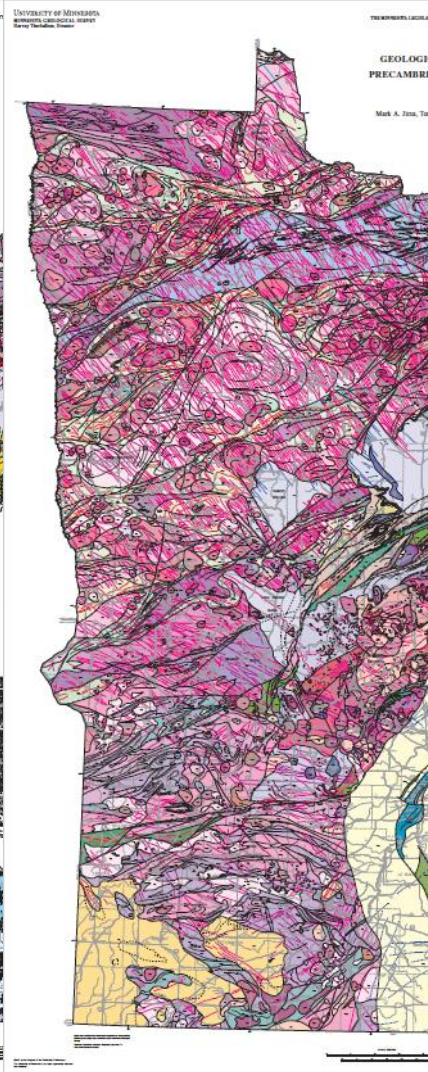
SCALE 1:100,000
0 10 20 30 40 50 MILES
0 20 40 60 80 100 MILES

This map was compiled and generated in a geographic information system (GIS).

GIS: Debra Adams
Data: Debra Adams
Map Design: Debra Adams
Map Production: Debra Adams
Map Distribution: Debra Adams
Map Review: Debra Adams
Map Approval: Debra Adams
Map Contact: Debra Adams
Map Copyright: © 2016, DNR

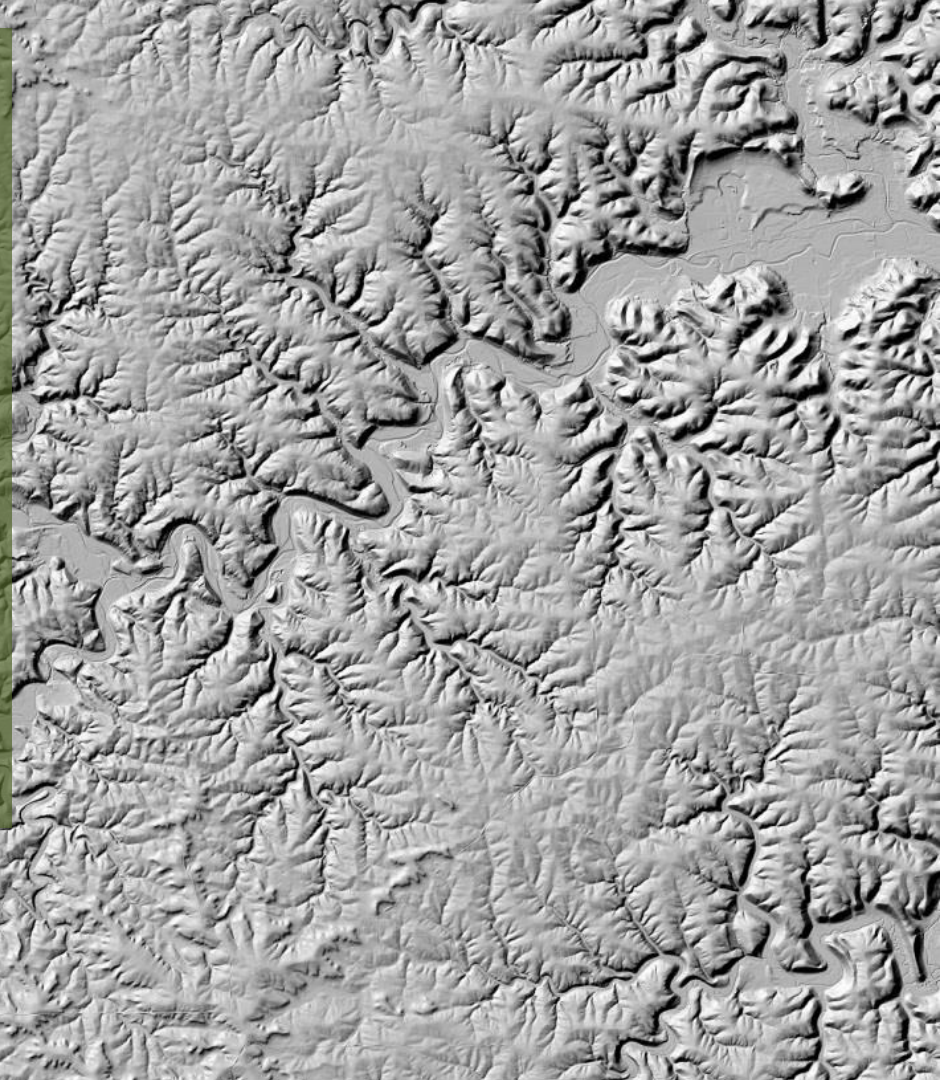


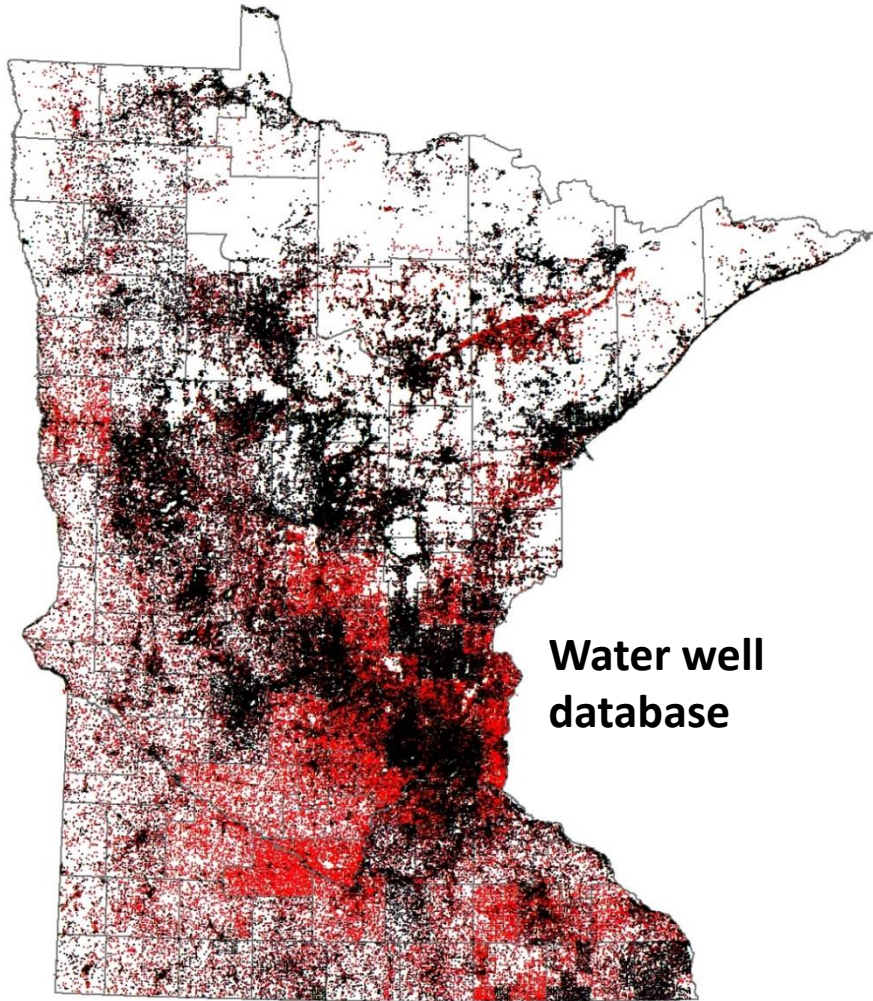
Progressively more seamless geological polygons, at 1:100,000 and 1:500,000, are tending to have thickness indicated, while properties, heterogeneity, and uncertainty will gradually be more specified. Parsing of legends, to facilitate queries, is using broadly accepted, well-defined terminology, and quantitative support, to facilitate optimal inference of properties such as hydraulic conductivity



New 1:500,000 geologic mapping provides context and supports statewide analyses. The new bedrock map is layered, as Mesozoic and Paleozoic strata can be removed to reveal a Precambrian map, and we have plans to map Precambrian layers that also will be removable. A new state Quaternary map, also layered, is in development, due to much-appreciated support from the USGS Great Lakes Geologic Mapping Coalition

The geological mapping is supported by associated MGS spatial databases. In addition, the Minnesota Legislature funded acquisition of statewide lidar, which has very significantly improved our geological mapping. MGS also coordinates with the DNR drill core library and mineral exploration document archive, the Bell Museum fossil collection, and the DNR aquifer properties database





**Water well
database**

MGS geological databases include drillhole data, field observations, karst features, as well as sediment texture and lithology. The water well database is a major activity for MGS, with our partner in this role, the Minnesota Department of Health. We now have over 500,000 wells in the database

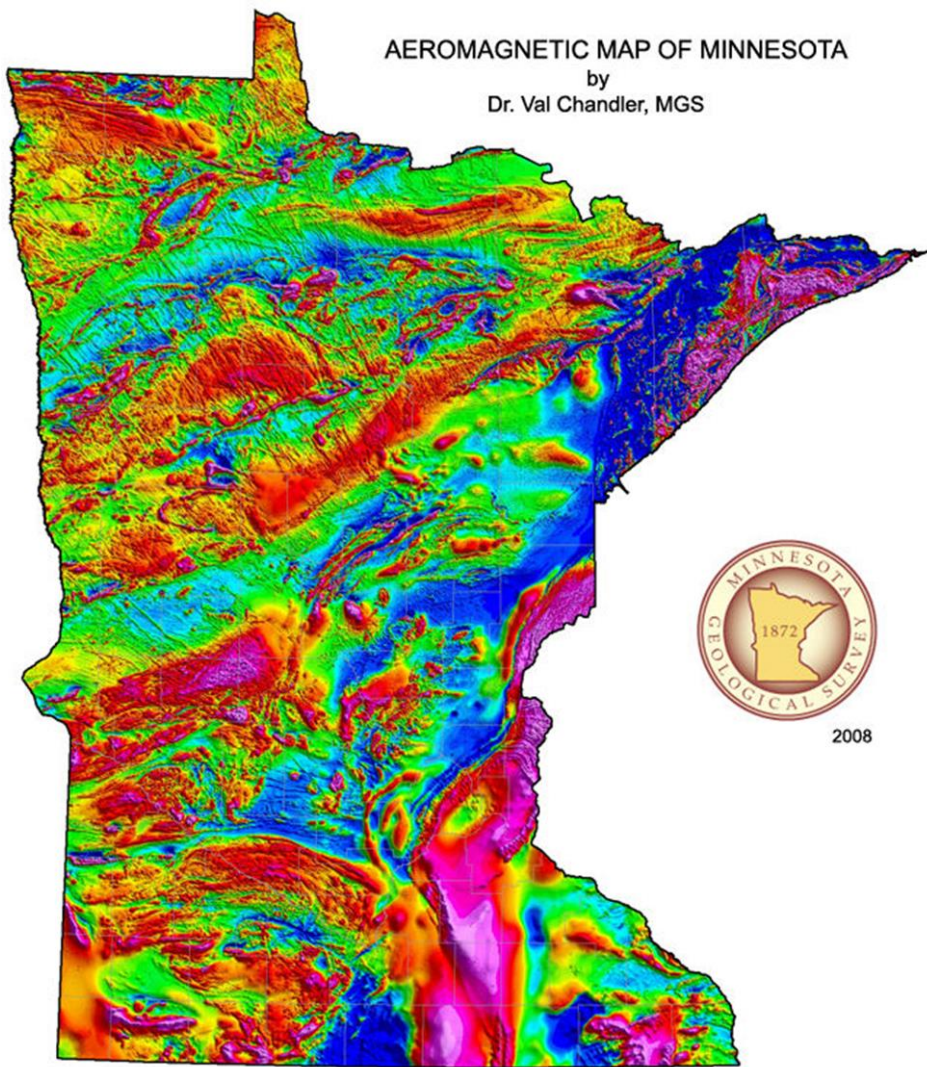


MGS geological collections include cuttings, geochemical samples, hand samples, sediment samples, and thin sections

AEROMAGNETIC MAP OF MINNESOTA

by

Dr. Val Chandler, MGS



2008

MGS geophysical databases include magnetic, gravity, rock properties, borehole geophysics, and soundings. We have completely reprocessed the state magnetic database, and the state gravity database; in both cases, feature resolution was very significantly improved

Mississippi Geological Survey of Minnesota
 256282

NAME: BURNER LAKE PARK BLDG #
 WELLS NUMBER: 256282
 QUADRANGLE: COON RAPIDS 151A
 COUNTY: ANOKA
 LOCATION: SAGDAA
 TOWNSHIP: 32 RANGE: 34

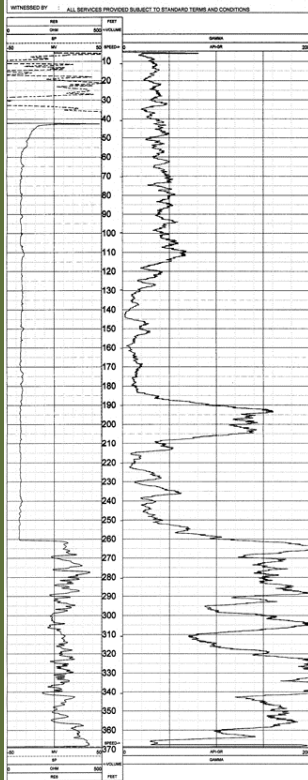
DATE: 05/14/03
 WELL BOTTOM: 201
 LOG TOP: 98.90
 LOGS DIVERTER: 4
 CALIBER TYPE: 0
 LOGS TECHNIQUE: 0
 BY: BJS
 MAGNETIC DECL: 0
 MATR. ENERGY: 2.71
 LOGS MATRIX: DASHIN

MOB CUTTINGS # :
 LOG MEASURED FROM :
 DR. MEASURED FROM :
 FIELD OFFICE :
 BLOODGRAN :
 BOREHOLE FLUID :
 RH :
 RH TEMPERATURE :
 THRESH: 300

FILE PROCESSED :
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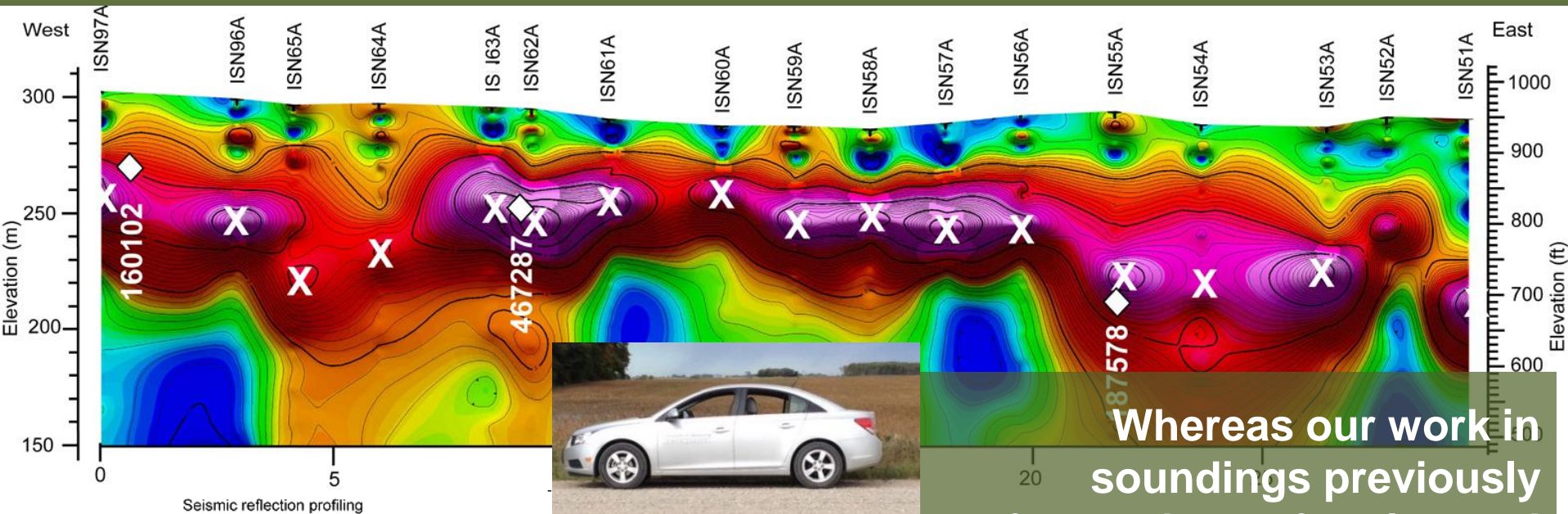
OTHER SERVICES:

APPROVED BY: ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS

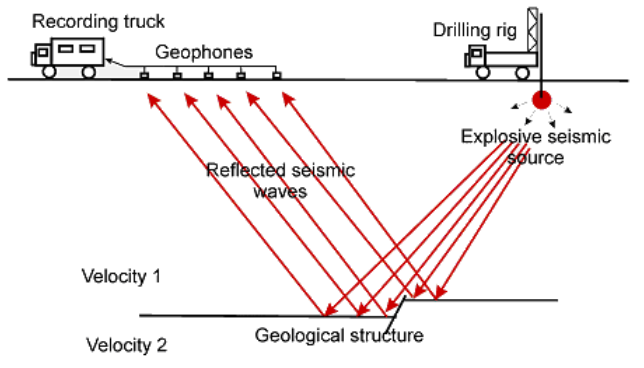


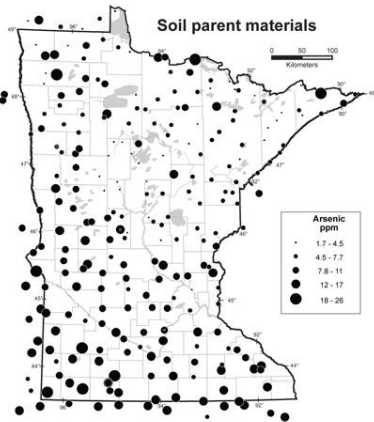
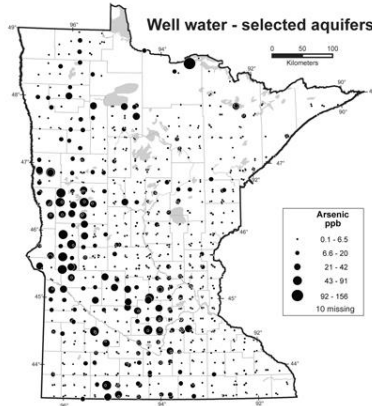
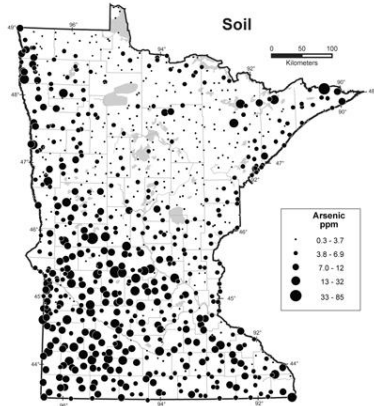
Borehole geophysical surveys are an ongoing activity for us, statewide – we have made much progress in digitizing previously-collected natural gamma logs, while our activity is broadening in multi-parameter, caliper, EM-flowmeter and borehole video logs





Whereas our work in soundings previously focused on refraction and reflection seismic, passive seismic is now a major emphasis for us, and a source of much helpful new data on depth to bedrock





SUMMARY

The rocks and soils that are the foundation of our environment leave an imprint on the chemistry of our water and our lives. This chemical landscape reflects a combination of natural history and cumulative human impacts, and presumably has an influence on biodiversity and human health.

Understanding this landscape requires geochemical mapping. The Minnesota Geological Survey (MGS) and the Minnesota Pollution Control Agency (MPCA), in cooperation with the United States Geological Survey (USGS), have assembled the Minnesota Geochemical Database; a collection of maps and tables that show selected statewide geochemical data. Construction of the database was funded by the Minnesota Minerals Coordinating Committee (MCC).

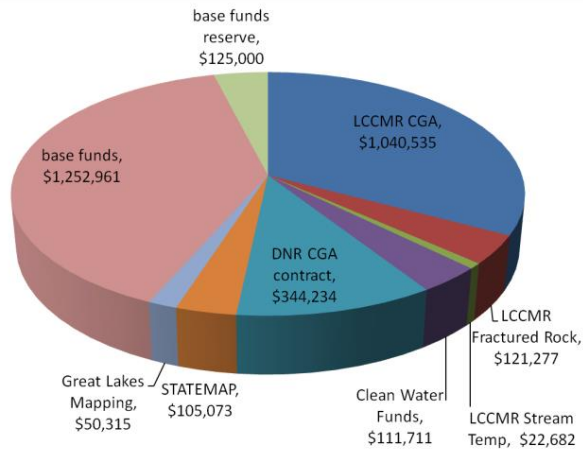
Soil, soil parent material, and well water were analyzed following USGS, Environmental Protection Agency (EPA), and Geological Survey of Canada protocols. The 1,352 points on the soil map show combined results from soil in the top 0.2 meters and at about 0.5 meters depth, as well as stream sediments. Soil and some stream sediments were collected in 2004 and 2005. Most stream sediments were collected in 1979, mainly from western Minnesota under the National Uranium Resource Evaluation program, and were reanalyzed in 2005. Soil data were averaged; values below detection were set to half the detection limit. The soil parent material map shows results from 250 till samples from 1 to 2 meters depth. The analyzed size fraction for soils was <2 millimeters and for soil parent materials was <63 microns. The well water map shows results from MPCA sampling and analysis from 354 water wells that sampled 14 selected aquifers between 1992 and 1996. Map classes are based on natural groupings in the data using the natural breaks method. Class boundaries were established by the mapping software at relatively large jumps in the data values.

The geochemical database is both state-wide and multi-level, providing a regional context for exploration and environmental management efforts. Additional geochemical information is available for specific areas. Users of this map are referred to an accompanying report for more detailed information about data collection and limitations.

This and other maps, plus associated data, are available from the Minnesota Geological Survey. Additional information may be obtained from the MPCA and USGS.



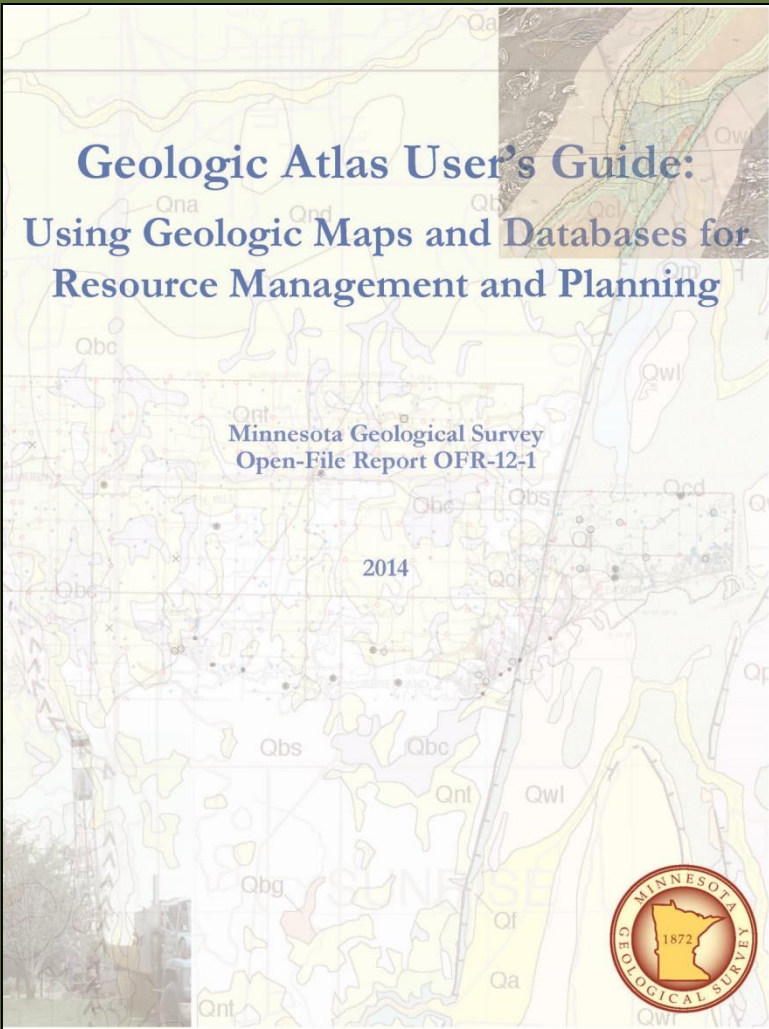
Our statewide geochemical databases, constructed with partners, include groundwater, soil, and soil parent materials, while geochronological databases are in development



While MGS annual funding averaged \$2.3M from 2003 to 2008, the average since then has been \$2.9M. MGS relies on about \$1.2 million in base funding, and about \$1.7 million in grants and contracts each year



MGS staffing was stable at 28 full-time-equivalents (FTE) from 2003 to 2012; since then, staffing has averaged 36 FTE. We currently are 28 geologists, 4 information professionals, 2 administrative staff, and 6 students equivalent to ~3 FTE



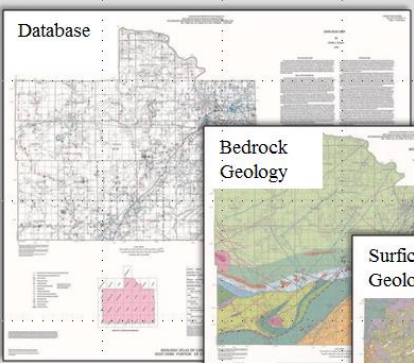
**Geologic Atlas User's Guide:
Using Geologic Maps and Databases for
Resource Management and Planning**

Minnesota Geological Survey
Open-File Report OFR-12-1

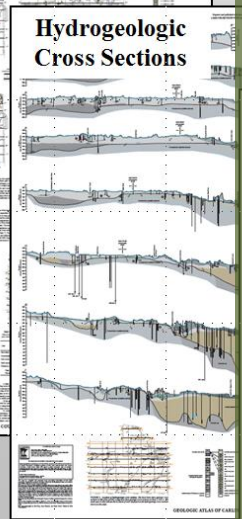
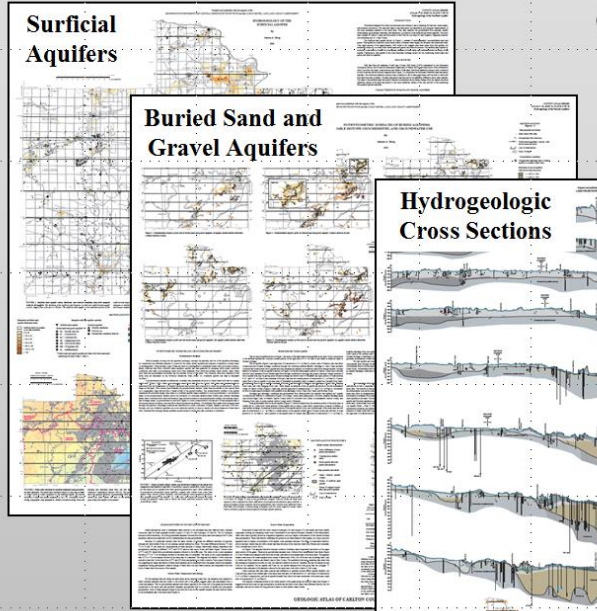
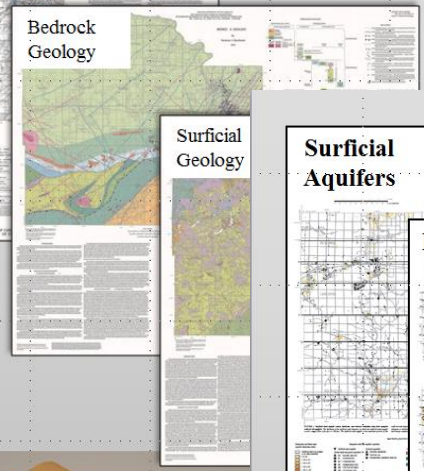
2014



Our focus is on County Geologic Atlases. A User's Guide to Geologic Atlases helps non-geologists, especially decision-makers, understand the information products and their uses. Atlases are available in print, or in digital formats, including pdfs and GIS files



COUNTY GEOLOGIC ATLAS Part A



COUNTY GEOLOGIC ATLAS Part B

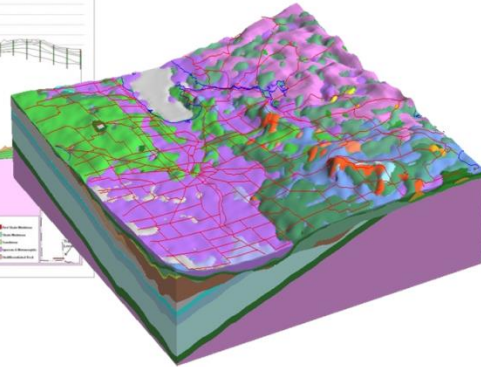
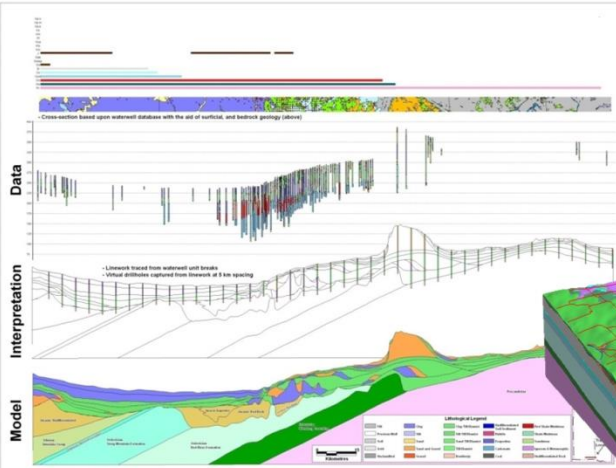
A complete atlas consists of a Part A prepared by MGS that includes the water well database and 1:100,000 scale geologic maps, and a Part B by DNR that includes maps of water levels in aquifers, direction of groundwater flow, water chemistry, and sensitivity to pollution



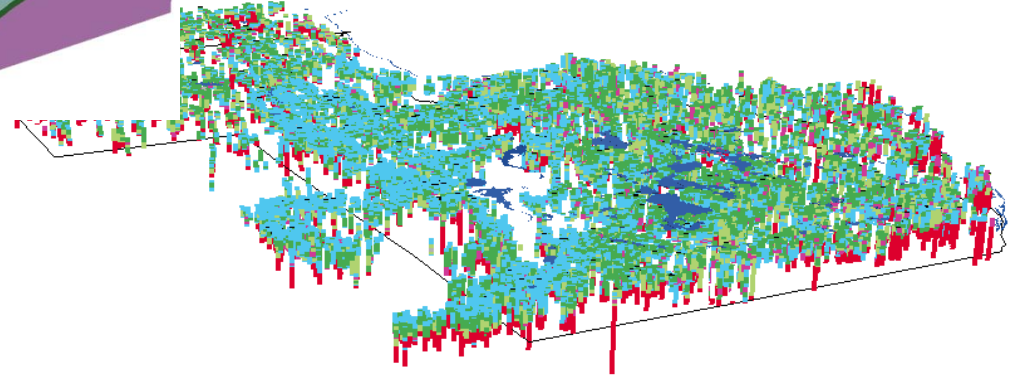
Cross-sections drawn through lithologic data

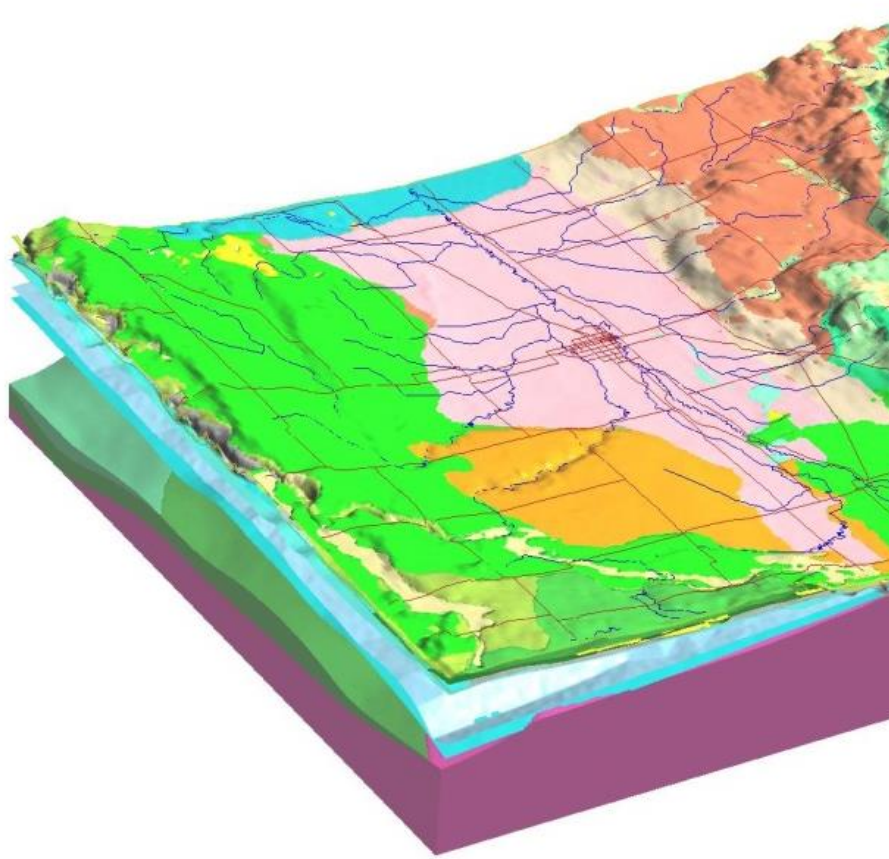
- this results in depiction of a fully plausible geology that conforms to the geological conceptual model, and from which data issues have been filtered by the geologist

- incorporation of new data is challenging

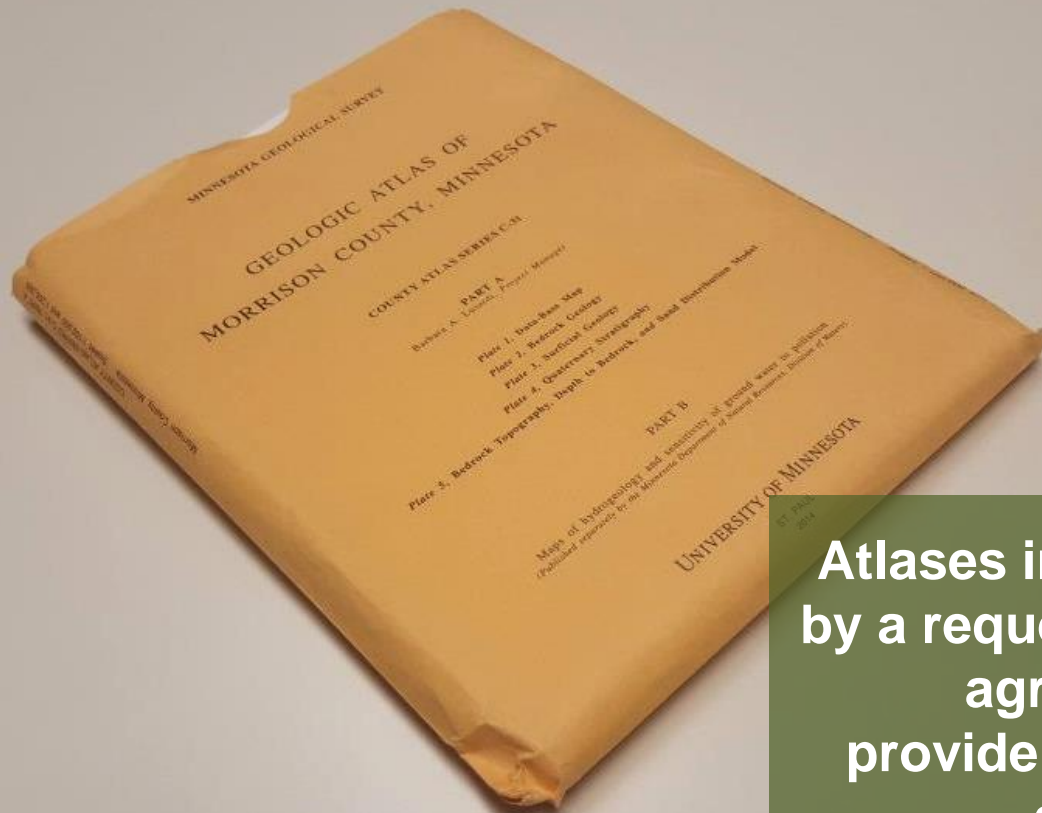


Our subsurface mapping utilizes a cross-section method that brings together new drilling and geophysical data, water well data, geostatistical analysis, and geologists' judgement





By mapping the geology, we define aquifer properties and boundaries, as well as the connection of aquifers to the land surface and to surface water resources, thus providing information essential to applications such as aquifer management, groundwater modeling, monitoring, permitting, remediation, well construction, and wellhead protection. Concurrently, the Atlases clarify mineral resources and engineering conditions

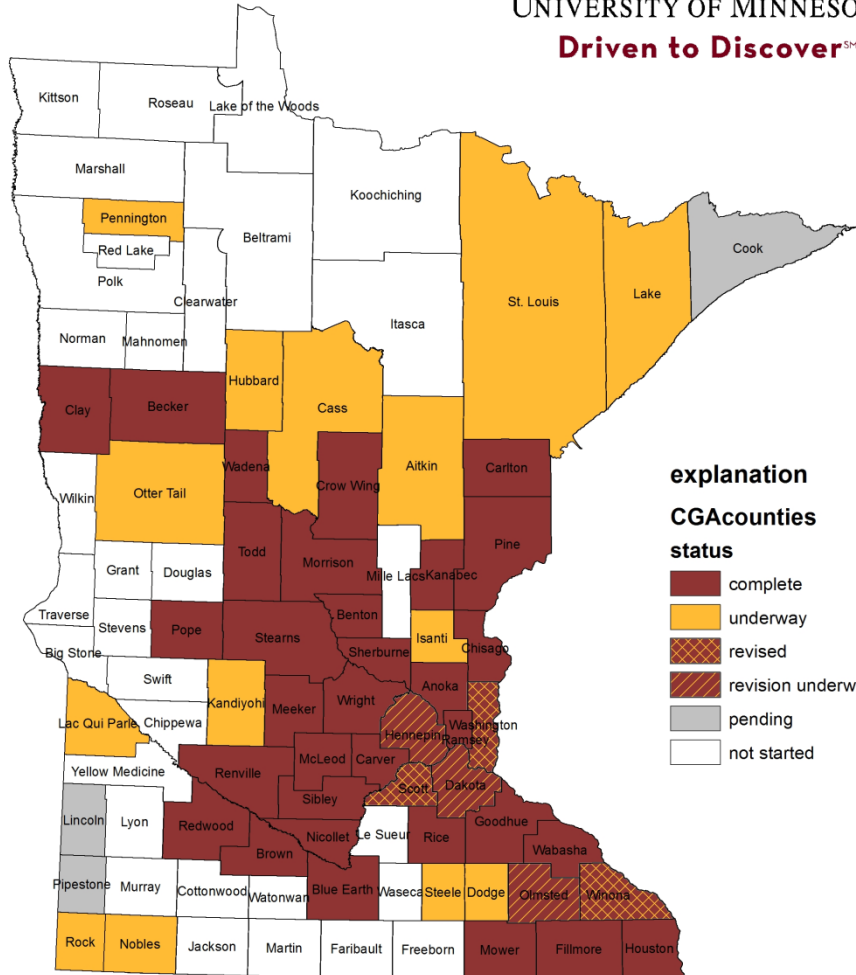


Atlases in most cases are initiated by a request from a County, and an agreement by that County to provide in-kind service. A typical atlas requires a total MGS expenditure of a half million dollars over about four years



UNIVERSITY OF MINNESOTA

Driven to DiscoverSM



38 counties are complete, 32 are not started, 3 are pending, 3 are revised, 3 revisions are underway, and 14 new Atlases are in progress. Atlases are being completed at a rate of ~5 per year, so with ~50 completions remaining, statewide atlas coverage will be achieved in a decade, depending on the pace of revisions and accompanying research – we foresee that we will then focus on Atlas revisions and associated activity



CRITICAL ISSUES WEBINAR

Co-Sponsors: AASG | AIPG | ASBOG | EEGS | GSA | SEG | SEPM

Geologic Mapping to Empower Communities

Examples from the Great Lakes

December 6th, 1:30 PM EST

<http://bit.ly/AGI-GreatLakesMapping-Webinar>

In summary, strong support from the Minnesota Legislature has allowed the Minnesota Geological Survey to grow, and to focus on the actual needs of the people statewide.

Concurrently, very helpful roles are being played by programs such as the USGS Great Lakes Geologic Mapping Coalition, and the National Cooperative Geologic Mapping Program. We welcome discussion and advice