Assessing the thermal impact of aggregate mining on a cold-water stream

Carrie Jennings, P.G, PhD

FRESHWATER

Outline

- Introduction—Aggregate mining in the metro
- Study Area—Vermillion River watershed
- Question—will mining at UMore impact the river?
  - Considerations—groundwater flow direction
- Modeling—using data from UMore
- Conclusions—general conclusions about safe distances from cold streams

Why Mine?

– **54 lbs/person/day**
  - (4.4 million people x 9.8 tons/person/year)
– **80% sand and gravel**
– **20% crushed rock**

Glacial Stream Sediment = Aggregate

Complex history of glaciation

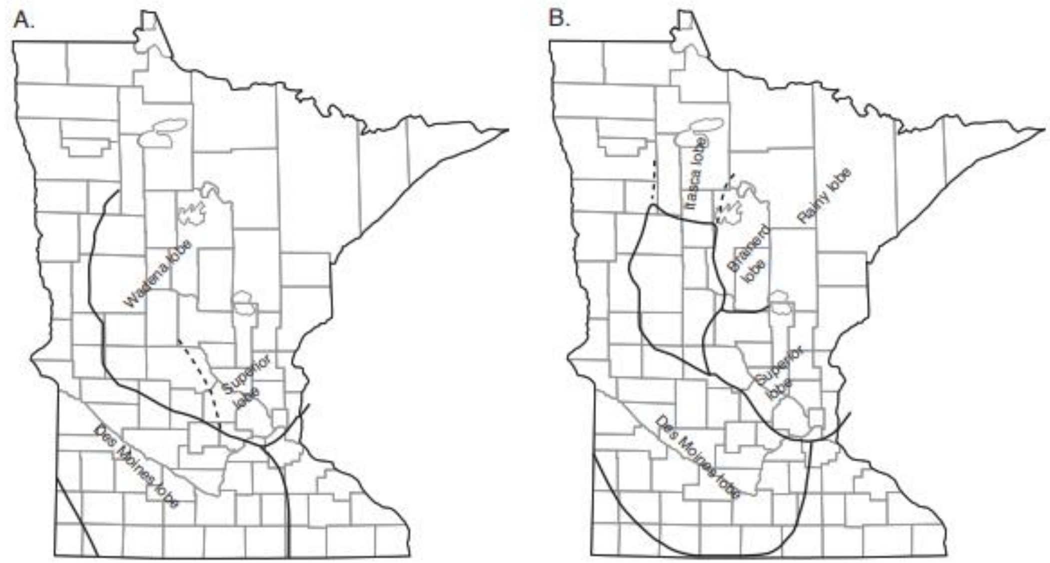
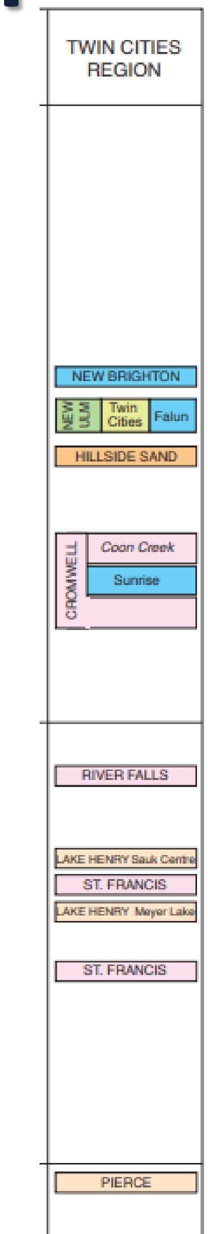


Figure 3. Names of glacial lobes used in this report. These diagrams are not meant to represent the paleogeography of the glacial lobes at precise times, but rather show the change in names as the geometry of the lobes evolved during the late Wisconsinan glaciation (MIS 2). The precise shapes of the lobes during earlier, pre-late Wisconsinan glaciations varied from those shown here.

A. Lobes during the last glacial maximum.

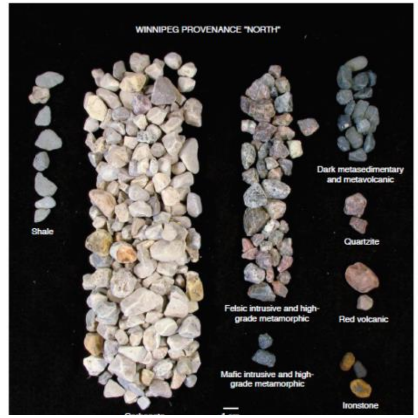
B. Lobes following retreat from the last glacial maximum.

C. Lobes of the latest glacial phases.



Aggregate Quality is Variable

Figure 6. End-member example of Riding Mountain-provenance material; 8 to 16 millimeter fraction from site N4 of Thorleifson and others (2007); from left to right: Cretaceous shale, Paleozoic carbonate, felsic intrusive and high-grade metamorphic, dark metasedimentary and metavolcanic, and from top down: reddish volcanic, ironstone, and quartzite.



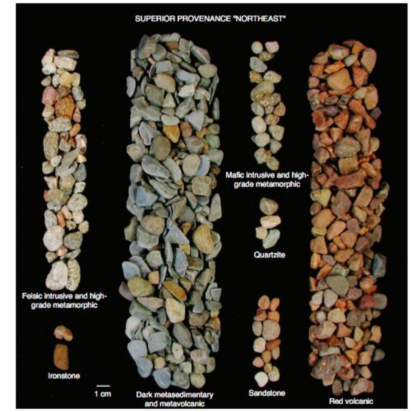


Figure 9. End-member example of Superior-provenance material; 8 to 16 millimeter fraction from site O11 of Thorleifson and others (2007); from left to right: felsic intrusive and high-grade metamorphic above ironstone, dark metasedimentary and metavolcanic, and from top down: mafic intrusive and high-grade metamorphic, quartzite, sandstone, and reddish volcanic rocks.

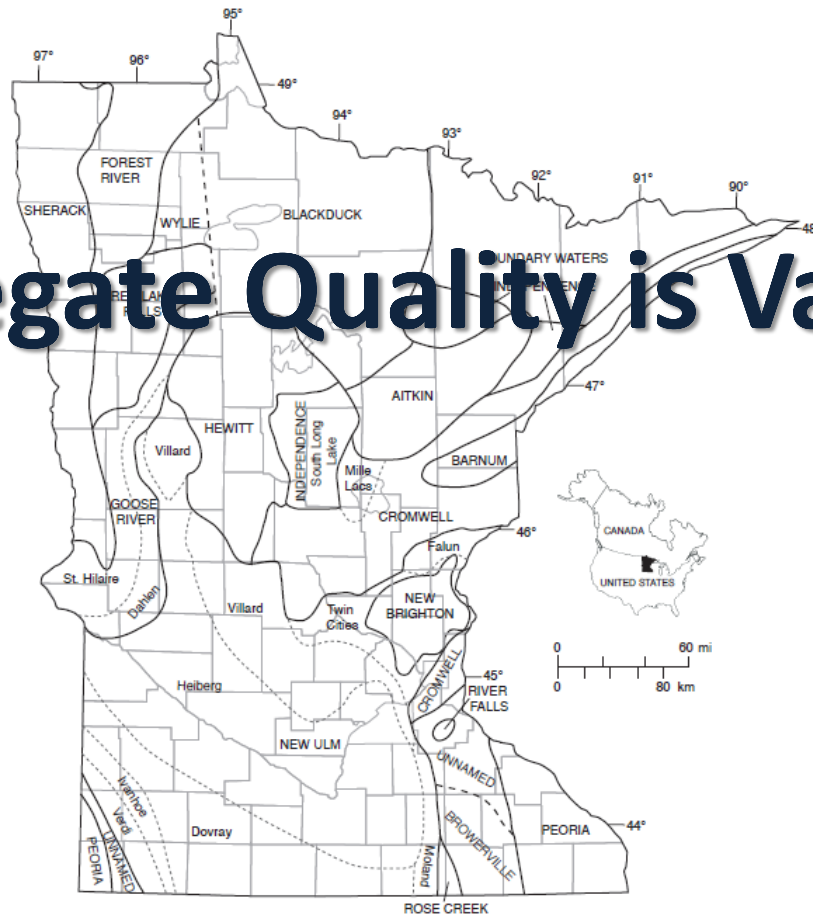
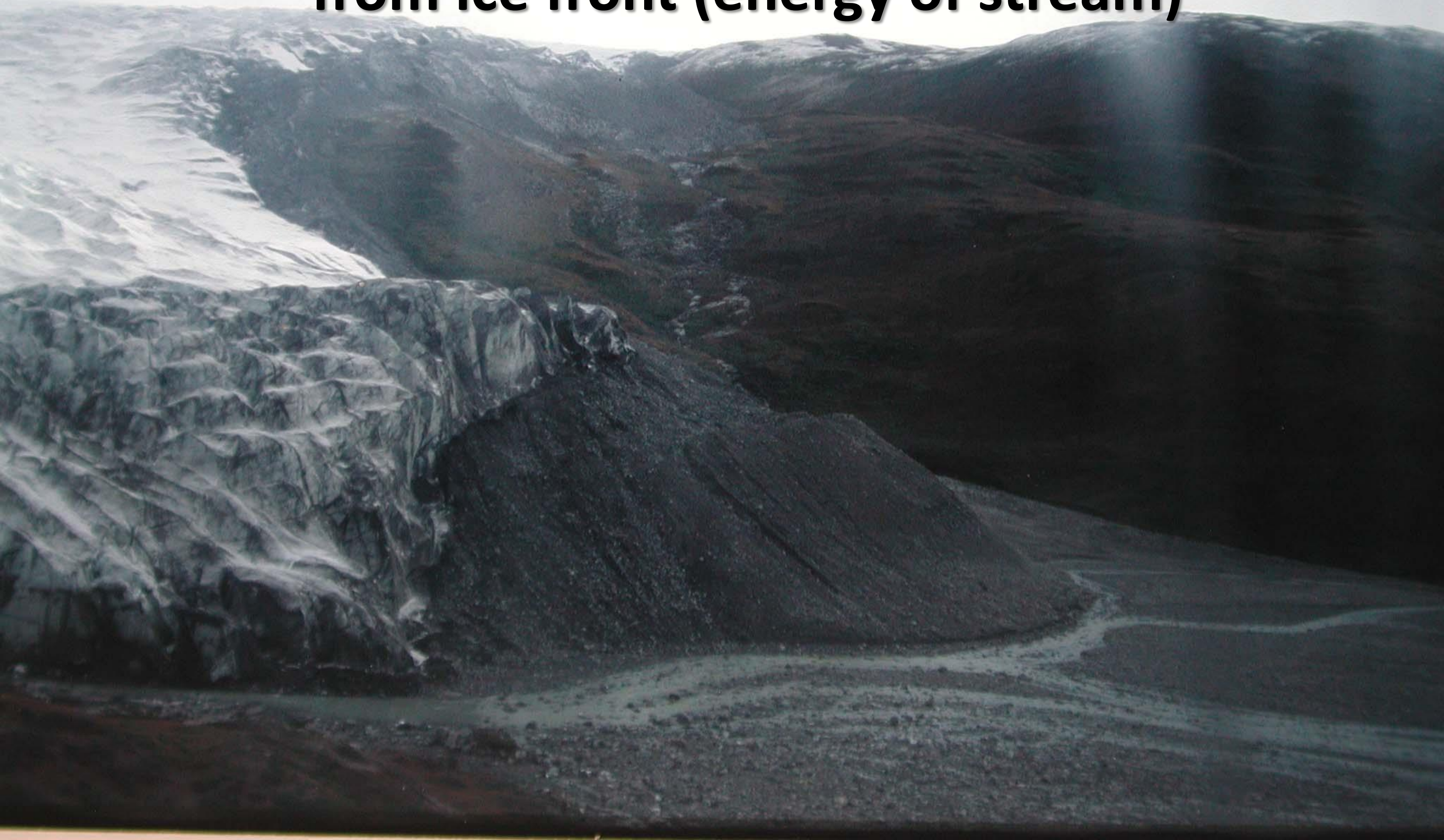


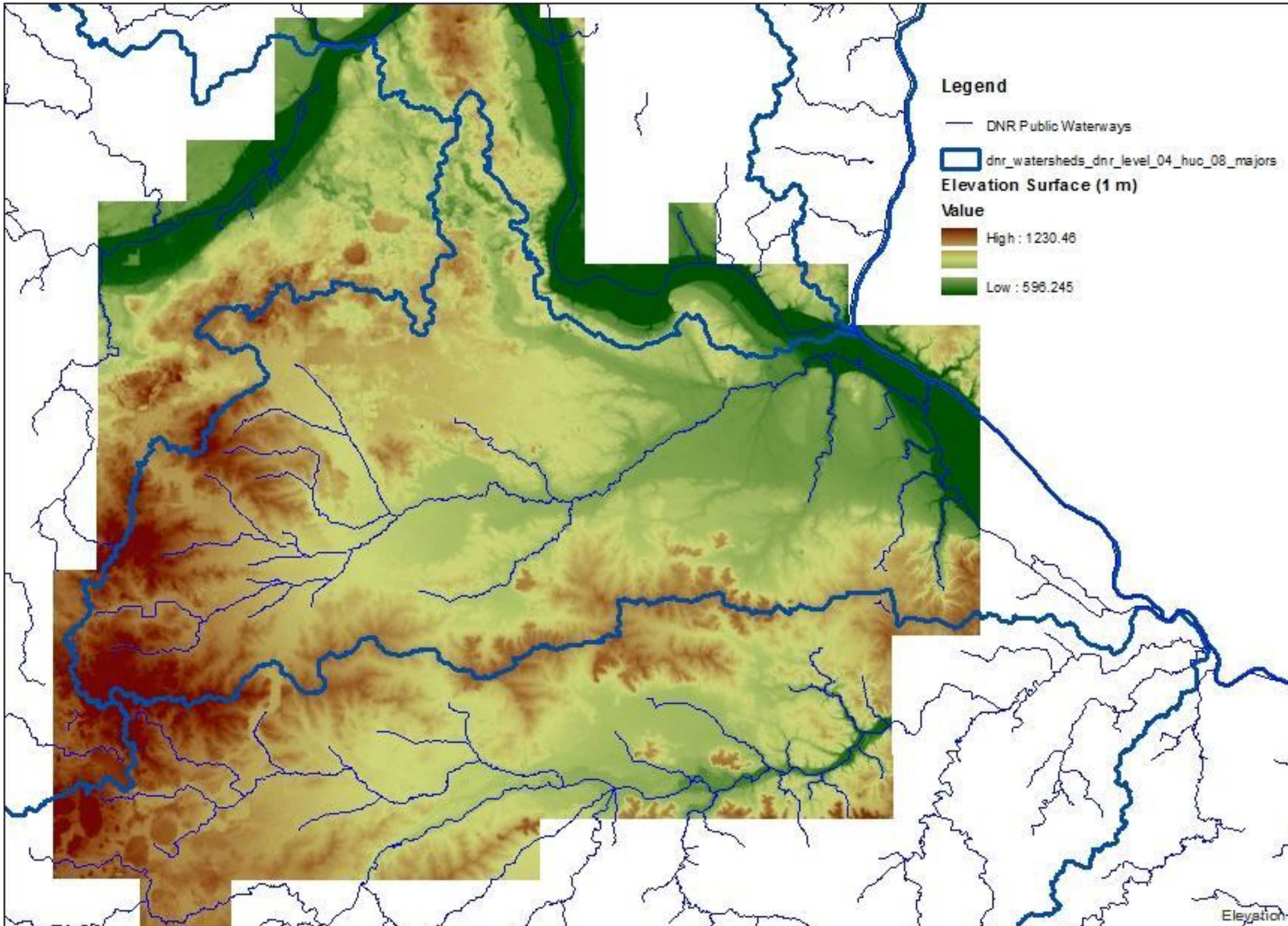
Figure 10. Surface lithostratigraphic units of Minnesota. Bold outlines represent the surficial extent of geologic formations, which are capitalized. Light dashed lines indicate the extent of members, written with lower-case letters. Bold, dashed lines are approximate formation boundaries.

Size of aggregate changes with distance from ice front (energy of stream)




Braided melt water stream, Canadian Rockies

Study Area—Vermillion River Watershed



MGS mapping of Aggregate Potential

Excellent to good (less than 1.5 percent total spall materials)

Good to moderate (less than 5 percent total spall materials)

Moderate to poor (generally more than 5 percent total spall materials)

Quality of sources where the water table is less than 20 feet below land surface (classifications 7 and 8):

Excellent to good (less than 1.5 percent total spall materials)

Good to moderate (less than 5 percent total spall materials)

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Potential secondary source—Classifications 4 and 5

Gravel pit—Active or inactive pit

Large gravel pit, or an area of more than one gravel pit or gravel-pit operation

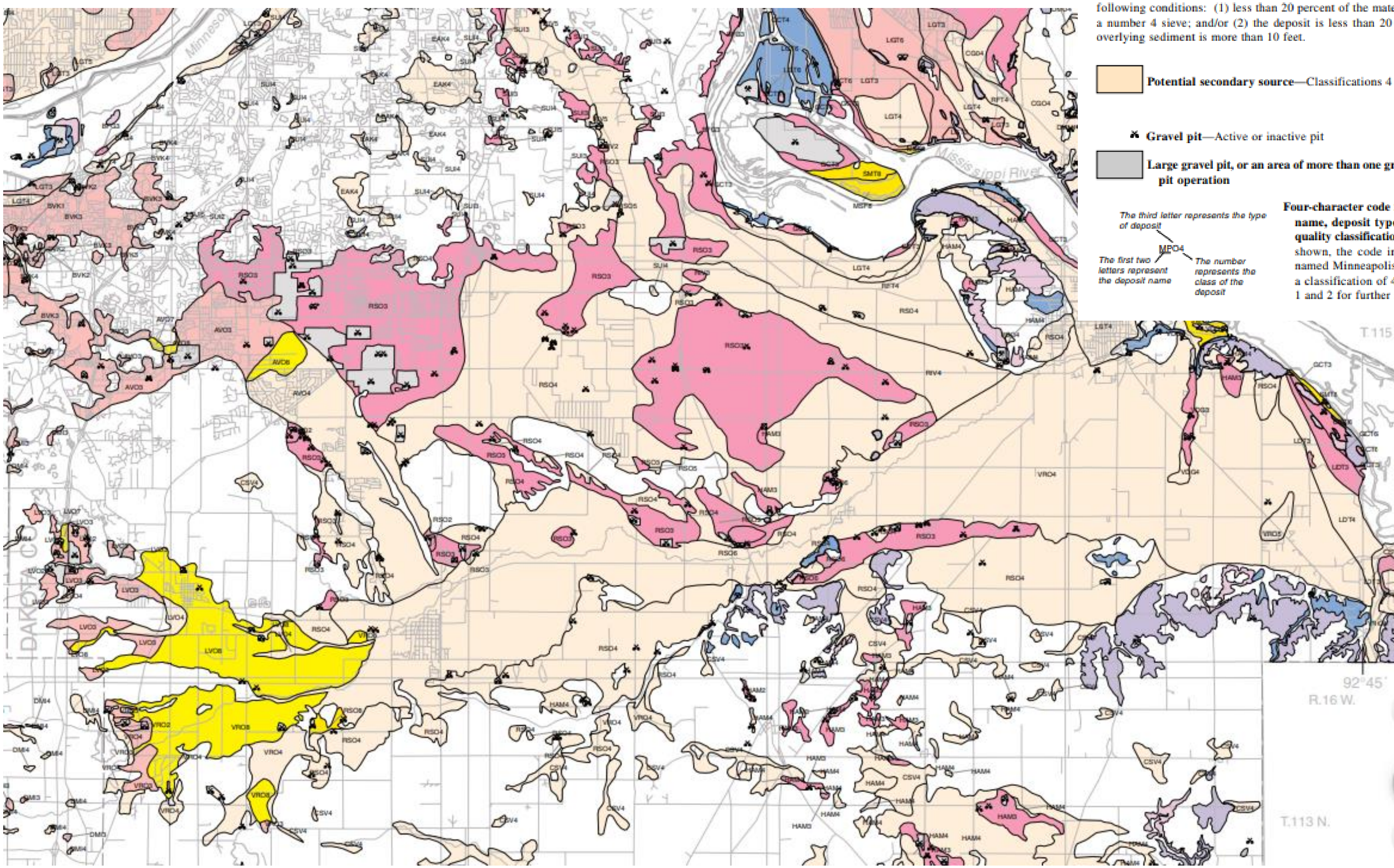
The third letter represents the type of deposit

MPO4

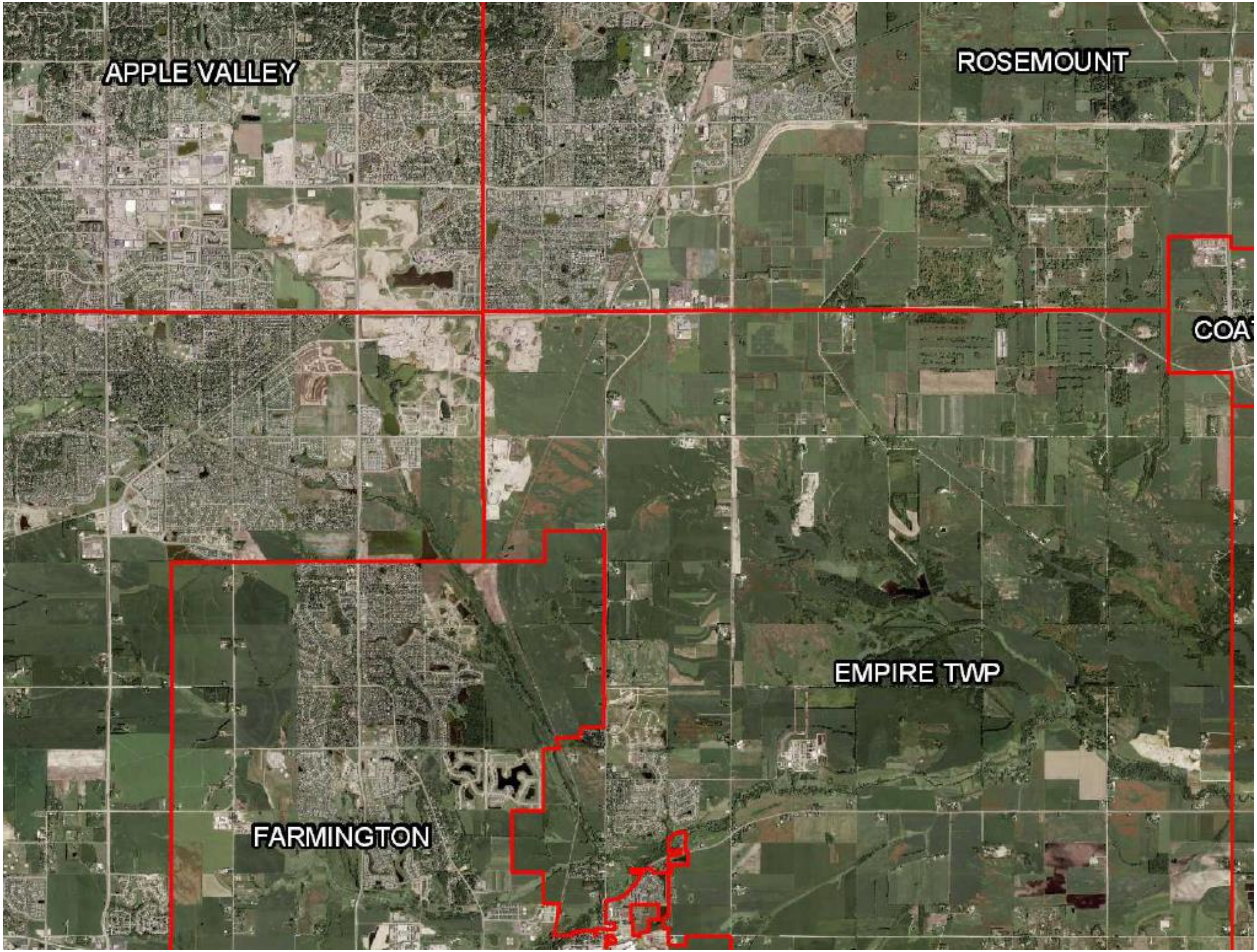
The first two letters represent the deposit name

The number represents the class of the deposit

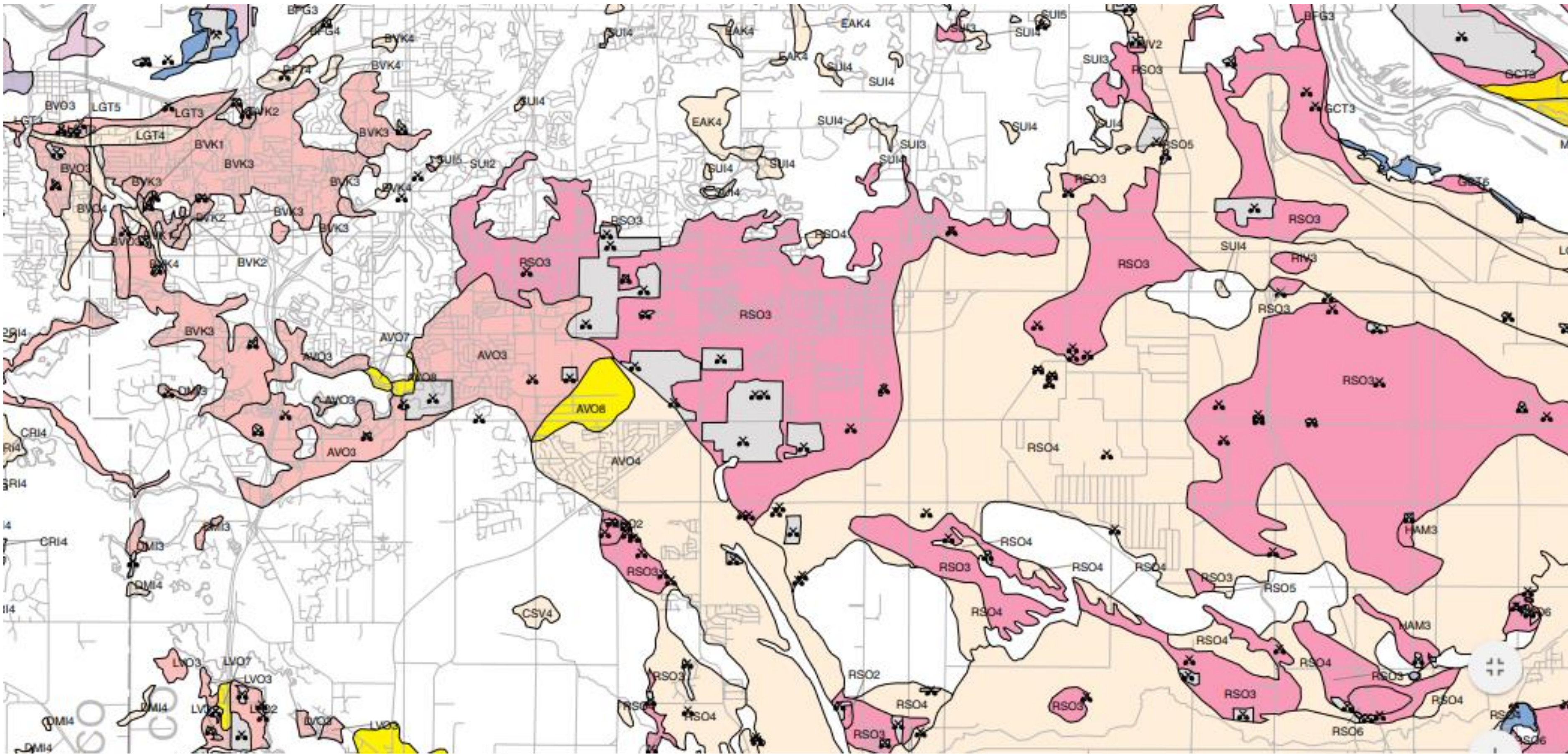
Four-character code indicating deposit name, deposit type, and aggregate-quality classification—In the example shown, the code indicates a deposit named Minneapolis outwash that has a classification of 4. Refer to Tables 1 and 2 for further information.



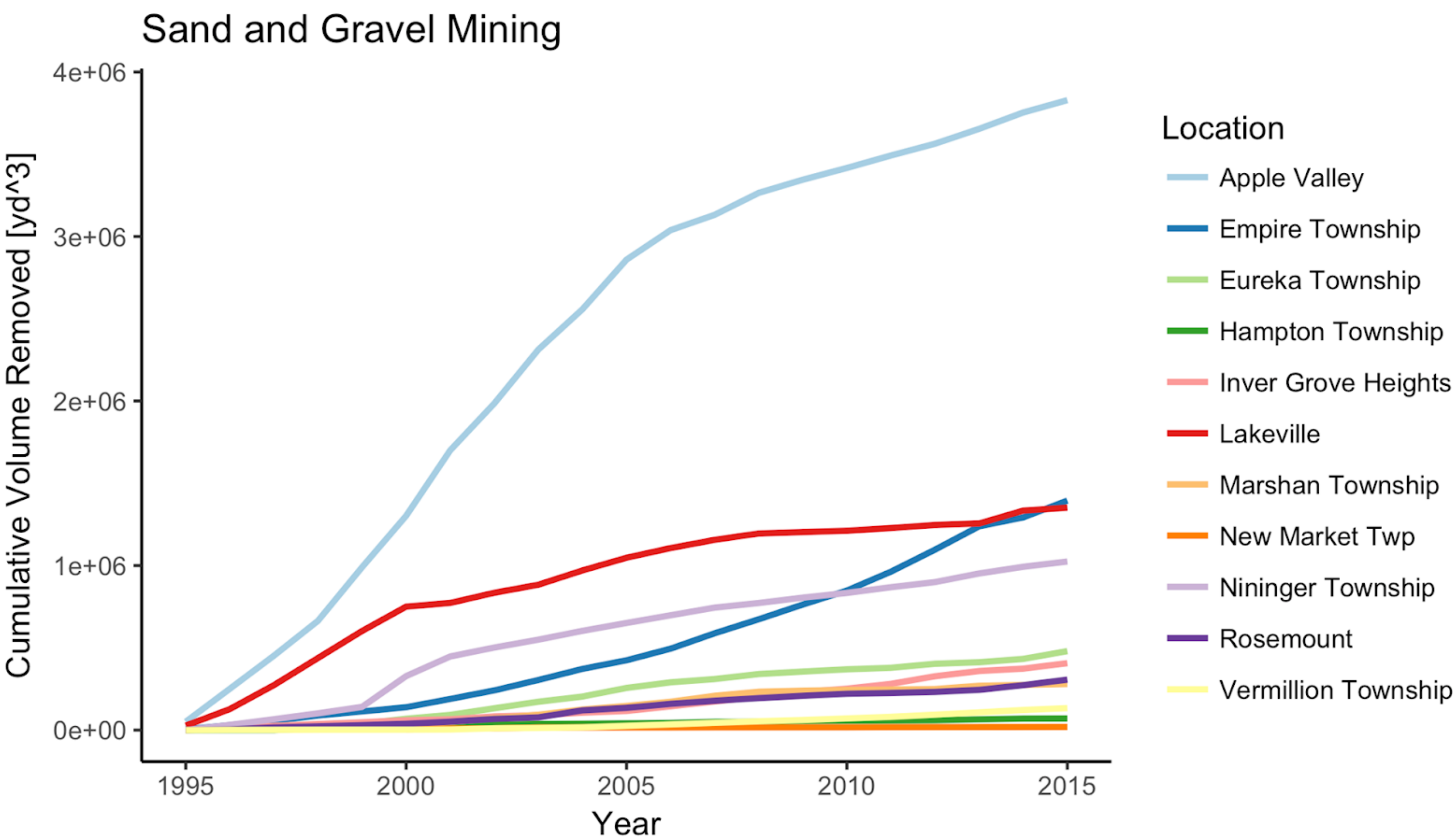
2006



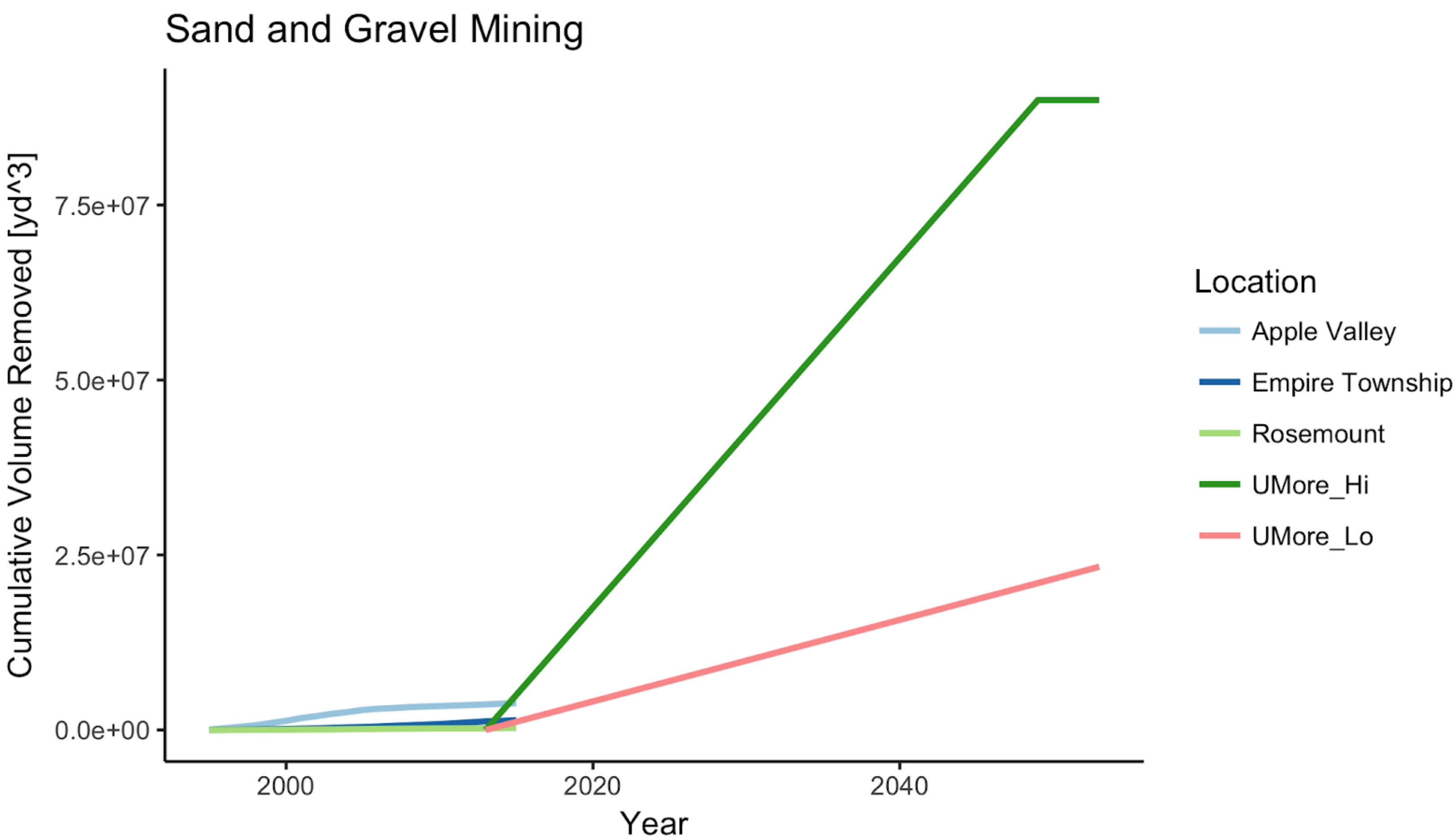
Apple Valley and Rosemount/Empire Township



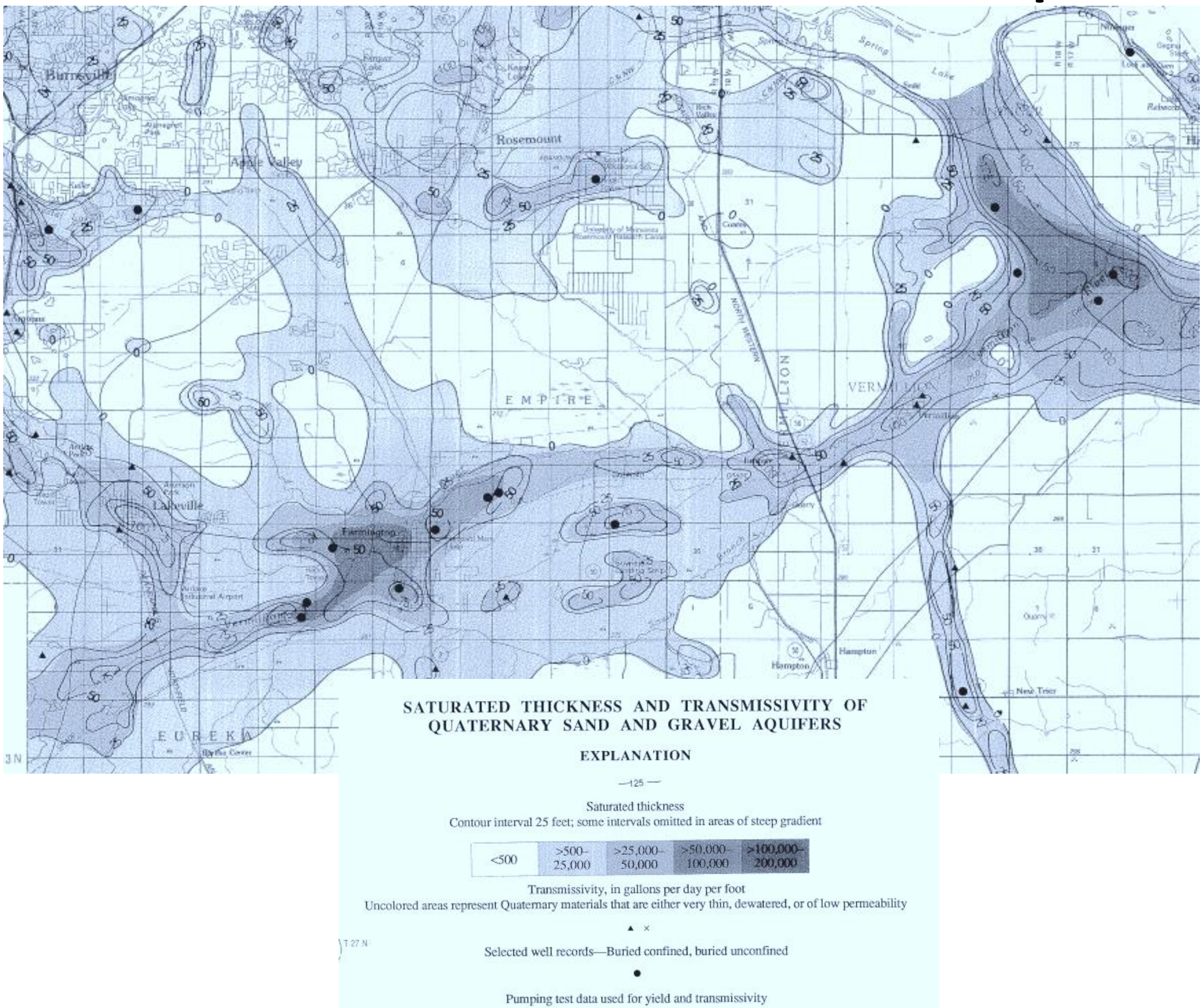
Volumes reported for taxation

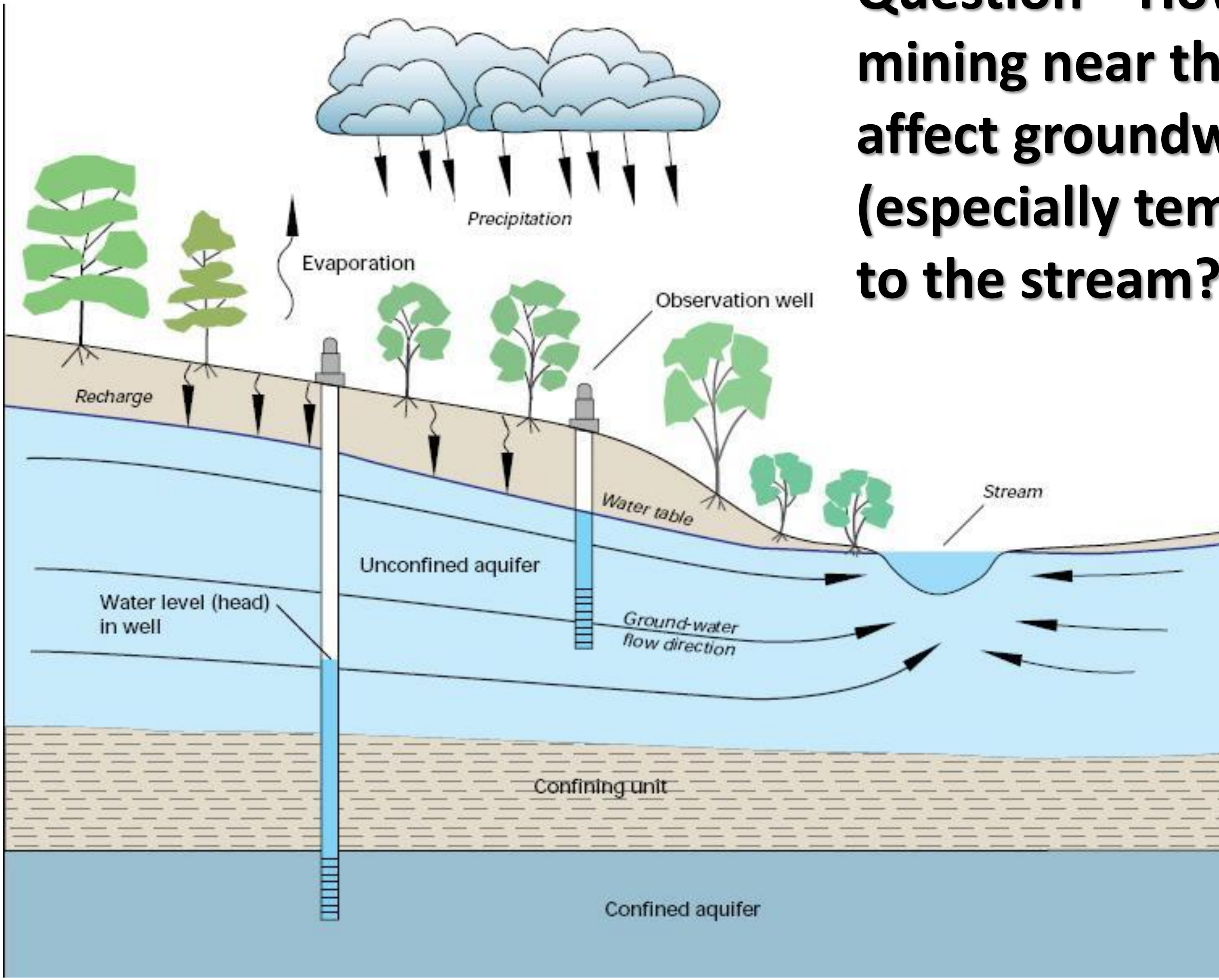


Volume projected by UMore



Glacial stream sediment=aquifers

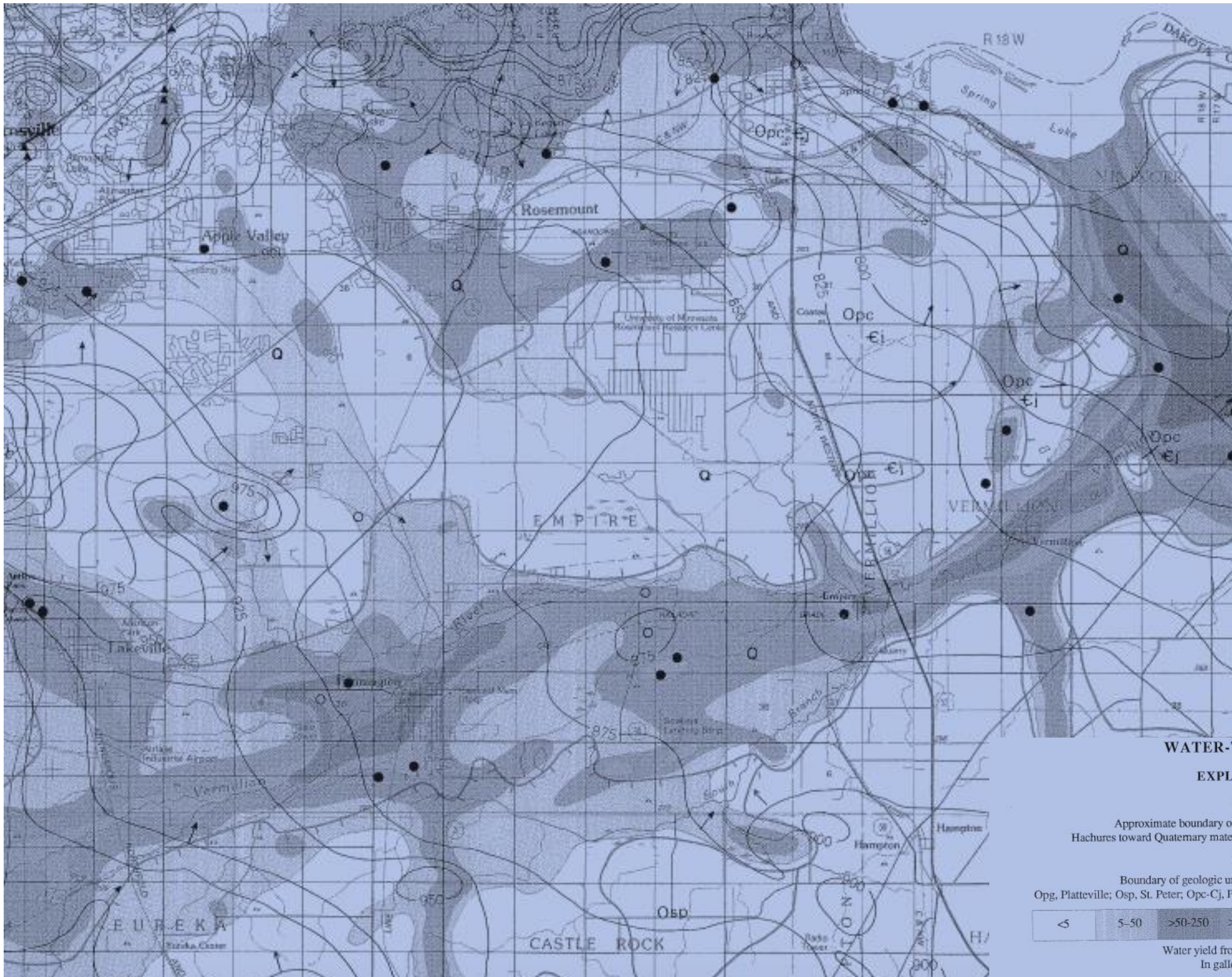


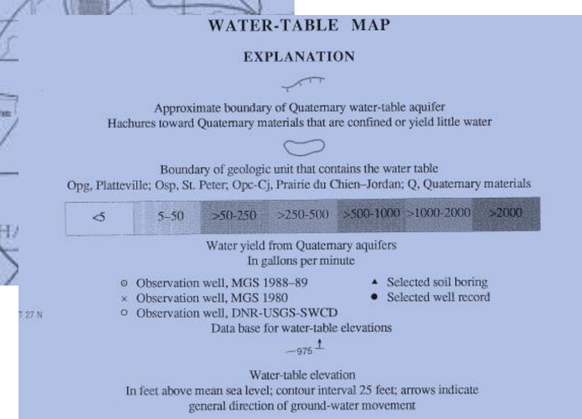


Question—How will mining near the river affect groundwater flow (especially temperature) to the stream?

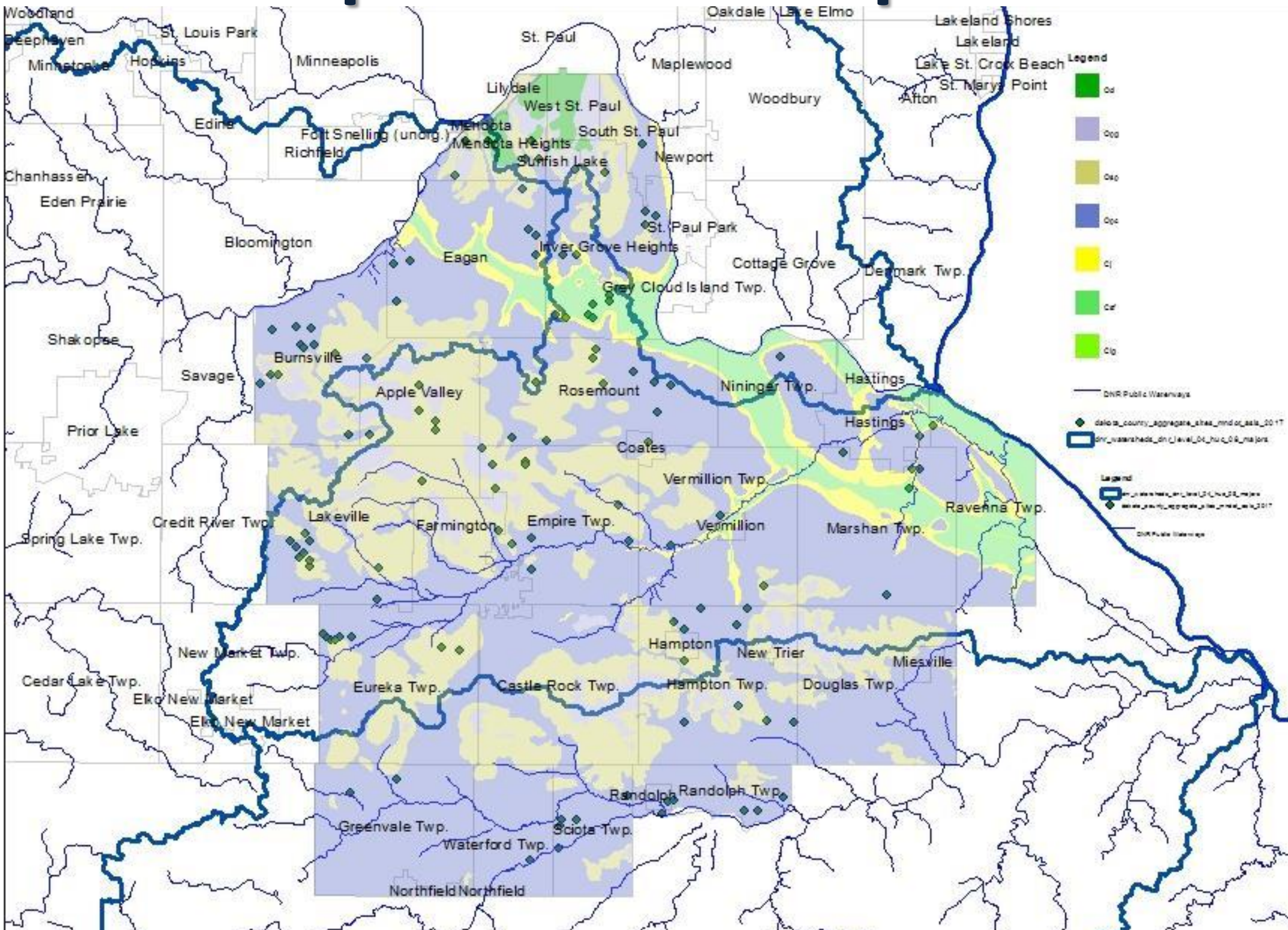
http://sonomacountygroundwater.org/wp-content/uploads/groundwter2.jpg

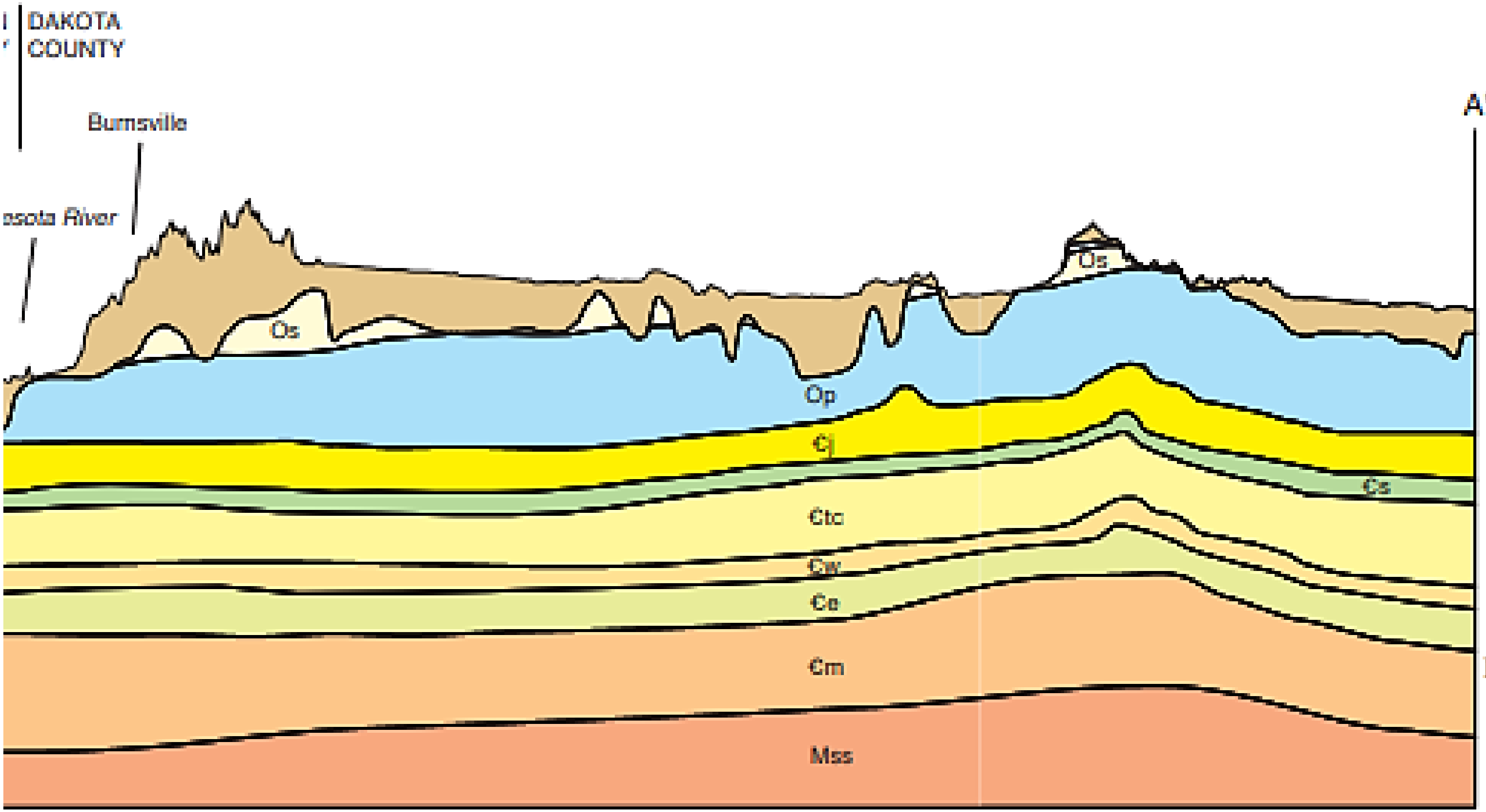
Water Table Aquifer Flow





Surface aquifers can be linked to deeper bedrock aquifers





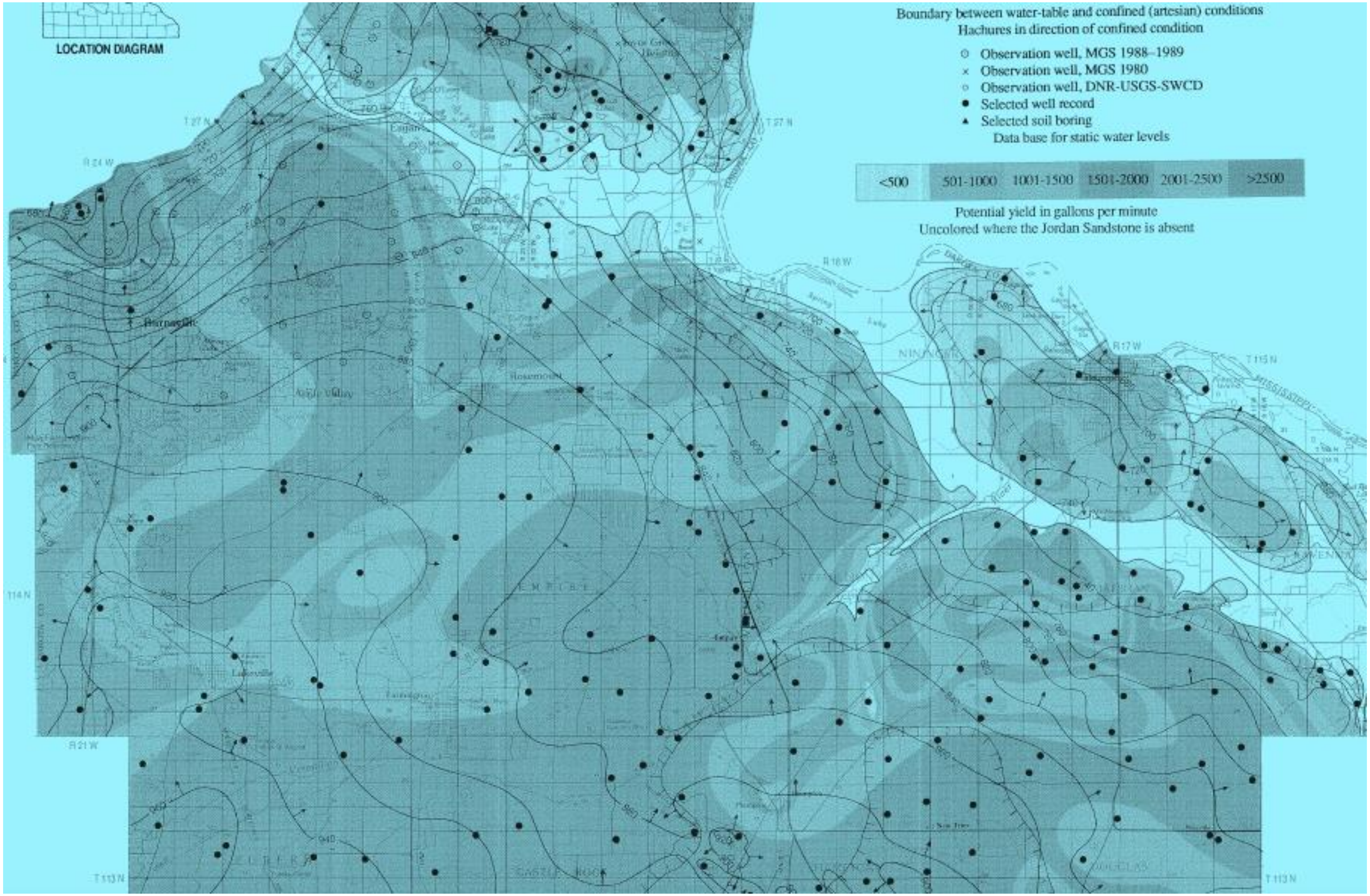
BEDROCK GEOLOGY OF THE TWIN CITIES TEN-COUNTY METROPOLITAN AREA, MINNESOTA

By

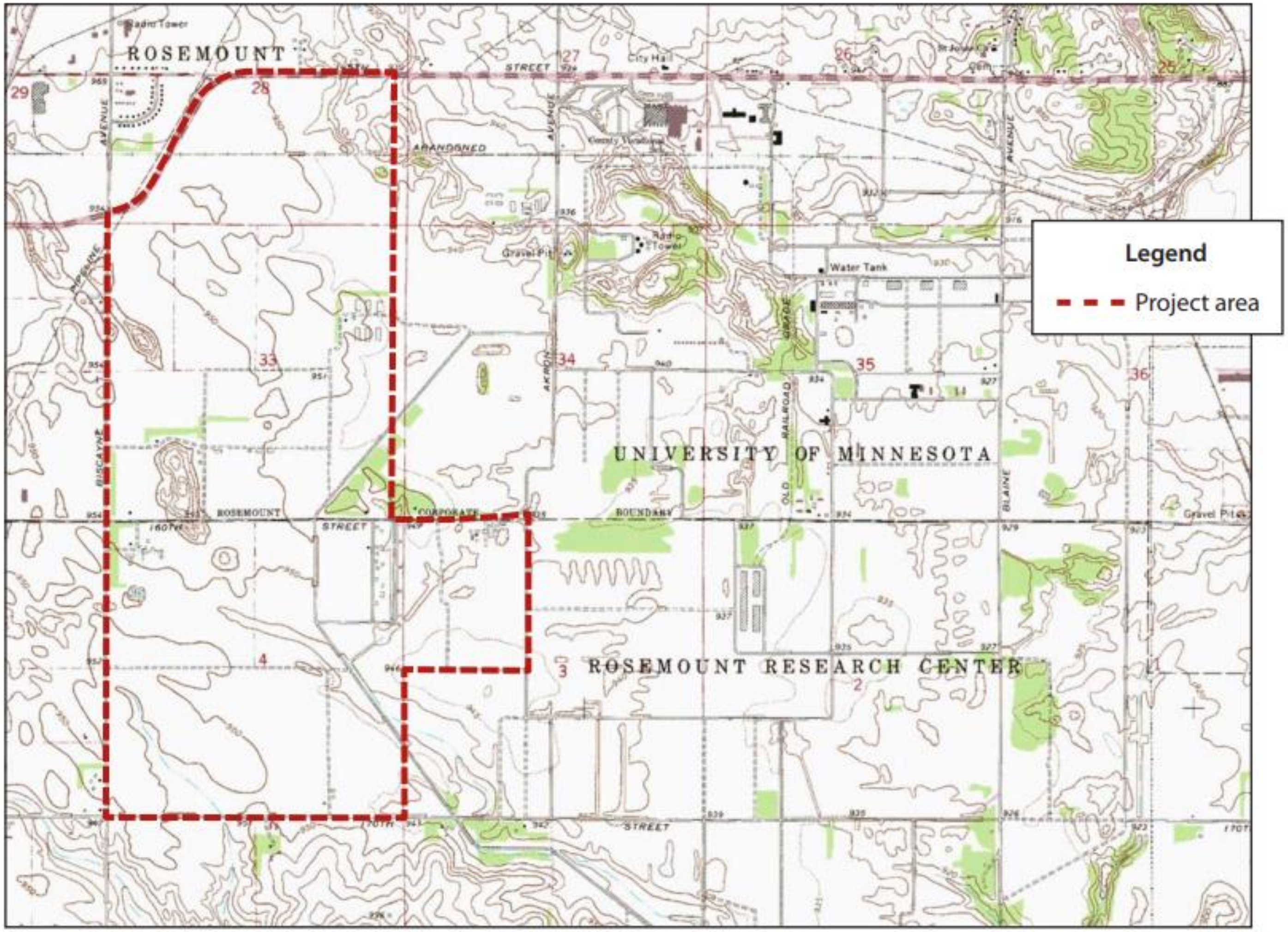
John H. Mossler

2013

Bedrock Aquifer Flow



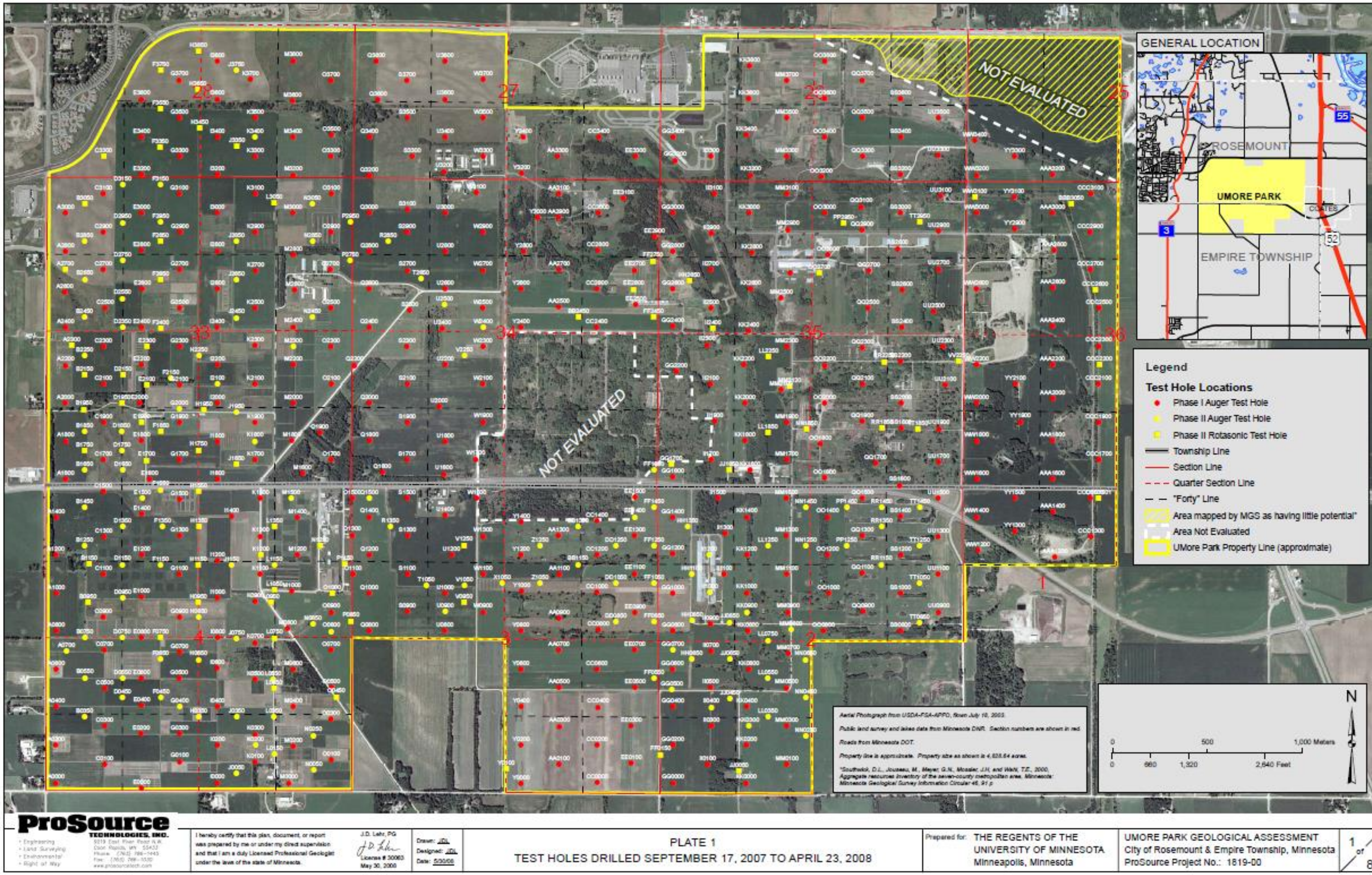
UMore



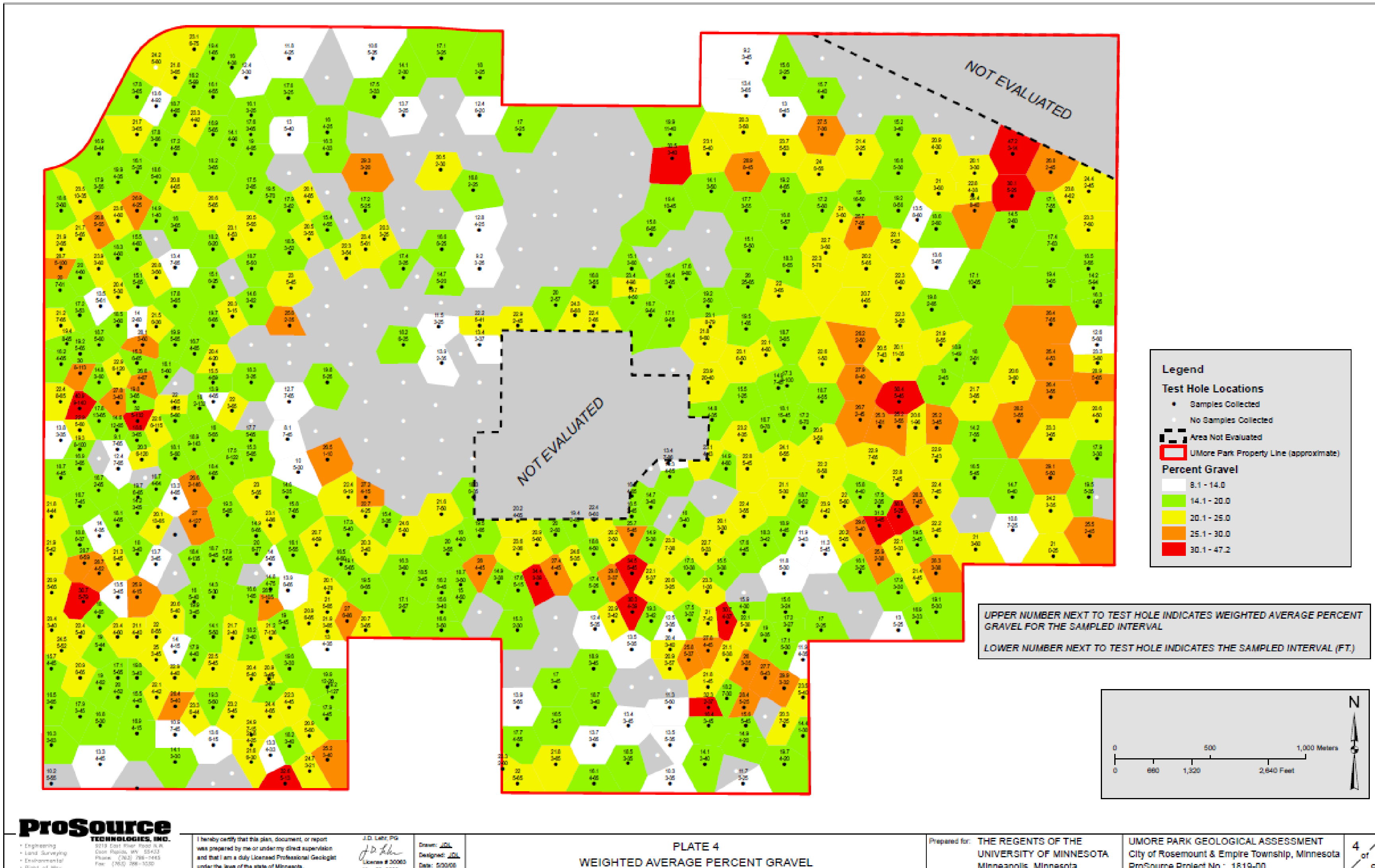
UMore Park Sand and Gravel Resources Scoping Environmental Assessment Worksheet	Figure 2 USGS Location Map	University of Minnesota Driven to Discover

April 2009

Test Holes

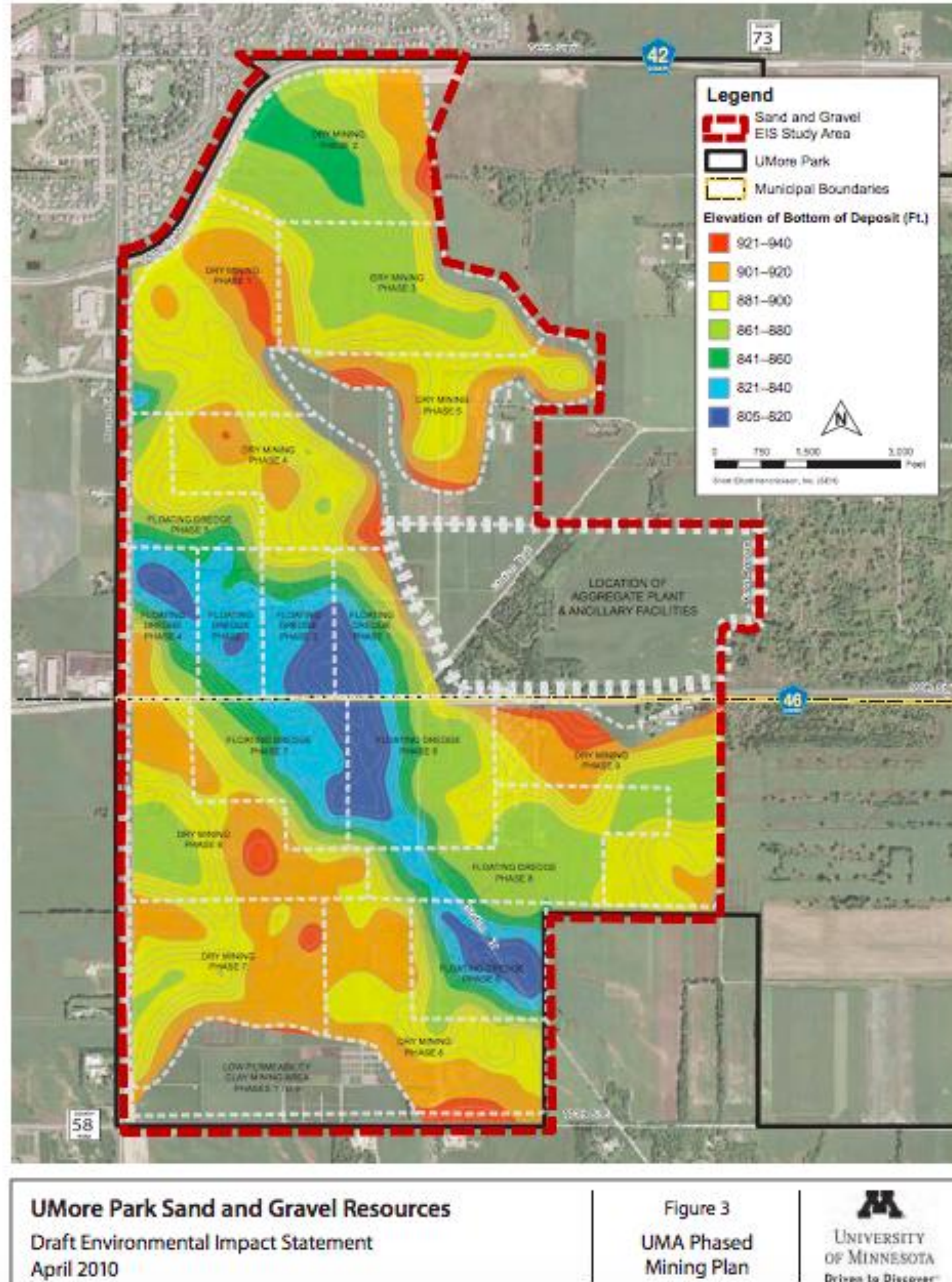

GENERAL LOCATION
ROSEMOUNT
UMORE PARK
EMPIRE TOWNSHIP
COATES
NOT EVALUATED
NOT EVALUATED
Legend
Test Hole Locations
Phase I Auger Test Hole
Phase II Auger Test Hole
Phase II Rotasonic Test Hole
Township Line
Section Line
Quarter Section Line
"Forty" Line
Area mapped by MGS as having little potential*
Area Not Evaluated
UMore Park Property Line (approximate)
N
0 500 1,000 Meters
0 660 1,320 2,640 Feet
ProSource TECHNOLOGIES, INC.
I hereby certify that this plan, document, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the laws of the state of Minnesota.
J.D. Lehr, PG
License # 30063
May 30, 2008
Drawn: JDL
Designed: JDL
Date: 5/30/08
PLATE 1
TEST HOLES DRILLED SEPTEMBER 17, 2007 TO APRIL 23, 2008
Prepared for: THE REGENTS OF THE UNIVERSITY OF MINNESOTA Minneapolis, Minnesota
UMORE PARK GEOLOGICAL ASSESSMENT
City of Rosemount & Empire Township, Minnesota
ProSource Project No.: 1819-00
1 of 8

Weighted Average Gravel Percent

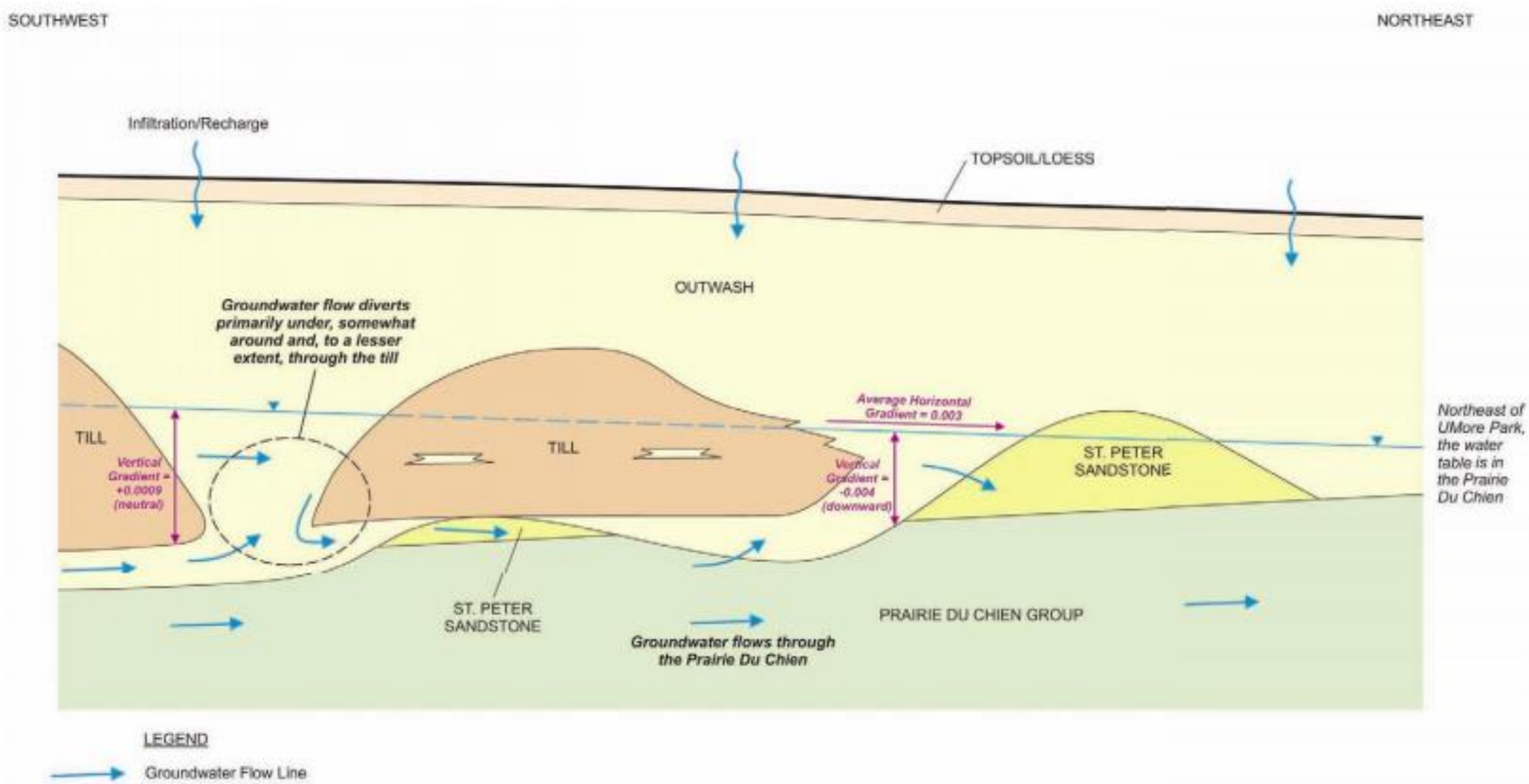


Bottom elevation of gravel deposit

- Ultimate depth of pit lake = 85’



Conceptual model of groundwater

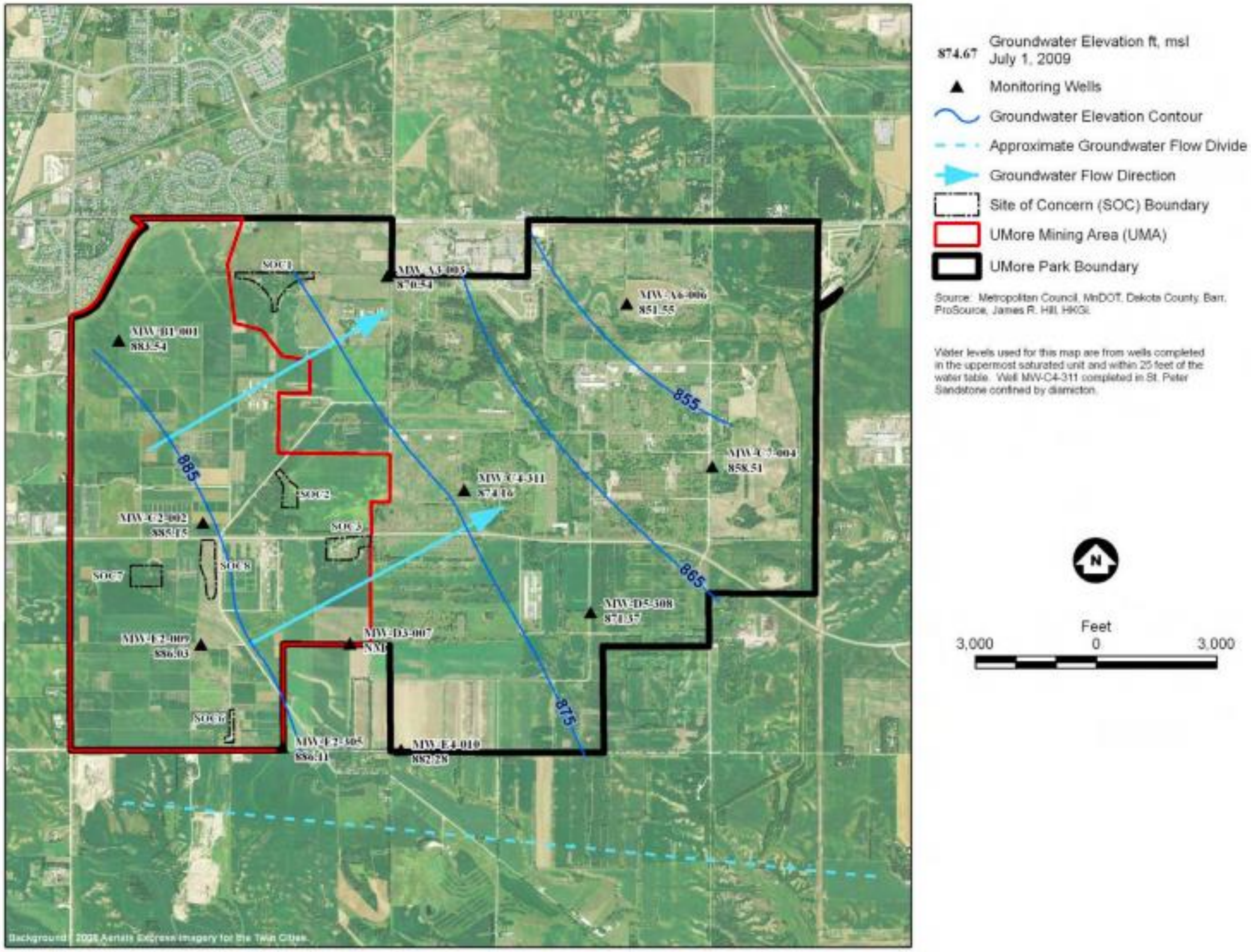


UMore Park Sand and Gravel Resources
Draft Environmental Impact Statement
April 2010

Figure 22
Conceptual Model Hydrostratigraphy

University of Minnesota
Driven to Discover

Groundwater Flow Map

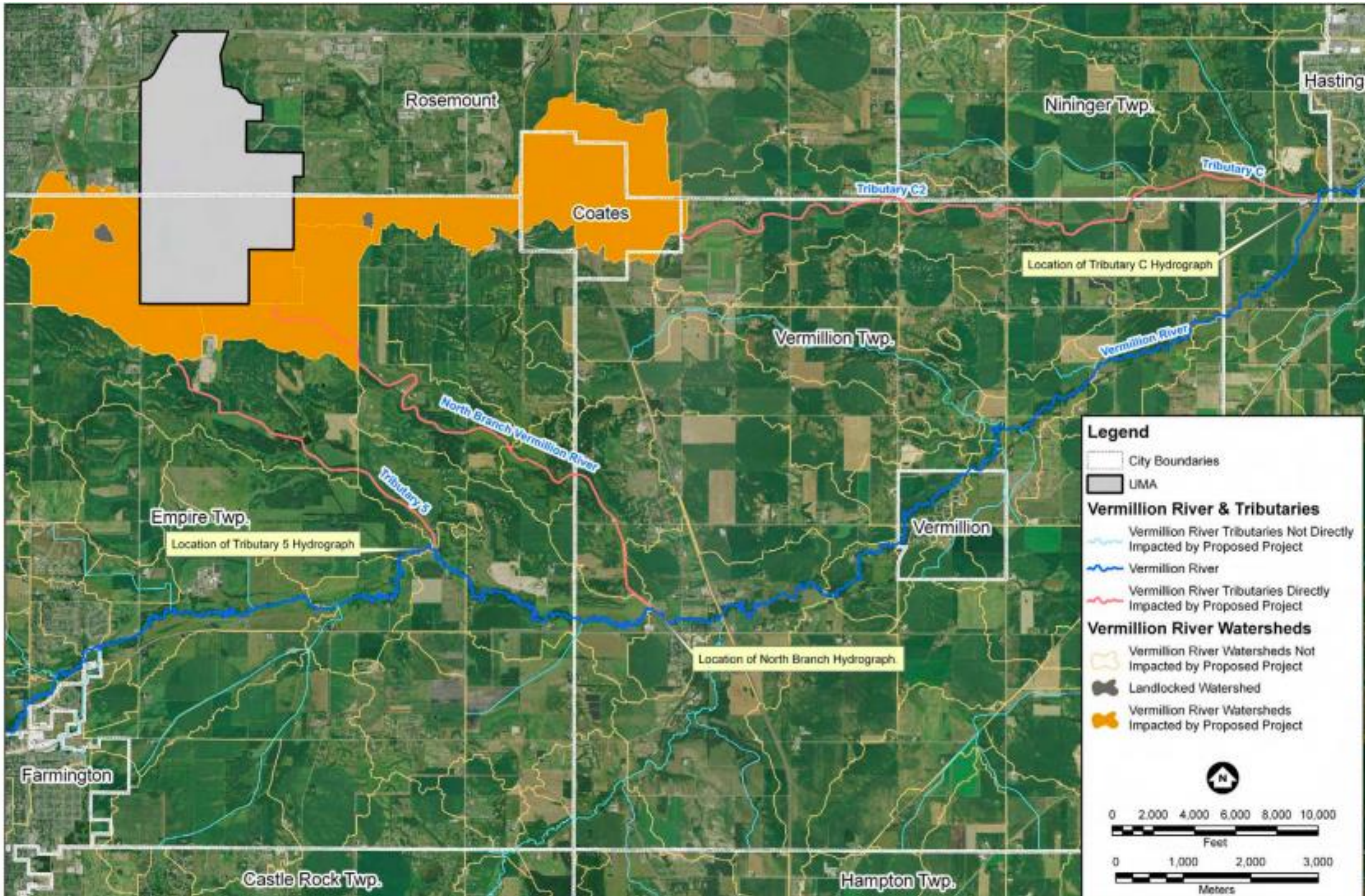


UMore Park Sand and Gravel Resources
Draft Environmental Impact Statement
April 2010

Figure 6
Groundwater Flow Map—
Uppermost Saturated Unit

UNIVERSITY OF MINNESOTA
Driven to Discover

Surface Water Impacts to Vermillion Minimal

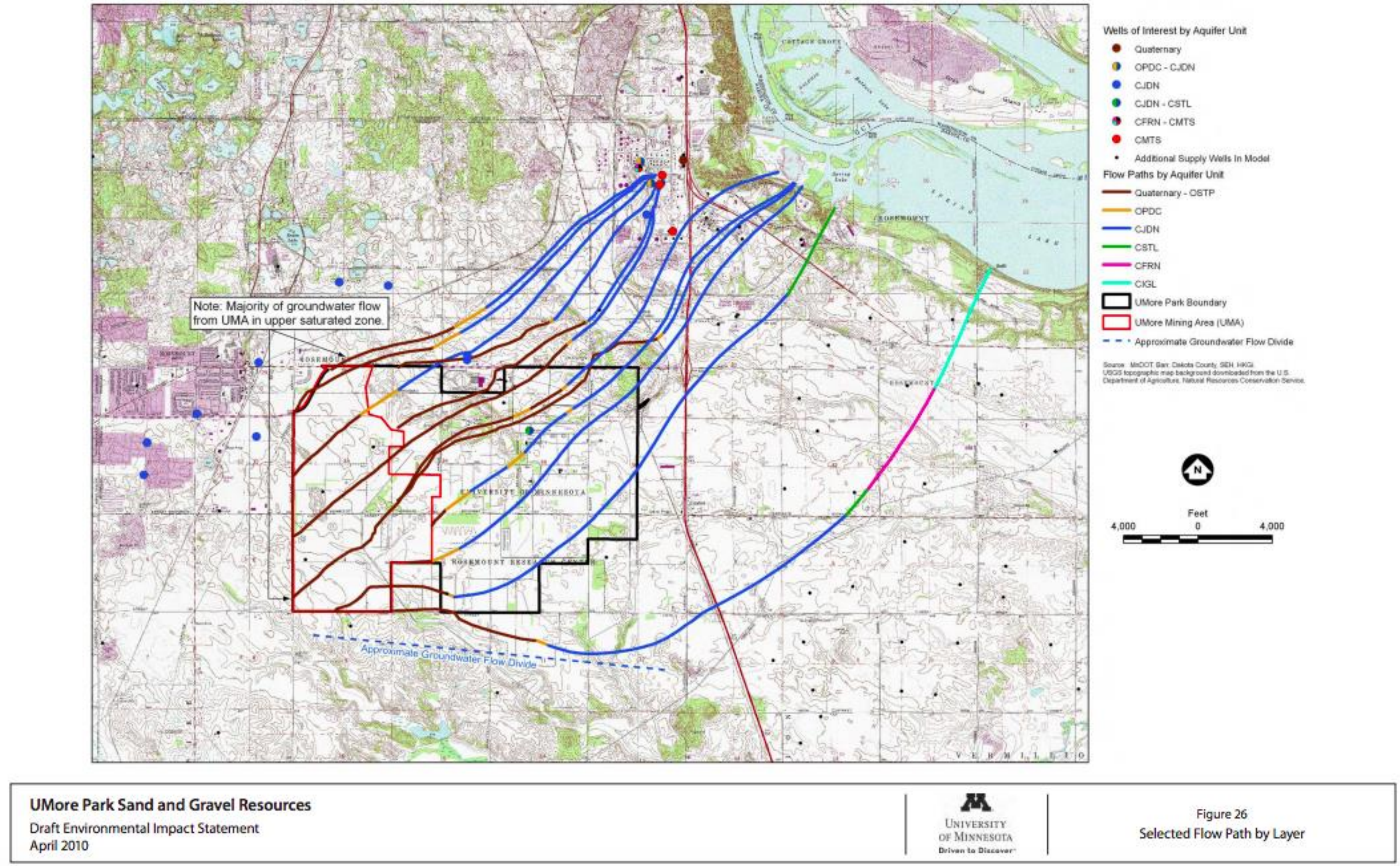


UMore Park Sand and Gravel Resources
Draft Environmental Impact Statement
April 2010

Figure 18
Impacts on Vermillion River

University of Minnesota
Driven to Discover

Groundwater Flow Path Towards Mississippi



Modeling Thermal impact

January 2012

Thermal Plume Transport From Sand and Gravel Pits Potential Thermal Impacts on Cool-Water Streams

Jeffrey M. Markle
The University of Western Ontario

Supervisor
Robert Schincariol
The University of Western Ontario

Graduate Program in Geophysics

A thesis submitted in partial fulfillment of the requirements for the degree in

Characterizing the Two-Dimensional Thermal Conductivity Distribution in a Sand and Gravel Aquifer
Markle, Jeff M;Schincariol, Robert A;Sass, John H;Molson, John W
Soil Science Society of America Journal; Jul/Aug 2006; 70, 4; GeoRef
pg. 1281

Journal of Hydrology (2007) 338, 174–195

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journal homepage: www.elsevier.com/locate/jhydrol

JOURNAL OF HYDROLOGY

Thermal plume transport from sand and gravel pits — Potential thermal impacts on cool water streams

Jeff M. Markle *, Robert A. Schincariol [1]

Department of Earth Science, University of Western Ontario, 1151 Richmond Street, London, ON, Canada N6A 5B7

Received 15 September 2006; received in revised form 7 February 2007; accepted 12 February 2007

Characterizing the Two-Dimensional Thermal Conductivity Distribution in a Sand and Gravel Aquifer

Jeff M. Markle,* Robert A. Schincariol, John H. Sass, and John W. Molson

Thermal Plume Transport from Sand and Gravel Pits – Potential Thermal Impacts on Cool Water Streams

Jeff M. Markle and Robert A. Schincariol
February 2007

Department of Earth Science, University of Western Ontario, 1151 Richmond Street, London, Ontario, Canada, N6A 5B7

Warm pit water migrates into aquifer

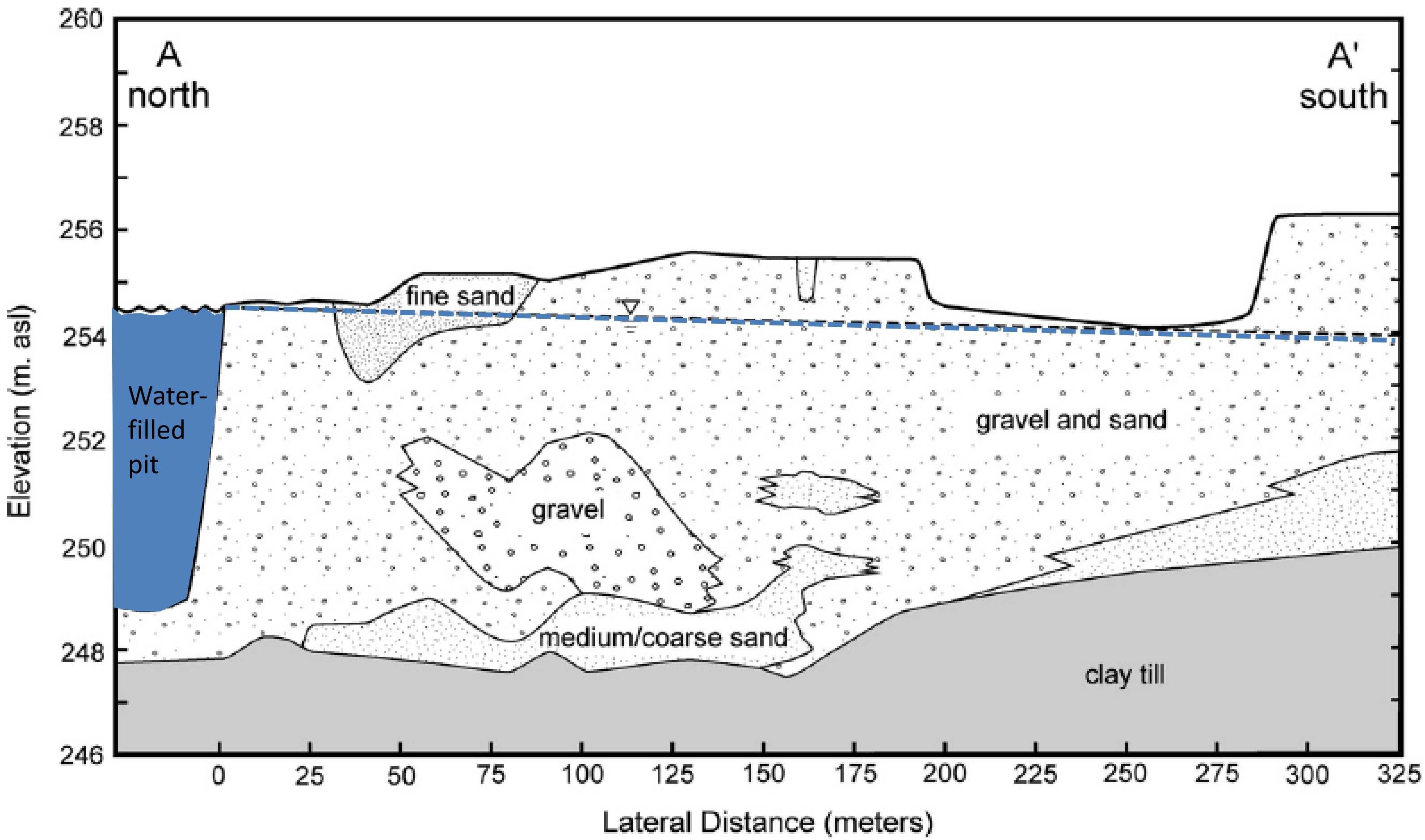


Figure 5 Geologic cross-section A–A′ through the outwash deposit.

Variables

Thermal Conductivity

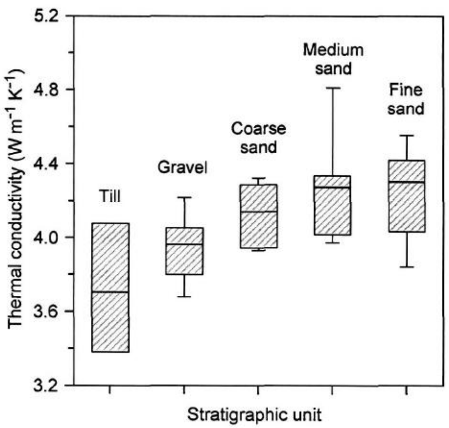
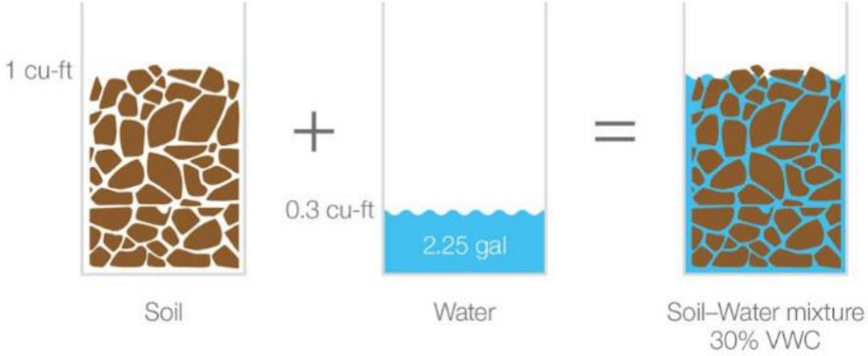


Fig. 2. Box-whisker plot of the measured thermal conductivity for the solid fraction of porous media grouped by stratigraphic unit. The caps at the end of each box indicate the minimum and maximum values, the box is defined by the lower and upper quartiles (25th and 75th percentiles), and the line in the center of the box is the median. No outliers were present in the data.

Flow

Volumetric Water Content



Groundwater temperature varies with depth and season

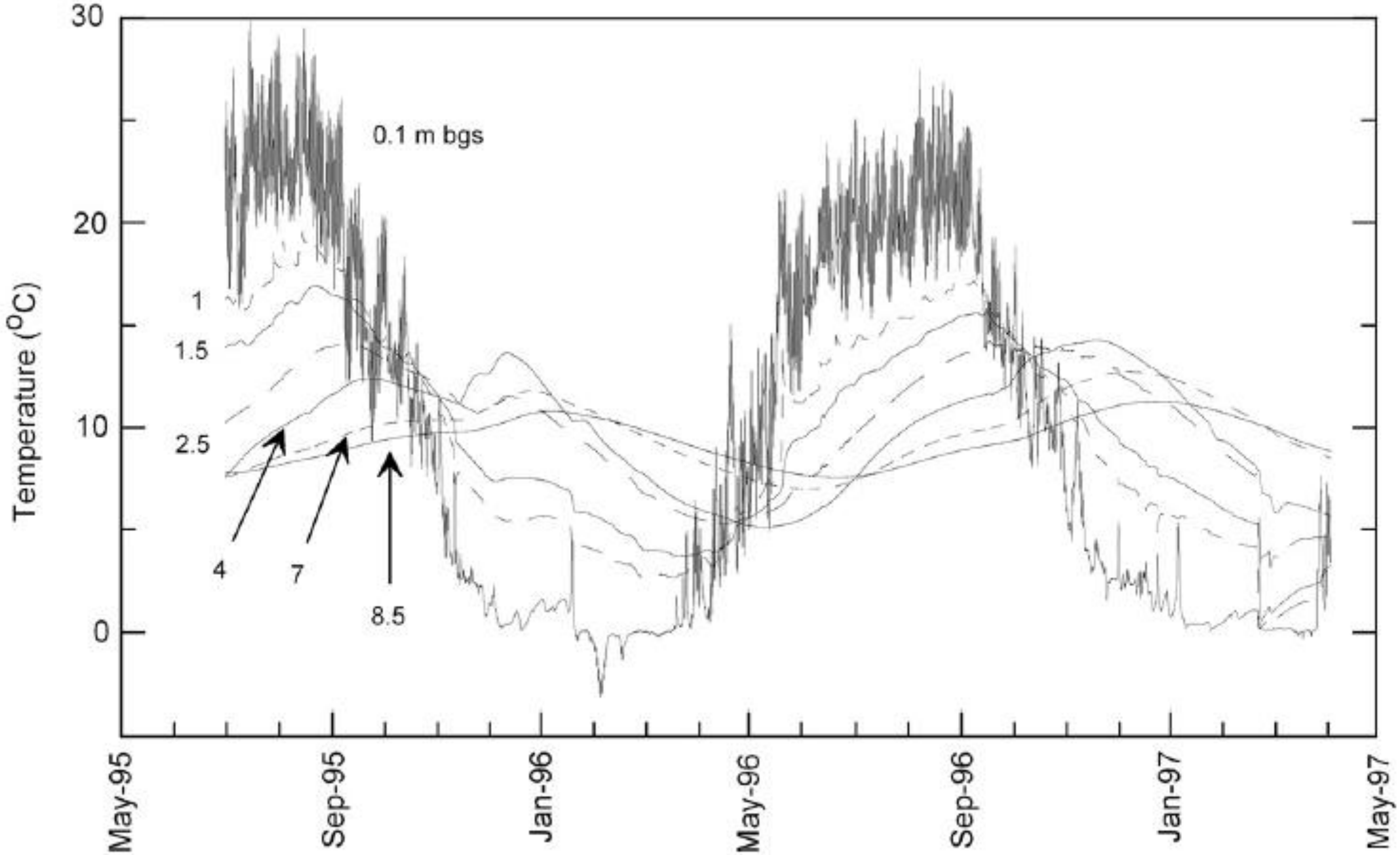
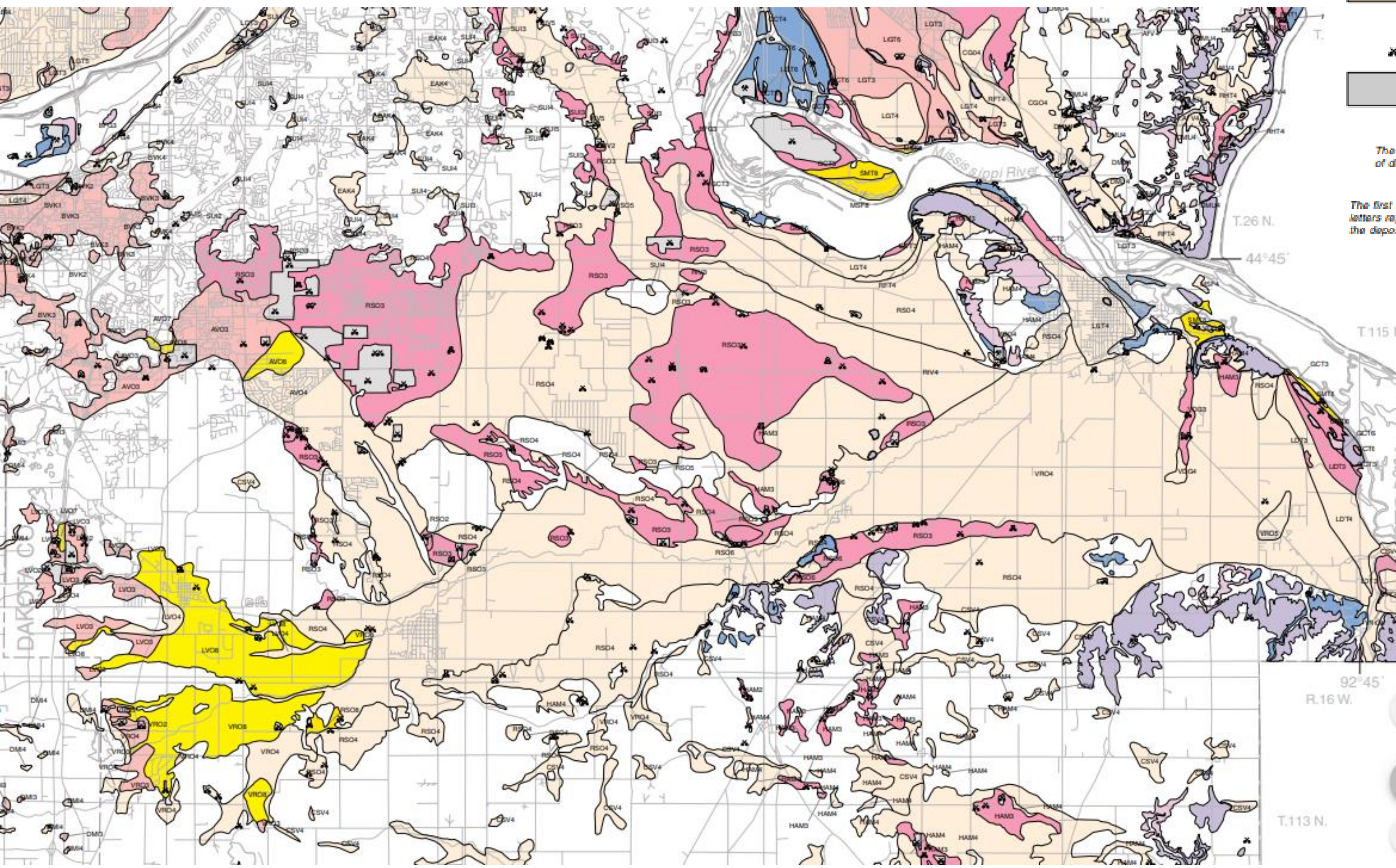


Figure 9 Temperature profile for the up-gradient multilevel well M0. The depths of the thermistors are reported as meters bgs (below ground surface). For clarity, the temperatures for only seven of the 12 thermistors are shown.

Their modeling results

- Thermal plume migrated 2.8 m/day
- Less than 1/2 the groundwater velocity (sand and gravel retains heat and causes a lag)
- Plumes persists for 11 months
- Migrates 250 m down gradient in that time
- Cool water ecosystems within this distance will be impacted

Apply to Vermillion Data



Excellent to good (less than 1.5 percent total spall materials)

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Moderate to poor (generally more than 5 percent total spall materials)

Quality of sources where the water table is less than 20 feet below land surface (classifications 7 and 8):

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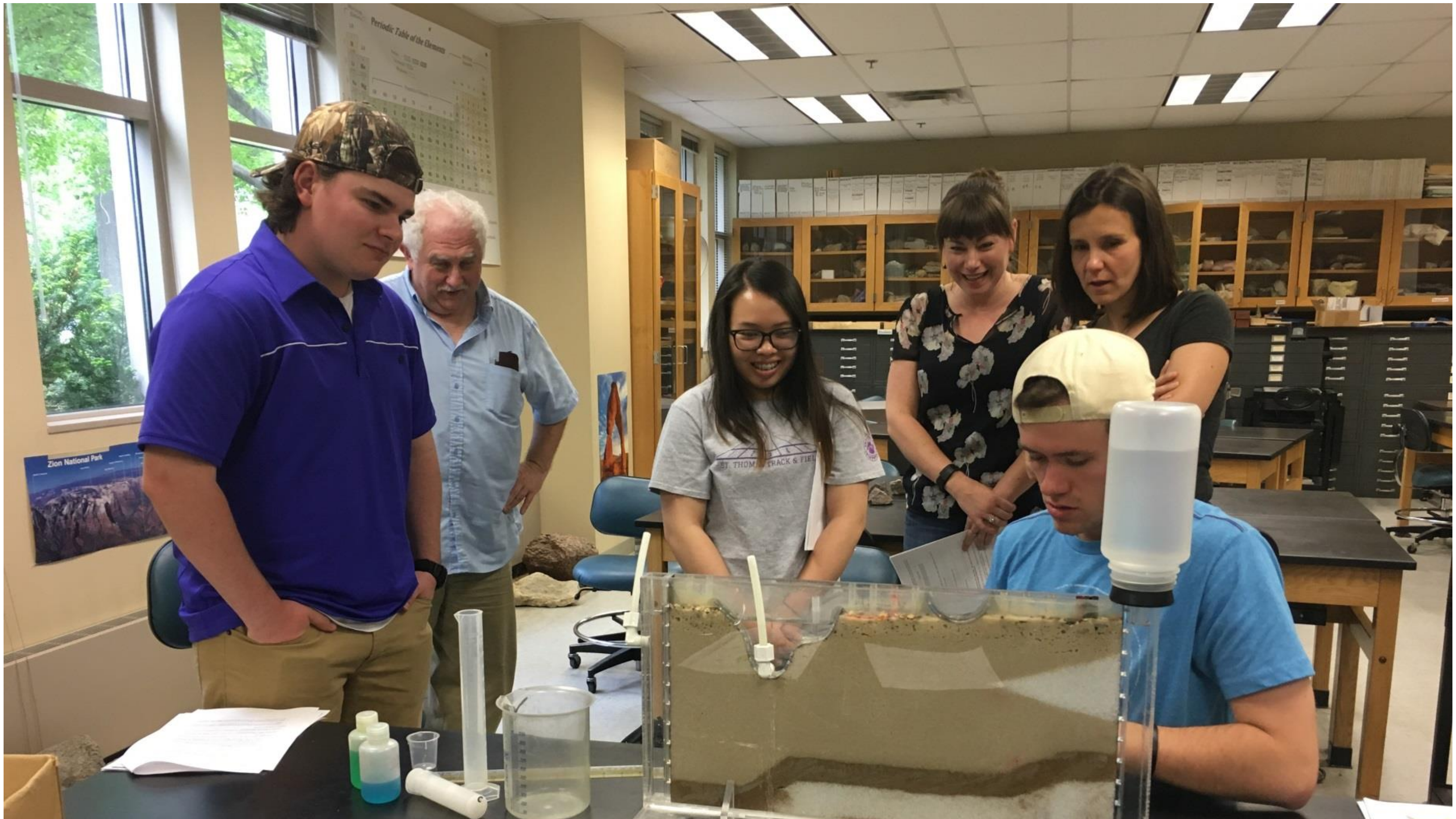
Visualizing aquifers and groundwater flow



Modeling Mining Impacts on Groundwater

Brad Walton, Erik R. Sundberg, Anh Vo,
Center for Applied Mathematics, University of St. Thomas,
Freshwater Society, St. Paul, MN

Univ. St. Thomas
Applied Math Summer Program

- Faculty-guided research experience
  - 2 math, 1 geology faculty
  - 3 students
- Summary paper
- Could form the basis for a RFP for a consultant

Student approach to modeling

- 2-D, finite difference method to solve advection-conduction equation, with boundary conditions

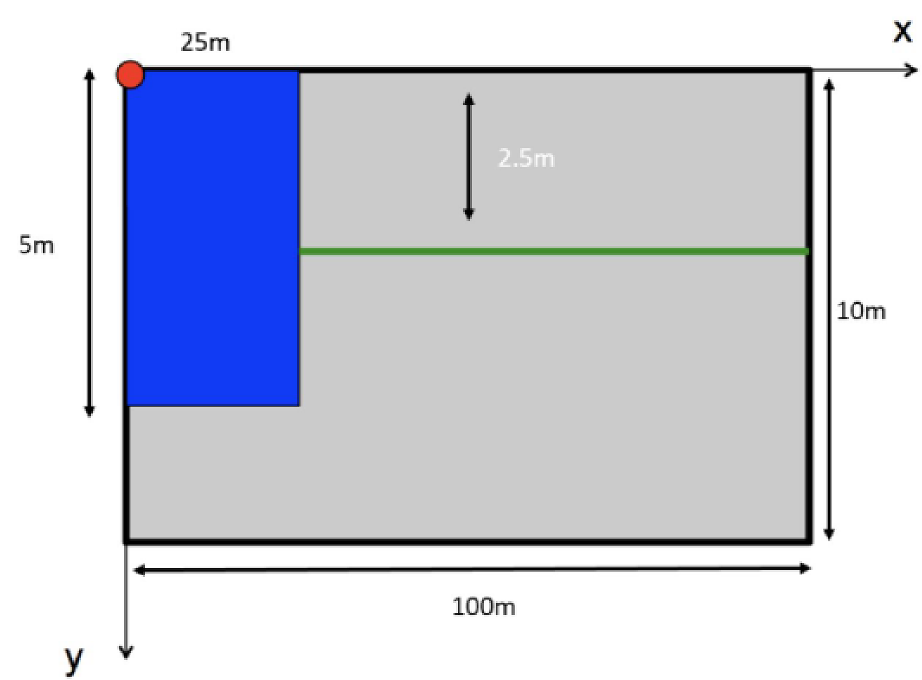
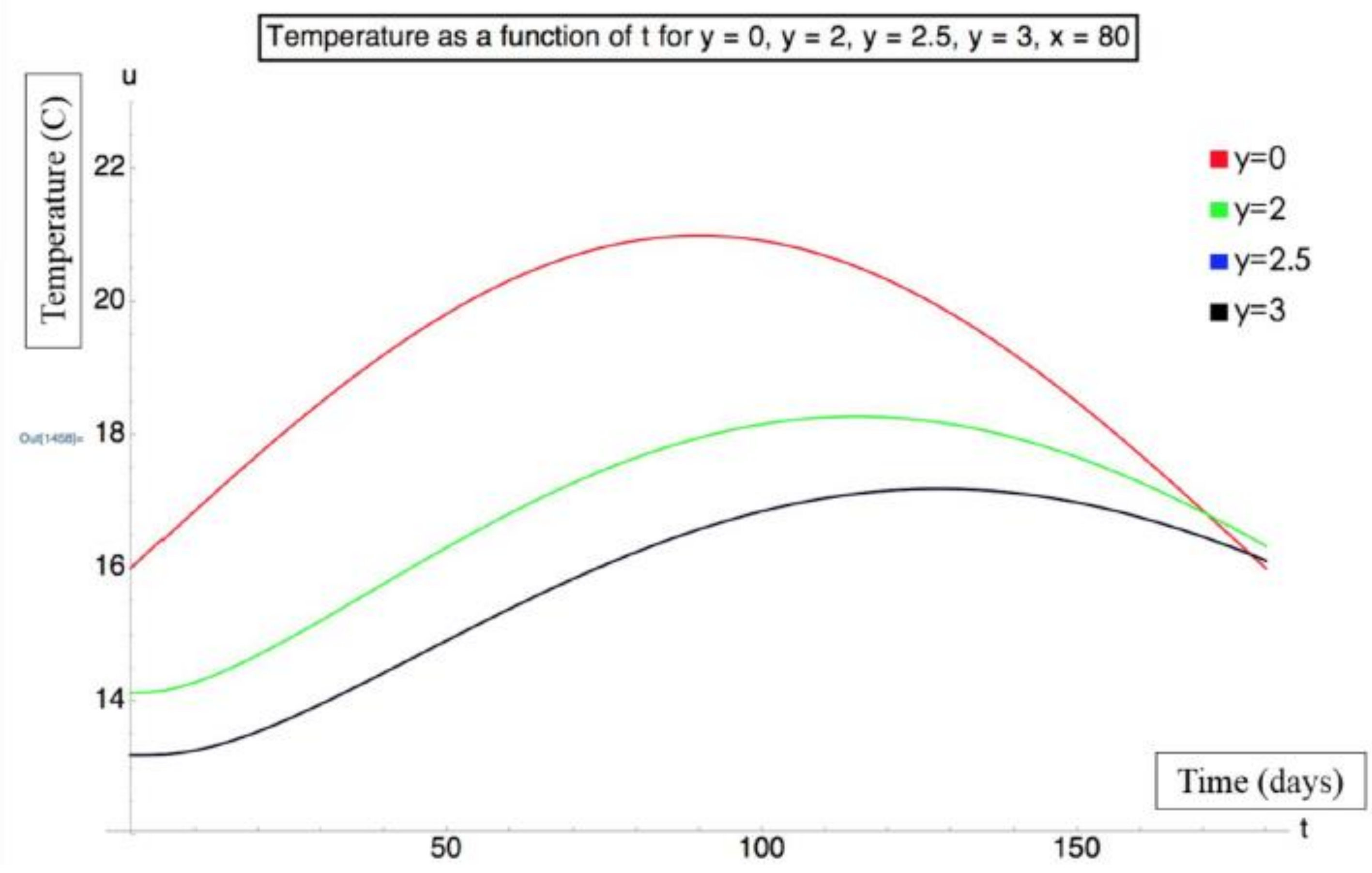


Figure 5.3 is a diagram of how we setup our background domain using a two-dimensional visual. The blue box indicates the potential pit lake with a horizontal distance of 25 meters and 5 meters in depth, the green line indicates the distance from the surface to where groundwater is found. The horizontal length is 100 meters and vertical depth is 10 meters. Although the values for the time step can be changed, we need to be careful with the units that we use so that it can fulfill the stability condition.

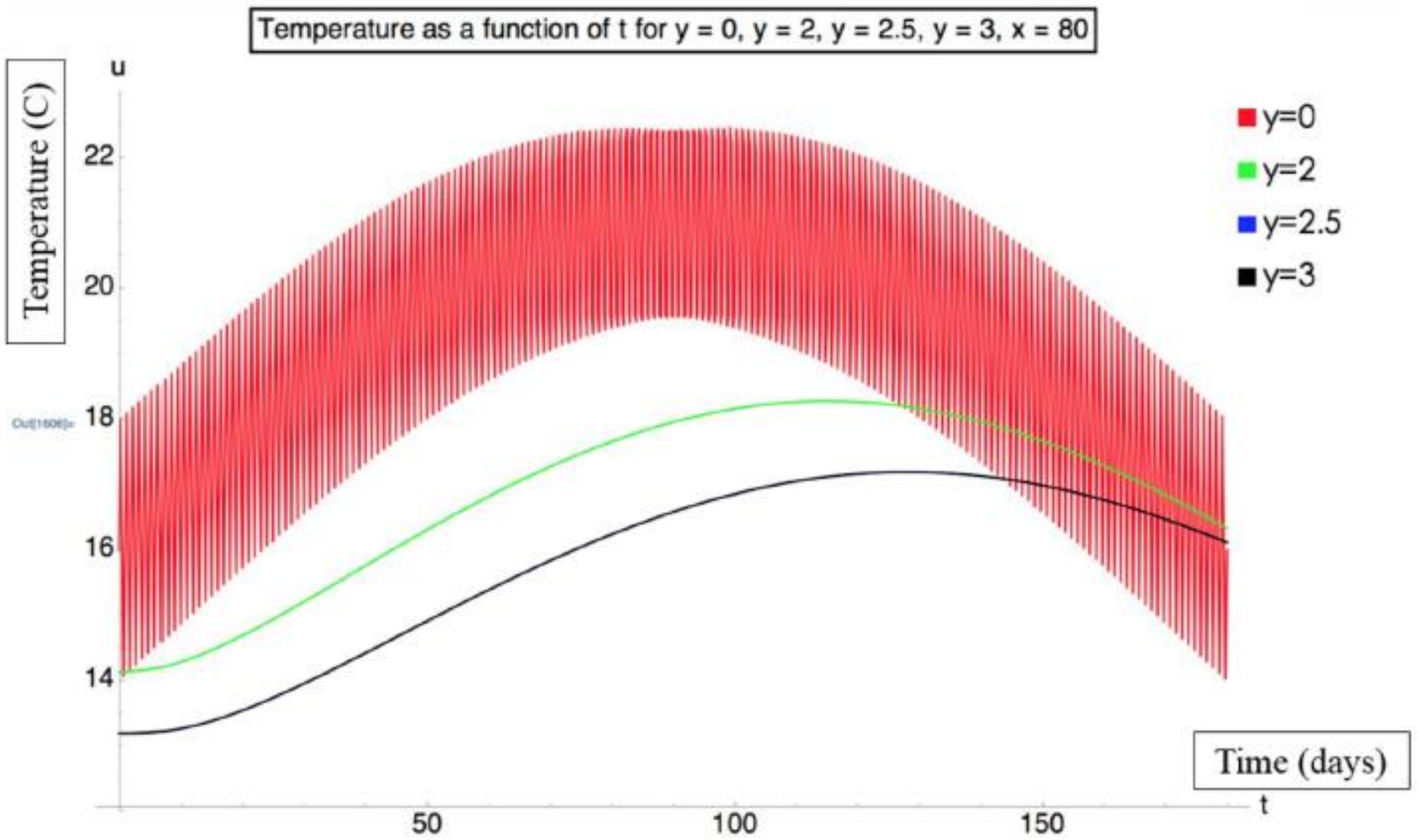
Temperature *vs.* days

Figure 6.1



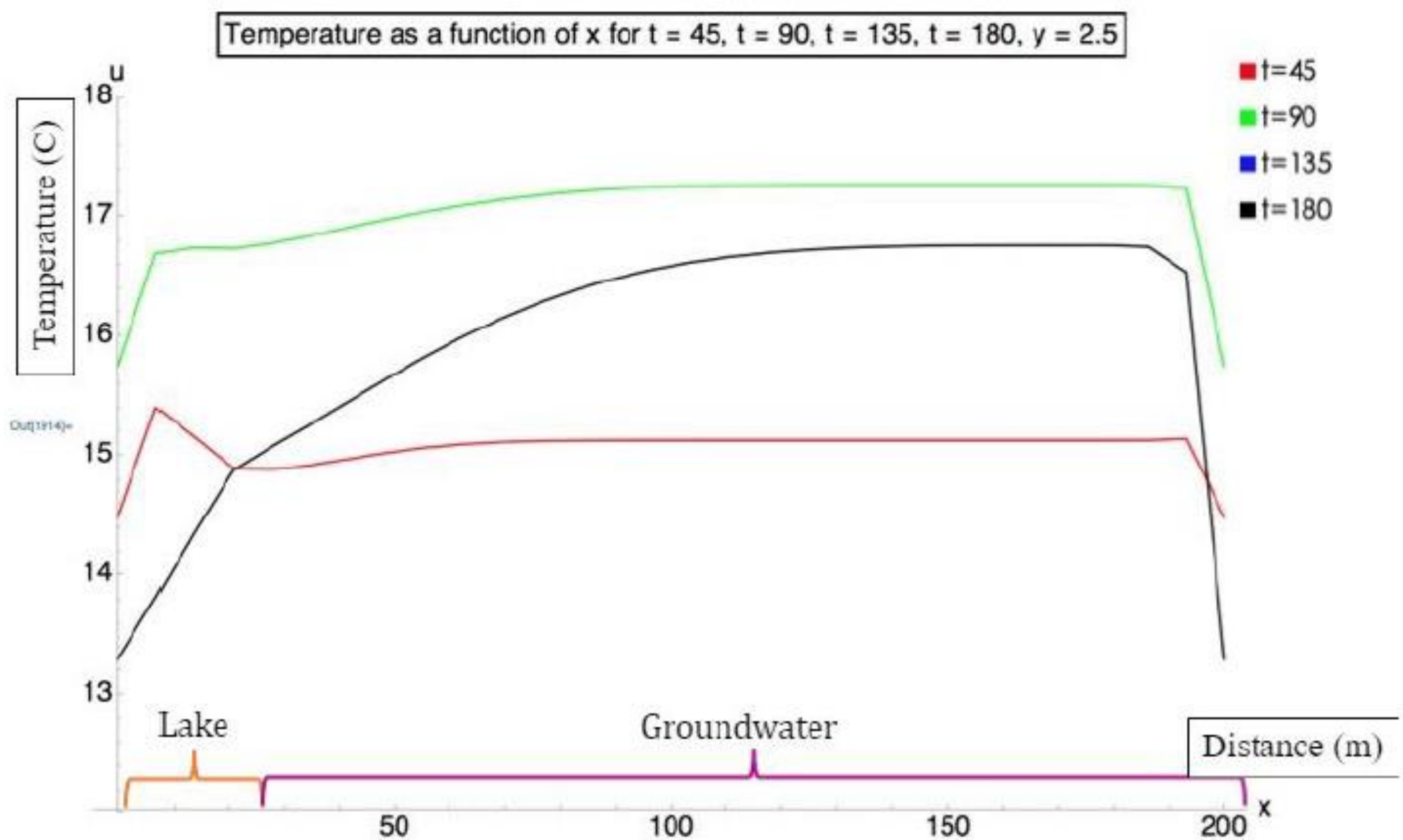
Adding daily temperature variations

Figure 6.2



Temperature with distance

Figure 6.5

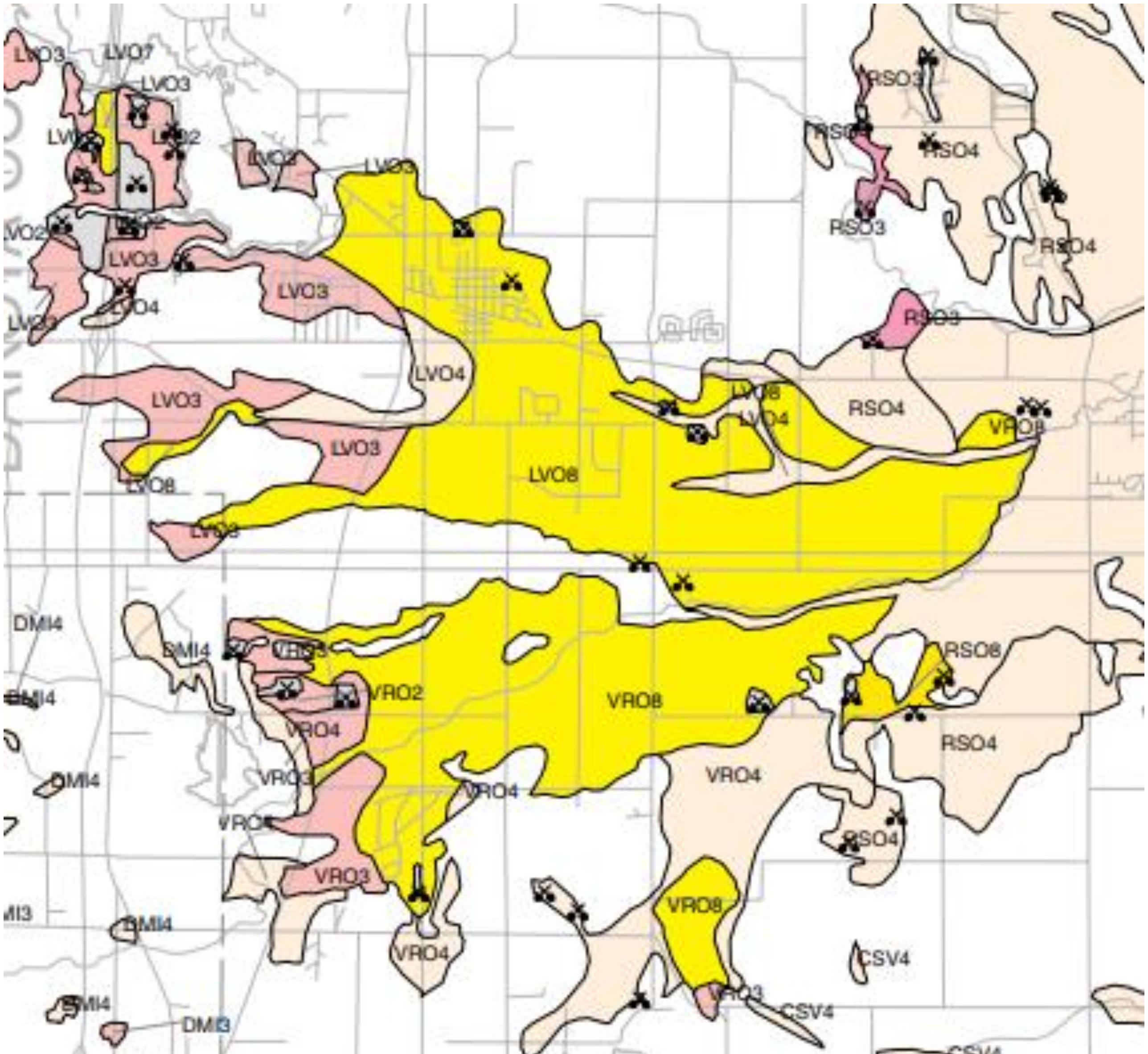


Similar, simpler conclusions

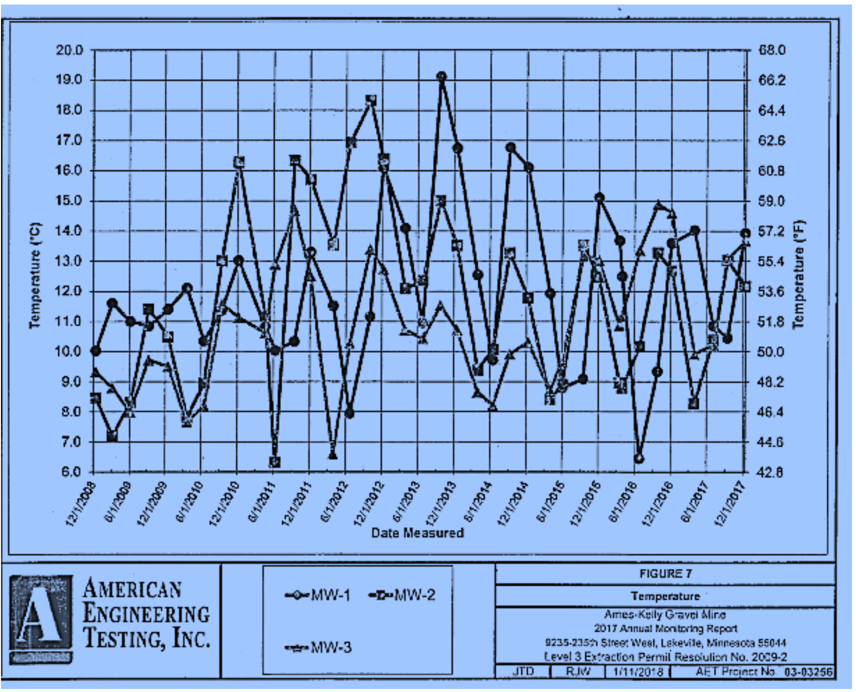
7. Conclusions and Recommendations

The results of this paper suggest that sand and gravel mining companies should adopt a 200 meter setback from lakes and rivers. Those results are comparable to the previous work done by Jeff Markle, who recommended a setback of 250 meters. However, before any regulations are implemented, further research should be done that involves implementing daily oscillations rather than yearly, stabilizing forward models, more models featuring lake inclusion/exclusion, implementation of sinks/sources, and finally, working in modeling software such as Hydrus or MODFLOW.

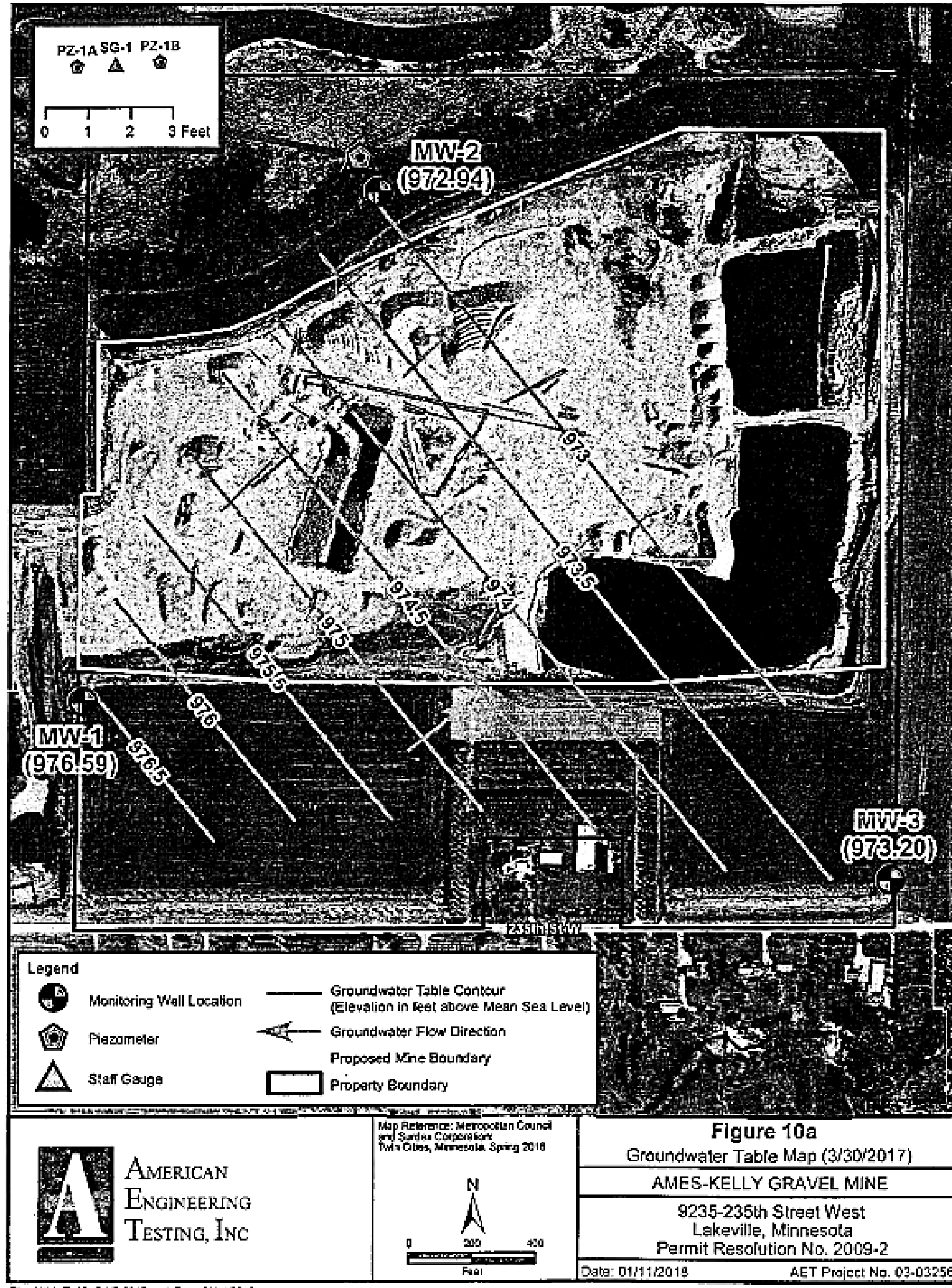
Lakeville/Eureka



Dakota Aggregates



Decade of quarterly temperature readings



Conclusions

- Extraction rates are steady & low volume in the S Dakota County townships since 1995
- Higher rates in Lakeville and Apple Valley have leveled off.
- Extraction rates in Empire Township and Rosemount will surpass those in Apple Valley.

Conclusions

- UMore Park has had extensive environmental review
- Surface water changes will be largely confined to the site
- A groundwater divide south of the property minimizes impact to the Vermillion watershed

Conclusions

- Studies of thermal plumes migration from mine-pit lakes include measurements of:
  - groundwater flow rate (advects heat);
  - thermal properties of the sand & gravel (dissipates heat)
  - annual temperature variations at the surface (background variability).

Recommendations

- Use datasets created for UMore to model thermal plume migration
- Develop an understanding of the sensitivity of aquifers recharging the Vermillion River
- Adopt a standard setback based on this modeling

Recommendations

- Dakota Co.Townships independently regulate aggregate extraction and have varying levels of oversight
- Model mining ordinance could be created for adoption by the townships
- Revise watershed standards to create monitoring consistency across the watershed

Recommendations-Streamline and improve State agency approach

- MPCA has authority over the quality of surface water discharge from mines but does not address quantity or where the water goes.
- DNR EcoWaters issues well permits and is concerned about the ecological impact of groundwater withdrawal on ecosystems
- DNR Lands and Minerals maps aggregate to protect it from development
- Coordinate activity of MPCA, DNR EcoWaters and DNR Lands and Minerals