

Appendix 3: 2040 Groundwater Model Projections

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SUBJECT: Metro Model 3 Application: Evaluating 2040 Water Demand

Metro Model 3 (MM3) was developed and calibrated for the primary purpose of predicting the effects of current and future groundwater withdrawals and land use on groundwater levels and the base flows of streams at a regional scale. These types of model predictions are useful for interpreting hydrogeologic data, informing future data collection, and for evaluating alternatives to enhance sustainable use of water resources in the metropolitan area.

Metro Model 3 is also available to use as a starting point for more subregional or localized analyses. For example, with refinement, it can be used for well impact evaluations, capture zone analysis, evaluation of surface water impacts, or to explore the impact of land use changes on recharge.

Benefits of this revision of the Metro Model include:

1. Incorporation of new information
2. Implementation of newer and better-supported software
3. Enhanced methods to understand parameter sensitivities and uncertainty in model predictions
4. Improved representation of Quaternary unconsolidated sediments and their influence on the groundwater-flow system
5. The ability to simulate seasonal effects of climatic and pumping stresses
6. An expanded model domain (Metropolitan Council 2014d)

Objectives and Application

Metro Model 3 was designed to help address a broad range of regional planning questions and to be as flexible as practical in order to accommodate new questions or scenarios, while still incorporating the best available data. Some examples of questions the model is intended to help address include:

- Given projected water demands, what impacts may be expected on groundwater levels and groundwater-dependent surface-water features?
- What combinations of source aquifers, well locations, and withdrawal rates can be used to achieve sustainable water consumption?
- How will projected water demand affect groundwater levels in each aquifer across the metropolitan area?

In its current design, Metro Model 3 successfully answers these questions. However, interpretation of the model results must recognize that any model is a simplification of a complex system and accuracy is limited by naturally variable geologic conditions and human error in measurements. For more information on Metro Model 3 please see the *Twin Cities Metropolitan Area Groundwater Flow Model Version 3.0* (Metropolitan Council 2014d).

2040 Regional Scenarios

Regional scenarios were run using the model to evaluate the effects of forecasted groundwater withdrawals to the region's aquifer system.

Assumptions

Population and Population Served

The 2040 population for the communities within the seven-county metropolitan area are the population forecast values developed by the Metropolitan Council. Communities that disagree with the Council population forecasts and are actively changing the population forecasts with the Council; the community supplied population forecast is being used. New growth is assumed to be served by the municipal system. For a more detailed explanation of population served please see the technical memorandum, *Water Demand Projection Methodology and Preliminary Results, dated February 13, 2015* (Metropolitan Council, 2015e).

Water Demand

Municipal water demand was projected to 2040 water use using 2002-2012 data and community input. For more information of water demand please see the technical memorandum, *Water Demand Projection Methodology and Preliminary Results, dated February 13, 2015* (Metropolitan Council, 2015e). Between 1988 and 2012 water use for industrial, agricultural, and commercial use has been fairly consistent when compared to municipal demand. Therefore, these uses are assumed to remain constant through 2040.

Water Sources and Well Locations

Sources for municipal use were assumed to remain the same as current sources. Communities were contacted and asked to comment on well locations and sources. Communities fell into four categories:

- Communities served by surface water or by another community
- Communities who do not plan to drill any more wells
- Communities who plan to drill more wells and provided the locations and aquifers
- Communities where locations and sources were the same as in Metro Model 2. For more information please see *Metro Model 2 Technical Report, 2010 Master Water Supply Plan, Appendix E*

See the Table 1 for a list of communities and the category where they fell. Projected water use in excess of 2003-2011 average water use was evenly distributed among future wells. When a community did not plan to drill future wells the excess water use was evenly distributed among the existing wells.

Table 1. Summary of how Twin Cities metropolitan area community public water supply wells were included in Metro Model 3 including: whether or not the community is supplied by another community, if new wells are planned for installation between 2015 and 2040, if community staff provided corrections to the draft well locations and sources shared with communities in December 2014, and if the well locations and sources remain the same as those used by Metro Model 2 to support the 2010 Master Water Supply Plan.

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
Andover			X	
Anoka				X
Apple Valley			X	
Arden Hills	X			
Bayport				X
Belle Plaine		X		
Birchwood	X			
Blaine				X
Bloomington				X
Brooklyn Center		X		
Brooklyn Park			X	
Burnsville		X		
Carver			X	
Centerville		X		
Champlin		X		
Chanhassen			X	
Chaska			X	
Circle Pines			X	
Cologne				X
Columbia Heights	X			
Columbus		X		
Coon Rapids				X
Corcoran	X			
Cottage Grove			X	
Crystal	X			
Dayton			X	
Deephaven	X			
Eagan			X	
East Bethel				X
Eden Prairie			X	
Edina		X		
Elko New Market			X	
Empire Township			X	

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
Excelsior		X		
Farmington				X
Falcon Heights	X			
Forest Lake			X	
Fridley				X
Golden Valley	X			
Greenfield				X
Hamburg				X
Hampton				X
Hastings			X	
Hilltop	X			
Hopkins		X		
Hugo			X	
Inver Grove Heights			X	
Jordan				X
Lake Elmo			X	
Lakeland				X
Lakeland Shores	X			
Lake St. Croix Beach	X			
Lakeville			X	
Lauderdale	X			
Lexington				X
Lilydale	X			
Lino Lakes			X	
Little Canada	X			
Long Lake		X		
Loretto		X		
Mahtomedi		X		
Maple Grove			X	
Maple Plain			X	
Maplewood	X			
Marine On St Croix				X
Mayer				X
Medina				X
Mendota	X			
Mendota Heights	X			
Minneapolis				
Minnnetonka		X		

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
Minnetonka Beach				X
Minnetrista			X	
Mound		X		
New Brighton		X		
New Germany		X		
New Hope	X			
New Prague				X
New Trier				X
Newport			X	
Northfield				X
North Oaks	X			
North St. Paul				X
Norwood Young America				X
Oak Grove			X	
Oak Park Heights				X
Oakdale				X
Orono				X
Osseo	X			
Plymouth			X	
Prior Lake		X		
Ramsey		X		
Randolph				X
Richfield		X		
Robbinsdale			X	
Rockford				X
Rogers		X		
Rosemount				X
Roseville	X			
Savage		X		
Shakopee			X	
Shoreview				X
Shorewood				X
South St. Paul			X	
Spring Lake Park		X		
Spring Park				X
St. Anthony				X
St. Bonifacious				X
St. Francis				X

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
St. Louis Park				X
St. Paul				X
St. Paul Park		X		
Stillwater		X		
Sunfish Lake	X			
Tonka Bay		X		
Vadnais Heights				X
Vermillion				X
Victoria				X
Waconia			X	
Watertown			X	
Wayzata			X	
West St. Paul	X			
White Bear Lake				X
White Bear Twp.		X		
Willernie	X			X
Woodbury			X	
Woodland	X			

“Business as Usual”

This scenario was designed to test the hypothesis that, given projected demands, metropolitan area communities can continue to use water and develop supplies using the traditional assumption of aquifer availability. Due to uncertainty regarding future population, the effectiveness of conservation practices and climate, a 20% increase of municipal water use and a 20% decrease of municipal water use was included in the “Business as Usual” scenario. The 20% increase and decrease was applied to all existing and future municipal wells in the seven-county metropolitan area.

Model Uncertainty

Groundwater models are used to make decisions, to analyze risk, and to manage water systems. While no model can be 100% correct, when properly constructed and evaluated, a model can be a useful and informative tool. Evaluating the uncertainty that exists within a model reinforces the output from the model and makes it more useable to the end user.

Sources of Uncertainty

Model uncertainty comes from four main factors:

1. *Conceptual framework*
2. *Model parameter*
3. *Calibration*
4. *Predictive*

In the Metro Model 3, key contributors to *conceptual framework and model parameter uncertainty* include old geologic atlases. While the geology hasn't changed in the past 20 years, we are now able to better map the geology of the area. Our evolving understanding about fault systems is one example of uncertainty in our conceptual framework. The following county geologic atlases are over 20 years old:

- Dakota
- Hennepin
- Ramsey
- Washington

Key contributors to *calibration uncertainty* include the quality of data in the County Well Index (CWI). CWI was weighted less than other more certain datasets, such as observation wells, but where observation wells are sparse CWI drives head during calibration. While broad spatially, CWI data are uncertain due to the following:

- Inaccurate water-level measurements
- Inaccurate well location
- Inaccurate elevation
- Unstable water level at the time of measurement
- Misidentification or incorrect assignment of hydrostratigraphic units in databases
- Seasonal pumping affects of water levels
- Long-term changes in water levels due to climate or growing water demand

The single biggest contributor to *predictive uncertainty* is uncertainty in future water demand. We do not know for sure how many people will live in the metro, where they will live, how much water they will use, or if sources of water will remain the same. This is where input from City Administrators and Engineers comes in. We recognize that no one knows the city and its water supply better than the city or utility staff. Therefore, we have been asking for input on population, population served, per capita water use, water sources, and well locations.

It is hard to predict water use given all the variables, but historically water use has been in about a +/- 20% range, which is why we are presenting results with this range.

Calibrated MM3

The steady-state Metro Model 3 model estimates average water levels between 2003 and 2011, within a range (plus or minus) about 17 feet.

Because it is a steady-state model, it does not represent water levels for a specific day and time. Instead, it is intended to illustrate where aquifer water levels will come to equilibrium under a given water budget (recharge, pumping, baseflow). In other words, it illustrates where things will ultimately end up.

In general, the model uncertainty is spread fairly evenly throughout the model. Areas where model uncertainty appears to be concentrated, and associated reasons for uncertainty, are:

- Northwest Hennepin County

- Areas of faulting
- Geologic atlas updated in 1989
- Few observation wells
- Eastern Scott County
 - Areas of faulting
- Rice County (note: not in 7 county metro; directly to south of the Twin Cities metropolitan area)
 - Geologic atlas updated 1995
 - Few observation wells
- Le Sueur County (note: not in 7 county metro; directly south of Scott County)
 - Geologic atlas updated in 1991
 - Few observation wells

Model Application

We know that MM3 has an average error of approximately +/- 17 feet and we know the sources of the error. What does this mean for the way the model is applied?

The Metropolitan Council recognizes the error in the model compared to the real world. This error can be minimized when comparing model output to model output. Drawdown shows you the change between two conditions, the starting and ending place doesn't matter as much as the difference between the two conditions.

Table 2: Uses for "out of the box" Metro Model 3

Acceptable	Marginally Acceptable*	Not Acceptable
Compare regional scenarios	General well field placement	Localized well field optimization
Compare sub-regional scenarios	Estimate groundwater/surface water connections	Site specific evaluations
Identify areas where more information is needed	Wellhead protection plans	Predicting time dependant water table elevations
Identify possible problem areas		

*The model can be used as a "back of the envelop calculation" giving the user an idea of a starting place for further analysis.

Calculations using Metro Model 3

Metro Model 3 is currently used by the Metropolitan Council for two specific calculations:

1. Drawdown
2. Available Head

These two calculations are visible in the drawdown figures provided in the Master Water Supply Plan.

Drawdown Calculations

The drawdown is the difference in head (water level) between two points in time. The drawdown (D_d) is calculated as the difference between the model head at 2010 pumping rates (H_{2010}) and the model head at 2040 pumping rates (H_{2040}). The model resulting from the 2010 pumping as reported in SWUDS was designated as the initial condition. This means areas with drawdown are showing an increase in pumping from 2010 pumping conditions.

$$D_d = H_{2010} - H_{2040}$$

The 2040 projected drawdowns are relative to the modeled 2010 pumping as reported in the Minnesota Department of Natural Resources State Water Use Data System (SWUDS). This has been a point of discussion with communities and agency technical staff, and the idea that the most people felt comfortable with is modeling the 2010 pumping as reported in SWUDS to use as a baseline condition. This links the model to a particular year and allows updates of the model to always use the same year so that there is not a moving baseline for calculating drawdown.

Available Head Calculations

Available head is not measured; it is calculated using the model. The available head is the difference between the head (water level) and the upper bedrock surface of the aquifer.

$$H_{available} = Elevation_{Model\ 2010\ pumping} - Elevation_{top\ of\ geologic\ formation}$$

If the calculated available head ($H_{available}$) is greater than 10 feet, then the aquifer is considered confined and the 50% head analysis takes place.

If $H_{available} > 10$ feet then:

The elevation of the top of the geologic formation ($Elevation_{top\ of\ geologic\ formation}$) is added to 50% of the calculated available head ($H_{available}$) to calculate the 50% head elevation ($H_{available\ elevation}$).

$$H_{available\ elevation} = Elevation_{top\ of\ geologic\ formation} + \frac{1}{2} * H_{available}$$

If the modeled head ($Elevation_{Model\ 2040\ pumping}$) is less than the 50% head elevation ($H_{available\ elevation}$) then that cell is flagged.

$$If\ H_{available\ elevation} < Elevation_{Model\ 2040\ pumping}$$

The 2010 pumping data from SWUDS is input into Metro Model 3 and the output is used to define the water level. The cumulative reported 2010 pumping is divided by 365 days to get average daily pumping, which is then input into the model. Note: If an area has 10 feet of head or less it is considered unconfined and removed from the analysis. Also note that Metro Model 3 is a steady-state model and does not account for seasonal or operational variation.