NOTE: Data is still draft. Local population and demand information, and related analyses, are expected to be refined based on input through the public review process.

Appendix 1. Water Supply Profiles

Purpose

This appendix summarizes water use, source, and potential issues for each community, county and watershed in the seven-county Twin Cities metropolitan area.

The information in each water supply profile is generally based on regional information and should be refined with more locally specific characteristics to better evaluate potential issues.

The profiles provide a useful starting place for local planning and can be used in several ways, including:

- To inform community water conservation programs by helping to target large water use categories
- To complete local water supply plans in a way that considers Metropolitan Council policy and the Master Water Supply Plan
- To inform water supply-related permit applications and environmental review documents

Target Audience

- Community planning staff
- Public water supply utility staff
- County planners
- Watershed planners

Methodology and Supporting Data – DRAFT: TO BE UPDATED WITH REVISED POPULATION FORECASTS AND MODELING.

Overview of water systems and use in the community

Information about the current status of the community's water system came from a review of past local water supply plans, data submitted to the MN Department of Natural Resources as part of the water appropriation permit program, and information submitted to the MN Department of Health and stored in the Minnesota Drinking Water Information System (MNDWIS). The information will be updated based on information provided through the public review process for the 2015 Master Water Supply Plan.

Number of high capacity wells permitted by DNR within the community

The number of high capacity wells in each major aquifer in the community was determined by counting the number of municipal and private water appropriation permits, as reported in MN Department of Natural Resources water appropriation permit database called the State Water Use Data System (SWUDS), located within the community boundaries.

Average annual water use by permitted users since 2003, in key water use categories

The average amount of water used by major categories between 2003 and 2012 came from MN Department of Natural Resources water appropriation permit database called the State Water Use Data System (SWUDS).

Available options for water supply sources

The list of available options for water supply sources was developed through a public outreach process that included input by sub-regional work groups. More information about the approach

NOTE: Data is still draft. Local population and demand information, and related analyses, are expected to be refined based on input through the public review process.

to outreach is available in Chapter 1 of the Master Water Supply Plan. More information about these options is described in Chapter 4 of the Master Water Supply Plan.

Municipal Water Use

Municipal water treatment

Information about municipal water treatment was taken from the MN Department of Health database called the Minnesota Drinking Water Information System (MNDWIS).

Rate structure

Information about the community's water rate structure came from MN Department of Natural Resources water appropriation permit database called the State Water Use Data System (SWUDS).

2012 [OR MOST RECENT] Permitted amount for municipal water supply

2012 permitted amount for municipal water supply is reported as the total amount of water appropriated by the community for public water supply purposes. A pie chart illustrates the amount of public water supply used for residential, industrial, commercial, irrigation, and non-revenue purposes.

2012 permitted amount for municipal water supply information came from MN Department of Natural Resources water appropriation permit database called the State Water Use Data System (SWUDS).

Historical municipal water use in the community

Historic water use information came from the MN Department of Natural Resources water appropriation permit database called the State Water Use Data System (SWUDS). Summer water use is represented by the month with the highest water use (usually July or August) and winter water use is represented by the month with the lowest water use (usually January or February).

Projected water use

Projected water use was developed by the Metropolitan Council with input from public water utility and community staff. The process is described in Appendix 2 of the Master Water Supply Plan. Some highlights are summarized below.

Population Served

Population served represents the number of people receiving water from the municipal water supply system. If the community sells water to a neighbor, the population served may be larger than the population of the community.

2020, 2030, and 2040 population served was projected by Metropolitan Council with input from communities. Values in this table should be assumed to range within 20% above and below the projection.

Total Population

Total population represents the total number of people who live in the community. 2020, 2030 and 2040 total population was taken from *Thrive MSP 2040*.

NOTE! *As of April 9, 2015 population data is aligned with data distributed to communities for review. They are subject to change and will be revised for system adoption.*

NOTE: Data is still draft. Local population and demand information, and related analyses, are expected to be refined based on input through the public review process.

Projected Average Daily Water Use (Million Gallons per Year)

Projected average daily water use represents the total amount of municipal water used in a year by the community for purposes that include: residential, commercial, industrial, serving neighbors, and non-revenue purposes.

2020, 2030, and 2040 average daily water use was projected by Metropolitan Council with input from communities. Values in this table should be assumed to range within 20% above and below the projection.

Total Per Capita Water Use (Gallons per Person per Day)

Total per capita water use represents the average daily water use by the community (see description above), divided by the population served (see description above).

This value represents more than water used by residents in their homes; it also includes commercial, industrial, irrigation, and residential use. This value should not be used to compare communities against one another, because it is strongly shaped by community differences in the composition of commercial, industrial and residential users.

2020, 2030, and 2040 total per capita water use was projected using the method described in Appendix 2 of the Master Water Supply Plan.

Total Per Capita Water Use, Assuming Total Water Use Remains at 2011 [OR MOST RECENT] Levels

Total per capita water use, assuming total water use remains at 2011 levels, illustrates how much water demand may have to be reduced, on a per person basis, to supply the community's future population with the same amount of water.

2011 total per capita water use, assuming total water use remains at 2011 levels, equals 2011 data reported by communities to the MN Department of Natural Resources through the water appropriation permit program.

2020, 2030, and 2040 total per capita water use, assuming total water use remains at 2011 levels, was determined by dividing 2011 total water use by the 2020, 2030, and 2040 population served (see description above).

The following will need to be addressed as water plans are updated

The issues identified here are generally based on regional information and can be refined for more local, site specific characteristics to better evaluate vulnerability.

Local water supply plans, permit requests, and environmental review documents should acknowledge potential issues and discuss actions to explore them further using more local information.

Regional information used to identify potential water supply issues came from several sources. The criteria and data sources used to identify each potential issue are described here:

Potential for water use conflicts and well interference

Due to the pervasiveness of private wells, the potential for well interference has been identified as a potential water supply issue throughout the region.

NOTE: Data is still draft. Local population and demand information, and related analyses, are expected to be refined based on input through the public review process.

Potential for significant decline in aquifer water levels

- DNR reports a declining trend in annual minimum water levels at an observation well within 1.5 miles of the area of interest. Trend information was taken from the *2014 Clean Water Fund Performance Report.*
- Regional groundwater flow modeling of the likely range of 2040 water demand, assuming currently planned sources are used, suggests that available head will drop by more than 50% over at least 60 acres (250,000 m^2) in one or more aquifers. Details about the Metropolitan Council's water demand projection process can be found in Appendix 2; details about the modeling process can be found in Appendix 3.

Potential for impacts of groundwater pumping on surface water features and ecosystems

- A trout stream is located within 5 miles of the community, based on mapping published by MN Department of Natural Resources (cite GIS dataset name)
- A fen is located within 5 miles of the community, based on mapping published by MN Department of Natural Resources (cite GIS dataset name)
- A spring is located within 1.5 miles of a community, based on mapping published by MN Department of Natural Resources (cite GIS dataset name)
- Surface waters within 1,000 feet of the community are likely to be directly connected to the regional groundwater system, based on regional screening by Metropolitan Council (CITATION for Barr).

Significant vulnerability to contamination

- Minnesota Department of Health has designated a Special Well and Boring Construction Area has been designated within the community
- A Drinking Water Supply Management Area (DWSMA) has been designated by the Minnesota Department of Health and [CITY NAME]; all or part of the DWSMA has been designated as vulnerable
- A sinkhole (karst) has been mapped within 1.5 miles of the community (CITATION for GIS dataset)
- The estimated vertical travel time from land surface to the regional water table is less than 50 years, based on hydrogeochemical mapping done by the Minnesota Geological Survey (CITATION for MGS report)

Significant uncertainty about aquifer productivity and extent

- No aquifer test or groundwater monitoring wells exist within 1.5 miles (cite MDH database)
- The most recent county geologic atlas is over 20 years old
- No DNR groundwater level observation well is located within 1.5 miles of the community (CITE DNR observation well database, online)

The following actions are recommended

Information about recommended action was developed by Metropolitan Council in partnership with state agencies, particularly DNR, and under the guidance of the Metropolitan Area Water Supply Advisory Committee and a community technical work group.

City (DRAFT DATA)

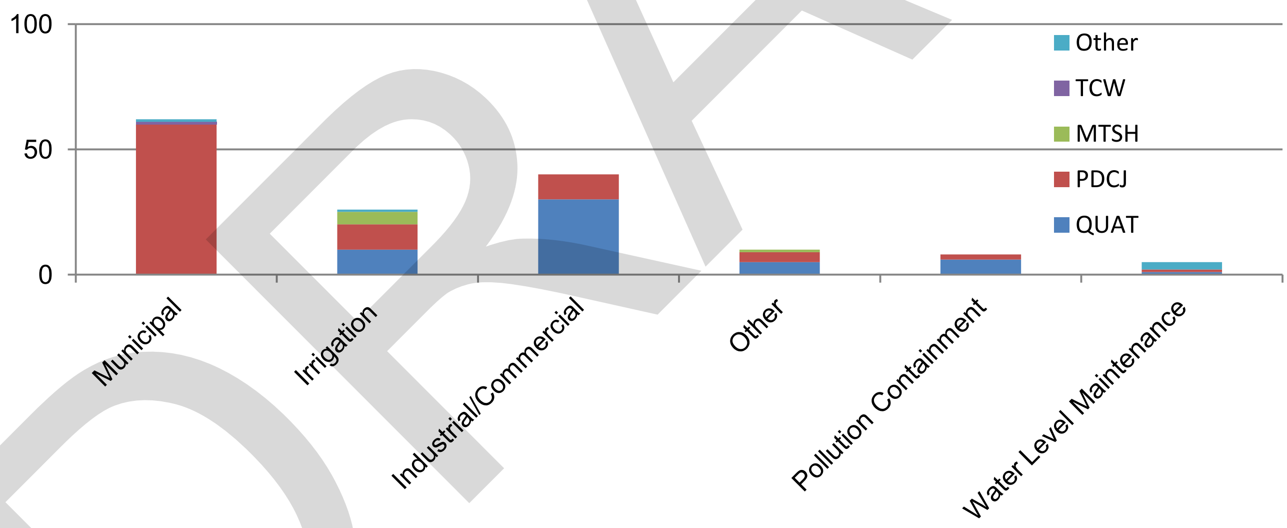
Overview of water systems and use in the community

The community owns and operates their own municipal water supply system. Private wells supply additional water demand to some users.

Number of withdrawals permitted by DNR within the community:

Source	Number of Municipal Wells or Intakes	Number of Non-Municipal Wells or Intakes
Mt. Simon-Hinckley (MTSH)	0	2
Prairie du Chien-Jordan (PDCJ)	16	10
Quaternary (QUAT)	0	2
Tunnel City-Wonewoc (TCW)	0	0
Other		
Surface Water		

Average annual water use by permitted users since 2003, in key water use categories:



Available options to meet current and future water demand:

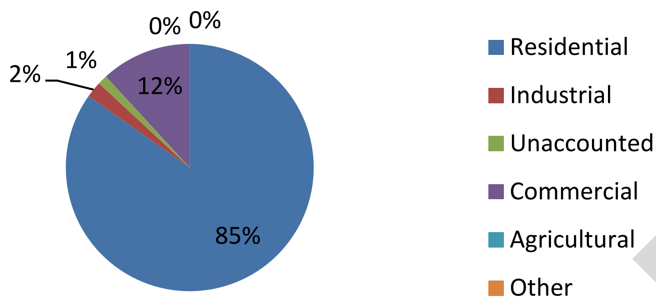
1. Conservation
2. Groundwater sources
3. Stormwater reuse
4. Reclaimed wastewater
5. Enhanced recharge
6. Surface water sources

Municipal water use

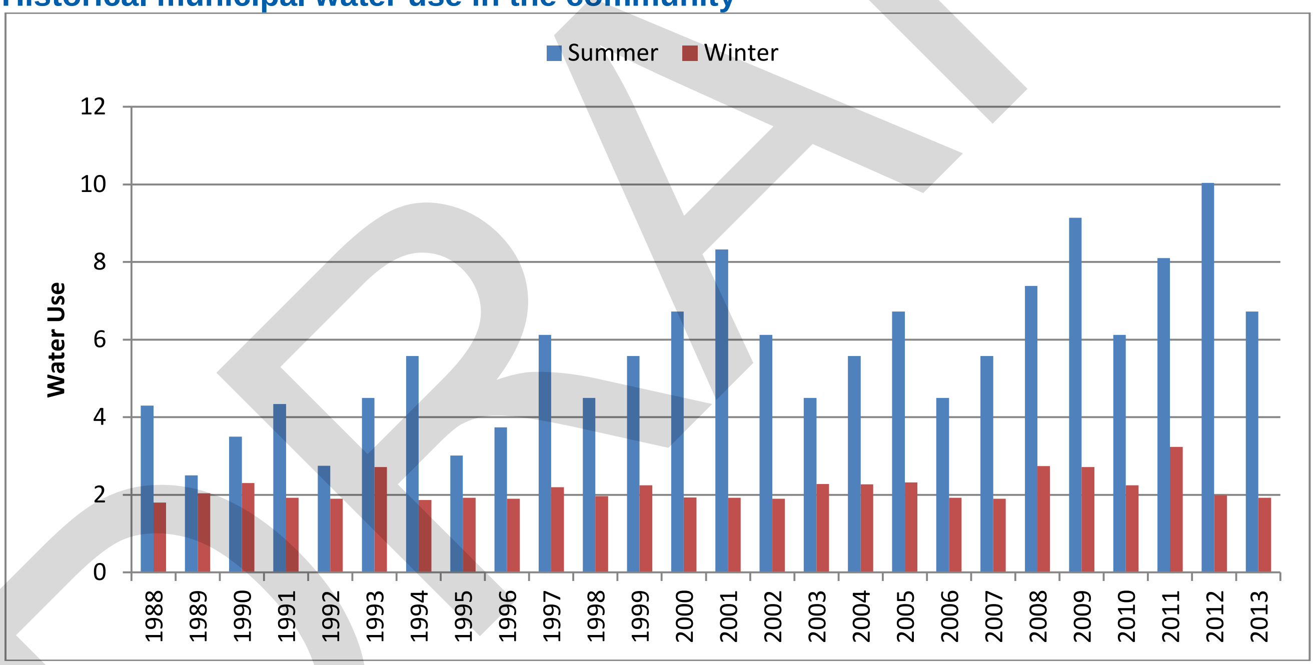
Municipal water treatment: Disinfection, Fluoride, Iron/Manganese Sequestration

Rate structure: Increasing block

2012 Permitted amount for municipal water supply (million gallons/year): 3,267



Historical municipal water use in the community



Projected water use

	2020	2030	2040
Population Served	Value	Value	Value
Total Population	74,000	84,000	87,200
Projected Average Daily Water Use (Million Gal./Day)	Range	Range	Range
Total Per Capita Water Use (Gal./Person/Day)	Range	Range	Range
Total Per Capita Water Use, Assuming Total Water Use Remains at 2011 Levels	95	84	81

The following will need to be addressed as water plans are updated:

- Potential for water use conflicts and well interference
  - Due to the pervasiveness of private wells in the metro area, there exists a potential for water use conflict and well interference for all appropriators
- Potential for significant decline in aquifer water levels
  - A nearby DNR observation well documents a declining trend in aquifer water levels
  - Regional groundwater modeling highlights areas where the range of projected 2040 water demand may exceed safe yield amounts, if current use patterns and water sources meet that demand; this may be considered a warning threshold to allow time for contingency plans to be in effect if water levels decline
- Potential for impacts of groundwater pumping on surface water features and ecosystems
  - A state-designated trout stream is located within 5 miles of the community
  - A state-protected calcareous fen is located within 5 miles of the community
  - A spring has been mapped within 1.5 miles of the community
  - Hydrogeologic information suggests a connection between groundwater and surface waters
- Significant vulnerability to contamination
  - A Special Well and Boring Construction Area has been designated within the community
  - A vulnerable Drinking Water Supply Management Area has been designated within the community
  - A sinkhole (karst) has been mapped within 1.5 miles of the community
  - Travel time from land surface to bedrock aquifers is estimated to be less than 50 years
- Significant uncertainty about aquifer productivity and extent
  - The Minnesota Department of Natural Resources does not have an observation well within 1.5 miles of the community
  - The Minnesota Department of Health has no record of an aquifer test within 1.5 miles of the community
  - The county geologic atlas is more than twenty years old
- Regulatory considerations
  - A Groundwater Management Area has been designated within the community

The Metropolitan Council's *Local Planning Handbook* contains interactive maps of all of these issues, and they are also summarized in Chapter 5 of this Master Water Supply Plan.

The following actions are recommended:

- Due to the benefits of efficiently managing water demand, explore and support water demand (water conservation) programs such as incentives, ordinances, education and outreach, rates and other approaches. The Metropolitan Council Water Conservation Toolbox can support water conservation efforts.
- Issues identified above can be included in local water supply plans and water appropriation permit applications, including any local studies done to evaluate the adequacy of local sources and monitoring needs or a plan to assess risks (including milestones, schedule, and potential partners)
- Explore and propose a plan to implement, as feasible, alternative/additional water supply approaches that considers the potential issues identified above
  - Identify potential partners, actions, and schedule to implement
  - Due to the risk of water conflict and well interference, before requesting water appropriations, all water appropriators in this area should evaluate the need to address water conflict and well interference including a) an inventory of all active domestic and public water supply wells near proposed well locations and b) an analysis of existing water level/water withdrawal data to identify where future groundwater level decline could affect domestic wells.
  - Due to the potential for significant decline in aquifer levels, before requesting water appropriations, all water appropriators should conduct a basic evaluation of the likelihood for

significant decline in water levels. The analysis should be determined in consultation with DNR and can vary from a graphical comparison of water levels to local groundwater flow modeling. If this analysis suggests future declines are likely to be unacceptable, a management plan should be developed and include additional water level and pumping rate monitoring, triggers and actions to protect aquifer levels, a schedule for periodic analysis of data to identify the need for action to mitigate impacts, and a schedule for periodic and timely reporting to DNR.

  - Due to the risk of impacting surface waters through groundwater pumping, consult with DNR to review existing information about groundwater withdrawals, water level, surface water flow, climate, and projected withdrawals and wells to predict the likelihood of a connection between aquifer withdrawals and surface water features. The classifications by the Metropolitan Council are generally based on regional information and should be refined for more local, lake specific characteristics to better evaluate vulnerability. If a connection is likely, a management plan should be developed and include aquifer testing, monitoring water levels and pumping rates and surface water flow, triggers and actions to protect aquifer levels, a schedule for periodic analysis of data to identify the need for action to mitigate impacts, and a schedule for periodic and timely reporting to DNR.
  - Due to the risk of contamination, consult with MDH about local actions to prevent the spread of contamination. The community's source water protection plan should include measures to mitigate public health risks due to potential contamination sources, which may include cooperating with MDH to increase monitoring of contaminants regulated under the Safe Drinking Water Act. Where significant contamination exists, MDH will continue enhanced monitoring and work with public water suppliers to ensure appropriate treatment processes are in place to meet Safe Drinking Water Act requirements and manage pumping to better control the extent and magnitude of the contaminant plume.
  - Due to uncertainty regarding aquifer productivity and extent, consider partner with agencies such as MN Geological Survey, DNR and MDH and with neighbors to collect data as feasible.
  - Due to regulatory considerations, partner with DNR and neighboring water users to use water in accordance with Groundwater Management Area plan, if applicable.
- Address other conditions, as identified by federal and state organizations:
  - Compliance with Safe Drinking Water Act standards
  - Conditions identified on existing and future water appropriation permits issued by the Minnesota Department of Natural Resources
  - Issues identified in Minnesota Department of Health Source Water Assessments

Guidance in provided in the local water supply plan template and the Local Planning Handbook, and Metropolitan Council water supply planning staff are available to provide additional assistance.

Appendix 2. Water Demand Projections

DATE: February 13, 2015

TO: Twin Cities Metropolitan Area Water Suppliers

FROM: Metropolitan Council Water Supply Planning Unit

SUBJECT: Water Demand Projection Methodology and Preliminary Results

This memorandum provides a summary of the methods used to project water demand for the public water supply systems in the Twin Cities Metropolitan Area. This work is being done in support of the regional Master Water Supply Plan update that is currently in progress. Presented are the data sources used, and assumptions made, in projecting water use through 2040 for each water system in the region.

Generally speaking, the method used is a per capita unit use coefficient approach for each of the municipal water utilities in the seven-county metropolitan area. This approach calculates a per capita water use for each community, based on historical water use, population data, and input received from community public water suppliers. Future water demand projections are obtained by multiplying future population projections by the estimated per capita unit use coefficient:

(Projected Water Use) = (Projected Population) X (Per Capita Water Use)

The discussion that follows describes the method used to calculate initial projections for each community. Input was also received from communities on draft projections that were distributed in October 2014. A second draft was distributed in January 2015, and a second round of comments were incorporated into the version that was used for running the regional groundwater flow model for the draft Master Water Supply Plan. Local forecasts were used in lieu of Metropolitan Council forecasts when they were provided by communities.

Historical Water Use Data

Water use data for annual use was obtained from the Minnesota Department of Natural Resources (DNR) water use database (SWUDS). The annual use data was taken from data published on the DNR website for each year between 2000 and 2010:

http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

Historical Population Data

Total Population

Total population for each community was obtained from US Census data for 2000 and 2010. Total population was interpolated linearly between 2000 and 2010. Metropolitan Council population estimates were used for 2011 and 2012.

Population Served

In many communities, there is a difference between total population and population served by the public water system. Data on population served by the public water system in each community were obtained from Water Supply Plans submitted to the DNR by each community. Those plans require public water suppliers to report estimates for total population of the community and population served by the water system for each of the ten years prior to plan submittal. For each year with complete data in the Water Supply Plan for each community, the population not served by the water system was calculated as the difference between the reported total population and population served. This unserved population was averaged over the number of years with complete data.

Year	Total Population	Population Served
1999	2698	2,588
2000	3588	3,513
2001	4330	4,295
2002	5010	4,935
2003	5580	5,505
2004	5760	5,685
2005	6716	6,641
2006	6750	6,683
2007	6971	6,901
2008	7200	7,128

Figure 1. Example of Population Reporting from Local Water Supply Plan

Following the calculations of average unserved population, the data were manually reviewed for inconsistencies and outliers. Adjustments were also made based on local input.

The average unserved population was used to calculate an estimated population served for each year between 2003 and 2012. The estimated population served was set equal to the interpolated census total population minus the average unserved population for each community. In this way, the estimated population served is tied to the recorded census population for each community.

(Population Served) = (Interpolated Census Population) – (Average Unserved Population)

Per Capita Water Use Calculation

Total per capita water use for each community was calculated for each year between 2003 and 2012 by dividing the reported water use by the estimated population served. The per capita water use was then averaged over this ten-year period. The average per capita water use based on population served is reported in this way for each community.

(Water Use Per Person) = (Total Water Use) / (Population Served)

This value represents the total water use per capita for each community. This includes all water use in the community, including commercial, industrial, institutional, and other uses. Therefore, it is not necessarily indicative of the amount of water used in each household. This is an important distinction since a community may have a large amount of water-intensive industry that drives up the total water use per capita. Therefore, the total per capita use by itself may not be an accurate indicator of the effectiveness of conservation programs for example.

Population Forecasts

Water demand projections were based in part on population forecasts from Thrive MSP 2040, the Metropolitan Council's updated regional development framework. These forecasts are derived from macroeconomic models, and more details can be found on the Metropolitan Council website:

http://metrocouncil.org/Data-and-Maps/Data/Census,-Forecasts-Estimates.aspx

Unless otherwise specified by a community, forecasted population served by municipal water systems was calculated by subtracting the average population not served, as previously described, from the total population forecast for each community. It is assumed by this method that the population currently not served by the public water system in each community will remain unserved through 2040. It is also assumed that future population growth and development will be served by the public water system.

In some cases, the unserved portions of a community will become served as a water system expands its service area. This would result in a projected population served that is too low by the current method. In other cases, future population growth and development could occur in areas that are not served by a public water system. This would result in a projected population served that is too high. Therefore, these potential inaccuracies for each community should be taken into account by local planners when utilizing these projections for water system planning purposes, and local knowledge should be used to adjust these projections where possible.

Water Demand Projections

Unless otherwise specified by a community, the projected population served was multiplied by the historical average per capita water use to calculate the water demand projection for each community. This method assumes that the historical average per capita water use, as estimated for each year between 2003 and 2012, is representative of future per capita water use.

Actual per capita water use is likely to fluctuate around an average value, depending primarily on weather, but also on economic factors. Therefore, actual water use could be higher or lower than the average values calculated by the method described in this memorandum. In addition to annual fluctuation in per capita water use, there are also long-term trends in per capita water use that are emerging in some locations and within specific water use categories.

For example, the Water Research Foundation and the US Environmental Protection Agency jointly commissioned a study in 2010 to investigate trends in residential water use[1]. This work found that newer homes tend to use less water indoors, and that older homes are reducing indoor water use over time through the retrofitting of older plumbing fixtures with newer water conserving fixtures. In communities with newer development, the reduction in water use indoors may be offset by other factors such as larger lots and automatic lawn irrigation systems.

There appears to be a trend toward lower per capita water use in many communities in the metro area. This is illustrated in Figure 2, which shows the trend in per capita use between 1990 and 2012 for the City of Richfield. Similar trends can be found for many communities in the region.

[1] Coomes P, Rockaway T, Rivard J, Kornstein B (Center for Infrastructure Research, University of Louisville, Louisville, KY). North America Residential Water Usage Trends Since 1992. Denver, CO: Water Research Foundation: 2010.

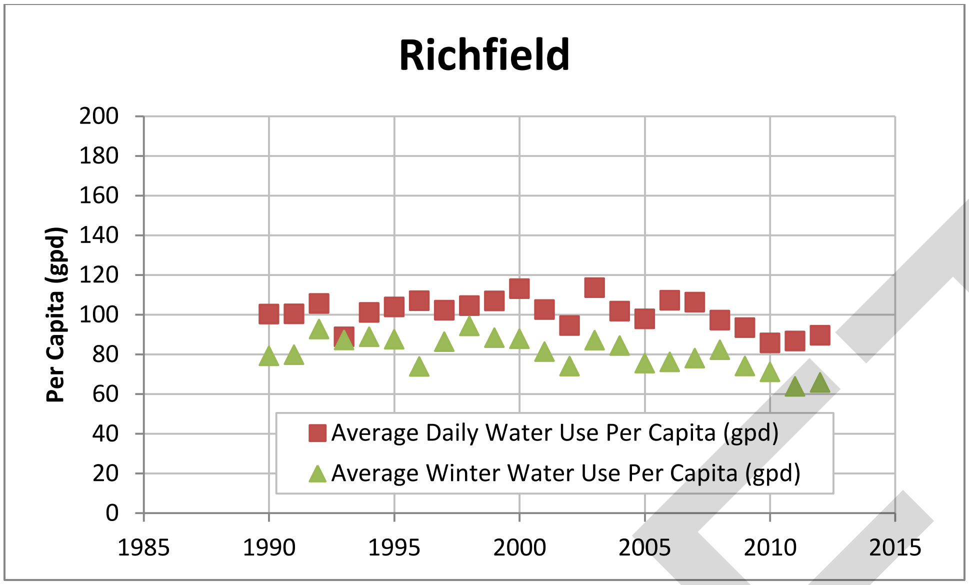


Figure 2. Historical Per Capita Water Use, 1990 – 2012, City of Richfield

While there appears to be a downward trend in this data for many communities in the region, the trend is not obvious for many other communities. Figure 3 shows the same series of data for Maple Grove, where the trend in per capita water use is not as apparent. The causes of the downward trend in some communities are not clear currently, though it could be related to more effective water conservation, economic drivers (especially in commercial water use), and/or climate. The observed trends in water use warrant further study in order to understand the causes and how they could impact future water use.

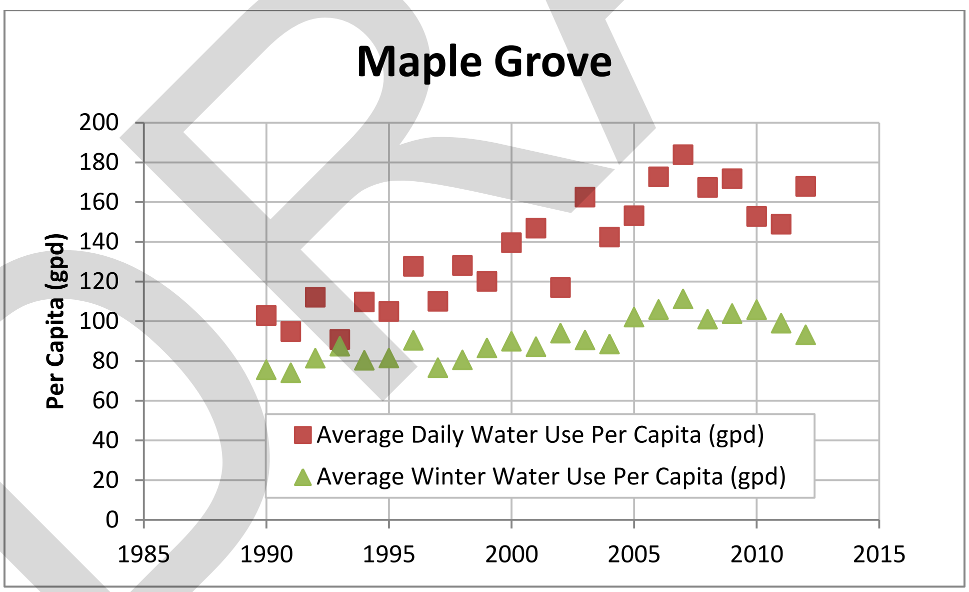


Figure 3. Historical Per Capita Water Use, 1990 – 2012, City of Maple Grove

The regional per capita water use is presented in Figure 4. As a region, there is not a significant trend in per capita water use between 1990 and 2012. However, the winter water use per capita (representing indoor water use) is declining. This has been accompanied by an increase in outdoor water use over the same time period on a per capita basis. Since 2007, there could be a downward trend in per capita water use for the region, though it is not a significant trend in the data at this point. Communities have reported that per capita water use has continued to decline through 2013 and 2014, and that mandatory tiered rate structures that have been implemented over the last couple of years may be the cause.

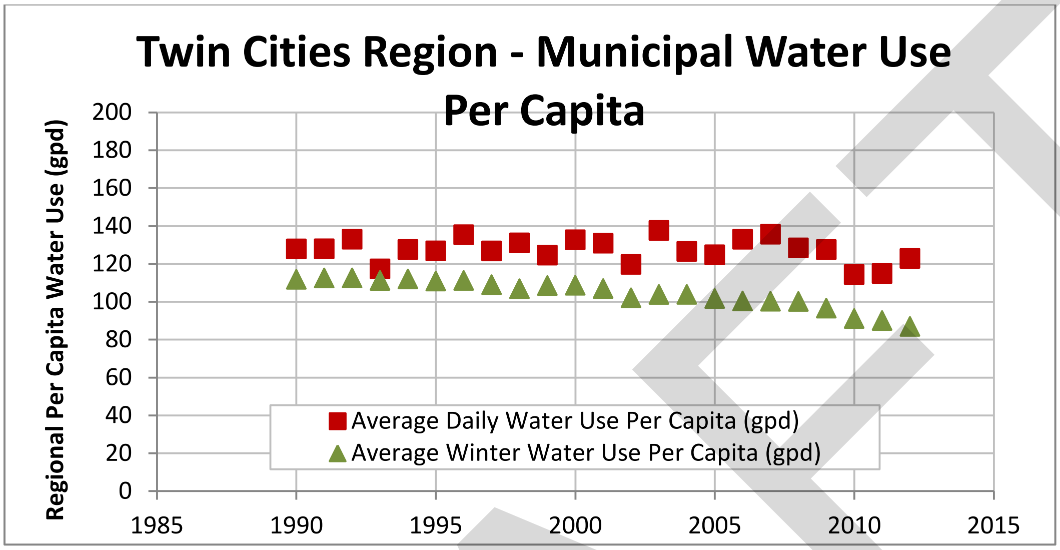


Figure 4. Historical Per Capita Water Use, 1990 – 2012, Twin Cities Metropolitan Area Public Water Systems

Use of Projections

The Metropolitan Council is developing these water use projections in support of the update to the regional Master Water Supply Plan, currently in progress. This information will help us to understand the magnitude and distribution of future water use in the region. The projections also serve as an input to our modeling efforts to predict resource constraints under future scenarios.

For the purpose of groundwater flow modeling, an average value of water use is appropriate. This is especially true with steady state modeling scenarios, where annual fluctuations in well pumping are not taken into account. For local water system capacity planning, it is important to plan for higher use conditions in order to avoid water shortages. Therefore, the projections presented in the Master Water Supply Plan generally should not be used for local water system capacity planning purposes.

Results

The results of the water demand projections for each public water supplier, as calculated by the methods described in this memorandum are attached. The overall demand projection for the region is presented in Figure 5. The light blue dashed lines above and below the projection indicate a +/- 20% uncertainty in our projections. The regional groundwater model will be run with a range of conditions to understand the sensitivity of model results to demand projection inaccuracy.

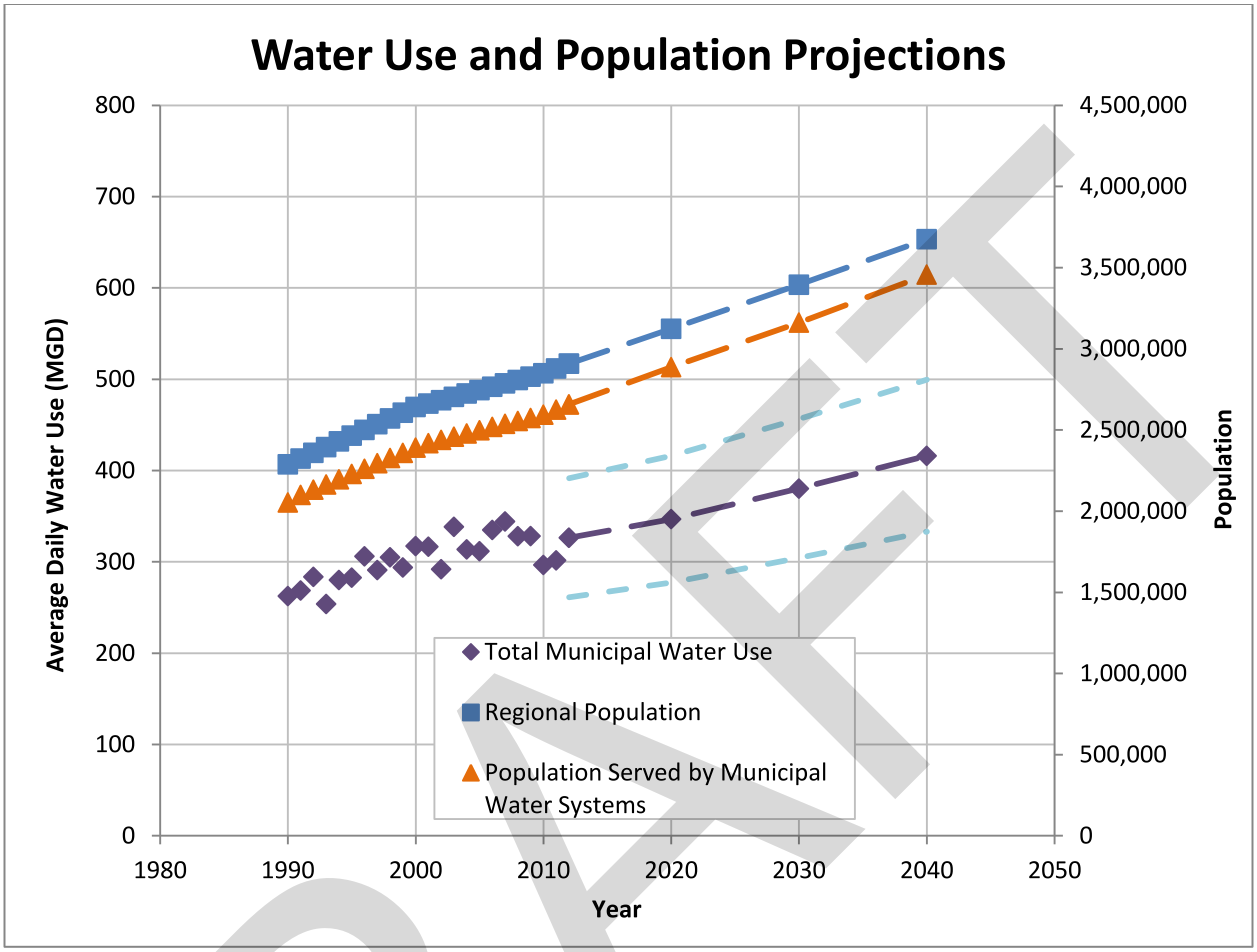


Figure 5. Projected Water Use - Twin Cities Metropolitan Area Public Water Systems

Appendix 3. Metro Model 3 Application: Evaluating 2040 Water Demand

DATE: March 18, 2015 (DRAFT)

TO: Water Supply Planning Unit, Metropolitan Council

FROM: Anneka Munsell, Environmental Scientist

SUBJECT: Metro Model 3 Application: Evaluating 2040 Water Demand

Metro Model 3 (MM3) was developed and calibrated to help the Metropolitan Council evaluate 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 for others to use as 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:

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

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, MM3 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 MM3 please see the *Twin Cities Metropolitan Area Groundwater Flow Model Version 3.0* (Barr, Metropolitan Council 2014).

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 *Water Demand Technical Memorandum, DATE.*

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 *Water Demand Technical Memorandum*. 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* (Metropolitan Council 2010)

See the table below 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.

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			

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
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	
Excelsior		X		
Farmington				X
Falcon Heights	X			
Forest Lake			X	
Fridley				X
Golden Valley	X			
Greenfield				X
Hamburg				X
Hampton				X

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
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				
Minnetonka		X		
Minnetonka Beach				X
Minnetrista			X	
Mound		X		
New Brighton		X		
New Germany		X		
New Hope	X			
New Prague				X
New Trier				X
Newport			X	

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
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. Bonifaceous				X
St. Francis				X
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

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
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 are:

- Northwest Hennepin County
  - Areas of faulting
  - Geologic atlas updated in 1989
  - Few observation wells
- Eastern Scott County
  - Areas of faulting
- Rice County (directly to south) 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 +/- 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 1: Uses for "out of the box" MM3

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

MM3 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 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 DNR SWUDS. This has been a point of discussion 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 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 the DNR SWUDS database is input into MM3 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 MM3 is a steady-state model and does not account for seasonal or operational variation.

Appendix 4. Metro Model 3 Application: Optimization

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Technical Memorandum

To: Lanya Ross, Anneka LaBelle, Ali Elhassan
From: Evan Christianson, Ray Wuolo
Subject: Metro Pumping Optimization 3
Date: April 2, 2015
Project: 23/62-1087.01

1.0 Introduction

This technical memorandum describes the optimization of pumping in the seven-county metropolitan area. The goal of the optimization was to maximize total pumping from existing permitted wells while meeting constraints on baseflow, hydraulic head, flow direction, and flux to/from surface water features as specified by the Metropolitan Council. The optimization uses the steady-state version of the Twin Cities Metropolitan Area Groundwater Flow Model, Version 3.0 (Metro Model 3; Metropolitan Council, 2014)

Optimizations described in technical memorandums dated August 15, 2014 and October 13, 2014 (Barr, 2014a and Barr, 2014b), herein referred to as Optimization 1 and Optimization 2, are similar and complimentary to the optimization described in this technical memorandum, herein referred to as Optimization 3.

2.0 Optimization Software, GWM-VI

The Groundwater Management (GWM) Process for MODFLOW, developed by the USGS (Ahlfeld et al., 2000), was used for the optimization. The version used was GWM-VI (Banta and Ahlfeld, 2013) which allows for parallel processing. No changes were made to the source code of GWM-VI for implementation of this project. All optimization algorithms described in Banta and Ahlfeld (2013) and Ahlfeld et al. (2005) are implemented with no change. However, several pre- and post-processing steps were used to overcome hardwired limitations on the type of constraints available with the standard GWM-VI implementation and are discussed in Section 2.3. Optimizations utilizing GWM-VI require two main inputs: decision variables and constraints; each is discussed below.

2.1 Decision variables

Decision variables are quantifiable controls that are to be determined by the GWM-VI optimization algorithms (Ahlfeld et al., 2000). Decision variables for both Optimizations 1, 2, and 3 were identical and were provided to us by Metropolitan Council. They include existing permitted wells in the seven-county metropolitan area open to any aquifer, except the Mt. Simon Hinckley aquifer, and with use codes from the SWUDS database shown in Table 1. A total of 2,074 wells were included in the optimization. The goal of the optimization was to maximize the objective function, which is essentially the sum of the pumping from all decision variable wells.

Table 1. SWUDS use codes for decision variable wells included in the optimization

Use Code	Description	Use Code	Description
211	Municipal	248	Non-metallic processing
212	Private waterworks	249	Industrial processing
213	Commercial and Institutional	263	Quarry dewatering
215	Fire protection	264	Sand/gravel pit dewatering
229	Power generation	266	Dewatering
232	Institutions	271	Pollution containment
241	Agricultural processing	277	Sewage treatment
242	Pulp and paper processing	289	Non-crop irrigation
246	Petroleum-chemical processing, ethanol	290	Major crop irrigation
247	Metal processing		

2.2 Constraints

Constraints impose restrictions on the values that can be taken by the decision variables (Ahlfeld et al., 2000). Three types of constraints were used: hydraulic head, flux between groundwater and surface-water features (baseflow and basin leakage and/or gain), and groundwater flow-direction. In general, Optimization 3 and Optimization 2 are constrained significantly less than Optimization 1. A summary of constraints imposed for each optimization is shown in Table 2 and details describing each constraint type are presented below.

Table 2. Comparison of constraints between Optimization 1, 2, and 3

Constraint Type	Optimization 1	Optimization 2	Optimization 3
Drawdown from available head for confined bedrock aquifers above the Mt. Simon-Hinckley	75%	75%	50%
Drawdown in the Mt. Simon-Hinckley aquifer	1 foot	1 foot	1 foot
Drawdown at groundwater dependent surface-water features (cancerous fens)	1 foot	1 foot	1 foot
Change in net baseflow to trout streams	-10%	-10%	-10%
Change in net baseflow to other river reaches	Not included	-15%	-15%
Change in net baseflow to the Mississippi River	Not included	-15%	-25%
Change in net groundwater flux for high and outstanding biodiversity	Not included	-15%	-15%
Change in net groundwater flux to potentially vulnerable lakes with wide littoral zone	Not included	-10%	-10%
Change in net groundwater flux for remaining lakes at grouped by Township	Not Included	-15%	-15%
Change in flow directions at site of groundwater contamination	10 degrees	10 degrees	10 degrees

Optimization 1 constrained the flux between groundwater and surface water for trout streams only. As described in more detail below, Optimizations 2 and 3 constrained the flux between groundwater and surface water for all lakes, streams, and wetlands simulated by Metro Model 3 within the seven-county metropolitan area.

2.2.1 Hydraulic Head Constraints

Hydraulic head constraints were used to impose three conditions on the optimization: 1) hydraulic head in confined bedrock aquifers can't drop below a "safe yield" threshold, 2) hydraulic head in the Mt. Simon–Hinckley aquifer can't drop more than 1 foot from the baseline condition, and 3) hydraulic head at groundwater dependent surface-water features (e.g. calcareous fens) can't drop more than 1 foot from the baseline condition. Hydraulic head, representing "safe yield" thresholds, were defined as:

$$Safe\ Yield\ Head = (H_b - Z) * 0.50 + Z$$

Where:
H_b is the base head condition for the aquifer, defined using pumping from the Metro Model 2;
Z is the elevation of the top of the aquifer

The base condition from which drawdown for the Mt. Simon-Hinckley aquifer and groundwater dependent surface-water features were determined was the hydraulic head from the steady-state version of the Metro Model 3.

Hydraulic head constraints representing "safe yield" and limits on drawdown of the Mt. Simon-Hinckley aquifer were implemented at the cell location (row and column) of all pumping wells in the seven-county metro area. Including these head constraints in every model cell is not practicable as it would dramatically increase the total run time for the optimization. These head constraints are more likely to be violated at the location of high pumping stress, compared to distances far from the wells. Vertically, at each cell location, constraints were included only for model layers representing bedrock aquifers being pumped and layers above these aquifers. For example, if the Prairie du Chien is being pumped and lower aquifers are not being pumped, "safe yield" constraints were only included for the Prairie du Chien and St. Peter aquifer, not the deeper aquifers.

2.2.2 Flux between groundwater and surface-water features

All surface-water features in the Metro Model 3 are simulated using the River Package for MODFLOW. The River Package simulates the exchange of water between groundwater and surface water. River Package boundary cells were compiled into groups and the water fluxes into or out of the boundary cells were tracked and summarized for each group. Constraints were imposed to limit the change in flux from the baseline condition resulting from increased pumping. The baseline condition used was the flux simulated with the steady-state version of Metro Model 3.

Groundwater flux to all streams (baseflow) in the seven-county metropolitan area was constrained for the optimization (Figure 1). Each stream was divided into reaches approximately 5 miles in length. Baseflows for trout stream reaches are not allowed to be reduced by more than 10 percent from the baseline conditions. Baseflows for all other reaches, with the exception of the Mississippi River, are not allowed to be reduced more than 15 percent from baseline conditions. Baseflows for the Mississippi River were allowed to be reduced up to 25 percent. A total of 13 trout stream baseflow constraints and 79 non-trout stream baseflow constraints were imposed for the optimization.

River boundary cells that intersect sites of high and outstanding biodiversity identified by the Minnesota County Biological Survey (2013) were grouped together (Figure 1). The groundwater flux into these features was not allowed to decrease more than 15 percent and/or flux out of these features was not allowed to increase more than 15 percent from the baseline simulation. A total of 108 biodiversity area constraints were imposed.

River Package boundary cells that represent lakes identified as being potentially vulnerable to groundwater pumping and having a wide littoral zone (Barr, 2010) were grouped together (Figure 1).

Lakes are considered to have a wide littoral zone if they are less than five feet deep over more than 20 percent of the total surface area. These lakes have a greater potential of being negatively impacted by reductions in stage. For these lakes (68 in the seven county metropolitan area), the water flux out was not allowed to increase more than 10 percent and/or the groundwater flux into these lakes was not allowed to decrease more than 10 percent.

All remaining River Package boundary cells that were not included in groups described above were grouped based on the public land survey township they are located in (Figure 1). This resulted in an additional 103 constraints. For these grouped boundary cells, the total groundwater flux in was not allowed to be reduced by more than 15 percent and/or total water flux out was not allowed to increase more than 15 percent. Grouping these River Package cells, rather than imposing constraints on individual cells or surface water features, was necessary to help keep the total number of constraints to a manageable level to maintain reasonable solution times for the optimization algorithm.

2.2.3 Flow Direction Constraints

Flow direction constraints for Optimizations 1, 2, and 3 are identical and were included for areas of existing groundwater contamination provided by the Metropolitan Council. The flow direction in the vicinity of these contamination areas was not allowed to deviate from the baseline condition by more than 10 degrees. The baseline condition used was the flow direction simulated with the steady-state version of Metro Model 3.

2.3 Substitution of MMProc

GWM-VI uses a stand-alone executable, *MMProc.exe*, to write MODFLOW input files, execute MODFLOW, and extract head and cell-by-cell flow values from MODFLOW output files. *MMProc.exe* is hardwired to only read output from a small number of MODFLOW packages. Two major limitations of *MMProc.exe* necessitated the development of a separate and much more flexible pre- and post-processor: inability to read/write data for the River Package, and implementation of groundwater flow-direction constraints. Pre- and post-processing for Optimization 2 and Optimization 3 are identical. Pre- and post-processing Optimization 1 involved less constraints associated with River Package boundary cells. Description of the pre- and post-processing steps described in the technical memo from August 14, 2014 and is repeated below for completeness.

A python script, *pyMMProc.py*, was developed to handle the capabilities of *MMProc.exe* while being more flexible and allowing use of the River Package and flow-direction constraints. A comparison of how *MMProc.exe* and *pyMMProc.py* interact with GWM-VI and MODFLOW is shown on Figure 2a and Figure 2b.

The source code for this script is provided with the project deliverables and is documented internally. A brief description of how the script works is provided below for those not familiar with the python programing language.

GWM-VI creates a file called *MMProc.in.jtf* at the start of an optimization run that acts as a template file for well pumping rates. Throughout the optimization, GWM-VI (or a runner program called *jrunner* if running in parallel mode) uses *MMProc.in.jtf* to create a file called *MMProc.in* which contains pumping rates for MODFLOW to use. Updated pumping rates are pulled from *MMProc.in* and used by *pyMMProc.py* to generate a new Well (WEL) Package and Revised Multi-Node Well (MNW2) Package files for MODFLOW. *pyMMProc.py* then executes MODFLOW.

After MODFLOW is completed, *pyMMProc.py* extracts hydraulic head and river flux data from MODFLOW output files associated with the head and river observation packages. Selected hydraulic head data are used to calculate groundwater flow-directions by solving a three-point problem. The deviation in groundwater flow direction from a provided base condition is then determined. The change in river flux from the base condition is also calculated. All hydraulic head, change in flow direction, and change in river flux are written to a file called *Simulated_Values.out* which is read directly by GWM-VI.

pyMMproc.py also checks to make sure that MODFLOW converged and that no pumping rates were reduced by the MNW2 or Upstream Weighting (UPW) Package. Convergence status and pumping rate status are written to a file called *modflow.status* which is read directly by GWM-VI.

The use of pyMMproc.py necessitates slight modifications on how GWM-VI input files are set up that may not be initially intuitive. Input files were set up to treat all constraints, including baseflow and flow-direction constraints as head constraints. All constraint types are included in the head constraints (HEDCON) input file. This was necessary due to GWM-VI only supporting the Stream Package, whereas the Metro Model 3 uses the River Package. If GWM-VI input files were set up using the stream constraints (STRMCON) input file, GWM-VI would expect to find a Steam Package, which does not exist for Metro Model 3.

2.4 Limitations of GWM-VI

During the course of this optimization several hindrances were encountered that relate to the GWM-VI software. We have notified the developers of GWM-VI about these issues; however, there is currently no timeline for fixing them. A discussion of these issues and current workarounds to each are described below.

1.) **Solving of the linear program (LP) is not optimized or parallelized**. The SLP solver used by GWM-VI has two main phases: 1) calculation of the response matrix, which requires MODFLOW to be run once for every decision variable and 2) solving the LP. Previous versions of GMW (prior to GWM-VI) were not able to run is a parallel or distributed fashion. So, calculation of the response matrix was by far the most time consuming phase of solving the optimization problem. With the introduction of parallel processing in GWM-VI, calculation of the response matrix can be completed in a fraction of the time previously required, given that enough processors are available. During this project, we used up to 75 processors for calculating the response matrix. Solving the LP is not parallelized and must be completed on a single processor. The solution time for a single LP problem is roughly proportional to the number of constraints cubed.

2.) **Pumping from multi-node wells being reduced.** Wells simulated with the MNW2 Package can have their pumping rate automatically reduced if the head in the well or surrounding aquifer drops to levels that would not be able to supply the specified pumping rate for a well. This is an unfavorable occurrence for the GWM-VI algorithms because constraints may be met only because the pumping was automatically reduced by MODFLOW. GWM-VI overcomes this issue by checking information in the *modflow.status* file written by MMproc (or pyMMproc). If any wells have their pumping reduced it is indicated in the *modflow.status* file and GWM-VI automatically reduces pumping rates for all wells based on equation 73 in Ahlfeld (2005) and attempts an additional MODFLOW simulation. This continues iteratively until all MNW2 wells pump at the specified rates. The problem with this approach is that all wells have their pumping reduced if just a single MNW2 well is causing a problem. So, if many iterations of reducing pumping from all wells are required to prevent a single MNW2 well from pumping at a rate less than specified there is very little change in the total pumping.

Overcoming this issue required stopping GWM-VI at each iteration of the SLP solver and adjusting pumping rates wells that were causing problems. Implementing this process dramatically increased progress of the optimization. The process of adjusting pumping rates was automated for Optimization 2 and Optimization 3 but still required manually stopping and restarting GWM-VI at each iteration.

3.0 Results of Optimization

3.1 Pumping Rates

Total optimized pumping from the wells included in the optimization is 374 million gallons per day (MGD). This represents a 43-percent increase in the base pumping of 261 MGD, which is the pumping from the steady-state version of the Metro Model 3 and represents average pumping from 2003 to 2011. A comparison of optimized total pumping rates for Optimizations 1, 2, and 3 is shown in Table 3.

Table 3. Comparison of results from Optimization 1, 2, and 3.

Optimization	Total optimized pumping (MGD)
1	743
2	368
3	374

Further analysis of the optimized pumping is beyond the scope of this project but it is our understanding that it will be completed by the Metropolitan Council. However, we have tried to provide the Metropolitan Council with some insight, based on what we learned during the optimization process and a cursory inspection of the results. A discussion is provided in Section 4.0 below.

3.2 Binding constraints and shadow prices

While 5,237 constraints were imposed for the optimization, only a subset actually controls the formulation of an optimal solution. These constraints are said to "bind" the solution because they prevent decision variables (well pumping) from taking values that would further improve the optimization. Each binding constraint has a "shadow price" which reflects how sensitive the optimization is to the constraint. For additional discussion of binding constraints and shadow prices the reader is referred to Ahlfeld et al. (2005) pg. 51. Binding constraints and associated shadow prices calculated by GWM-VI during the last iteration of the optimization are presented in Attachment A. A total of 184 (out of 5,237 total) constraints were found to be binding. Overall, baseflow constraints (trout and other streams) were the most sensitive, constituting 12 of the top 30 constraints with the largest shadow price. Change in flux on the township and range scale constituted 9 of the top 30 constraints with the largest shadow price. Table A2 summarizes binding constraints by constraint type. Figure 3 shows the spatial distribution of binding constraints.

4.0 Discussion

Analysis of the optimization results are not part of the scope of this project and it is our understanding that such analysis is planned to be completed by Metropolitan Council staff. However, the following observations were noted during this project and may warrant further review, discussion, or follow-up optimization.

1.) Optimization 1 showed large increases in pumping sustained by induced leakage from River Package boundary cells. Significantly increasing the constraints imposed on River Boundary cells for Optimization 2 greatly reduced these issues, and hence reduced the total optimized pumping volumes. Optimization 3 imposed strictor constraints regarding safe yield (50% available head vs.

75% available head) and less restrictive constraints on baseflow to the Mississippi River. Overall Optimization 3 resulted in slightly more pumping than Optimization 2, primarily because the optimization is very sensitive to constraints imposed on baseflow of the Mississippi River. There may still be areas where induced leakage may be occurring beyond sustainable levels but are highly local and smaller than the scale to which we can impose constraints.

2.) Many of the constraints with the largest shadow price (see Section 3.2) are reaches of the Mississippi River. A constraint imposing no more than a 25 percent reduction in baseflow from baseline conditions was used for these reaches. Because these reaches are major groundwater discharge zones for the region, many wells, particularly in the deeper aquifers, affect baseflow to these reaches by capturing flow that would go to the river under lower pumping conditions. It should be noted that the constraint imposed does not represent a 25 percent reduction in total flow; the vast majority of flow comes from upstream. Allowing for a greater reduction in baseflow to these reaches would result in a higher optimized pumping volume, potentially significantly higher given the magnitude of the shadow price for these constraints.
3.) For some communities, the optimized pumping scheme results in municipal pumping being reduced to nearly zero. The reality and feasibility of such a scenario is uncertain.
4.) This type of optimization is very non-linear and typically non-unique. It is very likely that different distributions may result in nearly identical total pumping. We believe the addition of more constraints for Optimizations 2 and 3 has helped move toward the more unique solution. However, the level of uniqueness has not been quantified.

Limitations of the model, optimization, and choice of wells and constraints should be carefully considered when using these results for long-term planning. The optimization was limited to only existing wells and assumes that conditions have reached steady-state. New wells, added in undeveloped areas or aquifers, would certainly increase the total pumping of the region while still meeting imposed constraints. Also, in certain areas local concerns such as well interference or impacts to surface waters not accurately simulated at the scale of the Metro Model 3 may be deemed unacceptable even though all constraints imposed were met.

5.0 References

Ahlfeld, D.P., Barlow, P.M. and Mulligan, A.E., 2005. GWM—A ground-water management process for the U.S. Geological Survey modular ground-water model (MODFLOW-2000): U.S. Geological Survey Open-File Report 2005-1072, 124p.

Banta, E.R. and Ahlfeld, D.P., 2013. GWM-VI—Groundwater Management with parallel processing for multiple MODFLOW versions: U.S. Geological Survey Techniques and Methods, book 6, chap. A48, 33p.

Barr Engineering. 2014a. Metro Pumping Optimization, Technical Memorandum from Evan Christianson and Ray Wuolo to Lanya Ross, Anneka LaBelle, and Ali Elhassan, August 15, 2014.

Barr Engineering. 2014b. Metro Pumping Optimization 2, Technical Memorandum from Evan Christianson and Ray Wuolo to Lanya Ross, Anneka LaBelle, and Eli Elhassan, October 13, 2014.

Metropolitan Council, 2014. Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0. Prepared by Barr Engineering. Metropolitan Council: Saint Paul, MN.

Minnesota County Biological Survey. 2013. MBS Sites of Biodiversity Significance, Minnesota Department of Natural Resources, Division of Ecological Resources, shapefile geospatial data.

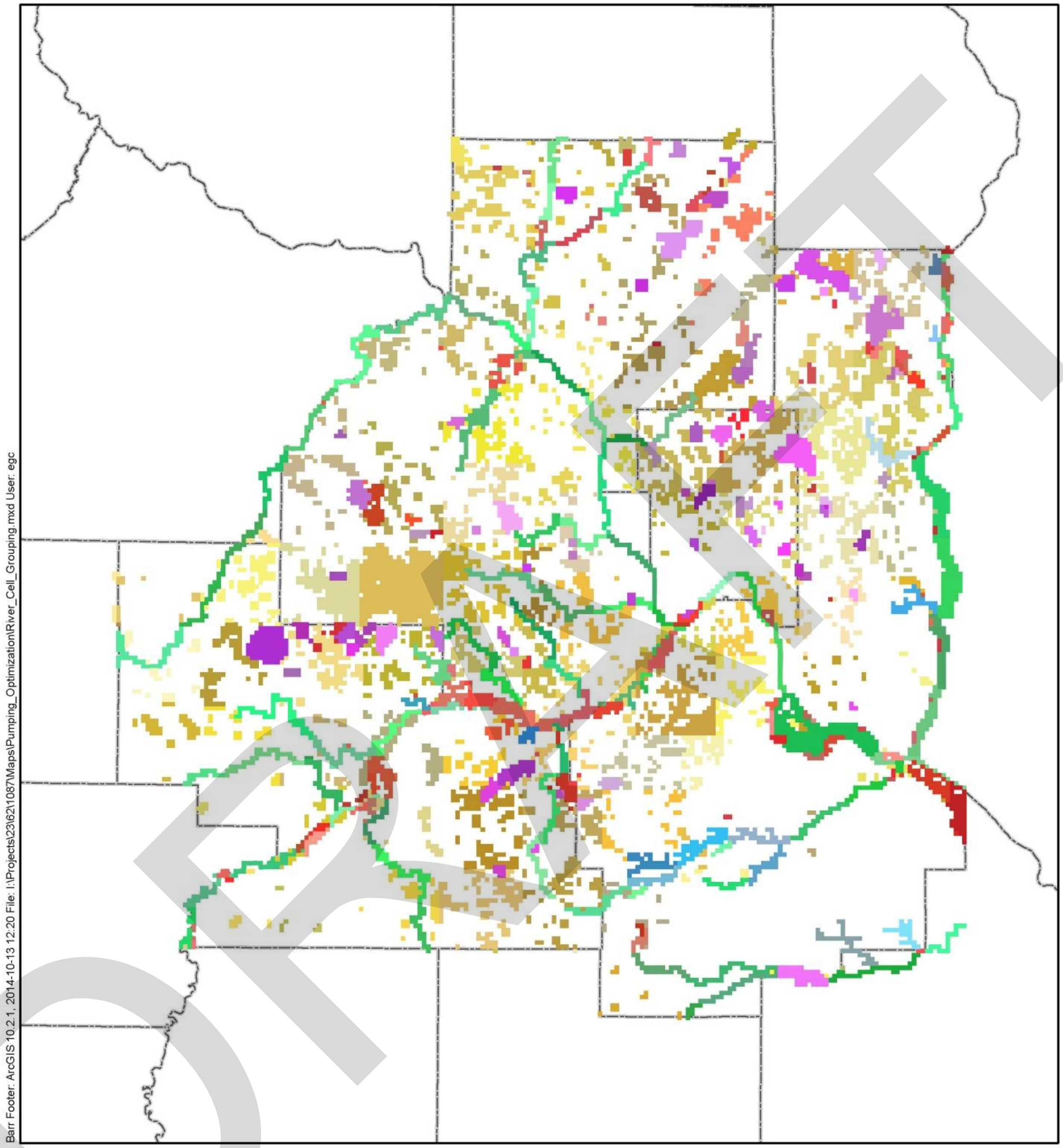
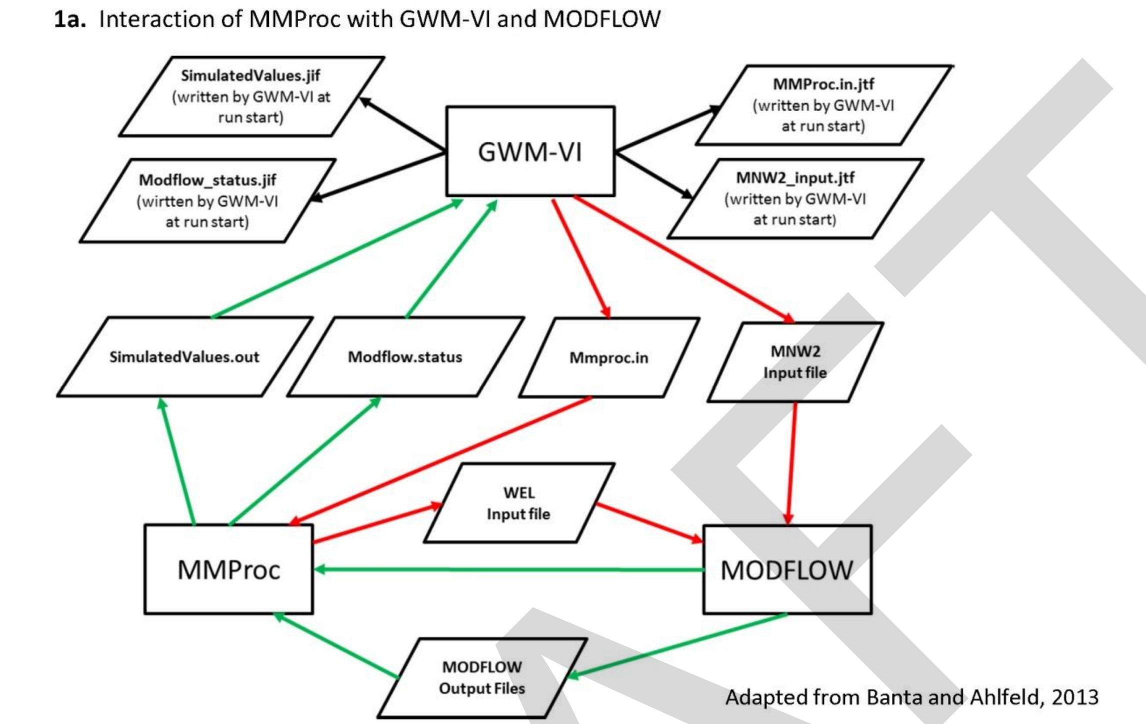


Figure 1

RIVER PACKAGE BOUNDRY CELL CONSTRAINTS
Pumping Optimization 3
Metropolitan Council



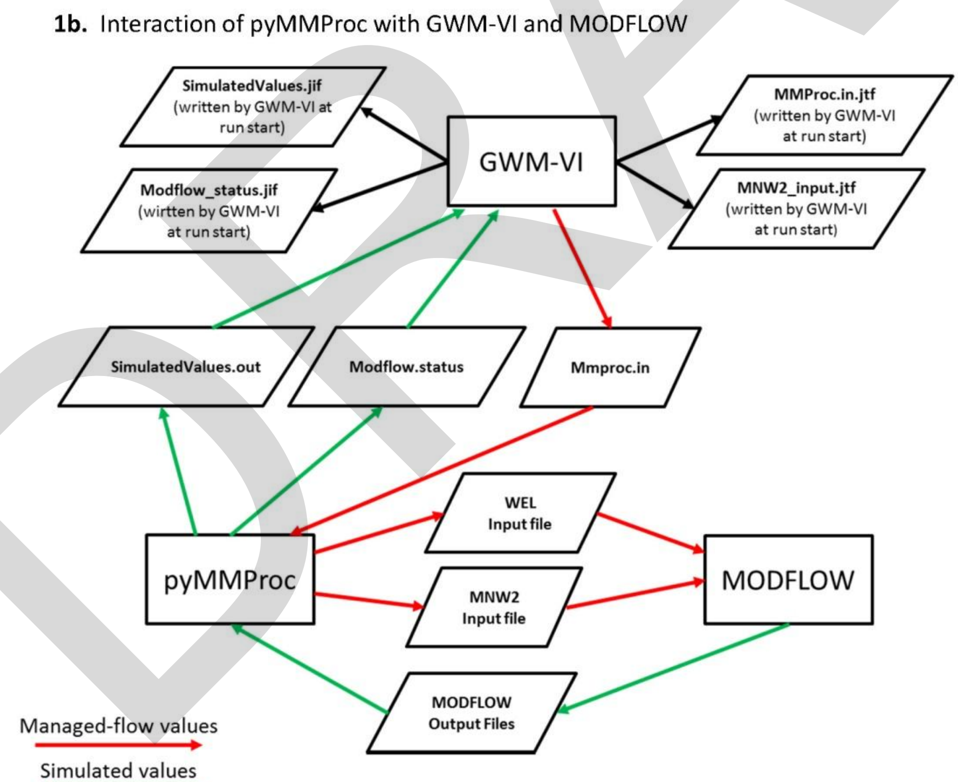


Figure 2

Comparison of MMProc and pyMMProc interaction with GWM-VI and MODFLOW
Pumping Optimization 3
Metropolitan Council

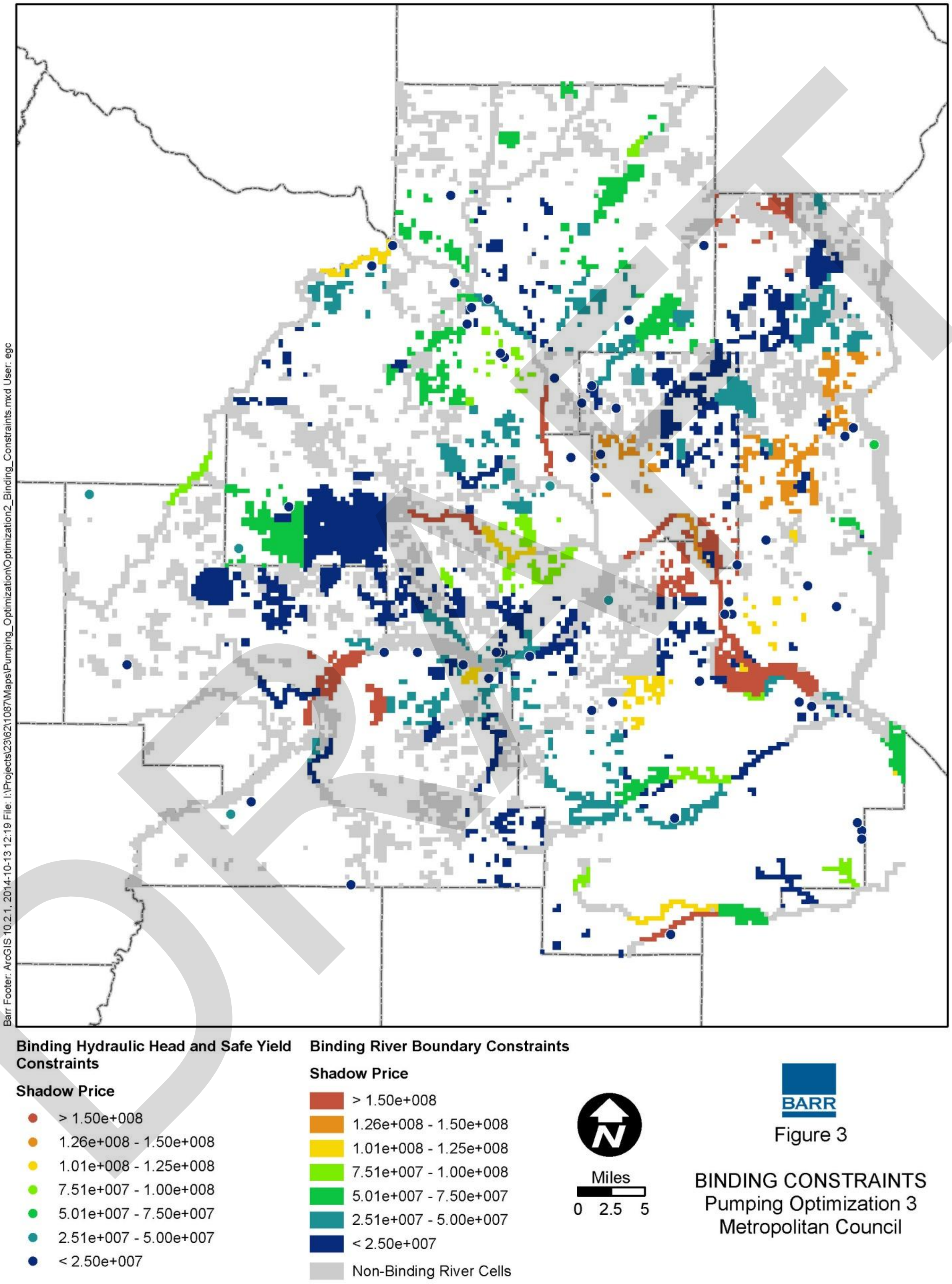


Figure 3

BINDING CONSTRAINTS
Pumping Optimization 3
Metropolitan Council

Attachment A

Binding Constraints and Shadow Prices

Table A-1
Binding Constraints and Shadow Price

Constraint Name	Description	Row	Col	Absolute Shadow Price
Riv_016	Mississippi River (Downtown St. Paul)	--	--	3.14E+08
Riv_013	Mississippi River (N. Minneapolis, Fridley, Brooklyn Center)	--	--	2.96E+08
T28_R22	Township 28, Range 22	--	--	2.56E+08
T32_R21	Township 32 Range 21	--	--	2.04E+08
Riv_165	Mississippi River / Sping Lake	--	--	2.00E+08
T115_R23	Township 115, Range 23	--	--	1.84E+08
Riv_018	Mississippi River (S. St. Paul, Invergrove Heights, Newport, St. Paul Park)	--	--	1.81E+08
Riv_136	Cannon River (Northfield, Randolph)	--	--	1.73E+08
Vul_083	Crosby Lake	--	--	1.62E+08
Riv_120	Minnehaha Creek (Minnetonka, Hopkins, St. Louis Park)	--	--	1.57E+08
Riv_055	Minnesota River (Chaska, Carver)	--	--	1.54E+08
T29_R21	Township 29 Range 21	--	--	1.50E+08
Riv_017	Mississippi River (St. Paul)	--	--	1.48E+08
T30_R20	Township 30 Range 20	--	--	1.33E+08
T29_R23	Township 29 Range 23	--	--	1.32E+08
Riv_135	Chub Creek	--	--	1.20E+08
Vul_023	Powers Lake	--	--	1.14E+08
Trout_03	Eagle Creek	--	--	1.13E+08
T27_R21	Township 27 Range 21	--	--	1.12E+08
T115_R19	Township 115 Range 19	--	--	1.12E+08
Bio_083	Ravenna 17	--	--	1.11E+08
Riv_121	Minnehaha Creek (St. Louis Park, Edina)	--	--	1.05E+08
Riv_033	Crow River (Rogers, St. Michael)	--	--	1.04E+08
Trout_07	Trout Brook	--	--	9.39E+07
Trout_12	Vermillion River (Empire)	--	--	9.00E+07
Riv_041	Crow River (Watertown, Delano)	--	--	8.60E+07
Bio_026	Rice Lake Natural Area	--	--	8.50E+07
T119_R21	Township 119 Range 21	--	--	8.19E+07
Bio_038	Chub Lake South	--	--	8.06E+07
Vul_066	Bryant Lake	--	--	7.91E+07
T28_R24	Township 28 Range 24	--	--	7.70E+07
Bio_031	Sedil East	--	--	7.61E+07
Bio_009	Mud Hen Lake Area	--	--	7.44E+07
Riv_113	Elm Creek (Maple Grove, Champlin, Dayton)	--	--	7.42E+07
T119_R22	Township 119 Range 22	--	--	7.40E+07
T32_R23	Township 32 Range 23	--	--	7.29E+07
T114_R16	Township 114 Range 16	--	--	6.85E+07
T31_R22	Township 31 Range 22	--	--	6.78E+07
Trout_11	Vermillion River (Farmington, Empire Twp)	--	--	6.76E+07
T32_R25	Township 32 Range 25	--	--	6.69E+07
Vul_005	Coon Lake	--	--	6.65E+07
T117_R24	Township 117 Range 24	--	--	6.53E+07
Bio_068	Linwood 5 Natural Area	--	--	5.99E+07
Vul_004	Byllesby Lake	--	--	5.63E+07
T28_R20	Township 28 Range 20	--	--	5.57E+07
Vul_016	George Lake	--	--	5.33E+07
T34_R23	Township 34 Range 23	--	--	5.29E+07
CM207_296	Mt. Simon Hinckley	207	296	5.07E+07
T29_R24	Township 29 Range 24	--	--	4.71E+07
Vul_064	Centerville Lake	--	--	4.62E+07
Vul_035	Medicine Lake	--	--	4.48E+07
Bio_002	Ninninger West	--	--	4.35E+07
Vul_065	Ham Lake	--	--	4.31E+07
Riv_011	Mississippi River (Champlin, Coon Rapids, Brooklyn Park)	--	--	4.22E+07
T115_R21	Township 115 Range 21	--	--	4.11E+07
Riv_148	S. Branch Vermillion River (Castle Rock Twp.)	--	--	4.10E+07
T113_R19	Township 113 Range 19	--	--	3.88E+07
Trout_13	S. Branch Vermillion R. (Castle Rock Twp, Empire Twp., Vermillion Twp.)	--	--	3.88E+07
T120_R23	Township 120 Range 23	--	--	3.82E+07
T31_R20	Township 31 Range 20	--	--	3.74E+07
CM296_141	Mt. Simon Hinckley	296	141	3.48E+07
Vul_058	Gervais Lake	--	--	3.42E+07
Bio_007	St. Lawrence 13	--	--	3.32E+07
Trout_09	Vermillion River (Eureka Twp.)	--	--	3.29E+07
Riv_115	Rice Creek (Mounds View, Arden Hills, Shoreview)	--	--	3.26E+07
CM219_107	Mt. Simon Hinckley	219	107	3.19E+07
Bio_074	Conley Lake Backwaters	--	--	3.17E+07
Vul_003	Turtle Lake	--	--	3.13E+07
Bio_078	North Ninninger 34	--	--	3.12E+07
Trout_10	Vermillion River (Lakeville, Farmington)	--	--	3.07E+07

Table A-1
Binding Constraints and Shadow Price

Constraint Name	Description	Row	Col	Absolute Shadow Price
Vul_089	Bone Lake	--	--	3.06E+07
T31_R23	Township 31 Range 23	--	--	3.02E+07
Vul_047	White Bear Lake	--	--	2.94E+07
Vul_001	DeMontreville Lake	--	--	2.92E+07
Bio_015	Nine Mile Creek	--	--	2.85E+07
T114_R20	Township 114 Range 20	--	--	2.83E+07
CM232_143	Mt. Simon Hinckley	232	143	2.73E+07
T115_R22	Township 115 Range 22	--	--	2.72E+07
GWSW1	Gun Club Lake South	--	--	2.67E+07
Riv_126	Purgatory Creek	--	--	2.62E+07
Trout_01	Assumption Creek	--	--	2.60E+07
CM217_218	Mt. Simon Hinckley	127	218	2.60E+07
T118_R21	Township 118 Range 21	--	--	2.56E+07
Riv_132	Unnamed (Burnsville)	--	--	2.48E+07
T117_R23	Township 117 Range 23	--	--	2.40E+07
Riv_097	Carver Creek	--	--	2.30E+07
Bio_099	Empire 15	--	--	2.25E+07
Riv_150	Vermillion River (Vermillion)	--	--	2.23E+07
Vul_062	Hannan Lake	--	--	2.12E+07
T29_R22	Township 9 Range 22	--	--	2.12E+07
Bio_066	East Rosemount 18	--	--	2.11E+07
Trout_06	Pine Creek	--	--	2.03E+07
T27_R22	Township 27 Range 22	--	--	1.88E+07
Riv_118	Basset Creek (Plymouth, Golden Valley)	--	--	1.85E+07
CM260_116	Mt. Simon Hinckley	260	116	1.80E+07
T119_R24	Township 119 Range 24	--	--	1.77E+07
Vul_050	Upper Prior Lake	--	--	1.72E+07
Vul_049	Unnamed (Cottage Grove)	--	--	1.69E+07
Vul_009	Long Lake	--	--	1.68E+07
Bio_019	Dean's Lake	--	--	1.64E+07
T32_R24	Township 32 Range 24	--	--	1.61E+07
Vul_021	Big Marine Lake	--	--	1.57E+07
T114_R18	Township 114 Range 18	--	--	1.53E+07
T115_R17	Township 115 Range 17	--	--	1.51E+07
CM264_254	Mt. Simon Hinckley	264	254	1.34E+07
T116_R22	Township 116 Range 22	--	--	1.19E+07
Riv_124	Nine Mile Creek	--	--	1.19E+07
Riv_100	Sand Creek (Jordan)	--	--	1.09E+07
T114_R19	Township 114 Range 19	--	--	1.09E+07
CM159_255	Mt. Simon Hinckley	159	255	1.07E+07
Bio_097	Camp Hduhapi	--	--	1.05E+07
Riv_146	Unnamed (Empire Twp.)	--	--	9.37E+06
CM257_178	Mt. Simon Hinckley	257	178	8.48E+06
Bio_060	Pigs Eye SNA	--	--	8.25E+06
GWSW4	Savage Fen	--	--	7.92E+06
T120_R21	Township 120 Range 21	--	--	7.80E+06
T112_R17	Township 112 Range 17	--	--	7.23E+06
Bio_091	Belwin Gravel Pit	--	--	6.81E+06
Riv_102	Credit River (Credit River Twp, Savage)	--	--	6.14E+06
Vul_039	Minnewashta Lake	--	--	6.03E+06
T30_R22	Township 30 Range 22	--	--	5.85E+06
T31_R21	Township 31 Range 21	--	--	5.53E+06
Vul_014	Lake Waconia	--	--	5.33E+06
T113_R21	Township 113 Range 21	--	--	5.08E+06
OP325_247	Praire du Chein Group	--	--	4.82E+06
CM177_237	Mt. Simon Hinckley	177	237	4.59E+06
CM168_195	Mt. Simon Hinckley	168	195	4.55E+06
T112_R20	Township 112 Range 20	--	--	4.42E+06
OP257_186	Praire du Chein Group	--	--	4.21E+06
Bio_058	Black Dog Lake area	--	--	4.16E+06
CM313_170	Mt. Simon Hinckley	313	170	4.05E+06
Vul_029	Olsen Lake	--	--	3.92E+06
T27_R24	Township 27 Range 24	--	--	2.98E+06
CM222_155	Mt. Simon Hinckley	222	155	2.96E+06
Bio_107	Grey Cloud Dunes East	--	--	2.78E+06
T31_R24	Township 31 Range 24	--	--	2.78E+06
Riv_127	Riley Creek (Chanhassen, Eden Prairie)	--	--	2.60E+06
Vul_025	Lotus Lake	--	--	2.56E+06
Bio_087	Wilder Forest	--	--	2.46E+06
CM178_198	Mt. Simon Hinckley	178	198	2.35E+06

Table A-2
Summary of Binding Constraints by Constraint Type

Group	Sum Total Shadow Price	Percent Total Shadow Price	Number of Constraints with Shadow Price	Average Shadow Price	Rank of Average Shadow Price
Township Range	2.47E+09	33.66%	45	5.49E+07	3
Stream/River	2.39E+09	32.48%	28	8.52E+07	1
Vulnerable Surface Water Basin	9.32E+08	12.69%	29	3.21E+07	5
Biodiversity Area	7.52E+08	10.24%	22	3.42E+07	4
Trout Stream	5.13E+08	6.99%	9	5.70E+07	2
Mt. Simon Hinckley Hydraulic Head	2.41E+08	3.28%	15	1.61E+07	7
Groundwater Dependent Feature (Fen)	3.46E+07	0.47%	2	1.73E+07	6
Safe Yield for Confined Bedrock Aquifer	1.42E+07	0.19%	31	4.57E+05	8
Flow Direction	3.16E+05	0.00%	3	1.05E+05	9

Table A-1
Binding Constraints and Shadow Price

Constraint Name	Description	Row	Col	Absolute Shadow Price
Riv_131	Unnamed (Eagan)	--	--	2.23E+06
Vul_028	Dutch Lake	--	--	1.92E+06
Vul_008	Lake Elmo	--	--	1.81E+06
Bio_076	Savage Fen, Credit River	--	--	1.75E+06
CM191_219	Mt. Simon Hinckley	191	219	1.44E+06
CJ269_278	Jordan Sandstone	269	278	1.16E+06
Vul_088	Weaver Lake	--	--	8.04E+05
CJ203_291	Jordan Sandstone	203	291	7.44E+05
Vul_011	Smetana Lake	--	--	7.12E+05
Vul_078	Pleasant Lake	--	--	6.14E+05
Vul_027	Murphy Lake	--	--	5.92E+05
CT293_146	Tunnel City	293	146	4.41E+05
Bio_072	Grey Cloud Dunes West	--	--	4.35E+05
CT159_180	Tunnel City	159	180	3.57E+05
OP236_263	Praire du Chein Group	236	263	2.94E+05
CJ205_289	Jordan Sandstone	205	289	2.87E+05
CJ246_287	Jordan Sandstone	246	287	2.82E+05
CT147_194	Tunnel City	147	194	2.74E+05
CJ270_281	Jordan Sandstone	270	281	2.70E+05
T116_R24	Township 116 Range 24	--	--	2.52E+05
CT164_175	Tunnel City	164	175	2.05E+05
FlowDir3	TCAAP Plume (St Anthony, Minneapolis)	--	--	165000.00
FlowDir2	TCAAP Plume (New Brighton)	--	--	145000.00
CJ300_293	Jordan Sandstone	300	293	1.26E+05
CJ302_293	Jordan Sandstone	302	293	9.49E+04
OP258_213	Praire du Chein Group	258	213	9.02E+04
CJ264_254	Jordan Sandstone	264	254	7.80E+04
CT172_203	Tunnel City	172	203	7.27E+04
OP257_205	Praire du Chein Group	257	205	6.08E+04
OP241_280	Praire du Chein Group	241	280	6.04E+04
OP257_206	Praire du Chein Group	257	206	5.96E+04
OP297_248	Praire du Chein Group	297	245	4.33E+04
OP269_233	Praire du Chein Group	269	233	3.57E+04
CT185_206	Tunnel City	185	206	3.13E+04
CJ298_292	Jordan Sandstone	298	292	2.09E+04
CT186_207	Tunnel City	186	207	1.88E+04
Riv_114	Rice Creek (Fridley)	--	--	1.41E+04
CJ230_270	Jordan Sandstone	230	270	1.20E+04
CT260_197	Tunnel City	260	197	9.75E+03
CT174_199	Tunnel City	174	199	7.56E+03
OP271_228	Praire du Chein Group	271	228	6.83E+03
FlowDir7	St. Paul Park Refinery	--	--	6450.00
CT279_287	Tunnel City	279	287	3.31E+03
CT186_206	Tunnel City	186	206	2.53E+03

Color Key

- Trout streams baseflow constraint
- Non-trout streams baselfow constraint
- Groundwater dependent features hydraulic head constraint (calcerous fens)
- Flow direction constraint
- Mt. Simon-Hinckley aquifer change in hydraulic head constraint
- Safe yield for confined bedrock aquifers constraint
- Surface water flux constraint (Township and Range groups)
- Vulnerable surface water features with wide litoral zone constraint
- Sites of high biodiversity constraint

Appendix 5. Example Water Supply Projects

A goal of the Master Water Supply Plan is to promote local and subregional efforts that improve the sustainability of water supplies in the region.

This appendix contains examples of local projects, which will be added to as information becomes available.

For each project, the goal is to summarize information about:

- Project Implementation
- Challenges
- Benefits
- What may help other Communities?
  - Partnerships and Incentives
  - Lessons Learned
- Awards and Recognitions
- Contacts at the Community

Rainwater Harvesting at CHS Field - Saint Paul, Minnesota

CHS Field is a regional ballpark in the heart of the Lowertown neighborhood of Saint Paul, Minnesota just a few hundred feet from America's greatest river. CHS Field is home to the Saint Paul Saints minor league baseball team. The ballpark has a capacity of 7,000 spectators, will host approximately 400,000 visitors annually and will be used for a both sporting and non-sporting events.

With population on the rise, Minnesota's groundwater supplies continue to decline and stormwater runoff pollutes local lakes and the Mississippi River. Ballparks require large amounts of water for irrigation, drinking and other operational activities. To reduce consumption of potable water as well as the amount of polluted runoff flowing to the Mississippi River, the City of Saint Paul, Saint Paul Saints, Metropolitan Council and Capitol Region Watershed District collaborated to collect and store rainwater and use it for irrigation and other uses at CHS Field. Why do this? Because even in the Land of 10,000 Lakes, water is a resource we can't afford to take for granted.

Project Implementation

Source

Rooftops provide a great opportunity to collect rainwater because the water flowing off roofs is relatively clean compared to streets or parking lots. CHS Field doesn't have a lot of roof cover, but the Metropolitan Council offered the roof area of the Green Line light rail Operations and Maintenance Facility (OMF) located next door. A pipe installed between the properties allows rainwater to flow from roughly ¾-acre portion of the OMF roof to a 27,000- gallon steel cistern tank below the ballpark concourse near center field.

Treatment

Harvested rainwater at CHS Field is used to irrigate the ball field and flush toilets. Before it can be used for those purposes, water is treated to ensure it is safe. A vortex filter removes large particles such as leaves and sediment (or baseballs!) from the water before it goes to the cistern. From there, a pump pulls water from the cistern and sends it through two filters that remove smaller particles. Finally, UV light is used to disinfect the water before it is sent to the irrigation system or toilets.

Irrigation

The harvested rainwater is used to irrigate the main playing field, which includes two acres of sod. The area is watered by 115 irrigation heads and 7,000 feet of irrigation pipe.

Toilet flushing

The public toilets located behind center field include nine water closets and four urinals which are serviced by water from the cistern. The remaining 127 public toilets are located too far away to be served by the cistern, but all toilets in the park include water-saving fixtures.

Plumbing Code

The rainwater harvesting design was reviewed and approved locally under Minnesota Plumbing Code Rule 4715.0330 *"Alternative Fixtures, Appurtenances, Materials, and Methods."* Criteria within Uniform Plumbing Code Chapter 17 (*"Non-Potable Rainwater Catchment Systems"*) were used to support the review and approval. Water quality treatment standards were derived from NSF/ANSI 350 for onsite residential and commercial water reuse treatment systems.

Challenges

- Obtaining approval from the plumbing inspector for rainwater reuse inside the building (toilets)
- Constructing the rainwater conveyance piping inside an active rail facility

- Maximizing the amount of water storage in a minimum amount of space

Project Benefits

The benefits include:

- Annual potable water reduction estimated at 450,000 gallons
- Annual cost savings of more than $1,600

What may help other Communities?

Partnerships and Incentives

- The Metropolitan Council granted $100,000 to the City for the rainwater harvesting system
- Capitol Region Watershed District granted $246,500 to the City for the rainwater harvesting system
- The Metropolitan Council funded the OMF rainwater conveyance retrofit ($82,800)
- All Metropolitan Council funds are sourced from the Clean Water Land and Legacy Amendment

Lessons Learned

- Take officials on tours of similar projects to help them feel comfortable about supporting innovative stormwater reuse projects
- Pay close attention to the roof; are there HVAC units that have condensate that should be piped away from the rainwater harvesting area?
- Work closely with MDH to determine the appropriate level of water treatment

Awards and Recognitions

- 2015 Clean Water Champion Award

Water Supply Partnership - Savage and Burnsville, Minnesota

For the past 6 years the Cities of Savage and Burnsville have worked together to utilize quarry water that was previously discarded to the Minnesota River as part of mining operations at the Kraemer Quarry in Burnsville. Annually, via a water use agreement, Burnsville provides more than 600 million gallons of potable water to Savage, which accounts for about 79% of their annual demand. The partnership has reduced groundwater pumping between the Cities of Savage and Burnsville by 1.1 to 1.2 billion gallons per year. This reduction in pumping has resulted in rebounding water levels in the Jordan Aquifer since the project came on-line in 2009.

The $14 million project included construction of a quarry surface water intake, supply watermains and water treatment plant addition and upgrades.

Project Implementation

Prior to construction agreements and funding between Burnsville and the City of Savage, State of Minnesota and Kraemer Mining and Materials were required. As lead agency, Burnsville constructed the surface water intake which consists of two pumping stations along with connecting water system infrastructure to convey water to the existing water treatment plant. An addition was made to the plant to allow for treatment of this water. Additional improvements to enhance water aesthics made by Burnsville after completion of the initial project included a Granular Activated Carbon building, surface water drainage improvements and baffling improvements to the finished water reservoir.

The project has been operating for 6 years and annually provides 1.1 to 1.2 billion gallons of potable water. This water supplements the 2 billion gallons of ground water pumped by the City.

Challenges

The primary challenges once operations began were related to the aesthics of the new water supply. The new mixed supply was harder and had a different taste and odor. Savage and Burnsville staffs worked together on several collaborative solutions to solve these issues. Communication, patience and cooperation were key in solving these issues. The water quality complaints related to the initial issues have virtually been eliminated in both communities.

Project Benefits

The benefits include:

- Reuse of 1.1 billion gallons of water annually
- Reduction of 1.1 billion gallons of groundwater pumping and rebounding water levels in the Jordan Aquifer
- Viable/sustainable long term source of water for the communities

What may help other Communities?

It can be done if communities are willing to work together, trust each other and collaborate. However, this type of partnership and success can't occur without state and agency help.

Partnerships and Incentives

This project would not have been possible without collaboration of Kraemer Mining and Materials, State of Minnesota, MDH, DNR and Cities of Savage and Burnsville. Below is the cost participation in the project:

- State of Minnesota $5.5 Million

- Kraemer Mining and Materials $3.0 Million
- City of Savage $2.0 Million
- City of Burnsville $3.5 Million
- Total SWTP Capital Cost $14.0 million

Community Commitment to Sustainability/Water Supply Security/Collaboration

The potable use of 1.1 billion gallons of previously discarded quarry water has resulted in rebounding water levels in the Jordan Aquifer locally, and will help ensure sustainability of the water supply for Savage and Burnsville.

Lessons Learned

- Mixing of surface and groundwater is complicated and upfront investment in pilot results will reduce issues
- Understand potential operational issues of connected system, such as impacts to chlorine levels
- Proactive education of Public, Council and City Staff on issues such as:
  - Potential changes in water aesthetics (taste, odor and hardness etc.)
  - Water is "safe" exceeds all standards

Awards and Recognitions

- 2009 City Engineers of Minnesota Project of the Year – Honorable Mention
- 2009Environmental Initiative Award
- National League of Cities Silver Award for Municiple Excellence
- 2010 Finance and Commerce Top Project Award
- 2010 Minnesota Society of Professional Engineers Merit Award
- 2010 American Council of Engineering Companies Grand Award
- 2010 American Council of Engineering Companies National Recognition Award

Contact the Community

Steve Albrecht
City of Burnsville
952-895-4544
steve.albrecht@burnsvillemn.gov