Metro Groundwater Model- Site Applications

By Andrew Streitz, John Seaberg and Doug Hansen

Introduction

It has been four years since staff at the Minnesota Pollution Control Agency (MPCA) reported on the Metropolitan Area Groundwater Model (Metro Model) project in a MGWA article. At that time we stated that our original goals were to assemble databases, develop a conceptual model, and build a regional groundwater flow model encompassing the Twin Cities seven-county Metropolitan area. Further, we wanted to pursue these goals so that the Metro Model was accepted and used by the environmental and groundwater modeling community.

In 1999, our original goals have been met, and it is time to set new ones. The most dramatic shift is toward use of this tool by the Agency, and we believe that the project can also provide support to many different types of hydrogeologic investigations, ranging from relatively simple reviews of geology to more complicated drawdown analyses. A large storehouse of shape files, maps and database files are available to all interested parties including unified Minnesota Geological Survey (MGS) Twin Cities bedrock coverages (Figure 1), geostatistically filtered calibration datasets, Quaternary sand-content maps, and stream discharge measurements. These databases can be used to solve hydrogeologic problems that do not require the building of a groundwater model.

If a model is required however, regional groundwater models covering the glacial drift to the Mt. Simon/Hinckley aquifers are ready for use as well. The Metro Model provides a platform from which expansion or development of other subregional models may be developed. And by collecting and reviewing the incremental changes made to the Metro Model, improvements can be shared with all participants. Though originally designed with groundwater contamination in mind, other uses that the Model can be put to include analyzing groundwater management issues such as sustainable development of groundwater, and delineating wellhead protection areas. Within the last year, the team has been working with a number of parties to apply the Metro Model and/or its databases to various groundwater modeling projects. To demonstrate the utility of this new strategy, this article will present two examples of modifications of the Metro Model to build local-scale groundwater models, following a brief review of the Metro Model effort.

The Metro Model—A Brief Review

The Metro Model is a regional groundwater flow model encompassing the Twin Cities seven-county Metropolitan area. The Metro Model provides the regional boundary conditions so that an end-user can insert local detail, thereby creating a more robust site-specific model in a shorter time than was previously possible.

The computer model simulates multi-aquifer groundwater flow and is based on a conceptual model that consists of five aquifer layers, four of which represent bedrock units, and one representing a glacial drift aquifer. Separate groundwater simulations now exist for all five layers and all three hydrologic provinces, metropolitan regions divided by the Minnesota and Mississippi Rivers. The software used is the Multi-Layer Analytic Element Model (MLAEM), based on the analytic element method pioneered by Professor Otto D.L. Strack of the University of Minnesota Civil Engineering Department. Improvements in modeling techniques are incorporated into the effort as they are developed to ensure that the Metro Model provides the best technical tool possible for groundwater management issues.

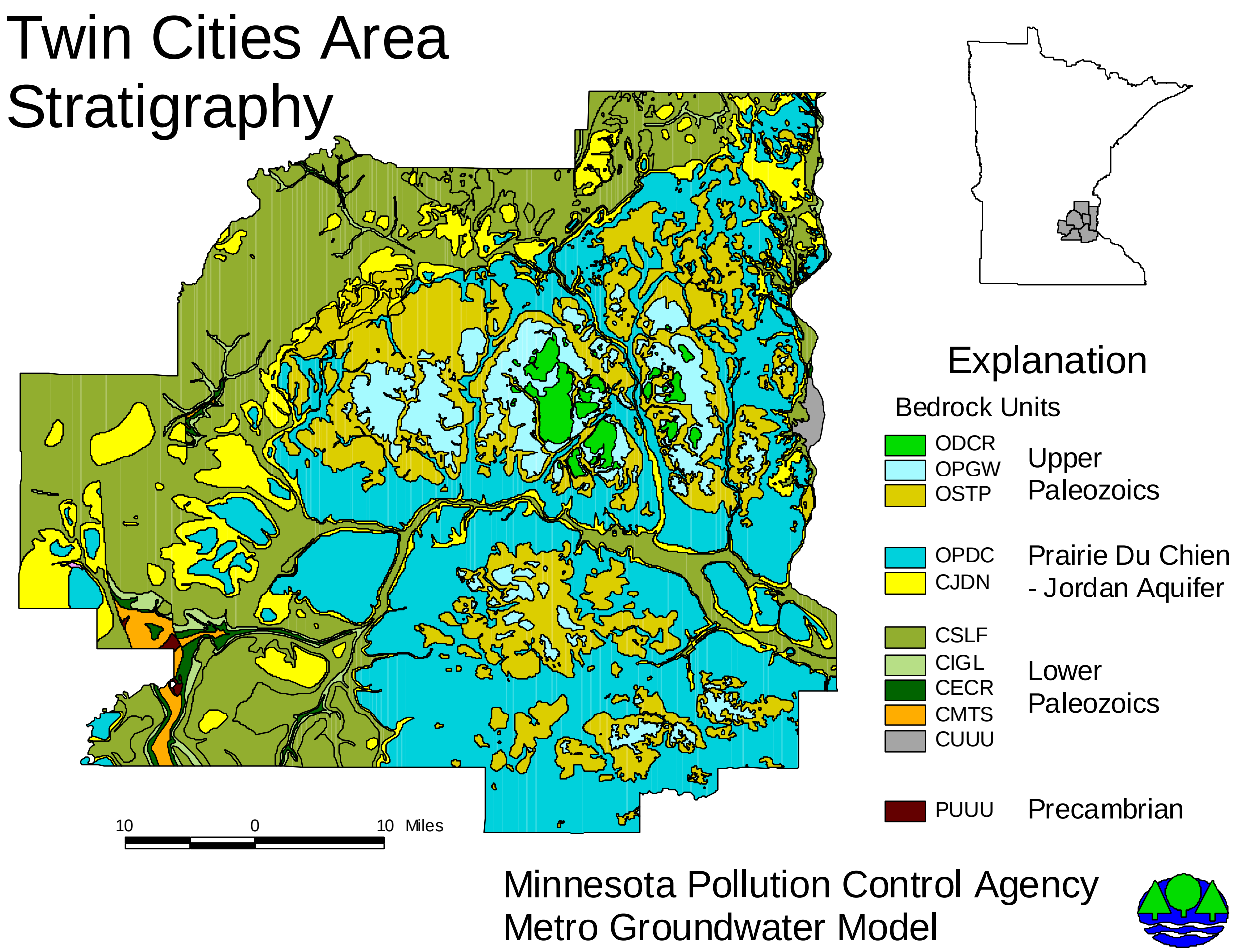

Figure 1

Site Use of the Metro Model

The most exciting new development in the Metro Model project has been the adaptation of the model for use on two local-scale sites. One was performed under contract to the Metro Model project, and the second was completed by an independent consultant for a third party client enrolled in the MPCA's Voluntary Investigation and Cleanup (VIC) program. Both local-scale models were developed in close cooperation with the Metro Model team. In each case the Metro Model and its supporting databases were easily converted to the needs of the smaller-scale models as described in the two sections below. More detailed information on all aspects of the Metro Model and the local-scale models is available upon request. Contacts are provided at the end of this article. Relevant geologic information from these local-scale models will be eventually incorporated back into the Metro Model, strengthening its simulation in these areas.

Reilly Superfund Site
The Reilly Tar & Chemical Superfund site was modeled to test the project strategy of applying the regional-scale Metro Model to local-scale sites. Kelton Barr of Kelton Barr Consulting, working with MPCA hydrologists and project staff, modified the Metro Model to meet the local site needs, adding detail in the form of model elements and calibration points where needed. This allowed the project team to analyze the use of the Metro Model with the goal to simplify the process.

The Reilly Tar & Chemical Site, in the Twin Cities suburb of St. Louis Park, was selected because of the lateral and vertical extent of groundwater contamination found at that location. The Reilly site is contaminated with coal tar compounds, which are found in the glacial drift and several underlying Paleozoic aquifers. The goals of the exercise:

- Adapt the Metro Model's northwest hydrologic province model,
- Determine if contaminated groundwater in the glacial drift and Platteville aquifers is effectively intercepted by the extraction wells in each aquifer, and
- Determine if the extraction wells are preventing contaminated groundwater from entering the bedrock valley to the east of the site and effecting the St. Peter aquifer.

The Platteville Limestone and Glenwood Shale are absent in an erosional valley southeast of the site that is a tributary valley to the larger buried bedrock valley that underlies the Minneapolis chain of lakes. The head of the valley is subdivided into at least two prongs extending generally to the northwest toward the site. The valley extends generally to the east (see Figure 2).

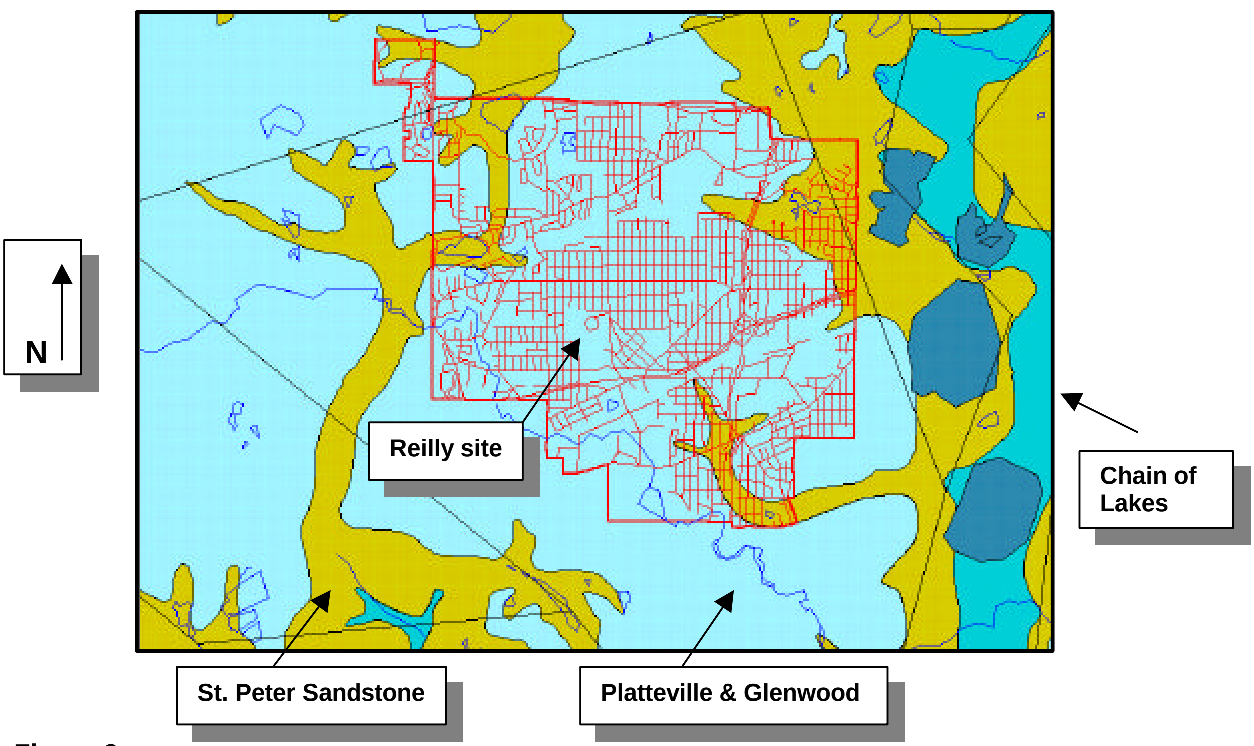

Figure 2

The groundwater flow in both the drift and Platteville aquifers is generally to the east. Flow in both aquifers is influenced by Minnehaha Creek, which meanders to the southeast in the area directly south of the site. The groundwater flow directions are also influenced by the occurrence of valleys eroded into the upper bedrock and long since filled in. This includes both the buried bedrock valley described above and another, less developed valley to the northeast of the site. An additional bedrock valley also is located to the west of the site, but does not likely exert much influence on local flow.

The general setting of the Reilly site is shown in Figure 2. Also included in the figure are the site location, the St. Louis Park street system, and Minnehaha Creek. Modeling based on these and other local-scale conditions led to the following conclusions:

1. The potentiometric surfaces of the Glacial drift and Platteville aquifer are reasonably simulated in the model developed for the Reilly site. The Metro Model's northwest province model was effective with minor modifications,
2. The extraction wells in the Platteville Aquifer appear to effectively capture groundwater from the site vicinity. Moreover, it appears that these wells are effective in preventing contamination from reaching the tributary bedrock valley.
3. Dissolved contamination either originating within the Platteville or migrating from the overlying drift into the Platteville within the site vicinity appears to be effectively contained by the extraction wells.

This local-scale model is currently being updated and will be used in future remedial decisions by the MPCA site team.

Voluntary Investigation and Cleanup Site Application
Richard Pennings of GME Consultants, Inc. (GME) recently applied a portion of the Metro Model to a hydrogeologic assessment of a site approximately 0.5 square mile in an area located in Brooklyn Park. The identity of the site is being withheld for proprietary reasons. It is a former industrial site contaminated with solvents and heavy metals, and is enrolled in the VIC program at the MPCA.

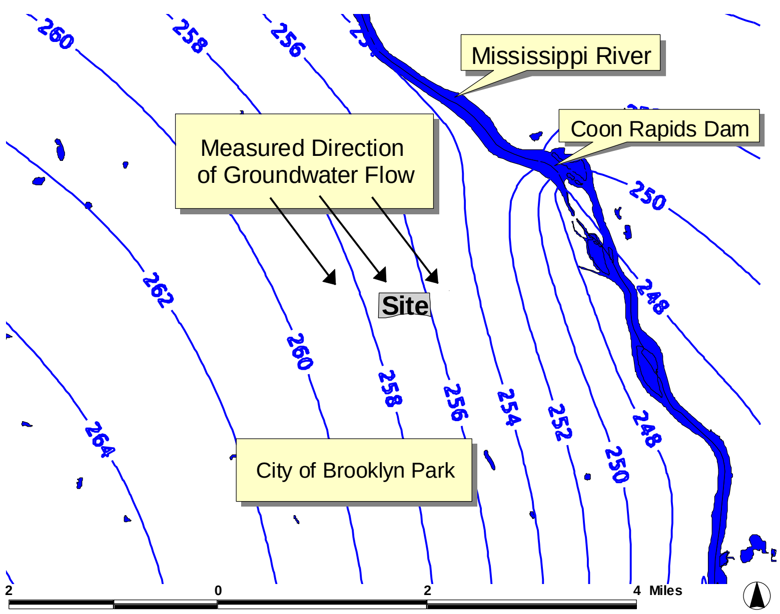

Figure 3

A local-scale model, based on the Metro Model, is being used to evaluate site conditions and to evaluate hydraulic control options. At GME's request, Metro Model staff provided the glacial drift aquifer portion (Layer 1) of the Northwest Province of the Metro Model, as well as head calibration data. Additionally, hydrogeologic data, including US Geological Survey topographic and MGS bedrock maps, provided on a database CD-ROM prepared by the Metro Model team were readily incorporated by GME into the analysis using ArcView Geographic Information System (GIS) software.

The aquifer that was modeled consists primarily of Quaternary sands overlying the St. Lawrence Formation, interpreted to be the aquifer base. Because the Metro Model is regional in nature, the first step was to tailor it to fit local site conditions. GME staff used 14 monitoring wells to help define local groundwater conditions. Further adjustments were made to simulate the phreatic aquifer, and to simplify the far-field conditions to allow for faster calculations. Although the model predicted a similar hydraulic gradient, the predicted direction of groundwater flow (easterly) differed from the observed direction (southeasterly), as shown in Figure 3.

Using ArcView GIS, the Graphical User Interface (GUI) in MLAEM, and the digital coverages that the Metro Model project team provided, GME inserted the appropriate local-scale features near the site, including wells, surface waters, and areal inhomogeneities. However, the model still did not reflect the local southeasterly flow direction. Further analysis using the MGS bedrock geology coverage, revealed a locally occurring but significant outlier of Jordan Sandstone above the St. Lawrence Formation. Insertion of an inhomogeneity representing decreased hydraulic conductivity for this portion of the aquifer influenced by the Jordan Sandstone (Figure 4) produced groundwater flow directions and gradients that were reasonably consistent with what has been observed at the site for the past couple years.

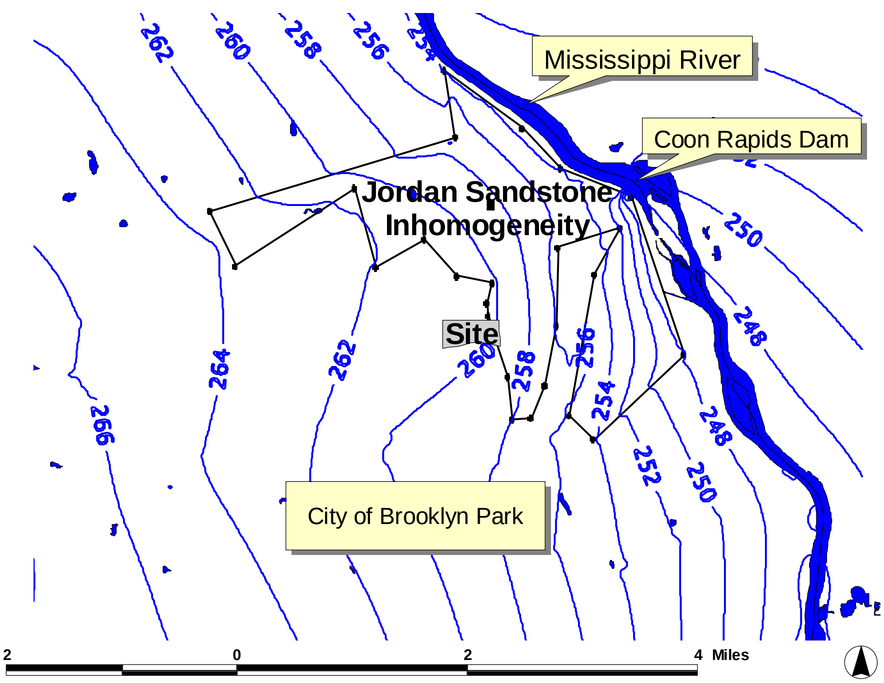

Figure 4

GME found that, because the Metro Model contained sufficient global detail and was regionally calibrated, they could use it as a basis from which they could construct a site-specific groundwater model. By using the Metro Model and its supporting databases, GME did not have to spend extensive time on the initial start-up and construction of their groundwater model. Future work by GME may include splitting the model into two layers—the first representing continuous Quaternary deposits above the Jordan Sandstone, and the second representing both the Quaternary deposits and Jordan Sandstone immediately above the St. Lawrence Formation.

Other Uses of the Model and its Supporting Databases
Examples of the use of the Metro Model include three recent Requests-for-Proposal issued by the Ramsey County Soil & Water Conservation District and the Minnesota Department of Health for the construction of regional models to be applied to problems of wellhead protection and groundwater management. All three stipulated extensive use of the Metro Model and its supporting databases as a necessary starting point for the consultants picked for the contracts. Additionally, the St. Croix Watershed Research Station of the Science Museum of Minnesota used the Metro Model and supporting databases on their 1997 Legislative Commission on Minnesota Resources project, Watershed Science: Integrated Research And Education Program.

Summary
After spending four years engaged primarily in the development of the Metro Model and its associated databases, project team members are shifting the emphasis towards its direct use in site remediation. Initial applications of the Metro Model project resources indicate that they can be used effectively as a tool in the support of groundwater management decisions. Project team members will now spend more time on applying the Metro Model to projects both within the MPCA and also outside, including providing assistance to private parties. However, they will also continue to refine and improve the existing project as new information, data, and modeling techniques become available. And they will bring lessons learned and resources to bear on MPCA projects in Greater Minnesota.

If you would like more information or think that the Metro Model project team can provide you with resources you need for your project, please contact the following:

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Footnote: The Metro Model was initially supported from 1995 through 1999 by the Legislative Commission on Minnesota Resources, with additional support coming from the US Environmental Protection Agency and the MPCA. As of July 1, 1999, the project has become a permanent part of the MPCA's Environmental Outcomes Division.