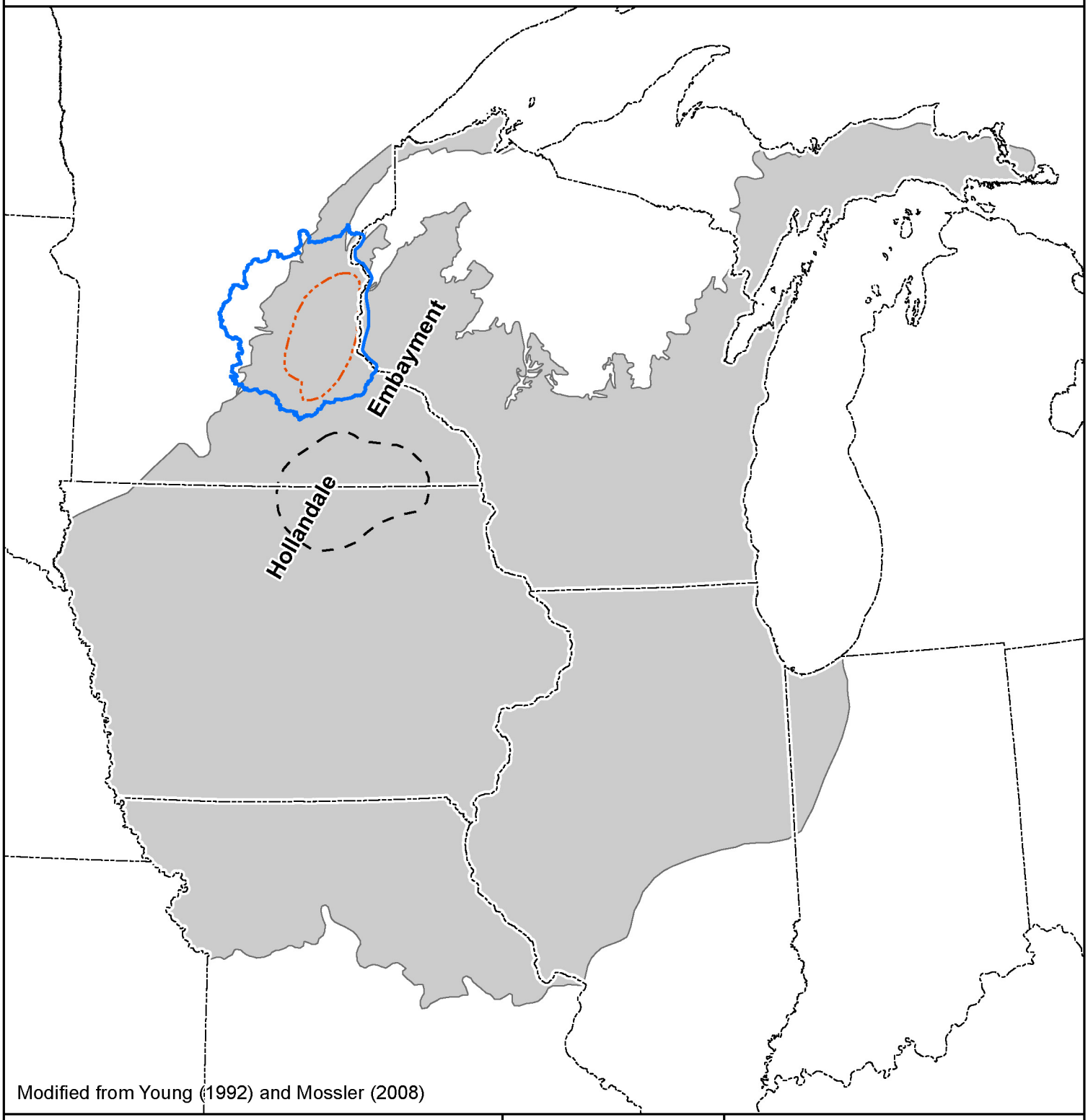
Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Modified from Young (1992) and Mossler (2008)

Model Boundary
State Boundaries
Galena Basin
Twin Cities Basin
Cambrian-Ordovician Aquifer System

N

0 50 100
Miles

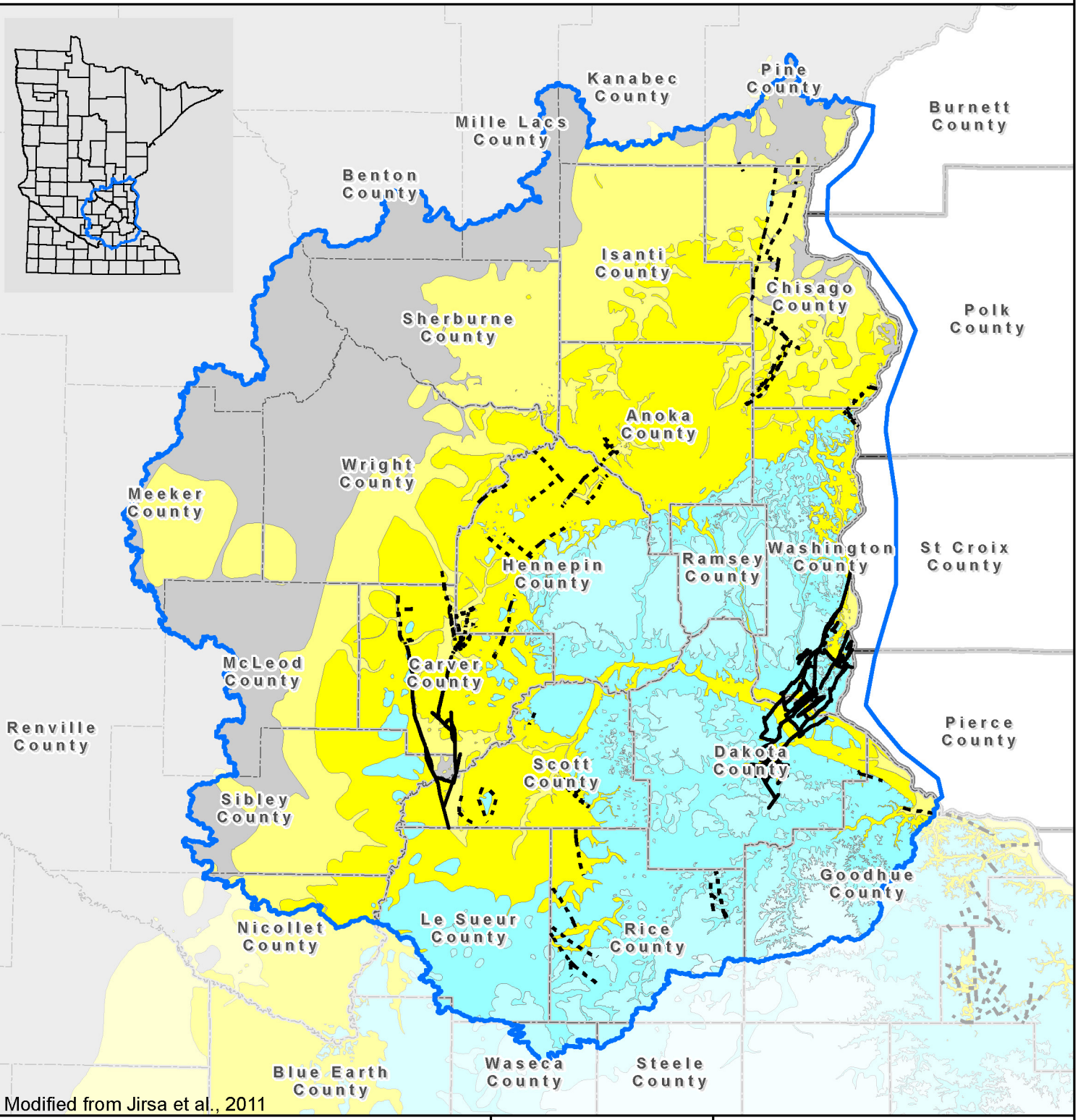
0 50 100 150
Kilometers

Figure 1
Geologic Setting and Cambrian-Ordovician Aquifer System

Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Regional_Aquifer_Extents.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Modified from Jirsa et al., 2011

Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Regional_Faults.mxd User: egc

Bedrock

- Upper Ordovician
- Middle and upper Ordovician
- Lower Ordovician
- Upper Cambrian
- Middle and Upper Cambrian
- Precambrian bedrock

- Model Boundary
- Fault zones where where inhomogeneity occurs in model layer
- Other mapped faults

N

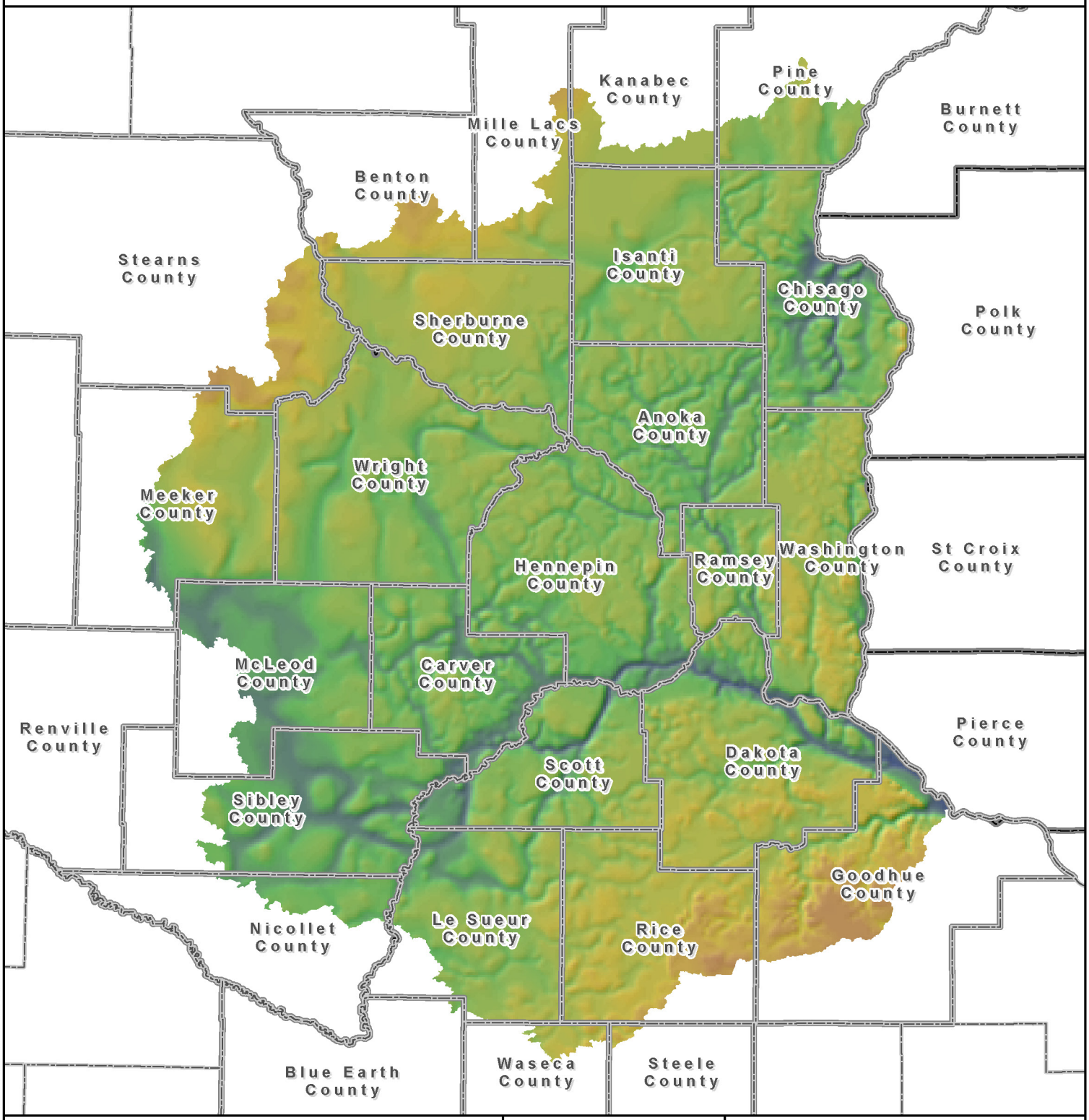
0 10 20
Miles

0 15 30
Kilometers

Figure 2

Paleozoic Bedrock and Faults

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Bedrock_Topography.mxd User: egc

Bedrock Surface

Elevation, meters above sea level

400
300
200
100

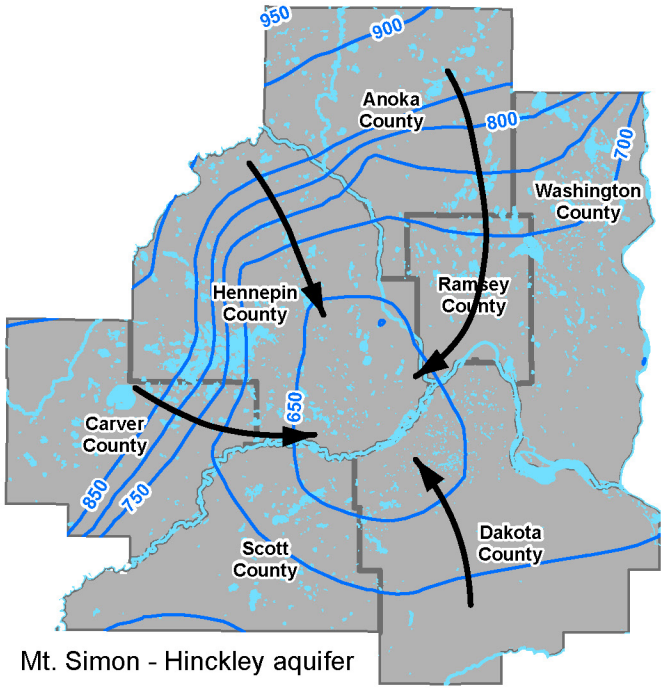
N

0 10 20
Miles

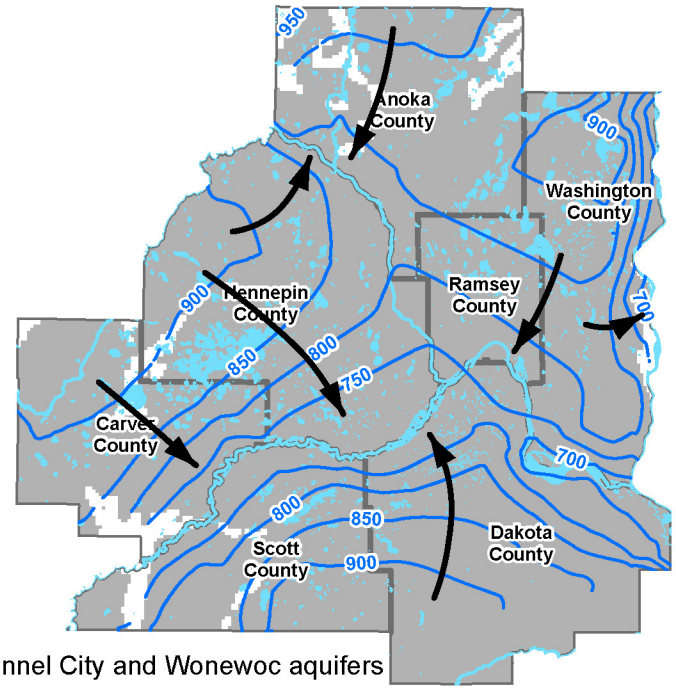
0 15 30
Kilometers

Figure 3

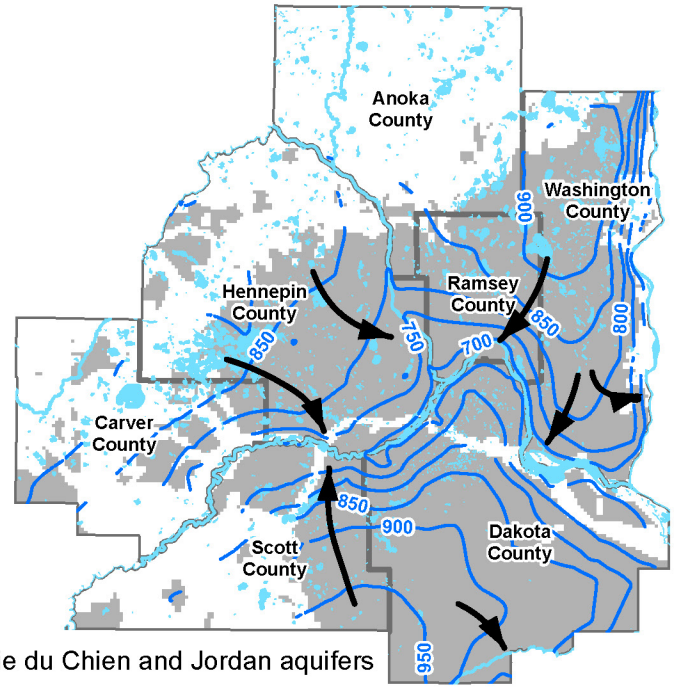
Bedrock Topography



Mt. Simon - Hinckley aquifer



Tunnel City and Wonewoc aquifers



Prairie du Chien and Jordan aquifers

Potentiometric Contour (ft)

Water Body

Aquifer Extent

Flow Arrow

N

0 10 20

Miles

0 15 30

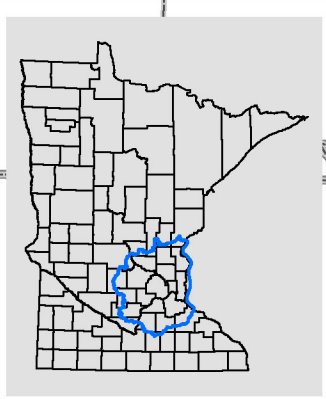
Kilometers

Potentiometric contours from Sanocki and others, 2009

Figure 4

Potentiometic Surfaces and Groundwater-Flow Directions

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Kanabec County
Pine County
Burnett County
Mille Lacs County
Benton County
Isanti County
Chisago County
Polk County
Sherburne County
Anoka County
Wright County
Meeker County
Hennepin County
Ramsey County
Washington County
St Croix County
McLeod County
Carver County
Renville County
Pierce County
Scott County
Dakota County
Sibley County
Goodhue County
Nicollet County
Le Sueur County
Rice County
Blue Earth County
Waseca County
Steele County

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Model Boundary

Type

- Constant Head
- General Head
- No Flow

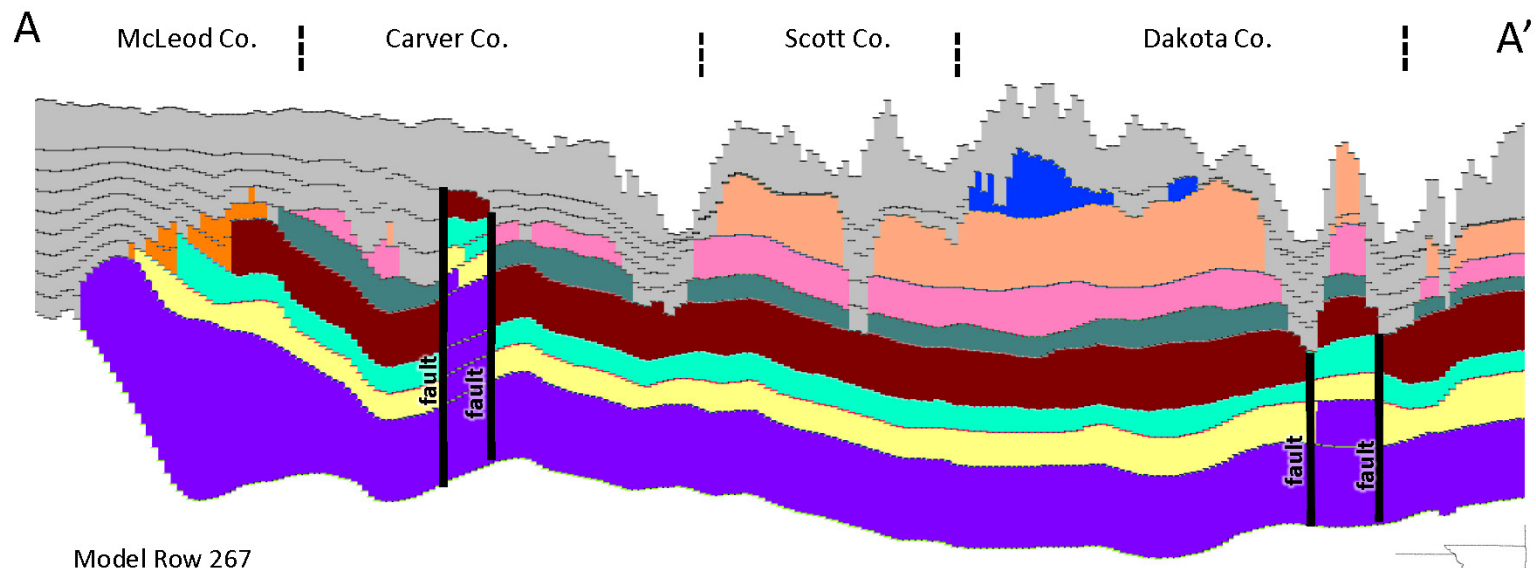
N

0 10 20
Miles

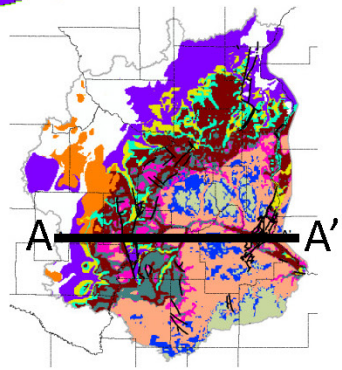
0 15 30
Kilometers

Figure 5

Groundwater Model Extent and Boundary Conditions



Model Row 267
Vertical exaggeration ~ 150x

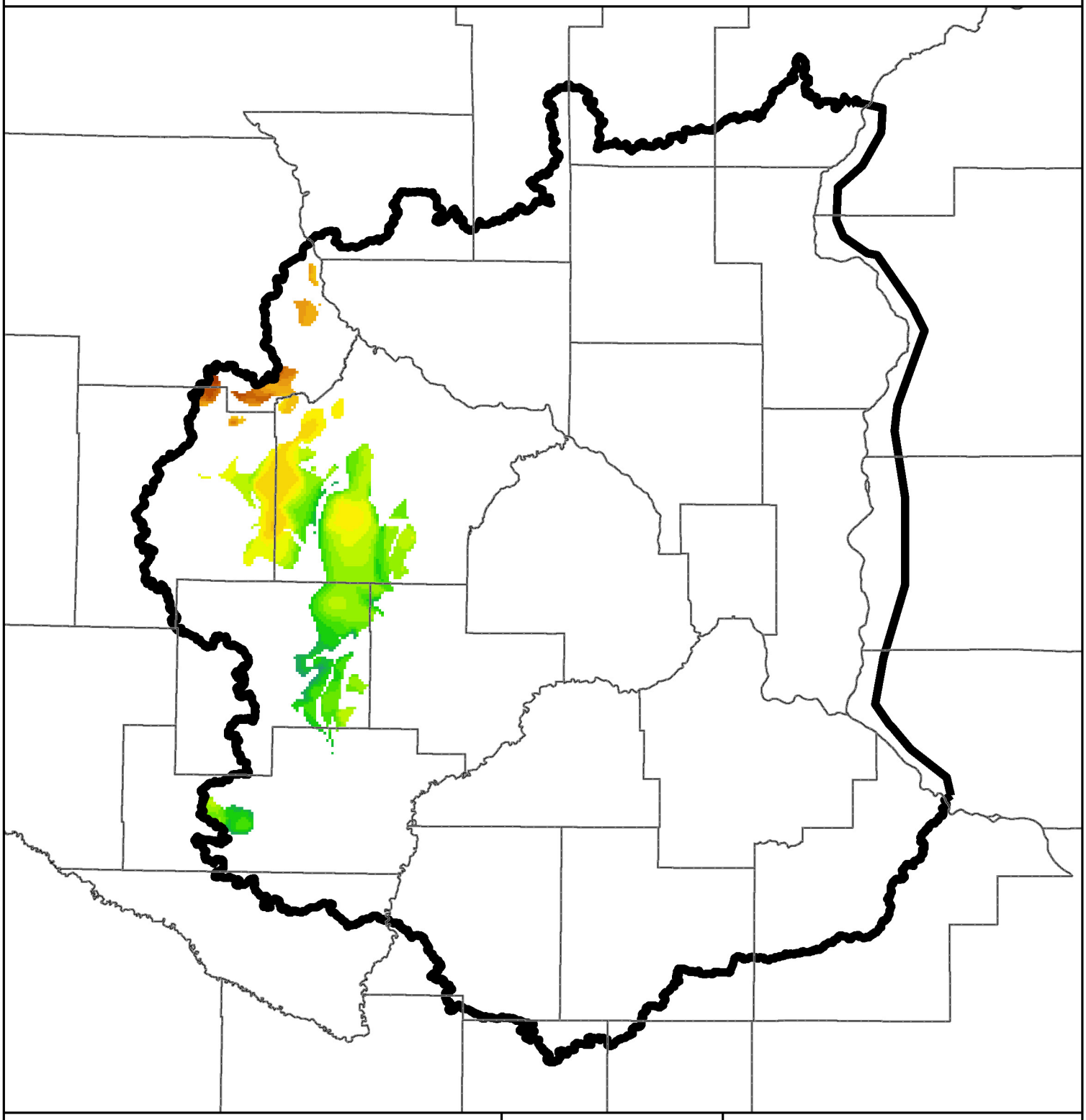


- Quaternary Sediments
- Cretaceous and Paleozoic sandstone and siltstone
- St. Peter Sandstone
- Prairie du Chien Group
- Jordan Sandstone
- St. Lawrence Formation
- Tunnel City Group
- Wonewoc Sandstone
- Eau Claire Formation
- Mt Simon – Hinckley Sandstone

Figure 6
Typical Cross Section Through Model Illustrating Model Layers and Assignment of Hydrogeologic Units

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Top_Ku_Pmu.mxd User: egc

Model Boundary

Elevation (meter above sea level)

- 176 - 180
- 181 - 190
- 191 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280
- 281 - 290
- 291 - 300
- 301 - 310
- 311 - 320
- 321 - 330
- 331 - 340
- 341 - 350

N

0 10 20
Miles

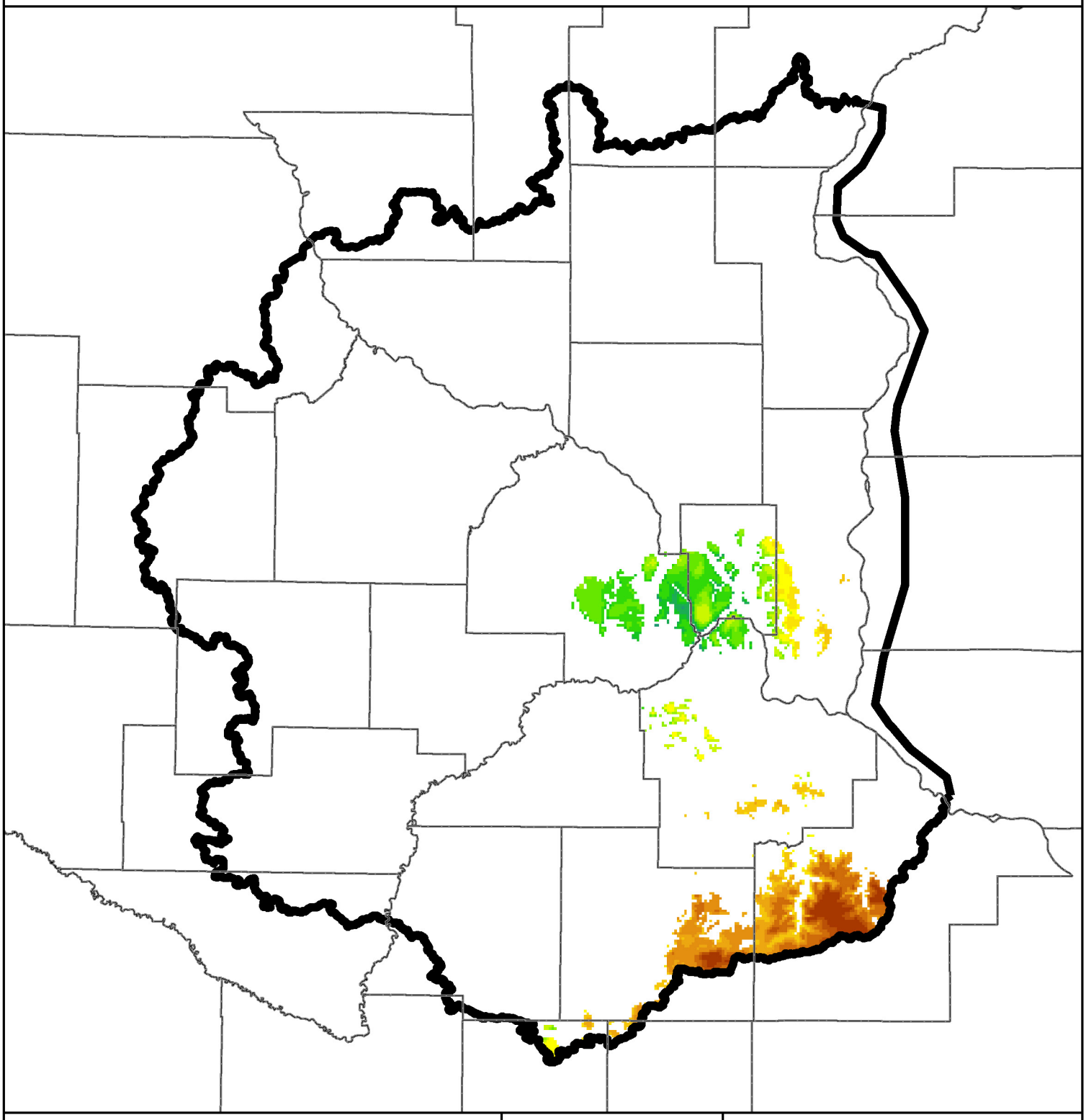
0 15 30
Kilometers

Figure 7

Top of Cretaceous and/or Unnamed Paleozoic or Lower Mesozoic Bedrock

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Top_Og_Od_Ogw.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 210 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280
- 281 - 290
- 291 - 300
- 301 - 310
- 311 - 320
- 321 - 330
- 331 - 340
- 341 - 350
- 351 - 360

N

0 10 20
Miles

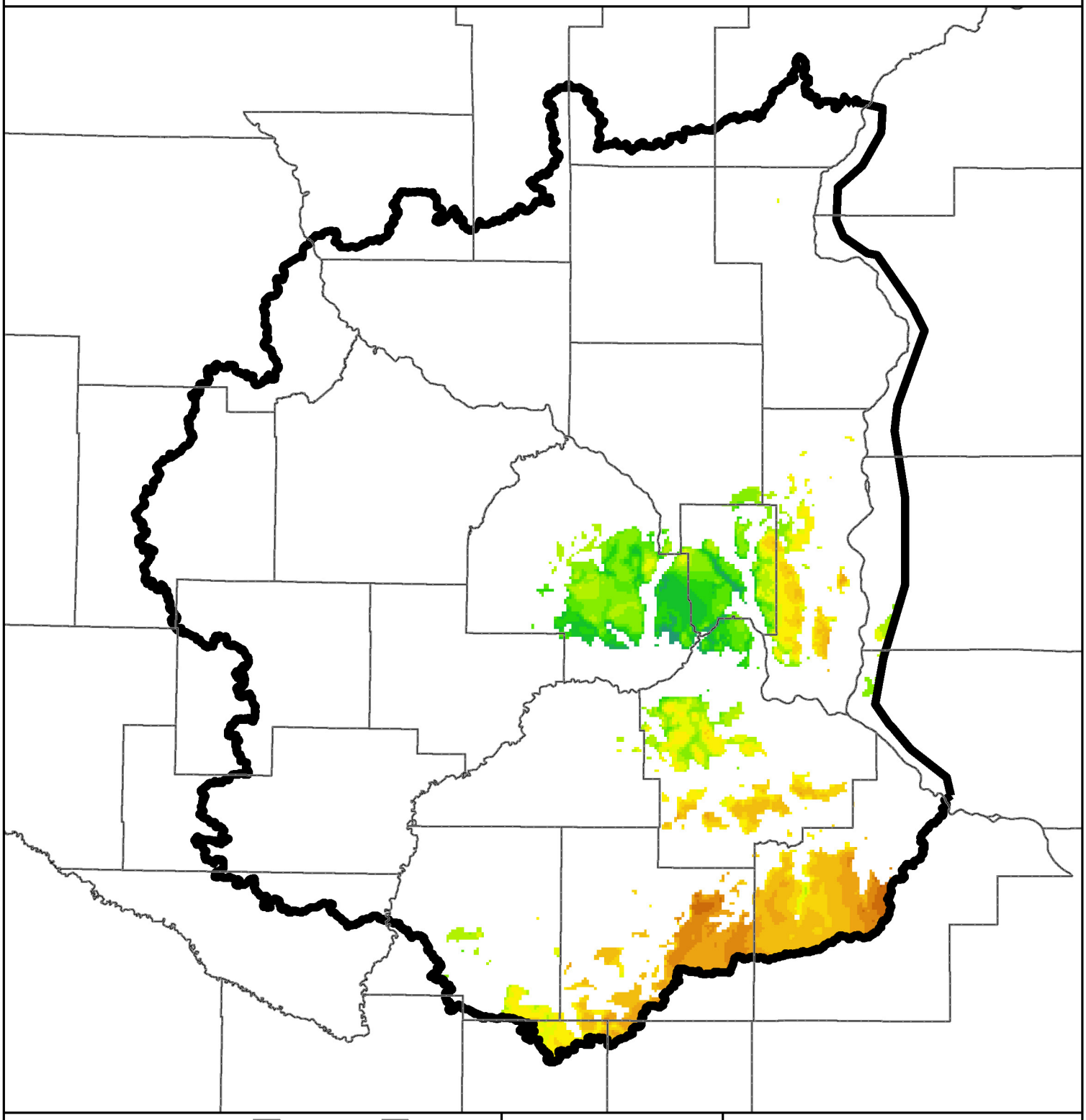
0 15 30
Kilometers

Figure 8

Top of Galena Group, Decorah Shale Platteville Fm. and Glenwood Fm.

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportTop_OSTP.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 190 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280
- 281 - 290
- 291 - 300
- 301 - 310
- 311 - 320
- 321 - 330
- 331 - 340
- 341 - 350

N

0 10 20
Miles

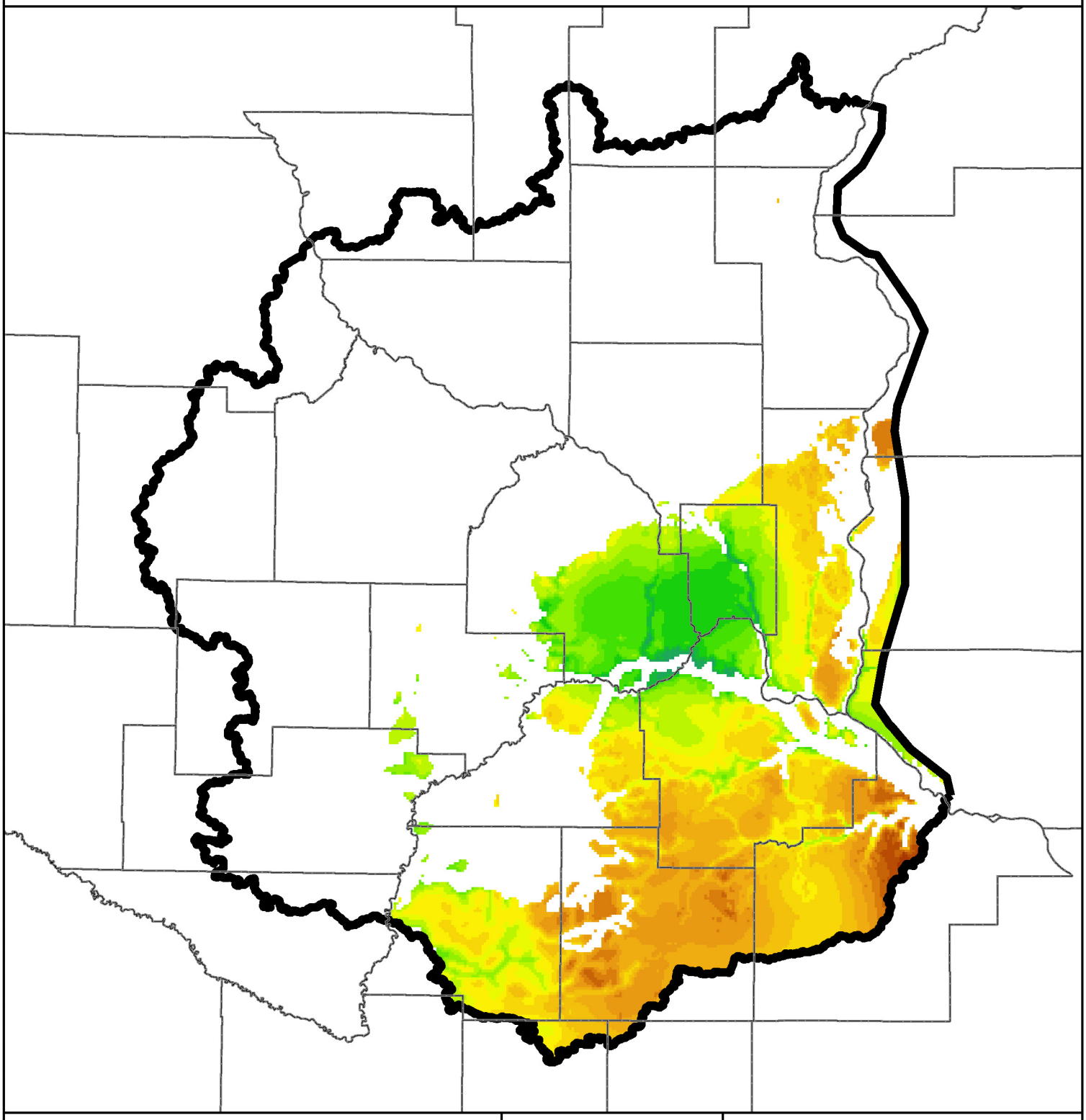
0 15 30
Kilometers

Figure 9

Top of St. Peter Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportTop_Op.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 156 - 160
- 161 - 170
- 171 - 180
- 181 - 190
- 191 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280
- 281 - 290
- 291 - 300
- 301 - 310
- 311 - 320
- 321 - 330

N

0 10 20
Miles

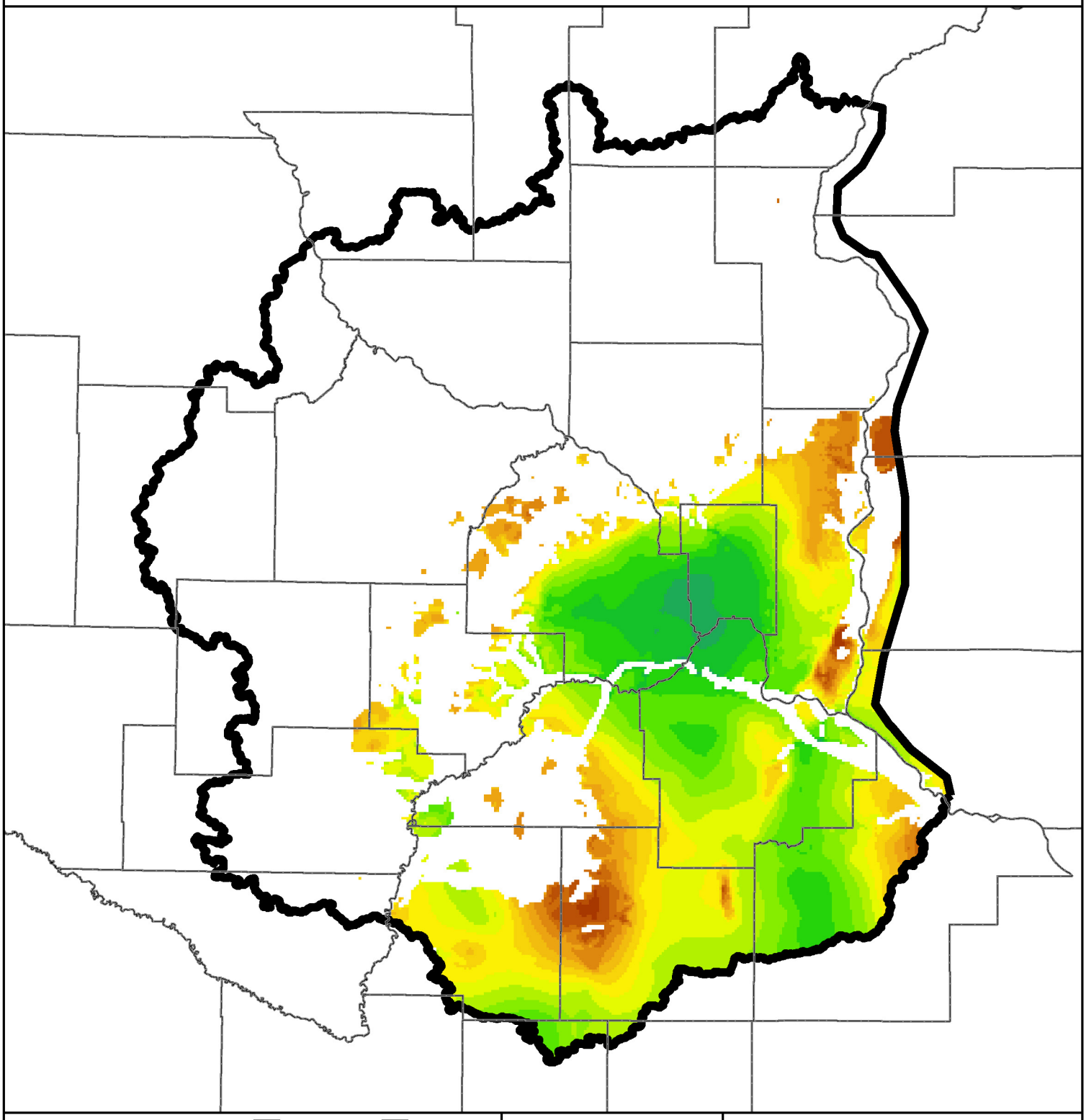
0 15 30
Kilometers

Figure 10

Top of Prairie du Chien Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportTop_Cj.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 138 - 140
- 141 - 150
- 151 - 160
- 161 - 170
- 171 - 180
- 181 - 190
- 191 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280
- 281 - 290

N

0 10 20
Miles

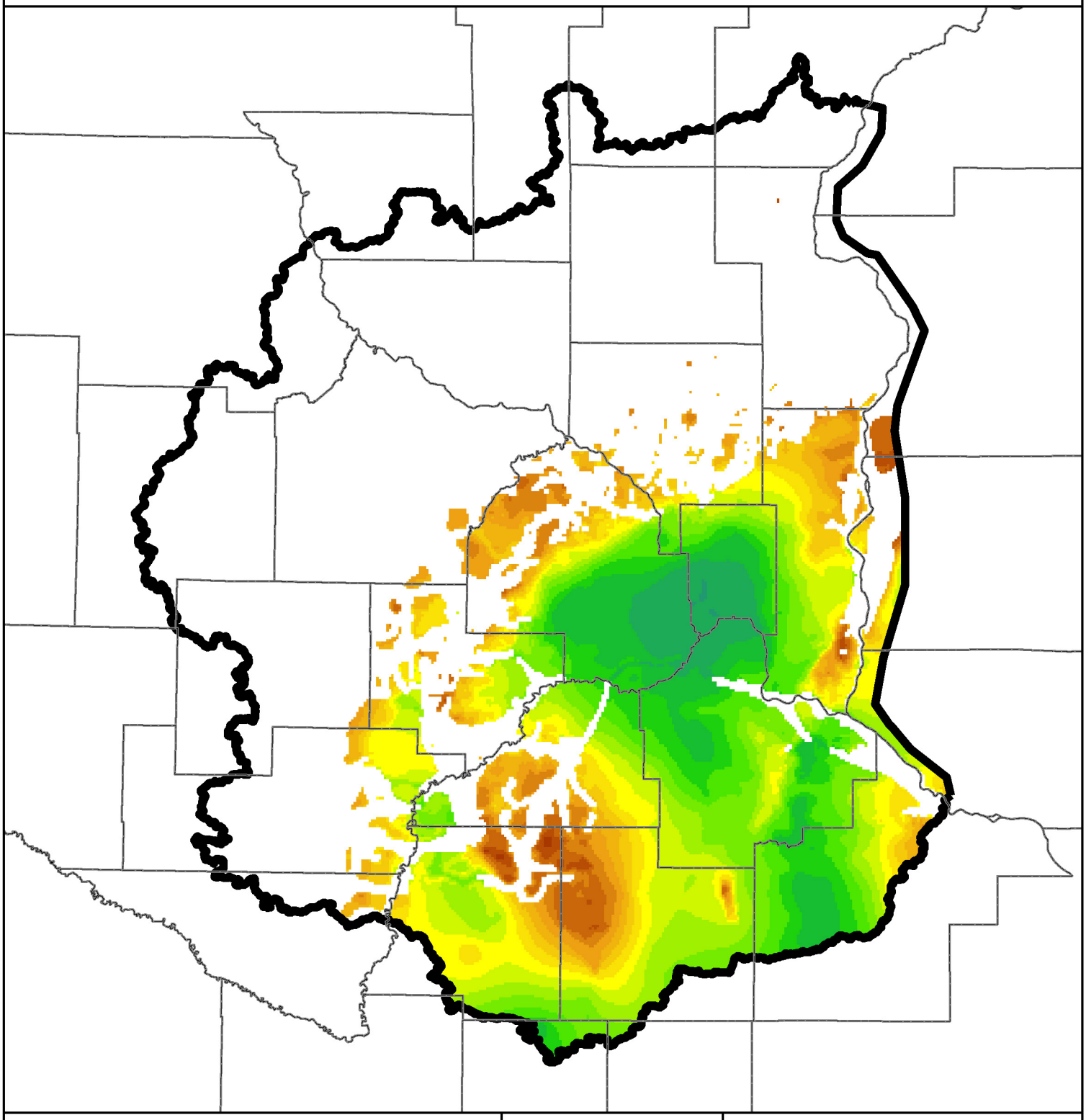
0 15 30
Kilometers

Figure 11

Top of Jordan Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Top_Csl.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 120 - 120
- 121 - 130
- 131 - 140
- 141 - 150
- 151 - 160
- 161 - 170
- 171 - 180
- 181 - 190
- 191 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280

N

0 10 20
Miles

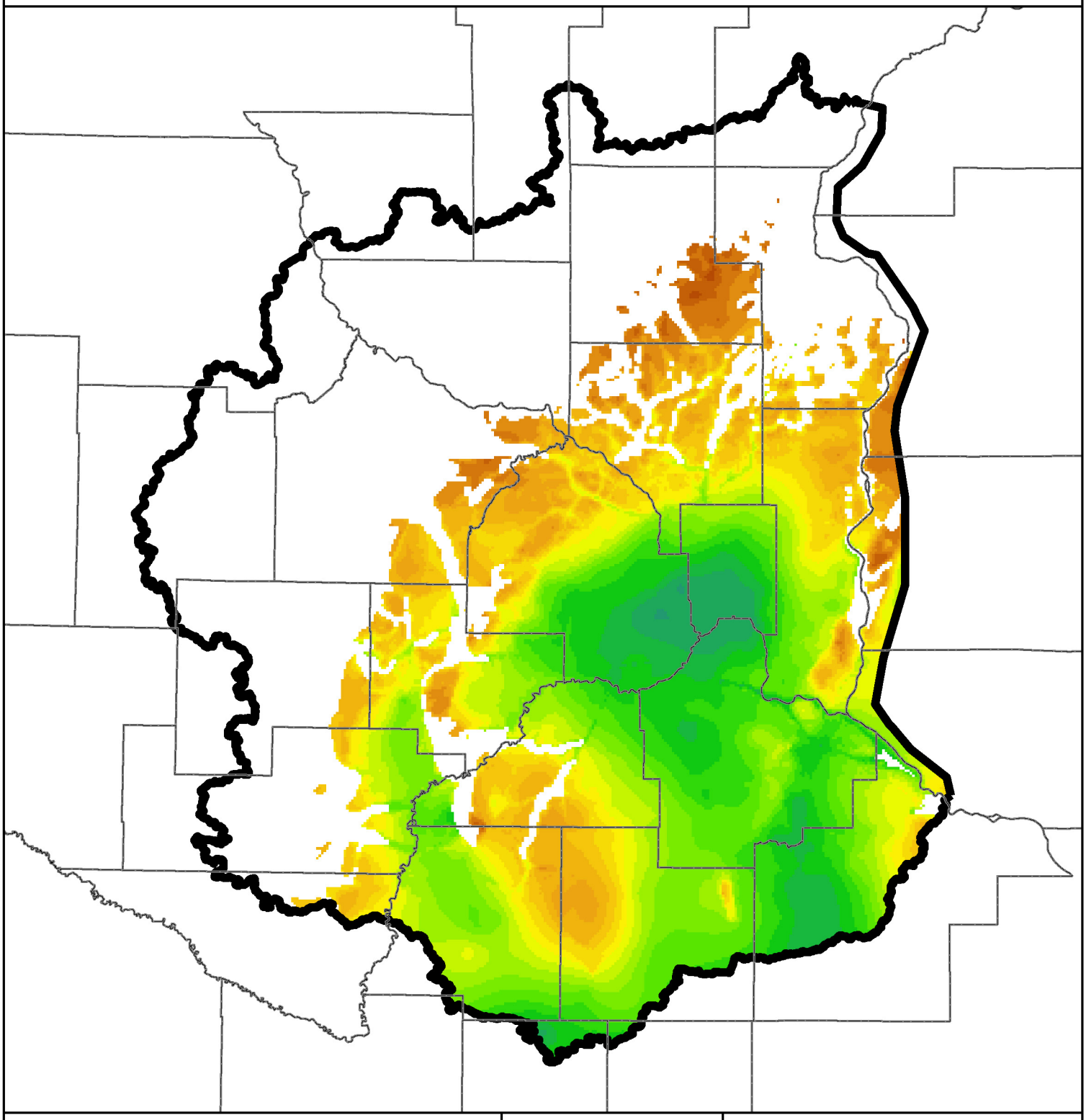
0 15 30
Kilometers

Figure 12

Top of St. Lawrence Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportTop_Ctc.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 97 - 100
- 101 - 110
- 111 - 120
- 121 - 130
- 131 - 140
- 141 - 150
- 151 - 160
- 161 - 170
- 171 - 180
- 181 - 190
- 191 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280
- 281 - 290

N

0 10 20
Miles

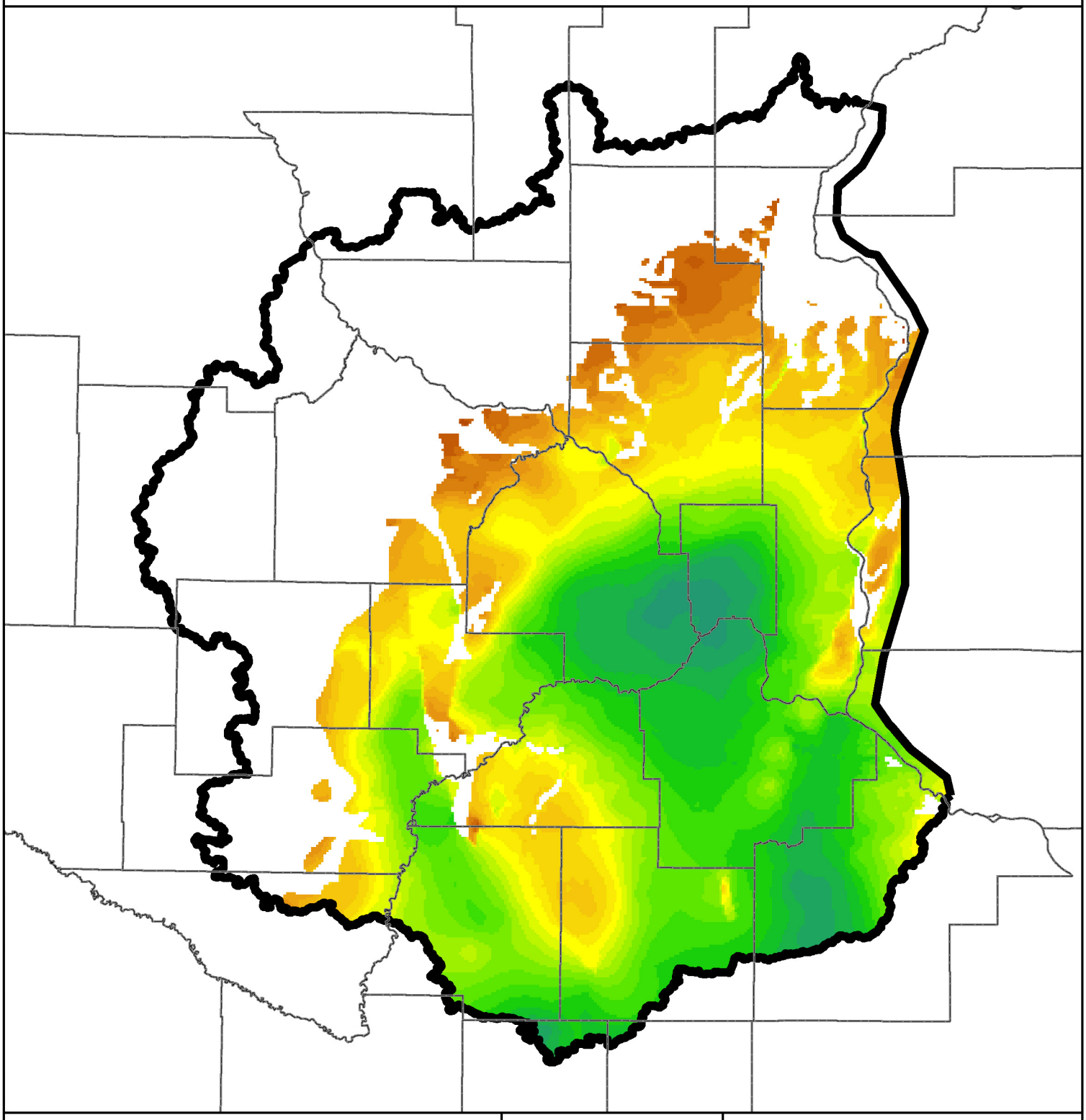
0 15 30
Kilometers

Figure 13

Top of Tunnel City Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportTop_Cw.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 53 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- 101 - 110
- 111 - 120
- 121 - 130
- 131 - 140
- 141 - 150
- 151 - 160
- 161 - 170
- 171 - 180
- 181 - 190
- 191 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280

N

0 10 20

Miles

0 15 30

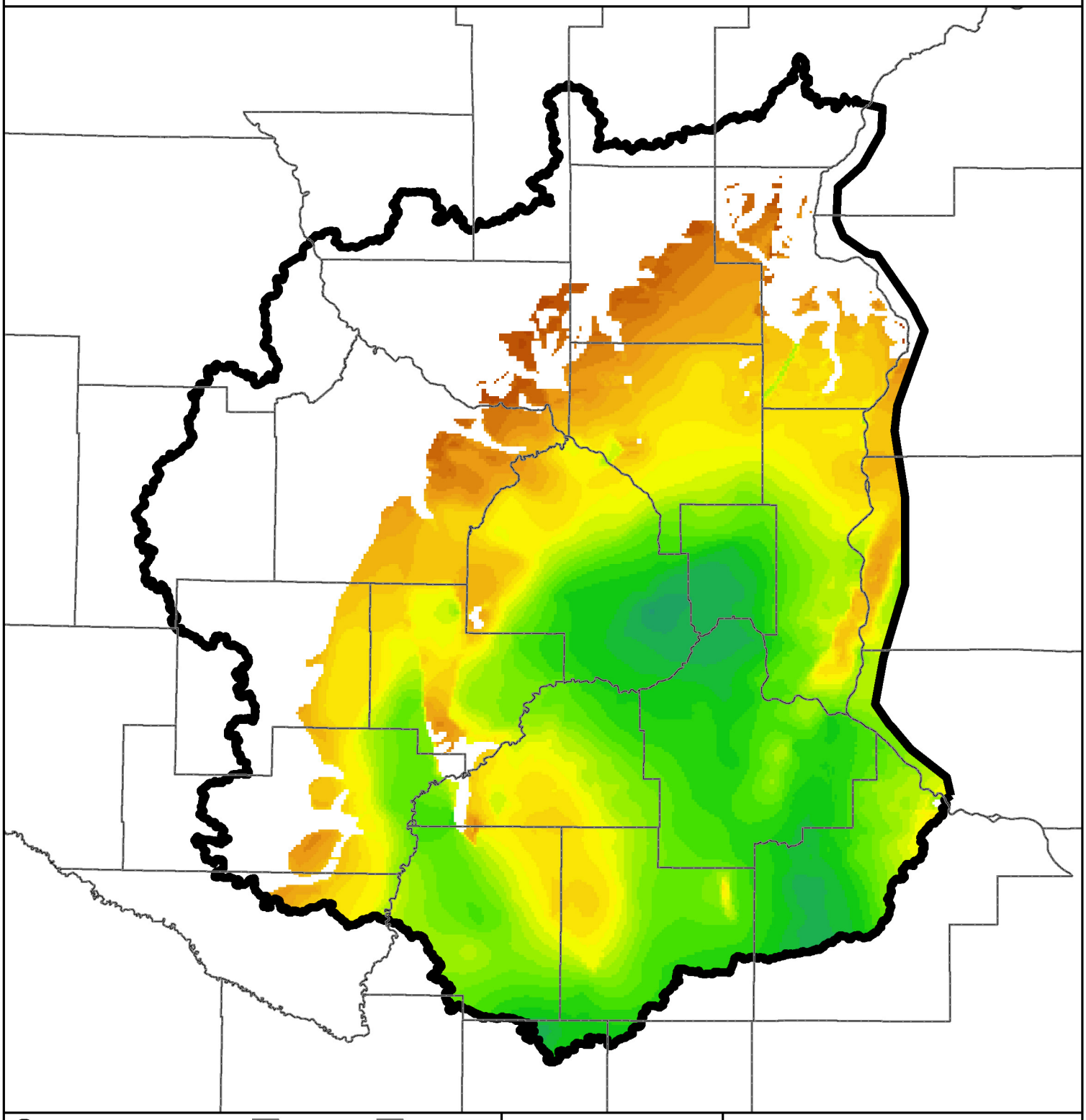
Kilometers

Figure 14

Top of Wonewoc Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportTop_Ce.mxd User: egc

Model Boundary

Elevation (meters above sea level)

- 28 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- 101 - 110
- 111 - 120
- 121 - 130
- 131 - 140
- 141 - 150
- 151 - 160
- 161 - 170
- 171 - 180
- 181 - 190
- 191 - 200
- 201 - 210
- 211 - 220
- 221 - 230
- 231 - 240
- 241 - 250
- 251 - 260
- 261 - 270
- 271 - 280

N

0 10 20

Miles

0 15 30

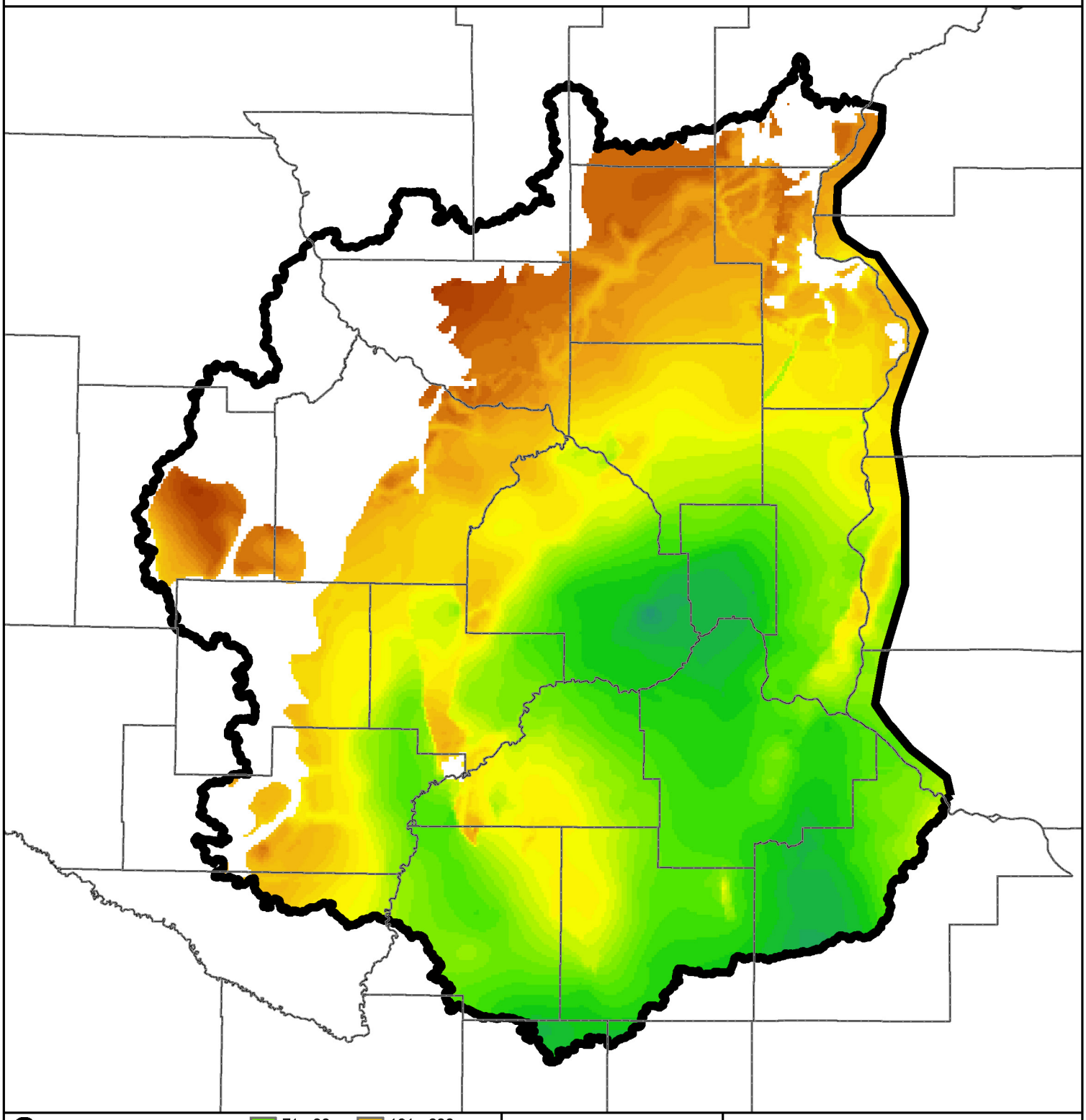
Kilometers

Figure 15

Top of Eau Claire Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Top_Cms.mxd User: egc

Model Boundary

Elevation (meters above sea level)

-18 - -10	71 - 80	191 - 200
-9 - 0	81 - 90	201 - 210
1 - 10	91 - 100	211 - 220
11 - 20	101 - 110	221 - 230
21 - 30	111 - 120	231 - 240
31 - 40	121 - 130	241 - 250
41 - 50	131 - 140	251 - 260
51 - 60	141 - 150	261 - 270
61 - 70	151 - 160	271 - 280
	161 - 170	281 - 290
	171 - 180	291 - 300
	181 - 190	

N

0 10 20

Miles

0 15 30

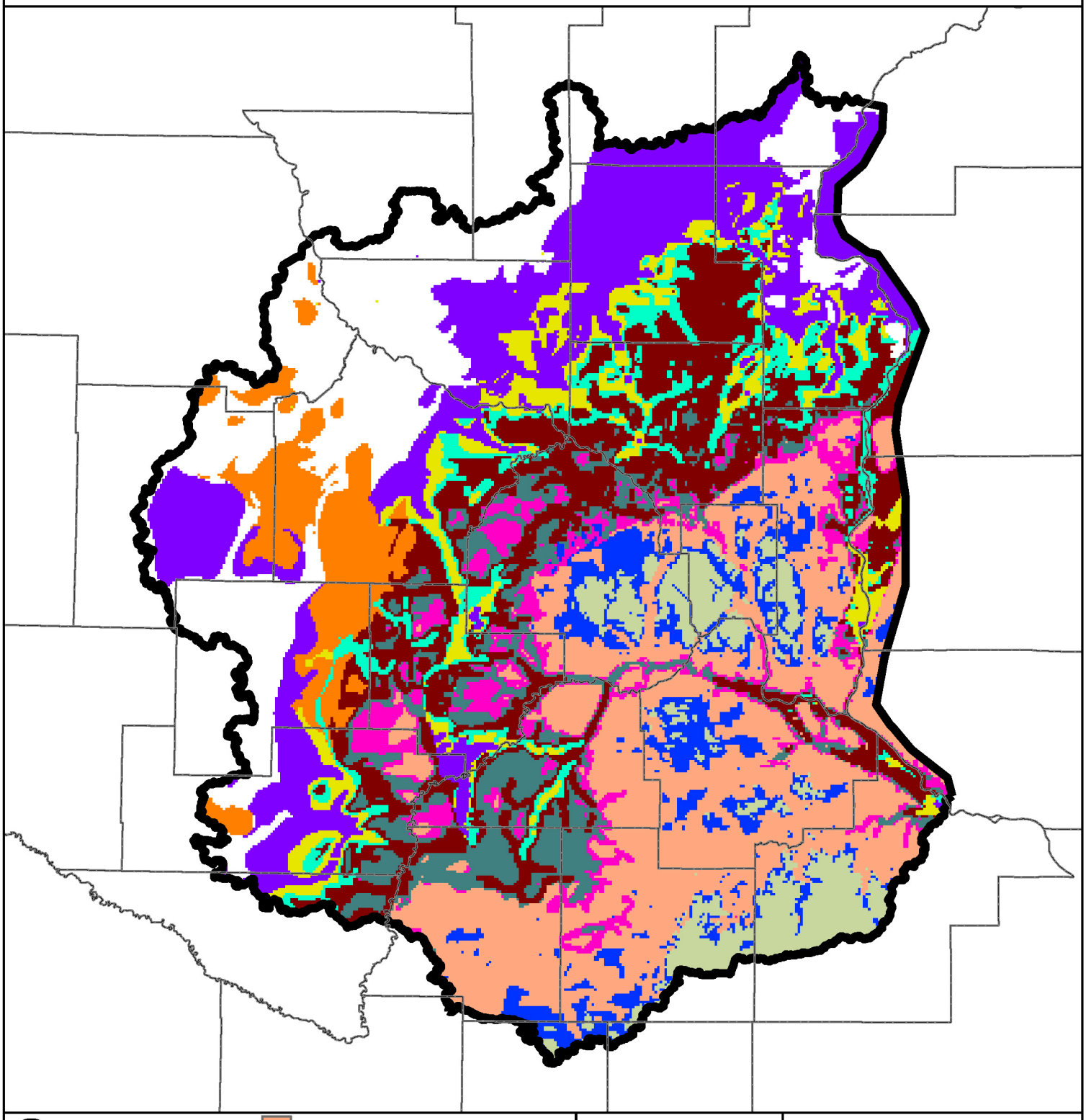
Kilometers

Figure 16

Top of Mt Simon Formation and Hinckley Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



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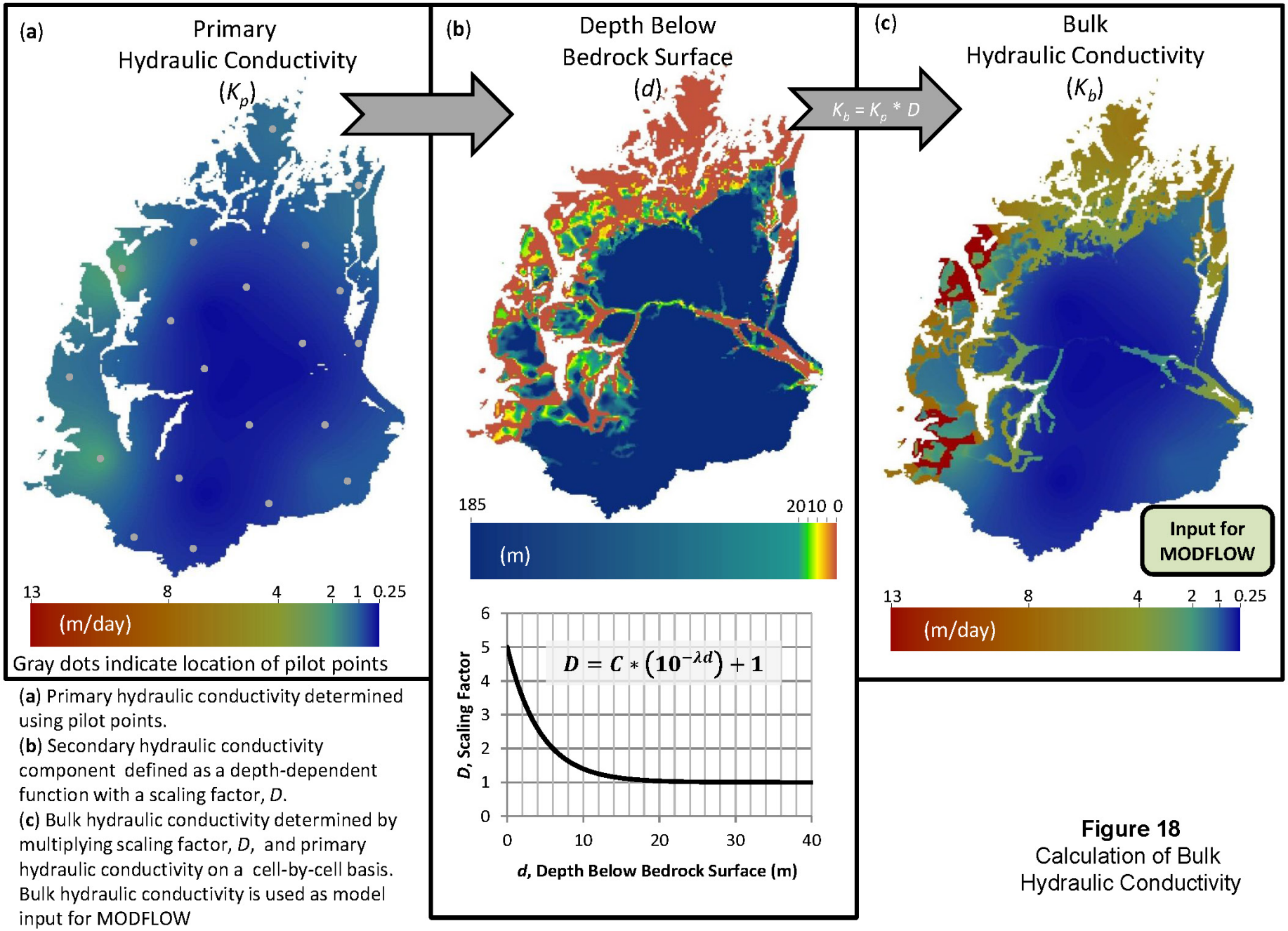
- Model Boundary
- Cretaceous and/or unnamed Paleozoic or Lower Mesozoic
- Galena Group, Decorah Shale, Platteville Fm. and Glenwood Fm.
- St. Peter Sandstone
- Prairie du Chien Group
- Jordan Sandstone
- St. Lawrence Fm.
- Tunnel City Group
- Wonewoc Sandstone
- Eau Claire Fm.
- Mt. Simon Fm. and Hinckley Fm.

N

0 10 20
Miles

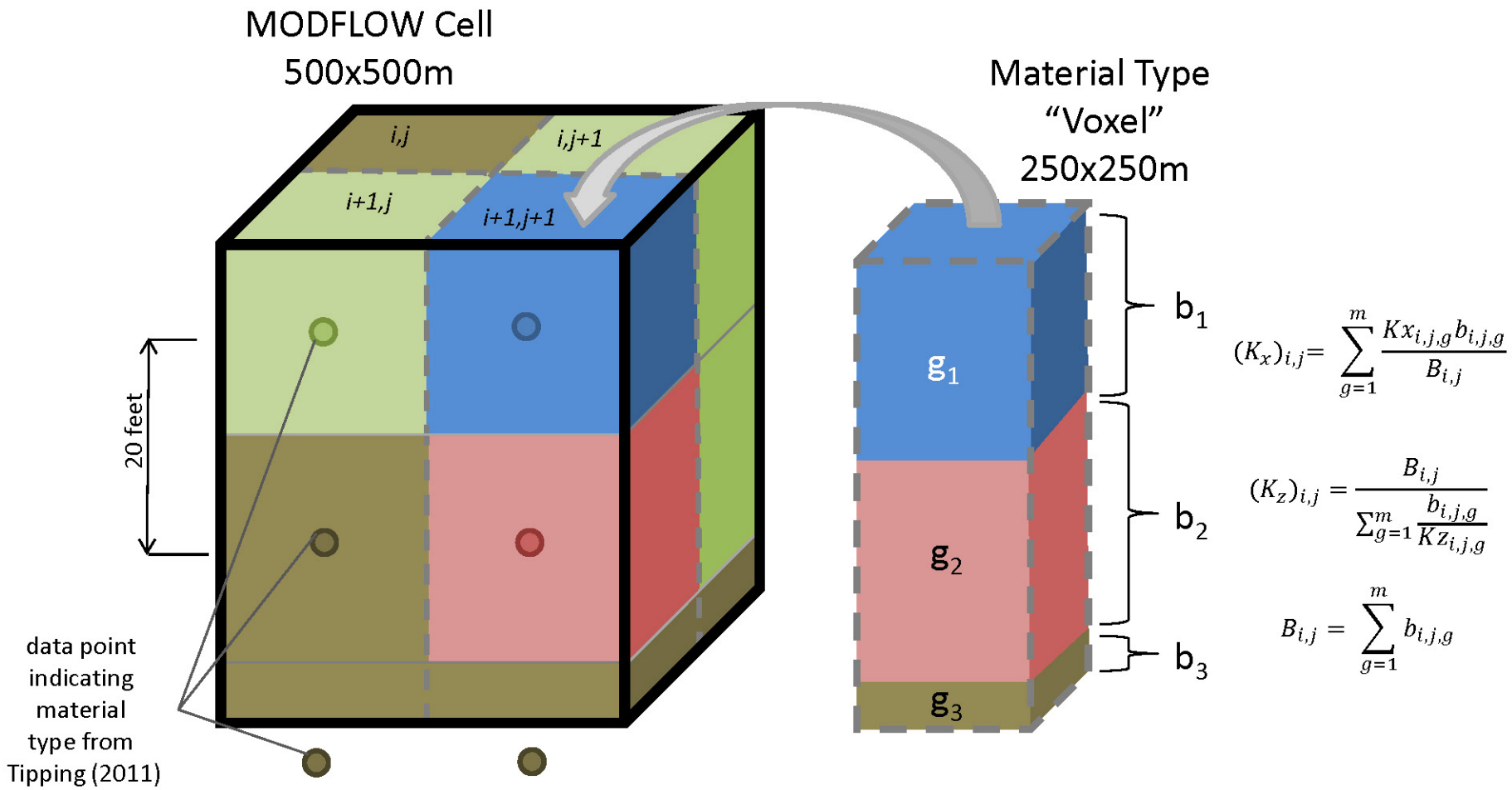
0 15 30
Kilometers

Figure 17
Bedrock Geology



(**a**) Primary hydraulic conductivity determined using pilot points.
(**b**) Secondary hydraulic conductivity component defined as a depth-dependent function with a scaling factor, *D*.
(**c**) Bulk hydraulic conductivity determined by multiplying scaling factor, *D*, and primary hydraulic conductivity on a cell-by-cell basis. Bulk hydraulic conductivity is used as model input for MODFLOW

Figure 18
Calculation of Bulk Hydraulic Conductivity

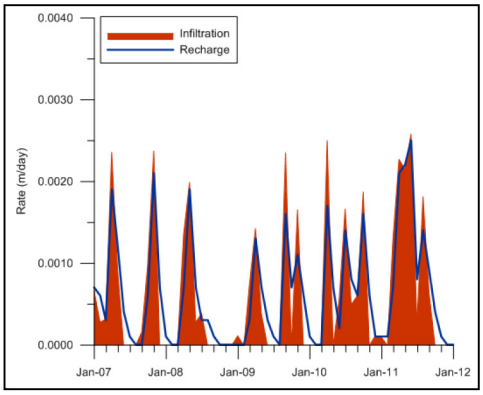


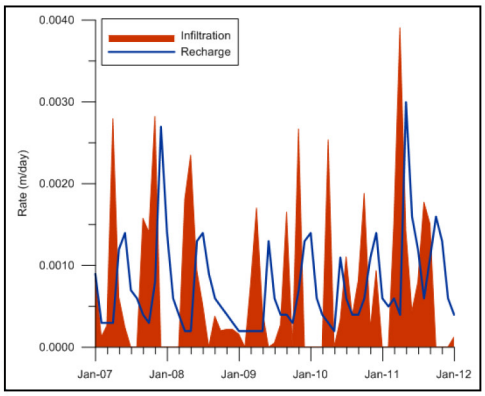
$$Kx = \frac{(Kx)_{i,j} + (Kx)_{i,j+1} + (Kx)_{i+1,j} + (Kx)_{i+1,j+1}}{4}$$

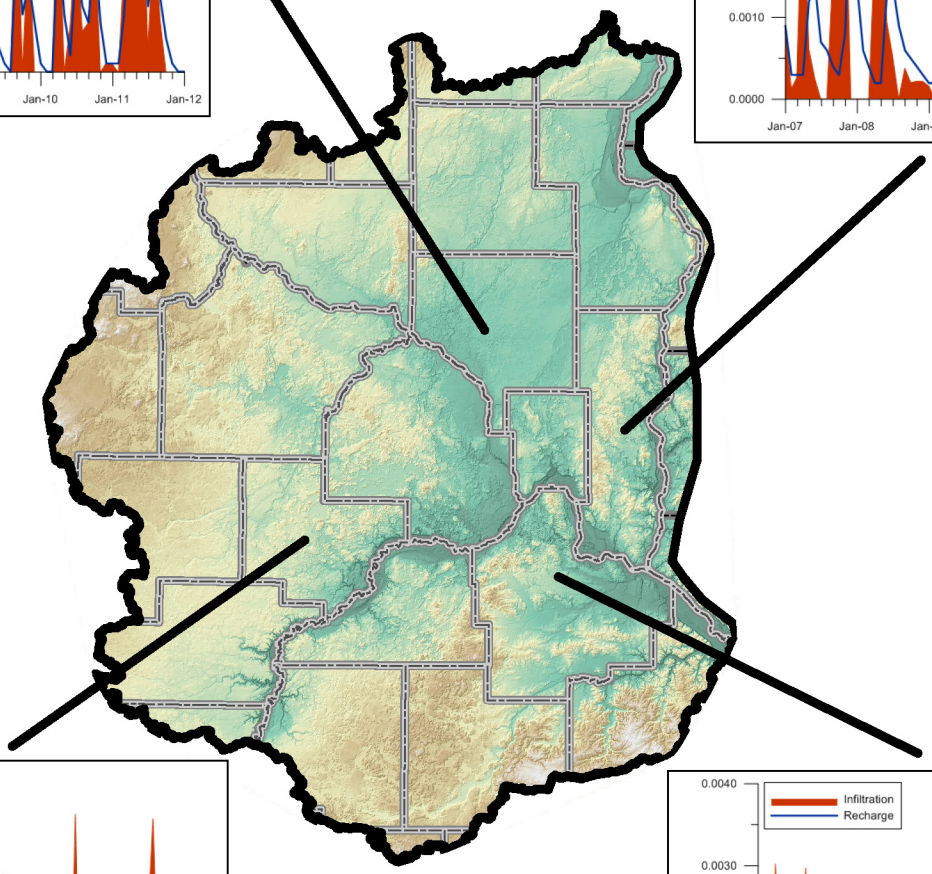
$$Kz = \frac{(Kz)_{i,j} + (Kz)_{i,j+1} + (Kz)_{i+1,j} + (Kz)_{i+1,j+1}}{4}$$

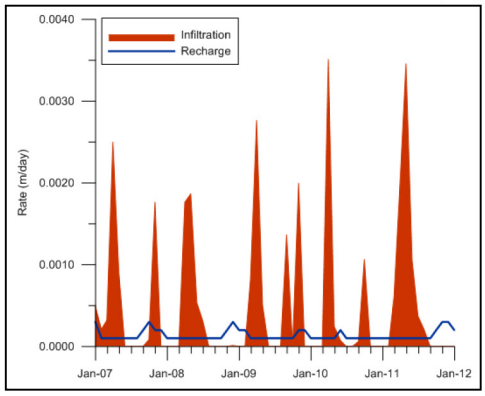
Figure 19
Calculation of Effective Hydraulic Conductivity

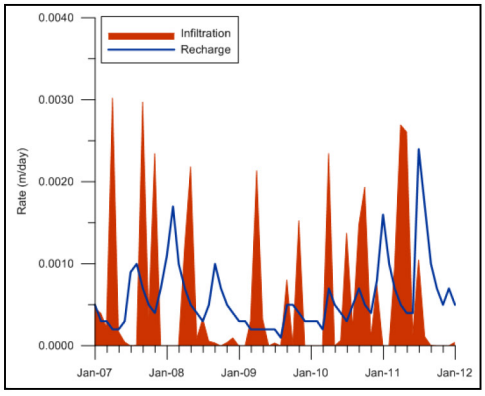
METROPOLITAN COUNCIL











Model Boundary

N

0 10 20
Miles

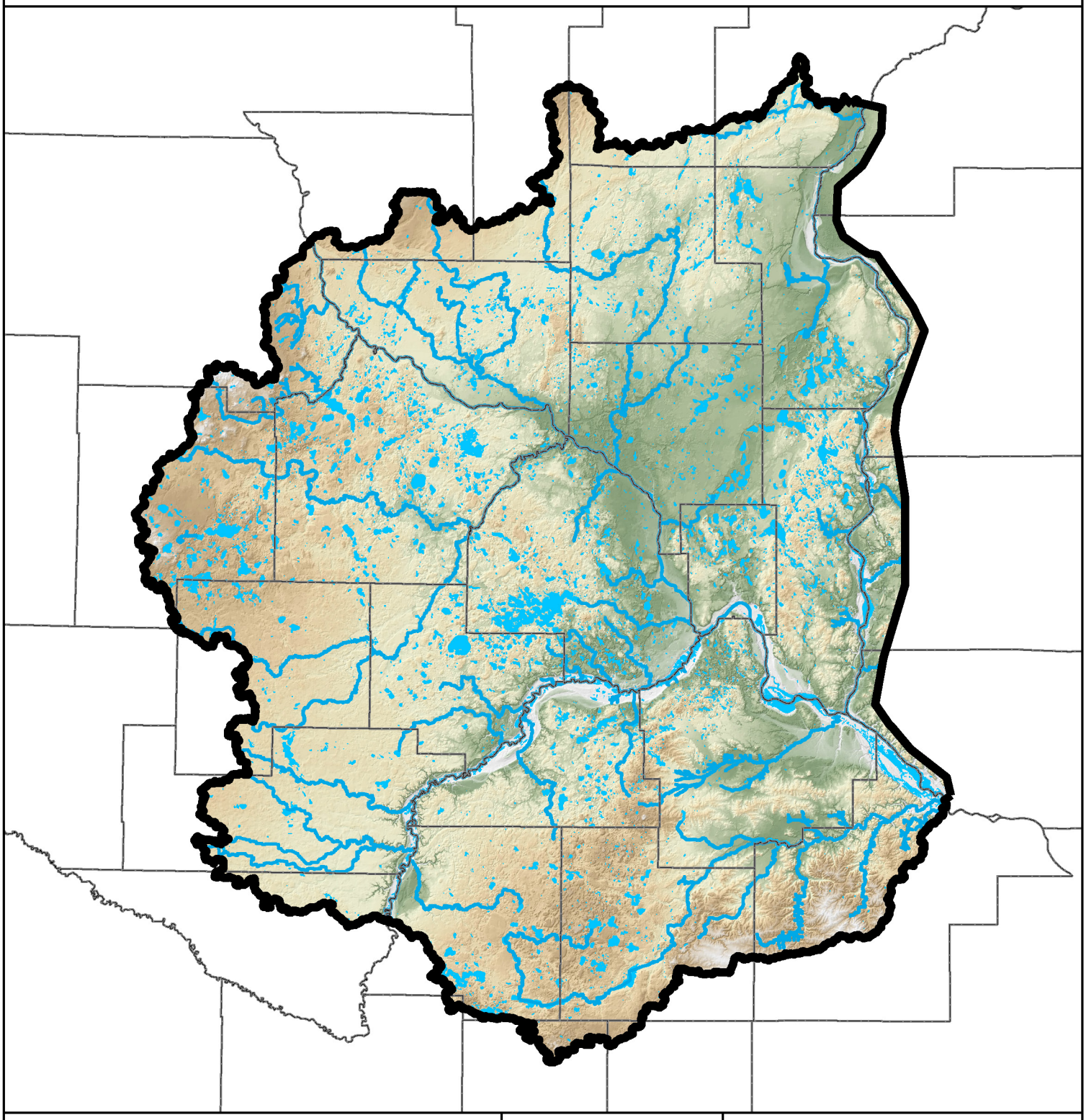
0 15 30
Kilometers

Figure 20

Comparison of
Recharge and Infiltration

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



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Model Boundary

Rivers

Lakes

N

0 10 20

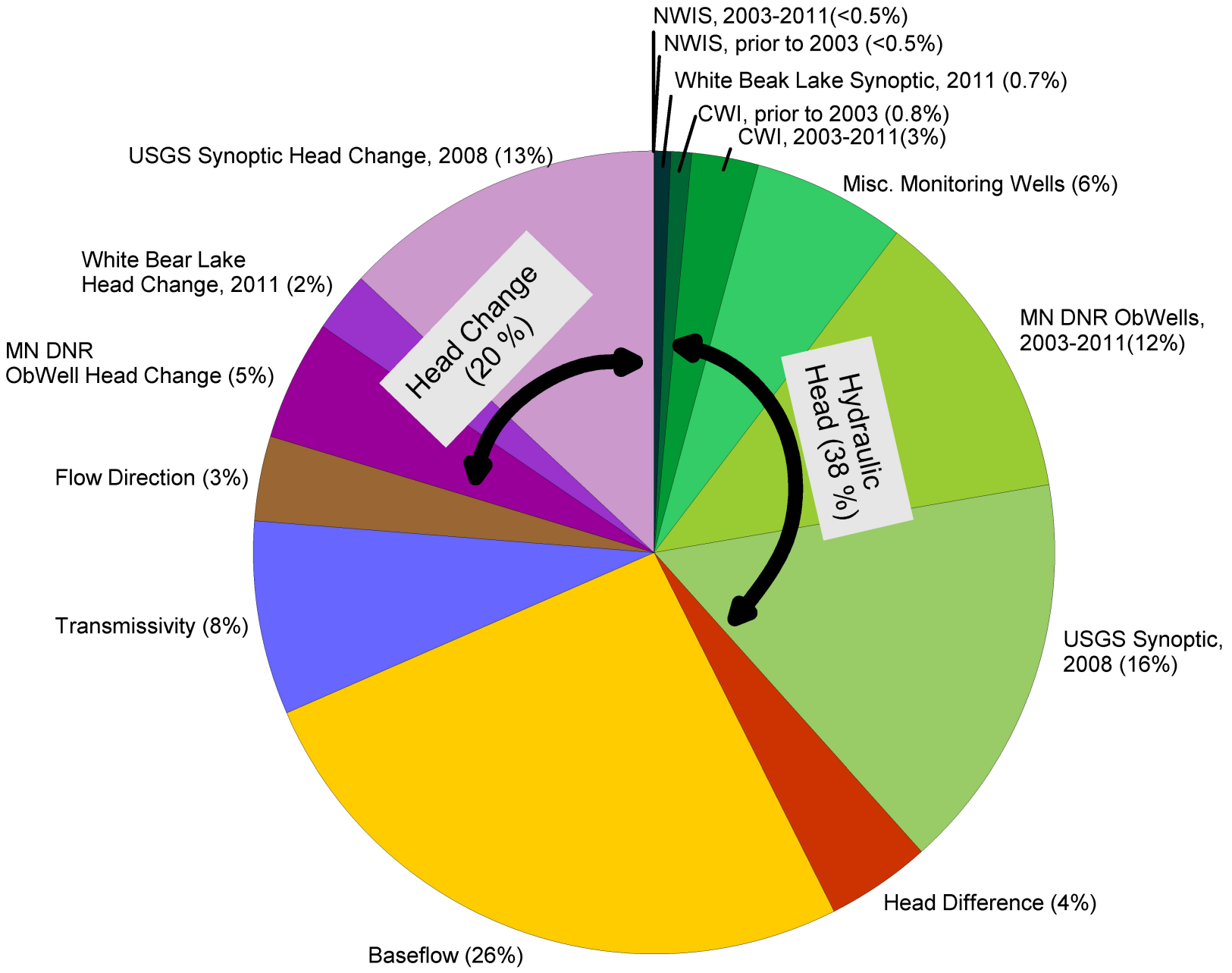
Miles

0 15 30

Kilometers

Figure 21

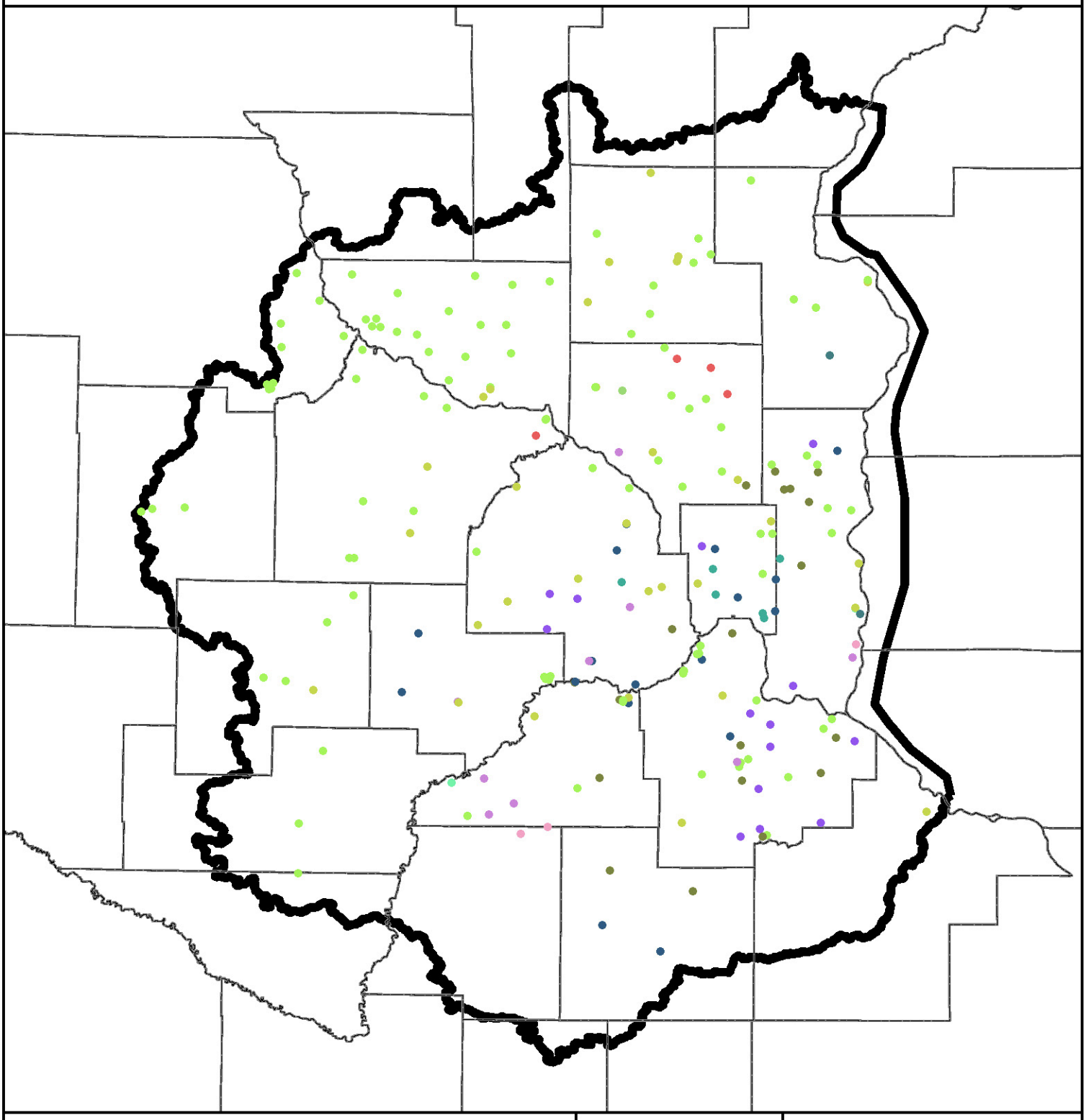
Surface Water Features Included in Simulation



Percentages represent contribution to total objective function

Figure 22
Initial Objective Function Distribution

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\2362\1087\Maps\Report\Head_Targets_DNR_ObWells.mxd User: egc

Hydrostratigraphic Unit(s)

- Qu
- Os
- Op
- Op-Cj
- Cj
- Csl
- Csl-Ctc
- Ctc
- Ctc-Cw
- Cw
- Ce
- Ce-Cms
- Cms

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

N

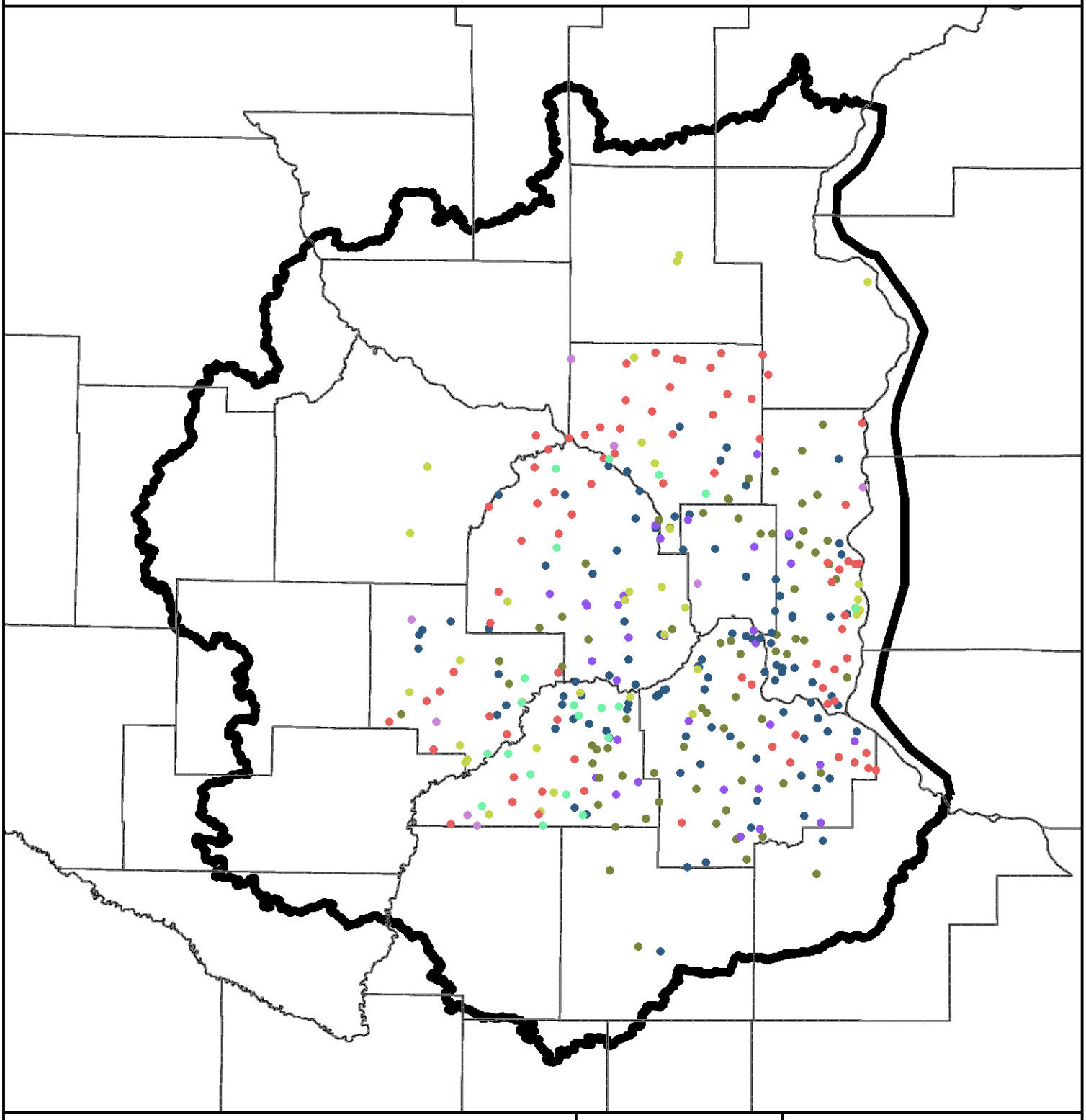
0 10 20
Miles

0 15 30
Kilometers

Figure 23

Spatial Distribution of Hydraulic Head Targets MN DNR ObWells

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Head_Targets_USGS_2008_Synoptic.mxd User: egc

Hydrostratigraphic Unit(s)

- Op
- Cj
- Ctc-Cw
- Cms
- Op-Cj
- Ctc
- Cw

N

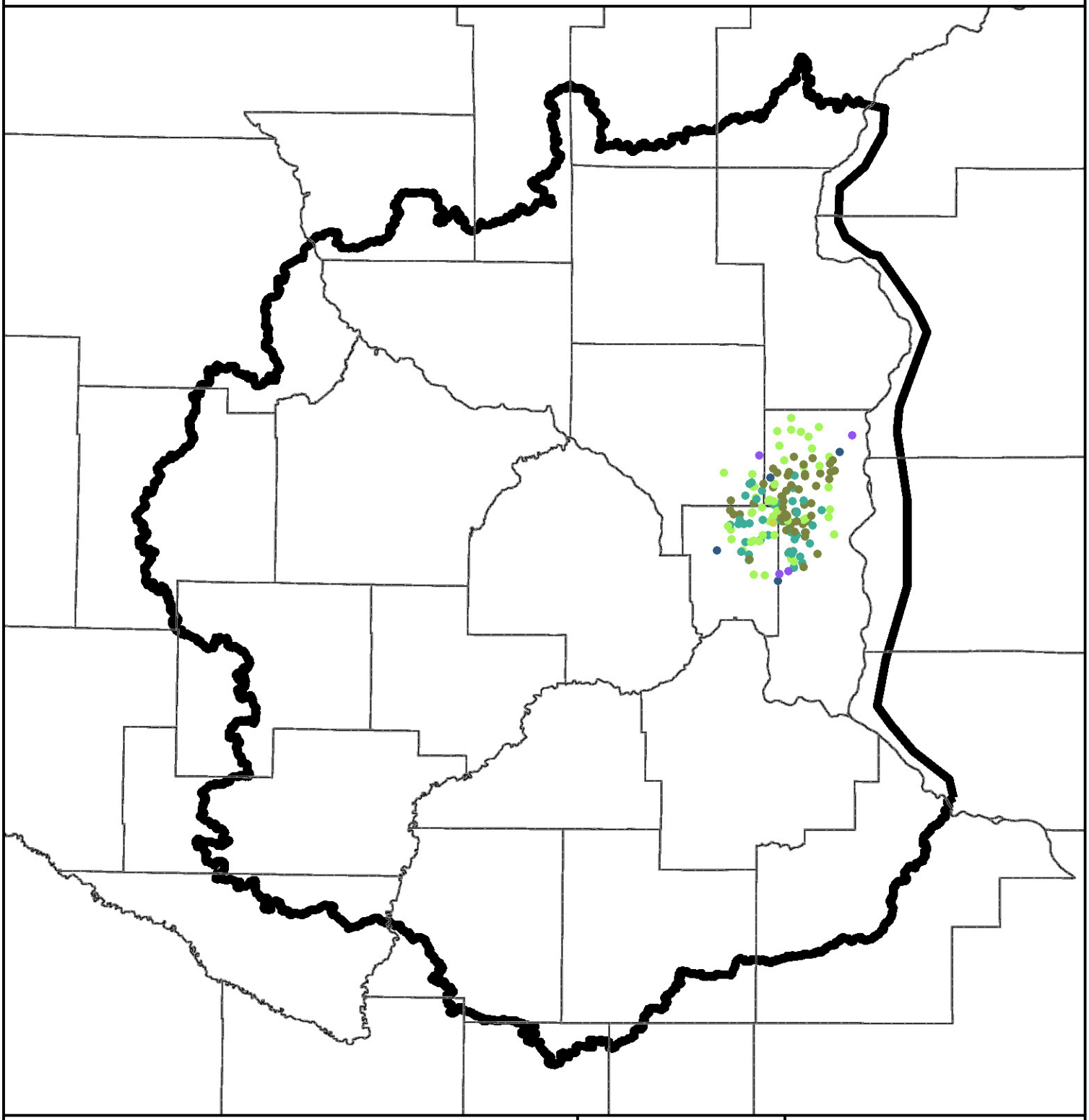
0 10 20
Miles

0 15 30
Kilometers

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

Figure 24
Spatial Distribution of Hydraulic Head Target USGS Synoptic Water Levels 2008

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer File: I:\Projects\23\62\1087\Maps\Report\Head_Targets_WB_Synoptic.mxd User: egc

Hydrostratigraphic Unit(s)

- Qu
- Os-Op
- Op-Cj
- Ctc
- Os
- Op
- Cj
- Cms

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

N

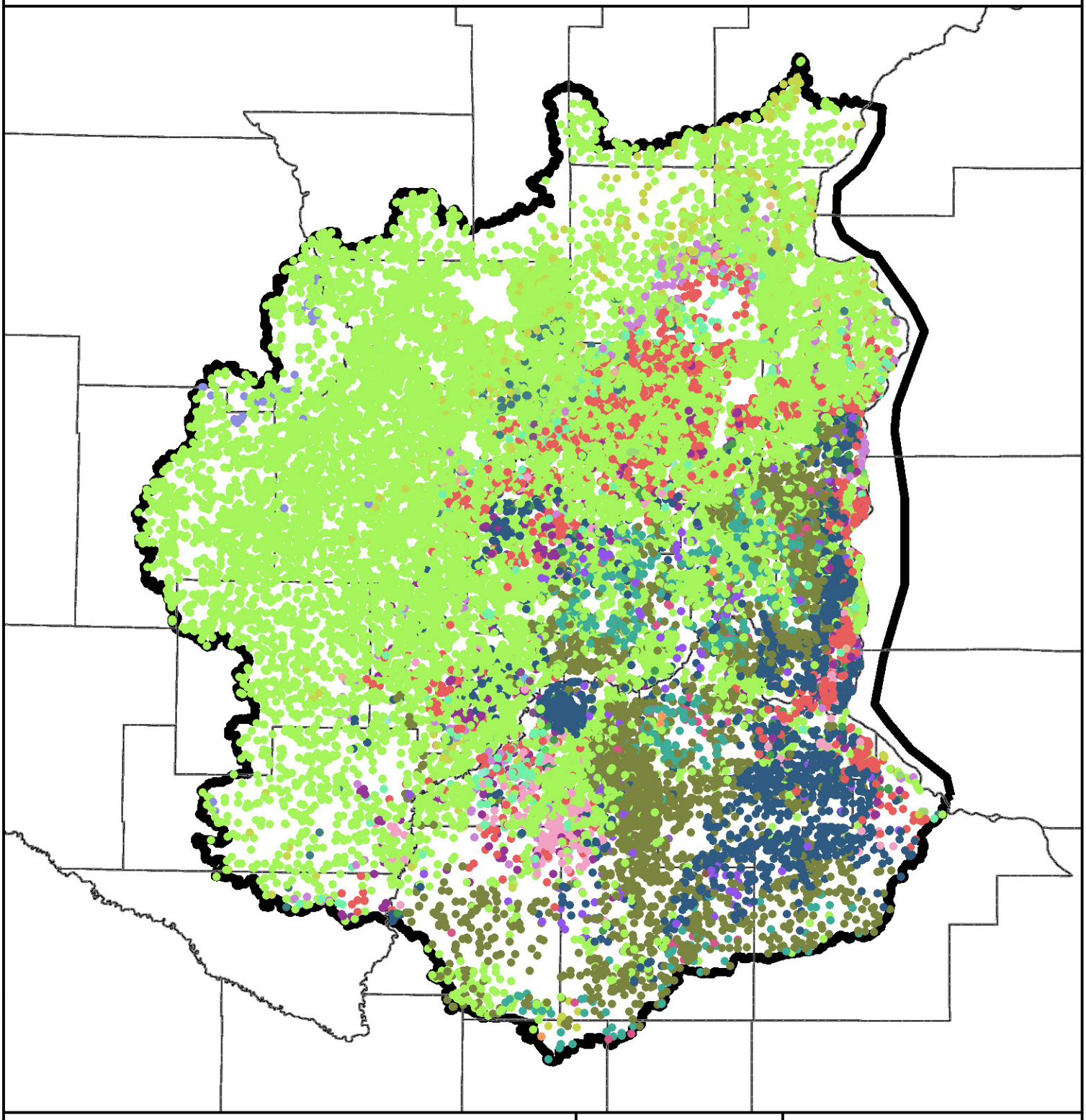
0 10 20
Miles

0 15 30
Kilometers

Figure 25
Spatial Distribution of Hydraulic Head Target White Bear Lake Synoptic Water Levels

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer File: I:\Projects\2362\1087\Maps\Report\Head_Targets_CWI_prior_2003.mxd User: egc

Hydrostratigraphic Unit(s)

Ku	Op	Cj	Ctc	Cw-Ce
Qu	Op-Cj	Cj-Csl	Ctc-Cw	Cw-Cms
Qu-Os	Op-Ctc	Cj-Cw	Ctc-Ce	Ce
Os	Op-Cw	Csl	Ctc-Cms	Ce-Cms
Os-Op	Op-Cms	Csl-Ctc	Cw	Cms

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

N

0 10 20
Miles

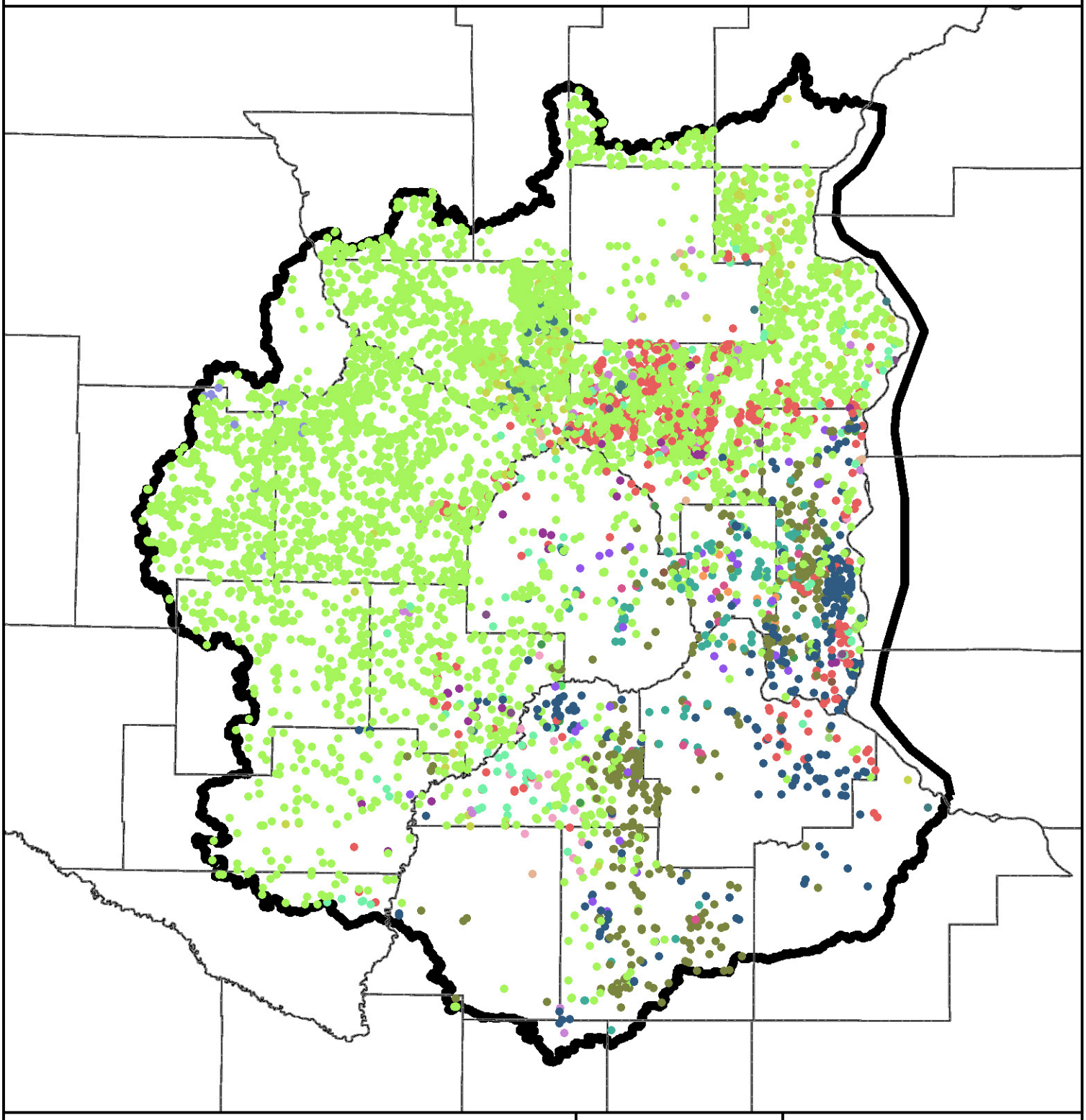
0 15 30
Kilometers

Figure 26

Spatial Distribution of Hydraulic Head Targets CWI Static Water Levels Prior to 2003

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer File: I:\Projects\23\62\1087\Maps\Report\Head_Targets_CWI_post_2003.mxd User: egc

Hydrostratigraphic Unit(s)

Ku	Op	Cj	Ctc	Cw-Ce
Qu	Op-Cj	Cj-Csl	Ctc-Cw	Cw-Cms
Qu-Os	Op-Ctc	Cj-Cw	Ctc-Ce	Ce
Os	Op-Cw	Csl	Ctc-Cms	Ce-Cms
Os-Op	Op-Cms	Csl-Ctc	Cw	Cms

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

N

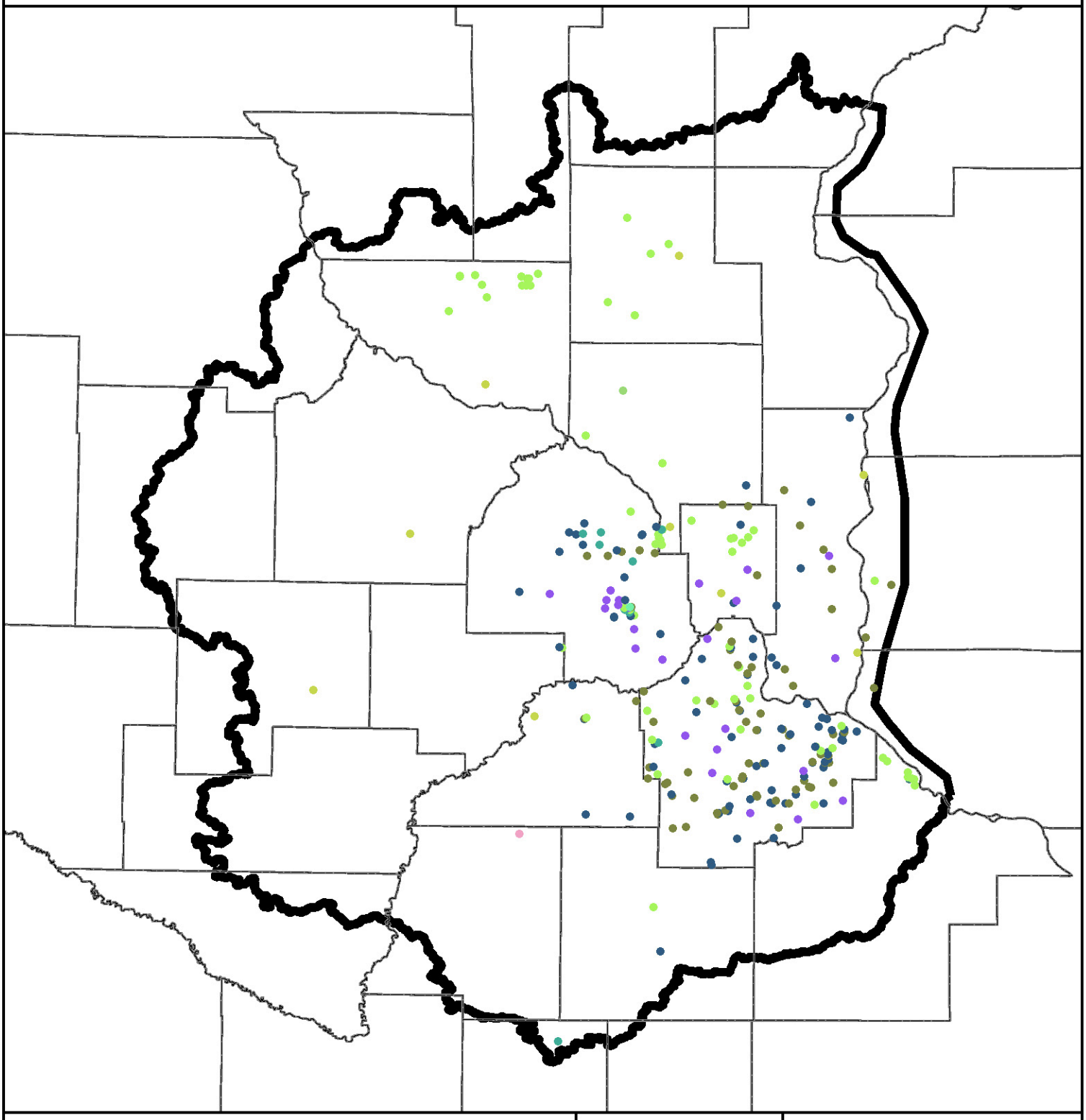
0 10 20
Miles

0 15 30
Kilometers

Figure 27

Spatial Distribution of Hydraulic Head Targets CWI Static Water Levels 2003-2011

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Head_Targets_NWIS_prior_2003.mxd User: egc

Hydrostratigraphic Unit(s)

- Qu
- Op-Cj
- Ctc-Cw
- Ce-Cms
- Os
- Cj
- Cw
- Cms
- Op
- Csl
- Ce

N

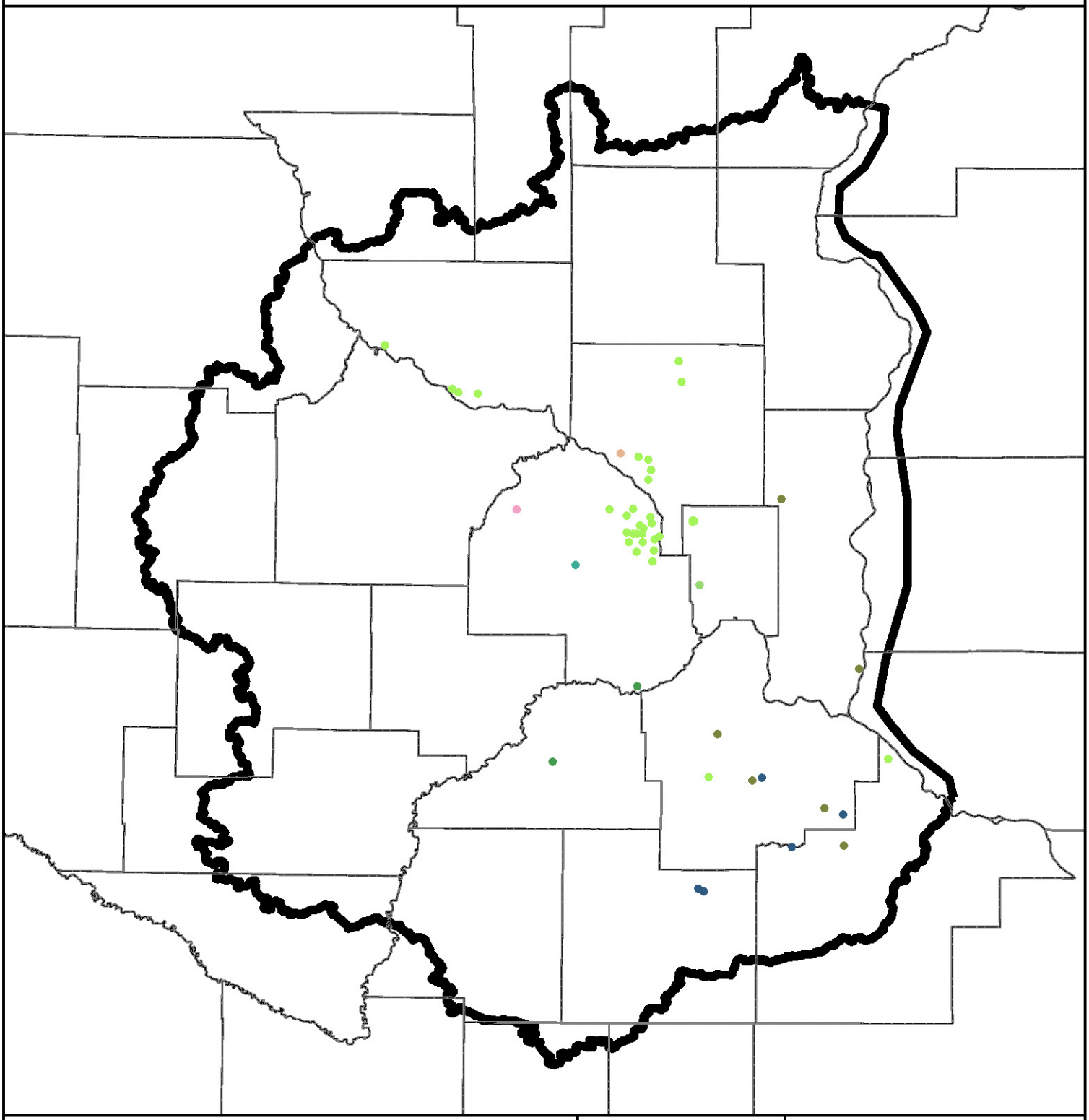
0 10 20
Miles

0 15 30
Kilometers

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

Figure 28

Spatial Distribution of Hydraulic Head Targets NWIS prior to 2003



Hydrostratigraphic Unit(s)

- Qu
- Os
- Op
- Cj
- Cj-Csl
- Csl
- Cw-Ce
- Ce

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

N

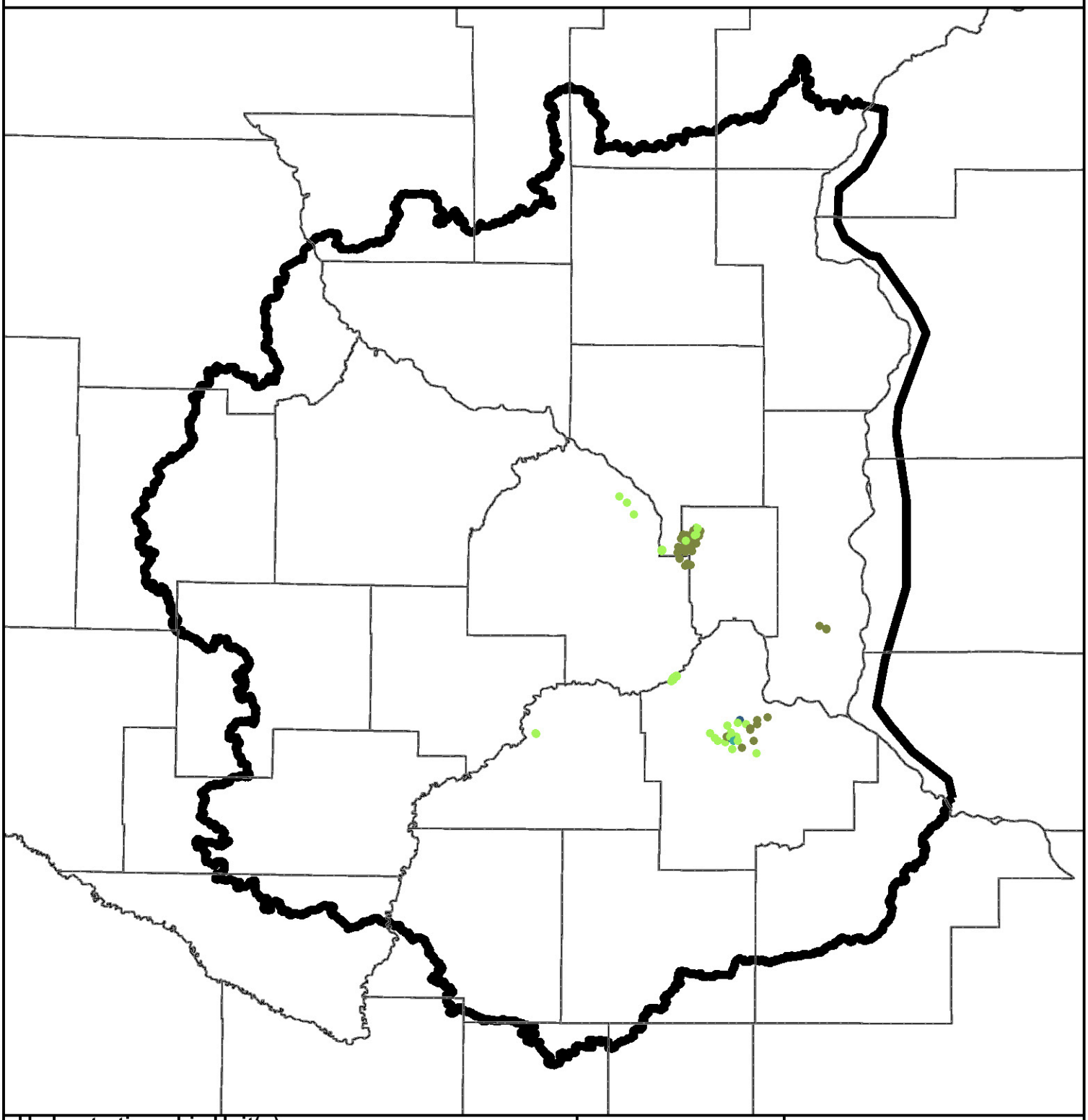
0 10 20
Miles

0 15 30
Kilometers

Figure 29

Spatial Distribution of Hydraulic Head Targets NWIS 2003-2011

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\2362\1087\Maps\Report\Head_Targets_Misc_MW.mxd User: egc

Hydrostratigraphic Unit(s)

- Qu
- Op
- Ctc-Cw
- Os
- Cj

N

0 10 20
Miles

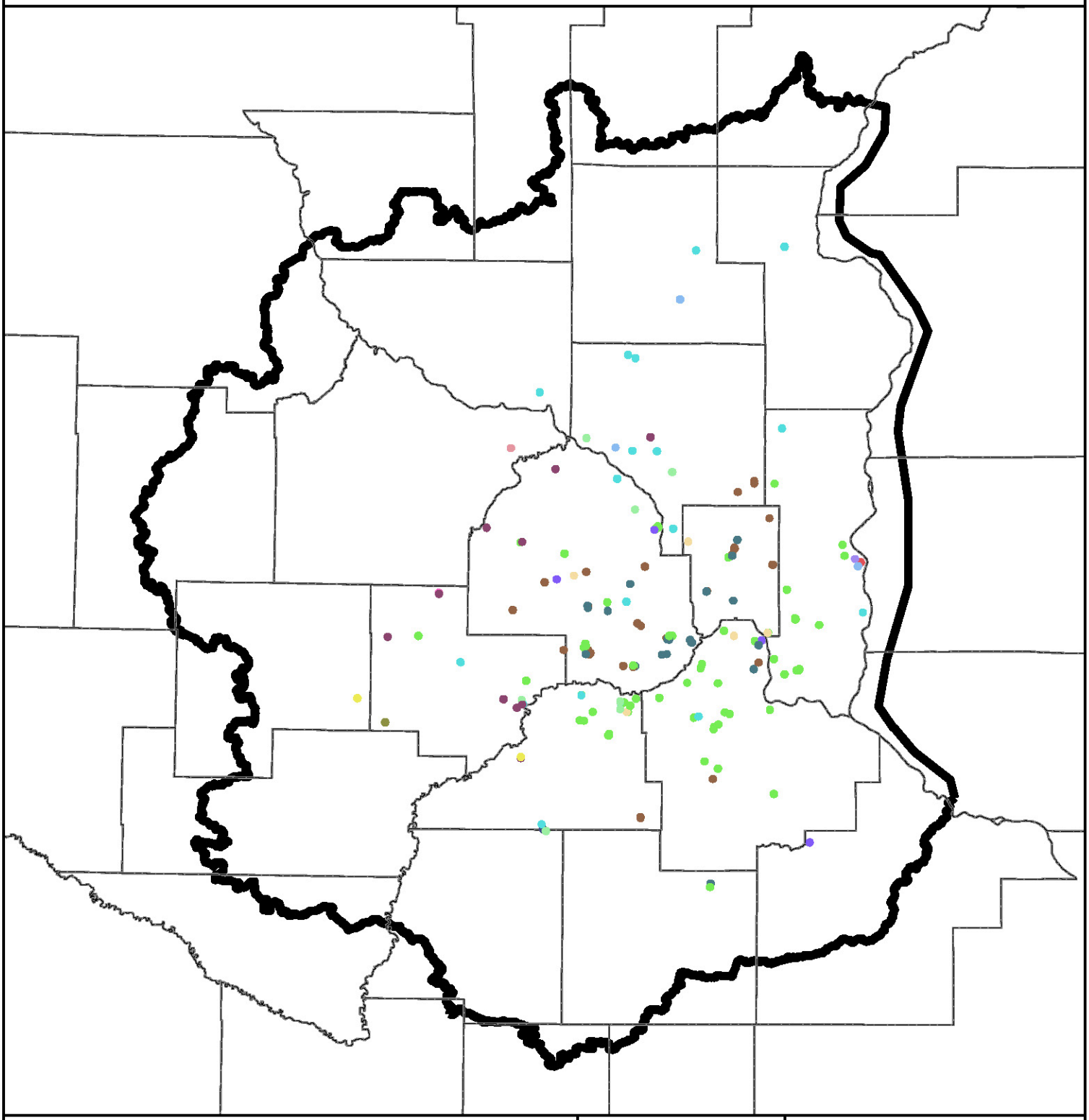
0 15 30
Kilometers

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

Figure 30

Spatial Distribution of Hydraulic Head Targets MPCA EDA database and Misc. Monitoring Wells

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\2362\1087\Maps\Report\Transmissivity_Targets.mxd User: egc

Aquifer

- Op
- Op-Cj
- Op-Csl
- Cj
- Cj-Csl
- Csl-Ctc
- Csl-Ce
- Csl-Cms
- Ctc
- Ctc-Cw
- Ctc-Ce
- Ctc-Cms
- Cw-Ce
- Cw-Cms
- Ce-Cms
- Cms

Note: see abbreviations and acronyms section in main report for key to hydrostratigraphic units

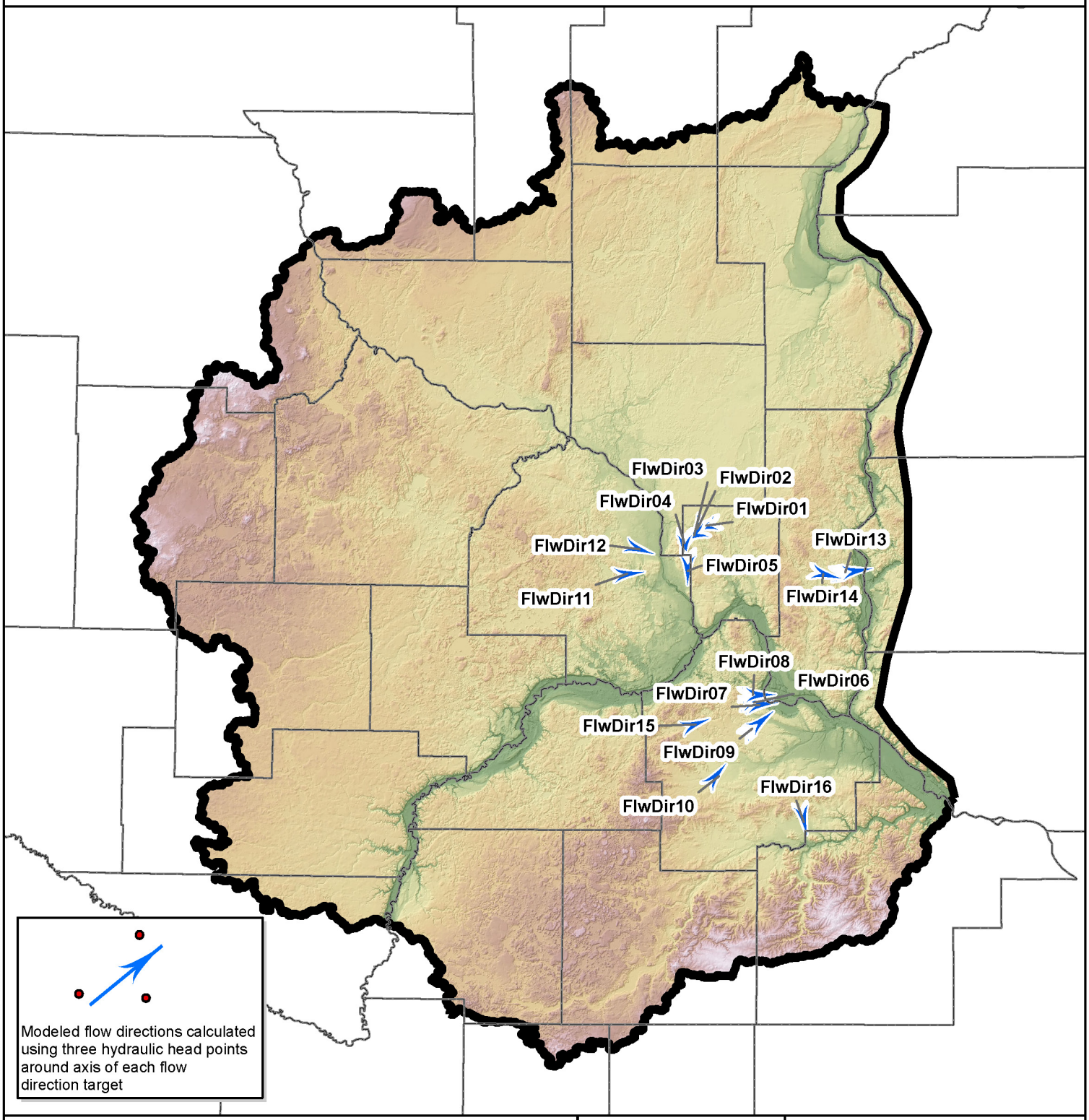
N

0 10 20
Miles

0 15 30
Kilometers

Figure 31
Transmissivity Targets

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Flow_Direction_Targets.mxd User: egc

Model Boundary

Flow Direction Targets

N

0 10 20

Miles

0 15 30

Kilometers

Figure 32

Flow Direction Targets

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

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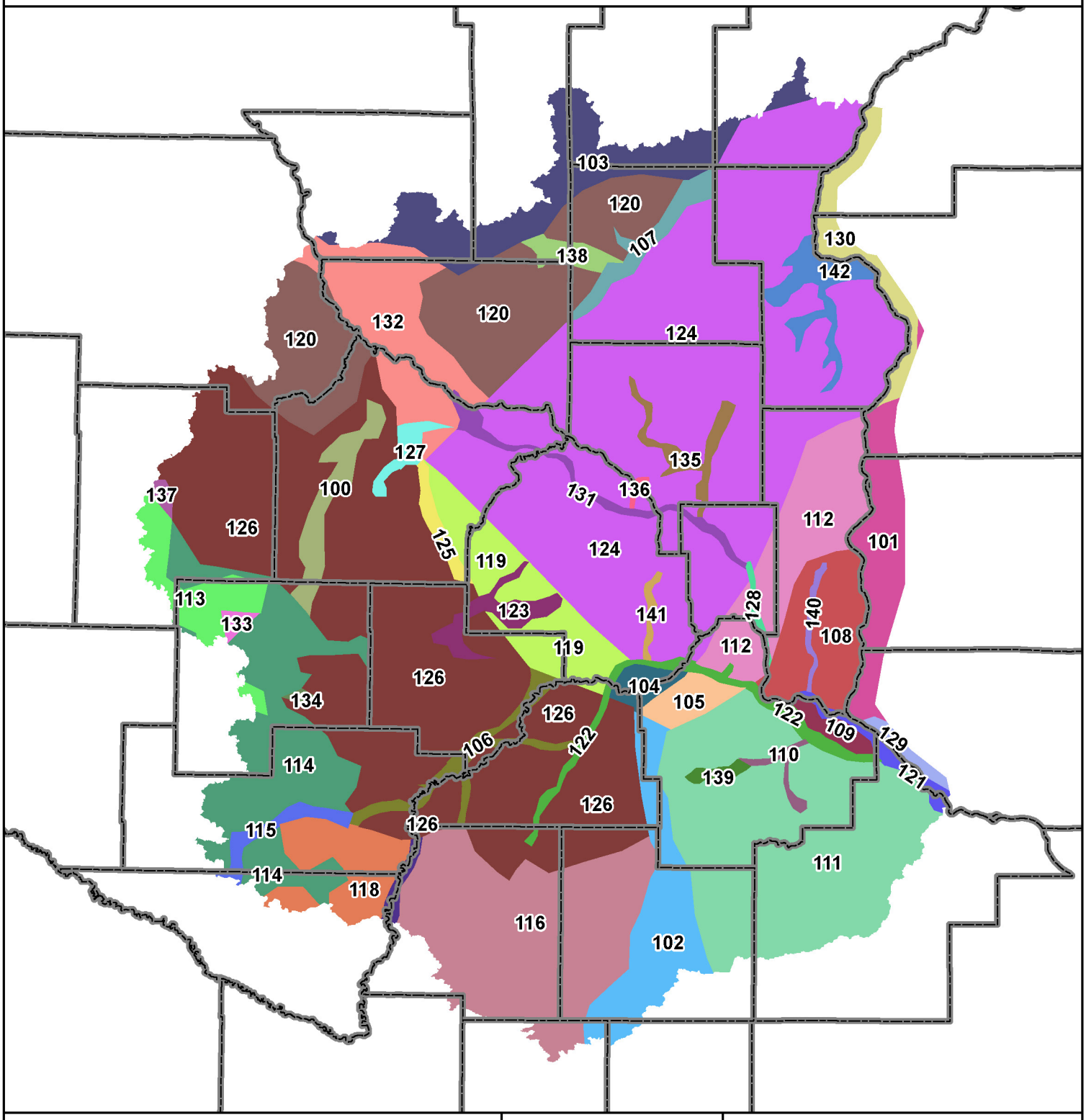


Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Unknown_Quat_Zones.mxd User: egc

County Boundaries

N

0 10 20

Miles

0 15 30

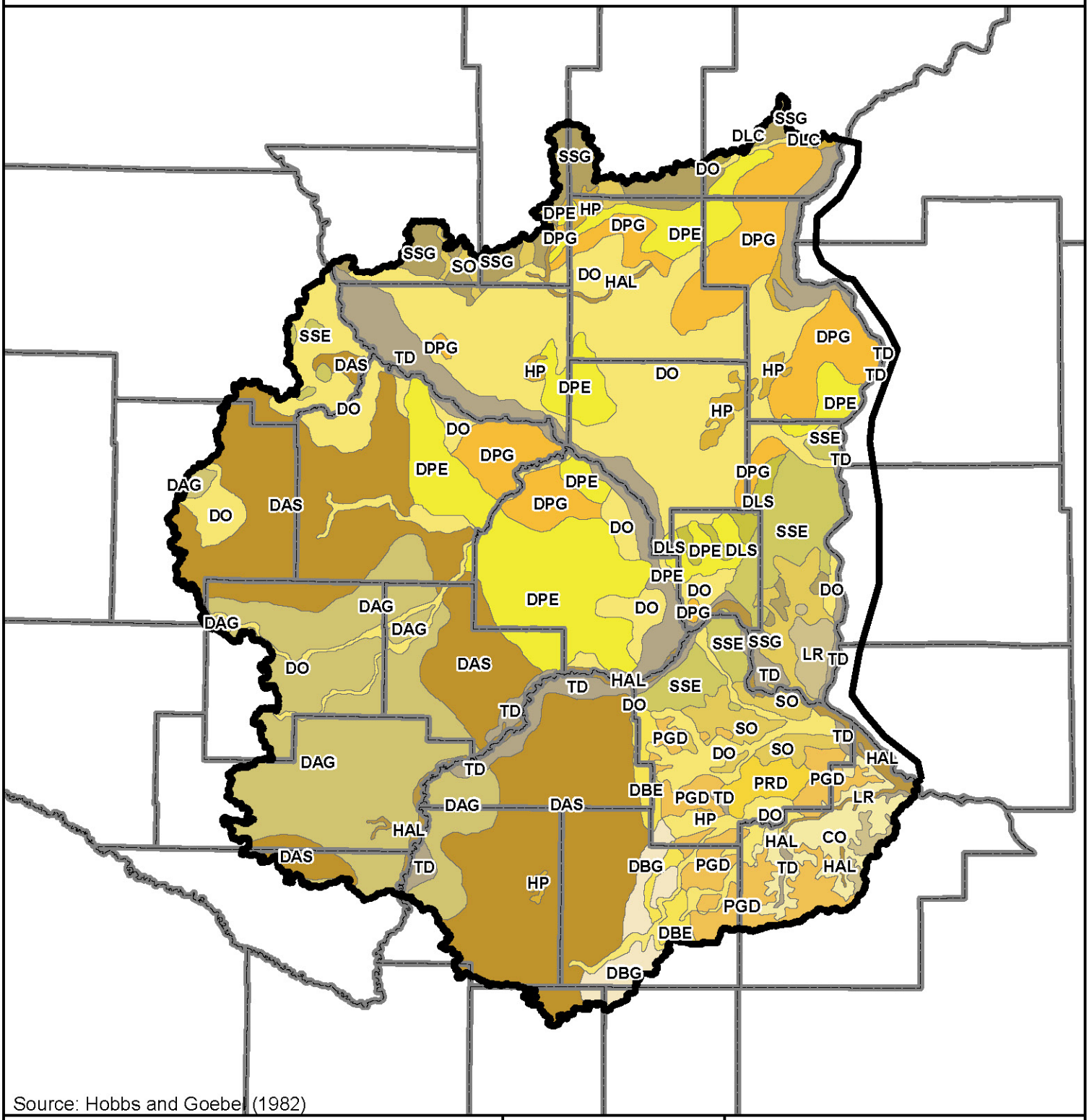
Kilometers

Note: Numbers indicate zone identification number

Figure 33

Unknown Quaternary Sediment Zones

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Source: Hobbs and Goebel (1982)

Bar Footer: File: I:\Projects\23\62\1087\Maps\Report\Surf_Geo_For_Lake_Zones.mxd User: egc

Quaternary Geology

CO	COLLUVIUM	DPG	GROUND MORAINE
DAG	GROUND MORAINE	HAL	ALLUVIUM
DAS	STAGNATION MORAINE	HP	PEAT
DBE	END MORAINE	LR	WEATHERING RESIDUUM
DBG	GROUND MORAINE	PGD	GRAY DRIFT
DLC	CLAY & CLAYEY SILT	PRD	RED DRIFT
DLS	SILT & FINE SAND	SO	OUTWASH
DO	OUTWASH	SSE	END MORAINE
DPE	END MORAINE	SSG	GROUND MORAINE
		TD	TERRACES

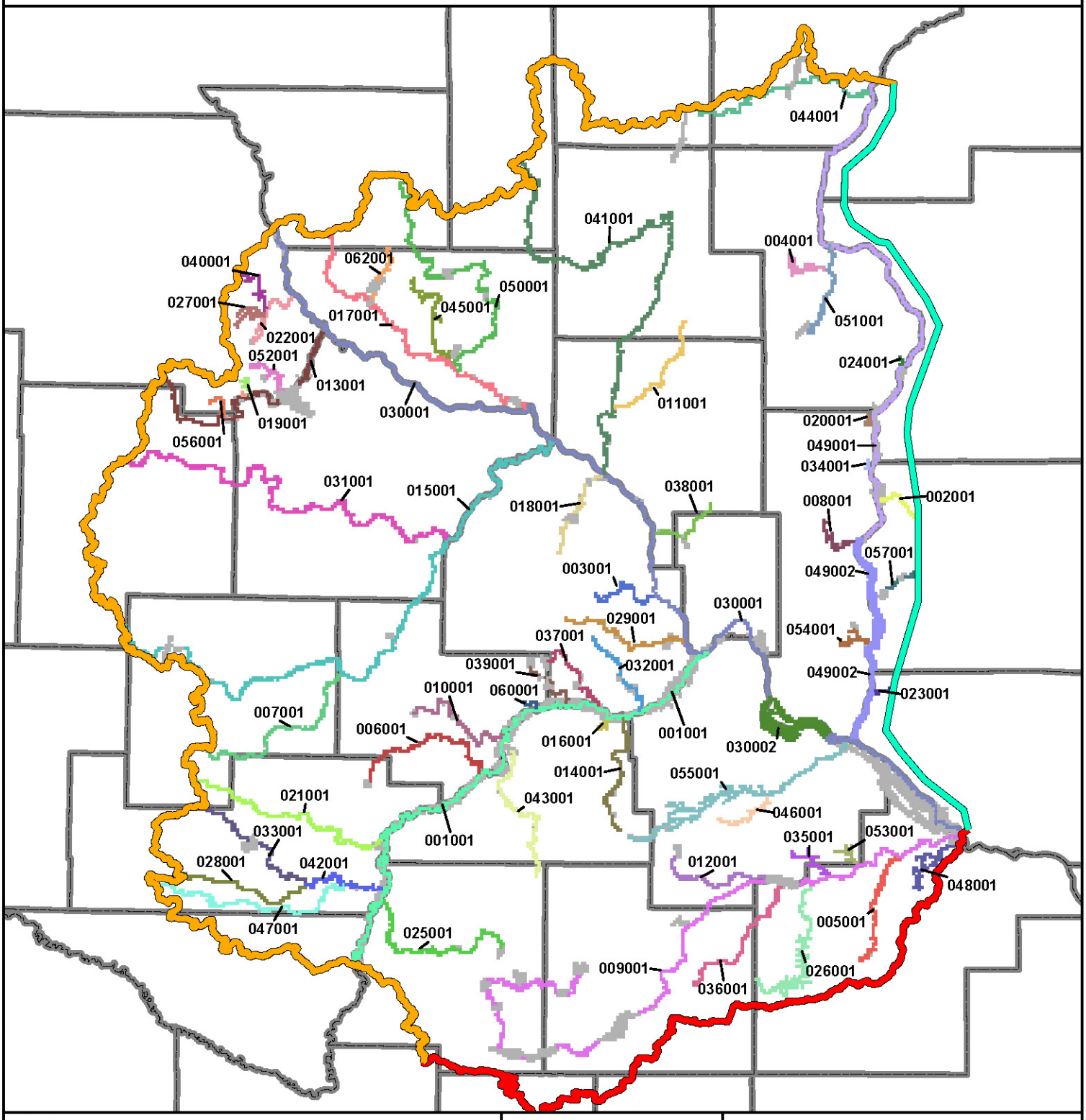
N

0 10 20
Miles

0 15 30
Kilometers

Figure 34
Quaternary Geology Used for Defining Lake Conductance Zones

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



County Boundaries

0 10 20
Miles

0 15 30
Kilometers

Note: Riverine lakes shaded gray and conductance based on surficial geology

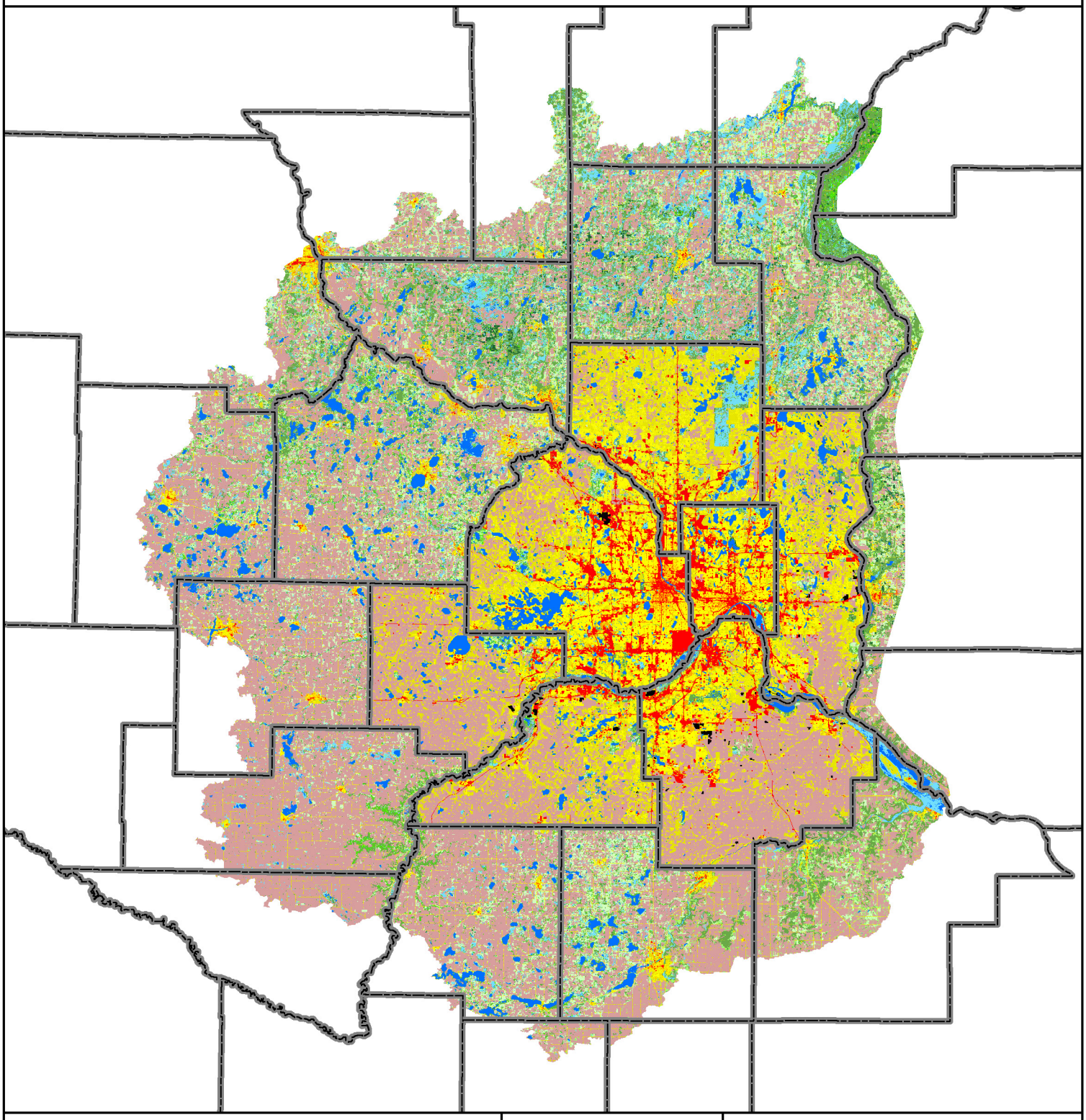
Numbers indicate reach identification numbers

Figure 35
River Condutance Reaches

Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\River_Conductance_Reaches.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\SWB_Lanuse_2010.mxd User: egc

- Open Water
- Low density Residential
- High density Residential
- Commercial/Industrial/Trans.
- Bare Rock / Sand / Clay
- Quarries and Pits
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrubland
- Grasslands / Herbaceous
- Pasture
- Row Crops
- Urban/Rec. Grasses
- Wetland

N

0 10 20
Miles

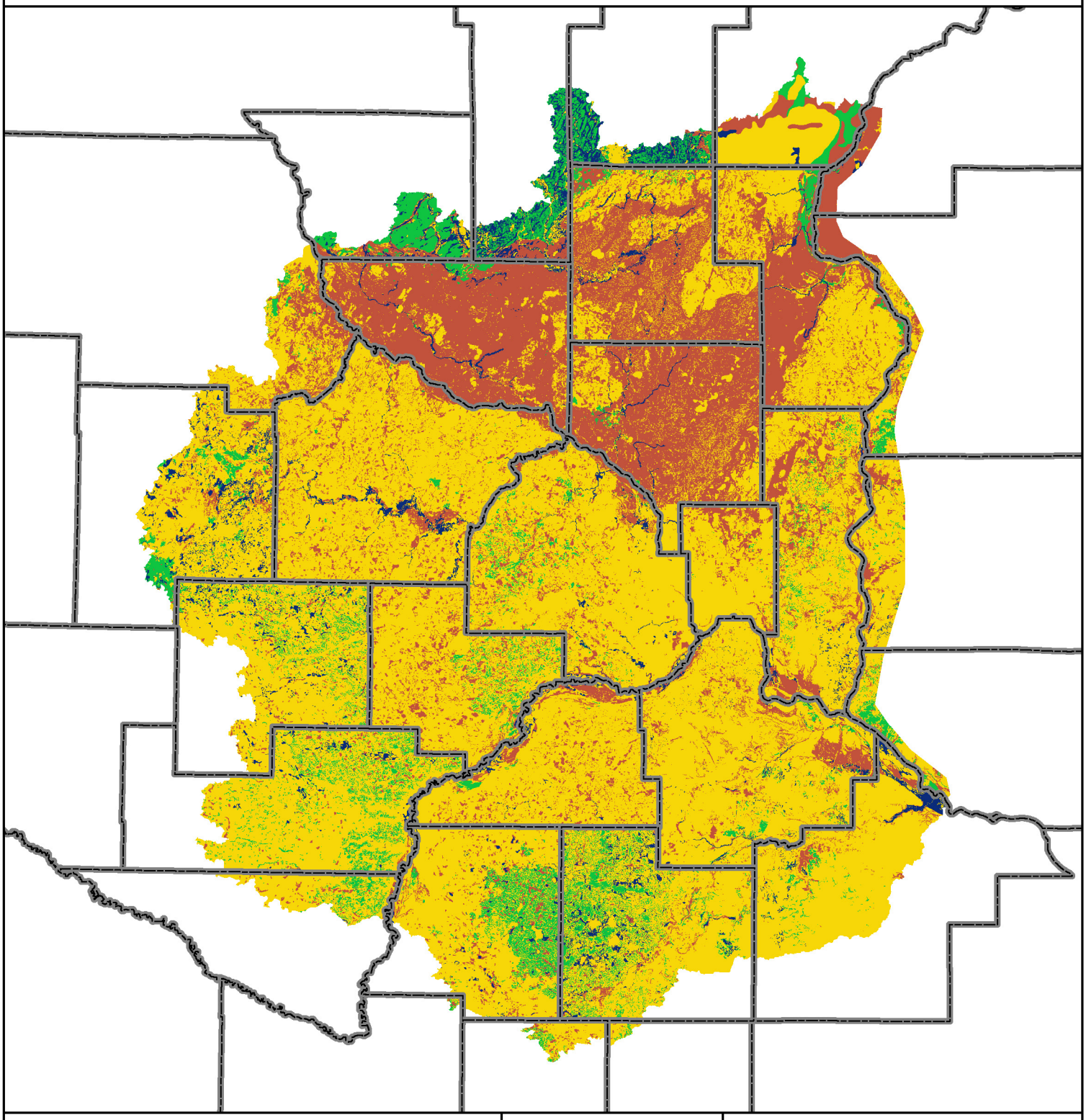
0 15 30
Kilometers

Figure 36

Land Use Input for SWB: 2010

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\SWB_Soils.mxd User: egc

Soil Hydrologic Group

- A Soils
- B Soils
- C Soils
- D Soils

N

0 10 20

Miles

0 15 30

Kilometers

Figure 37

Soil Hydrologic Groups Used by SWB

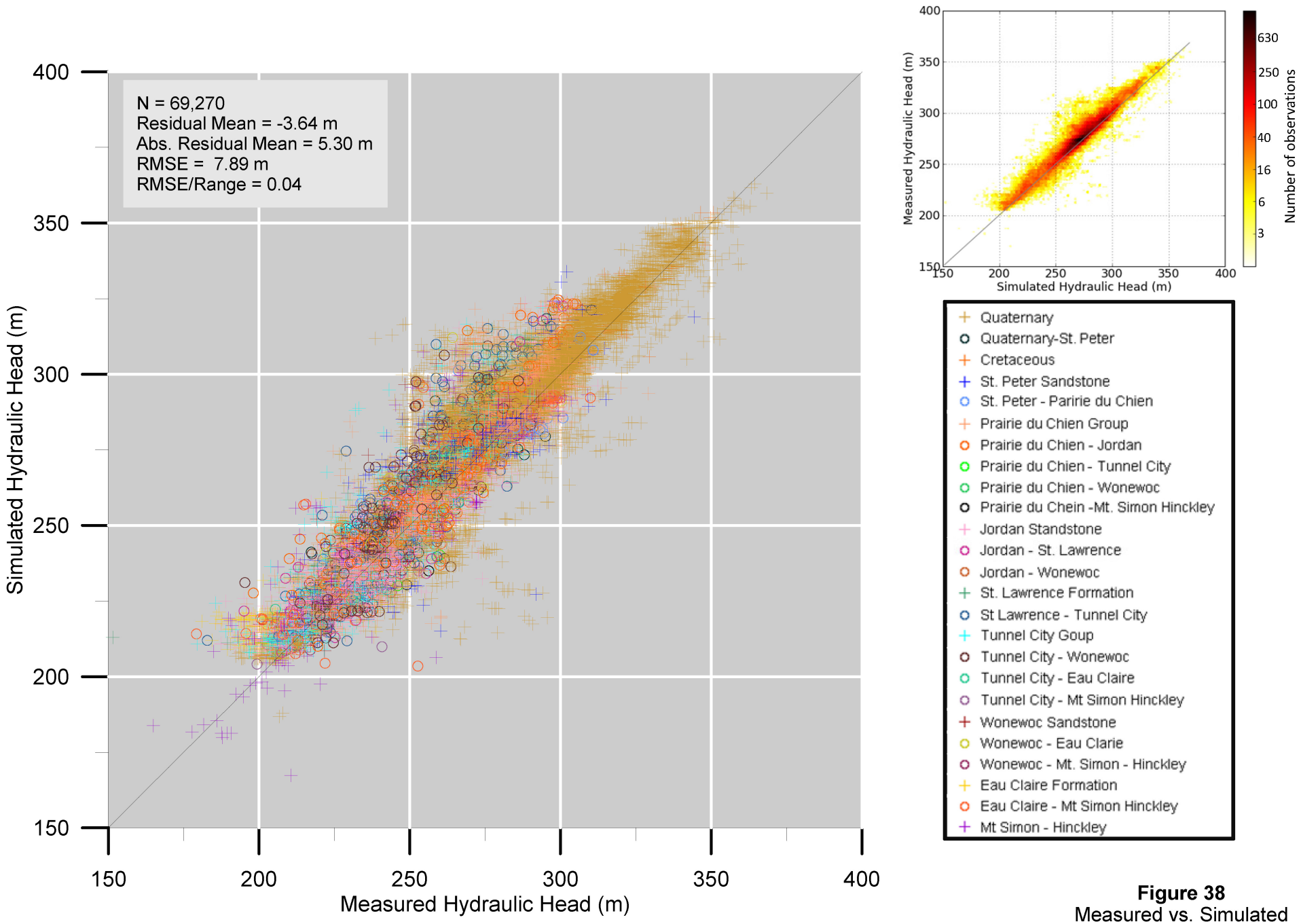


Figure 38
Measured vs. Simulated
All Hydraulic Head Targets

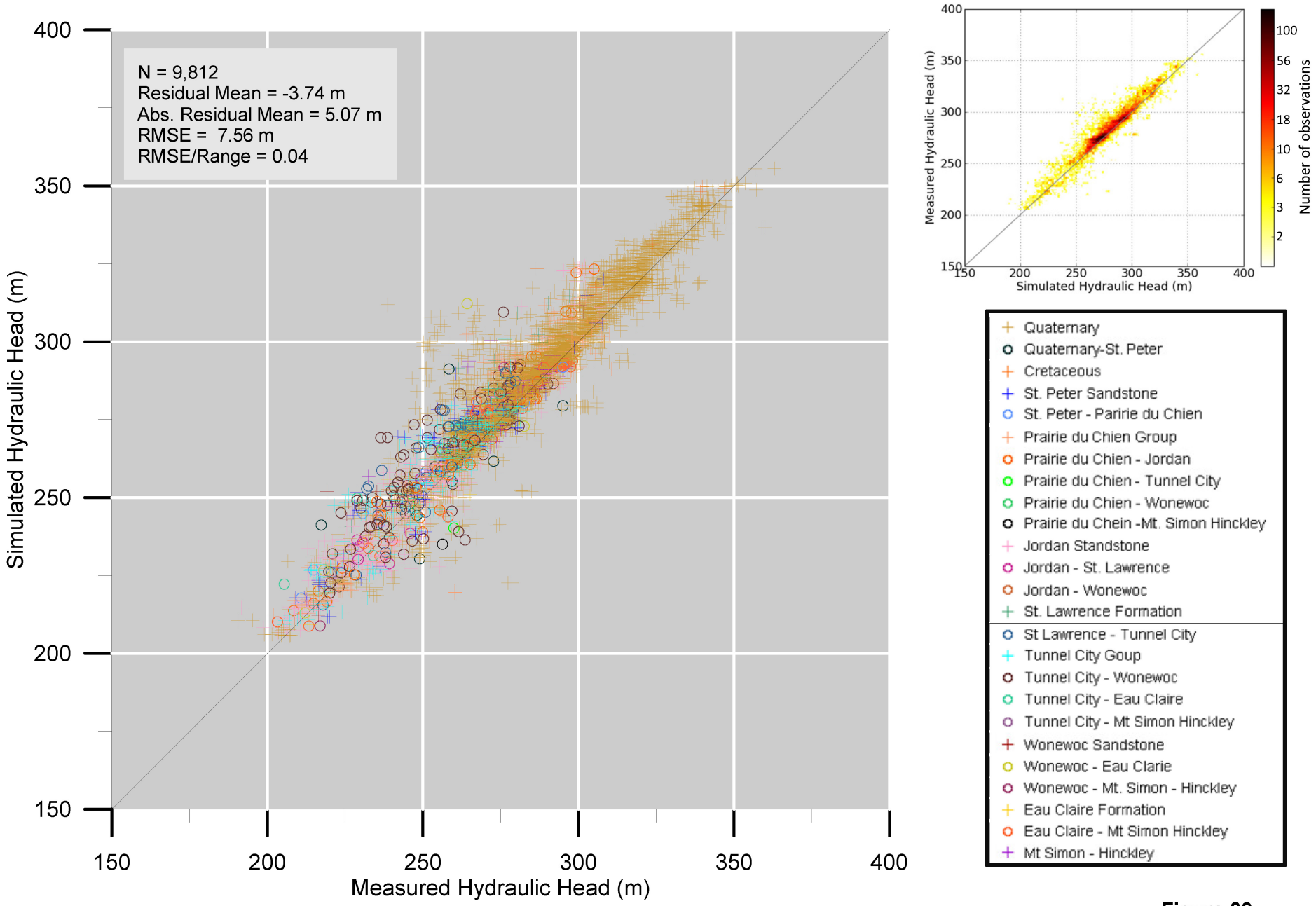


Figure 39
Measured vs. Simulated
CWI Head Targets
2003-2011

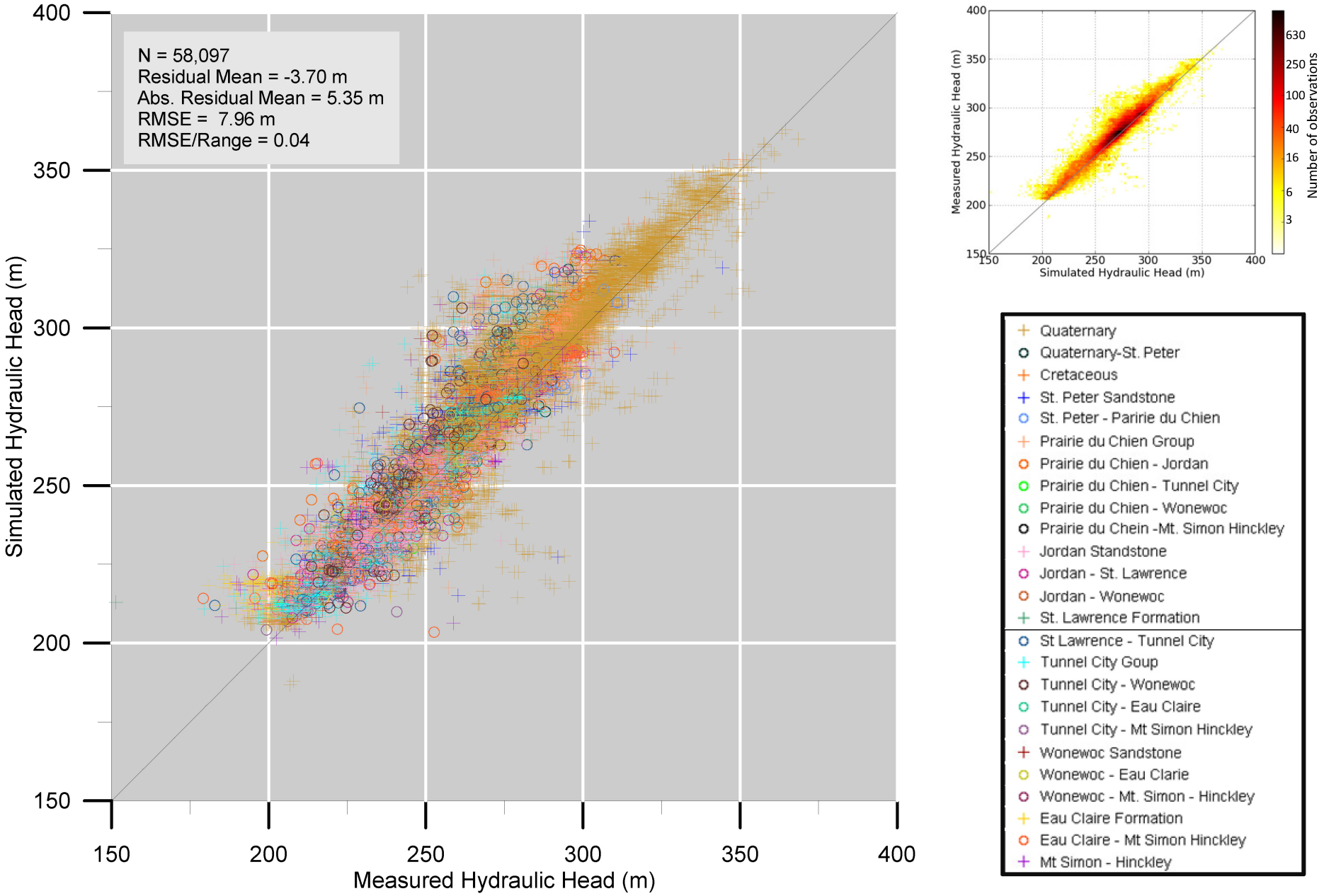


Figure 40
Measured vs. Simulated
CWI Head Targets Prior to 2003

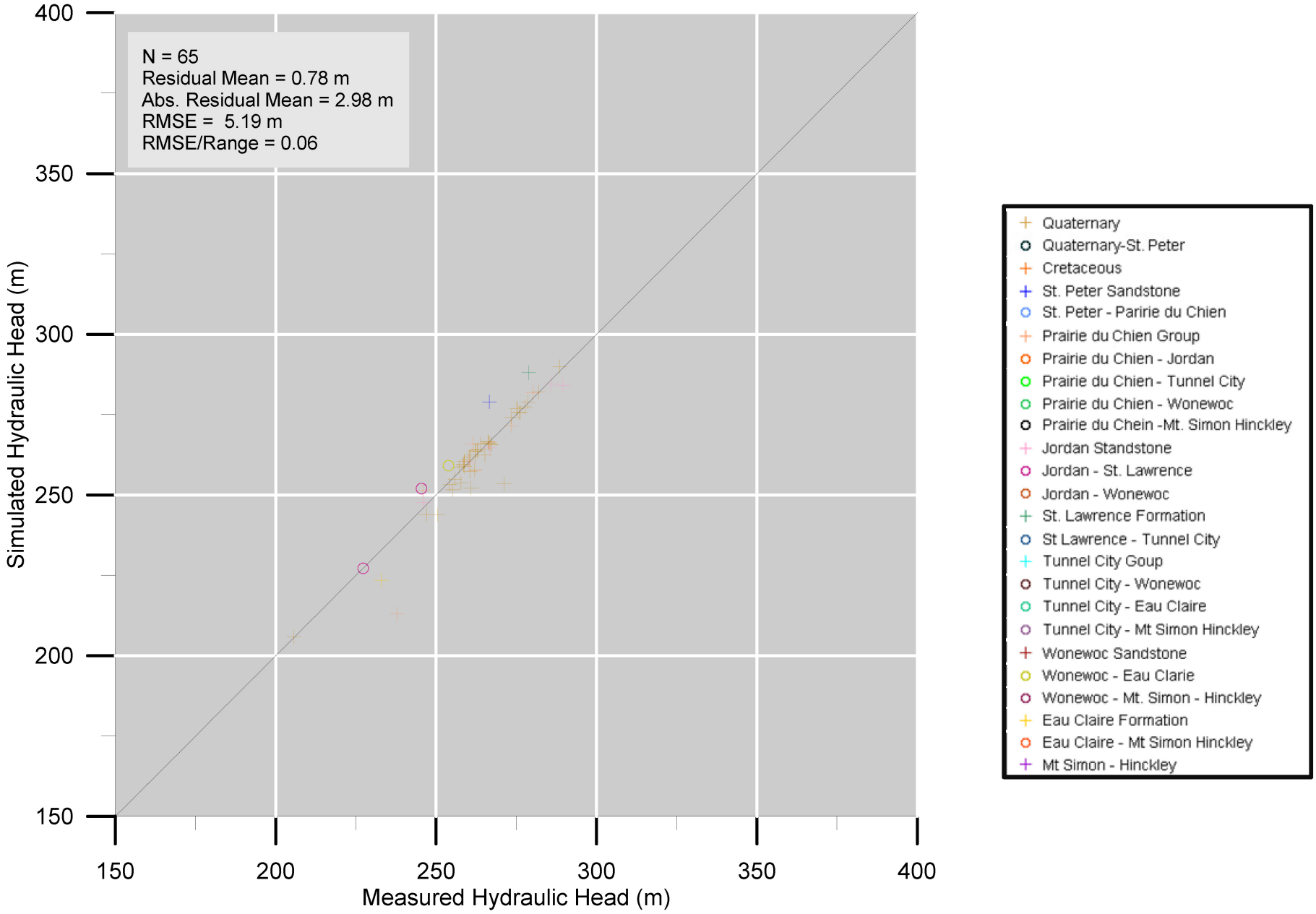


Figure 41
Measured vs. Simulated
NWIS Head Targets

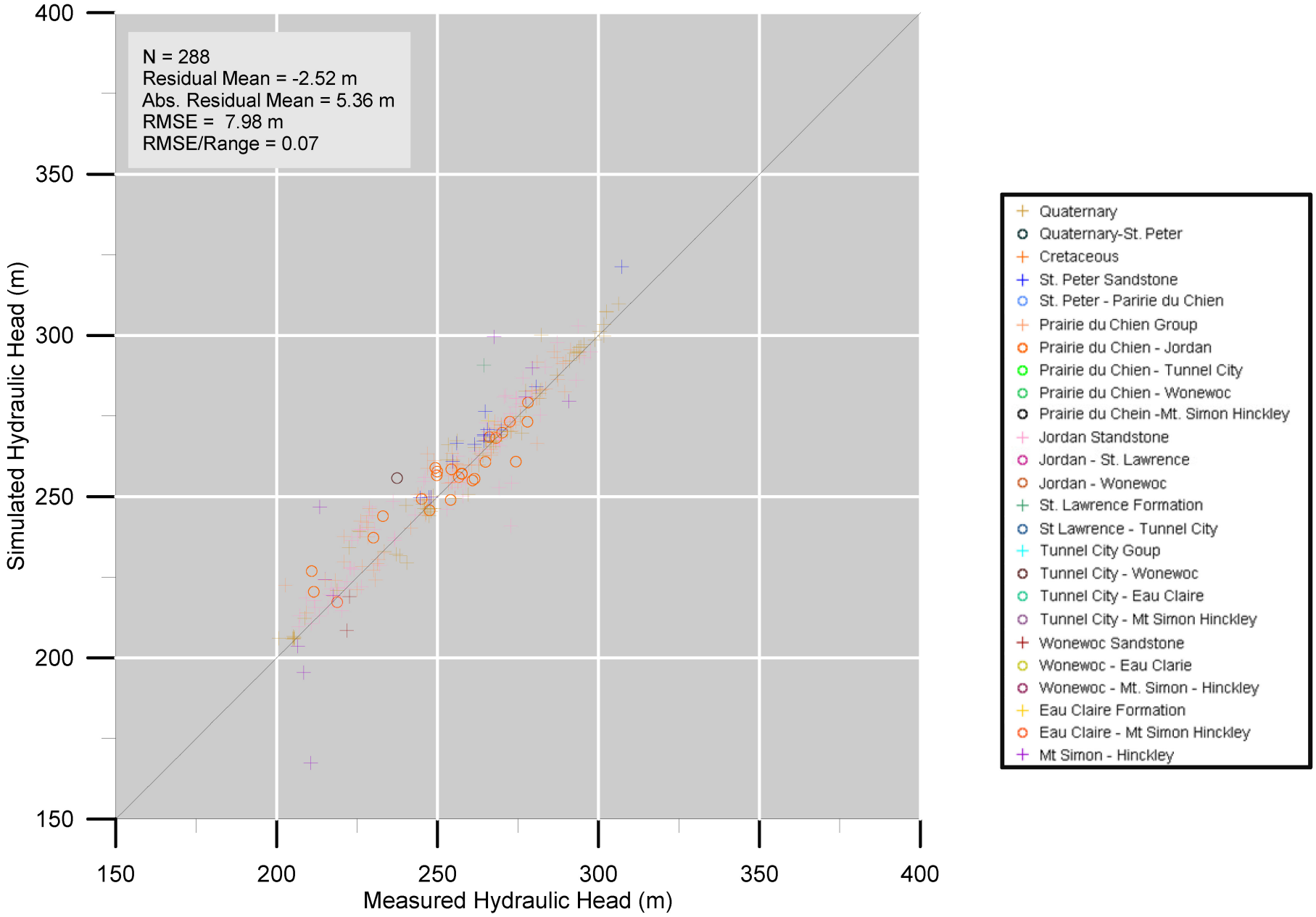


Figure 42
Measured vs. Simulated
NWIS Head Targets Prior to 2003

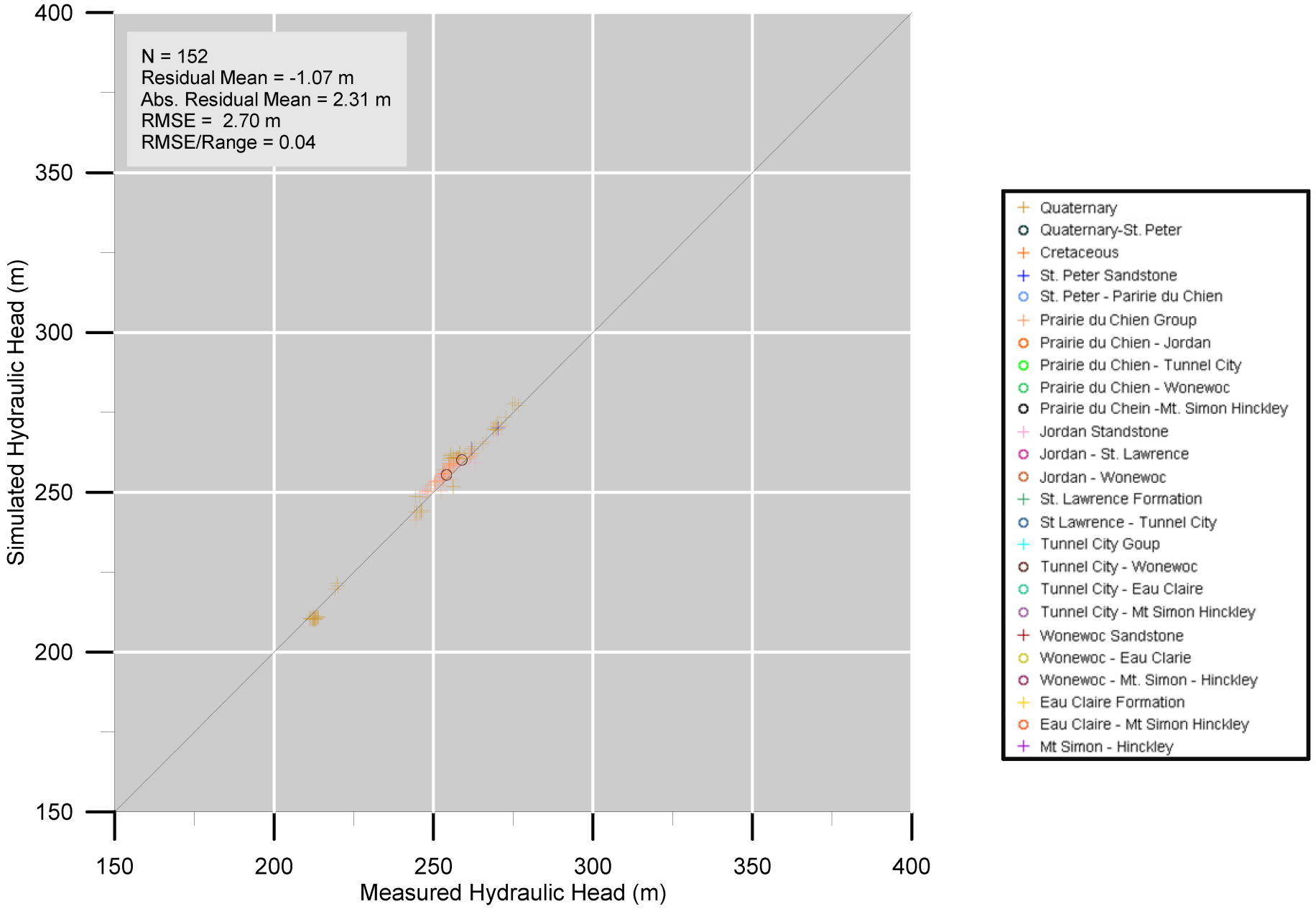


Figure 43
Measured vs. Simulated
Misc. Monitoring Wells

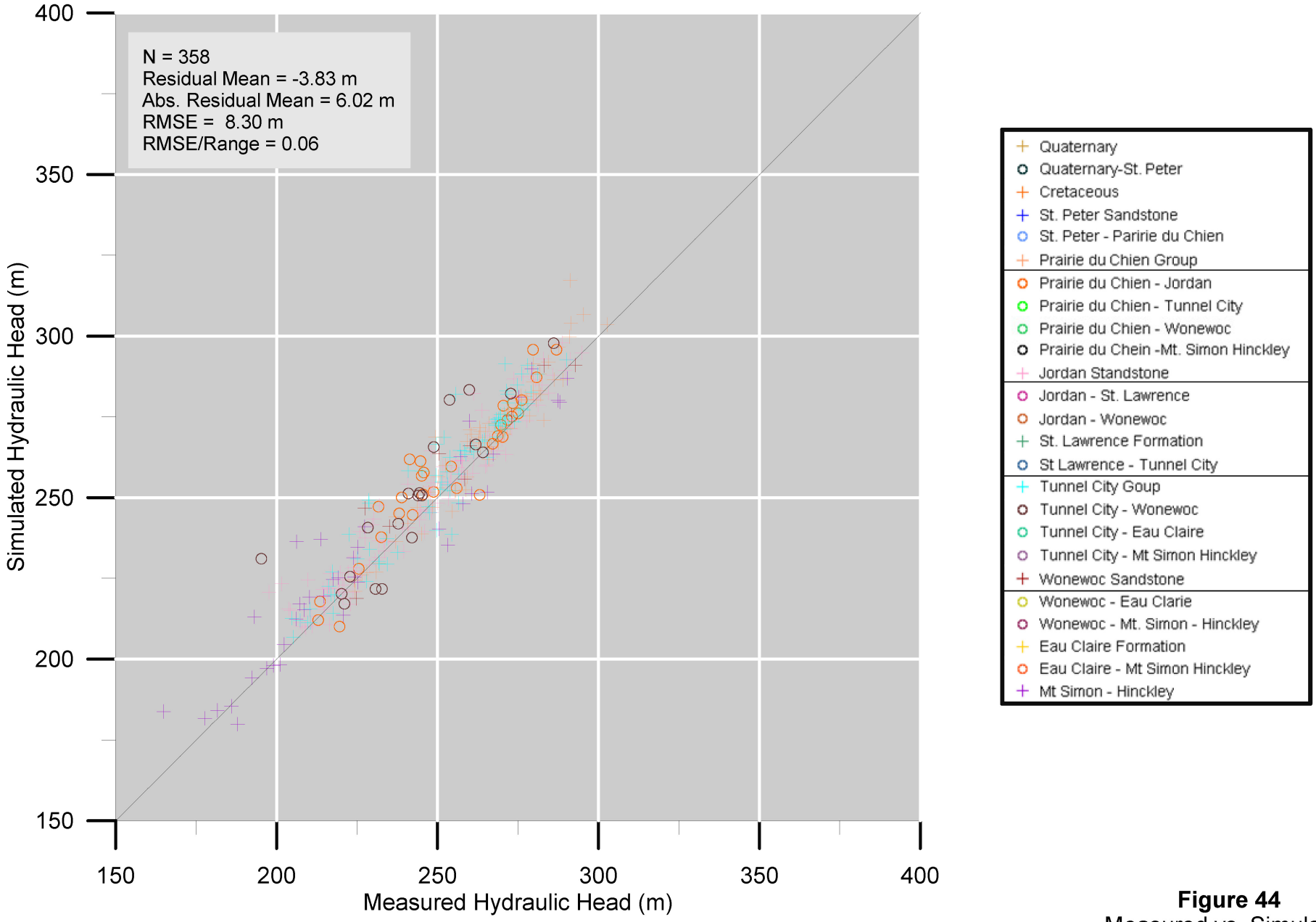


Figure 44
Measured vs. Simulated
USGS Synoptic
March and August 2008

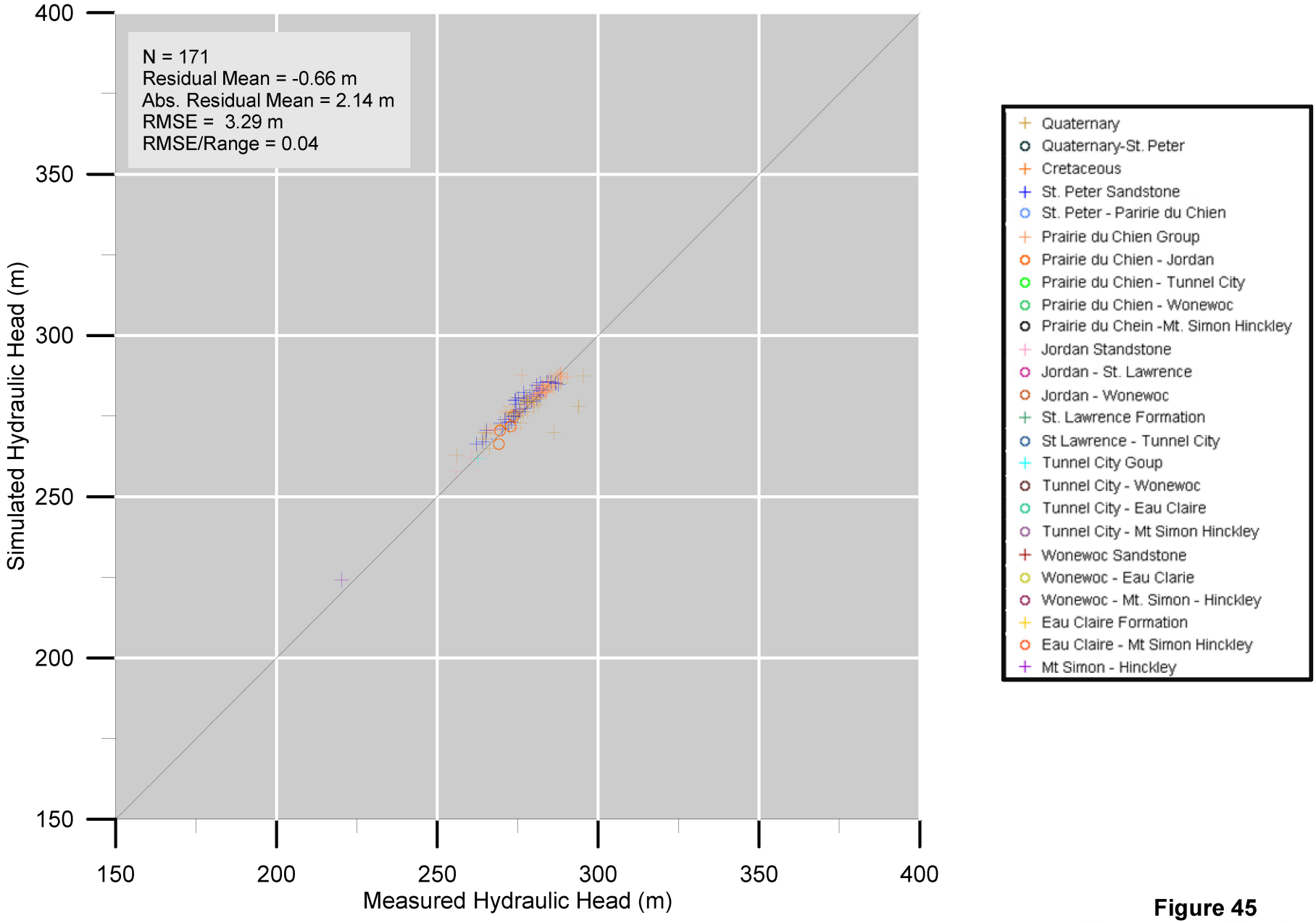


Figure 45
Measured vs. Simulated
USGS White Bear Lake Synoptic
Spring and Fall 2011

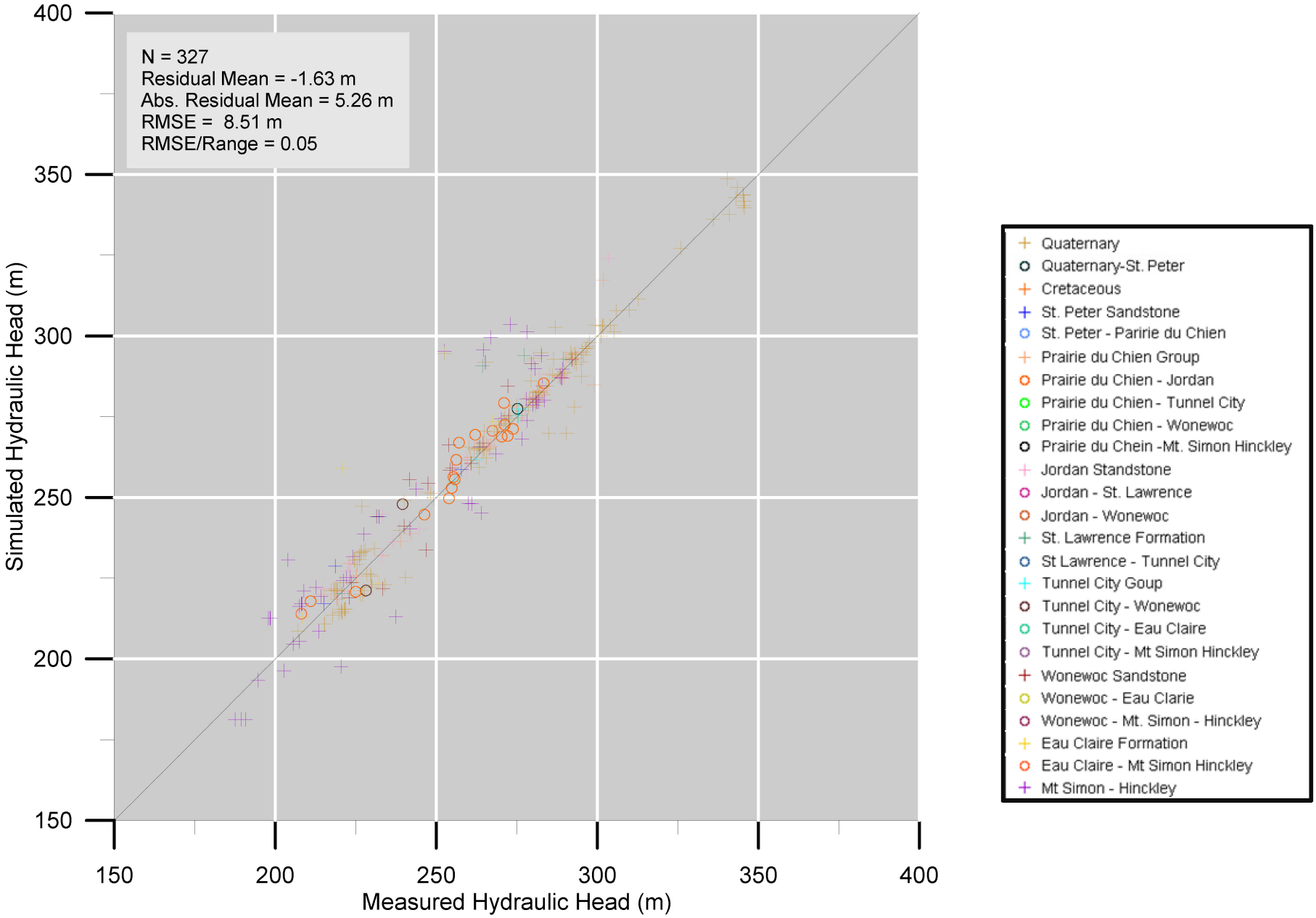


Figure 46
Measured vs. Simulated
Minnesota DNR Observation Wells

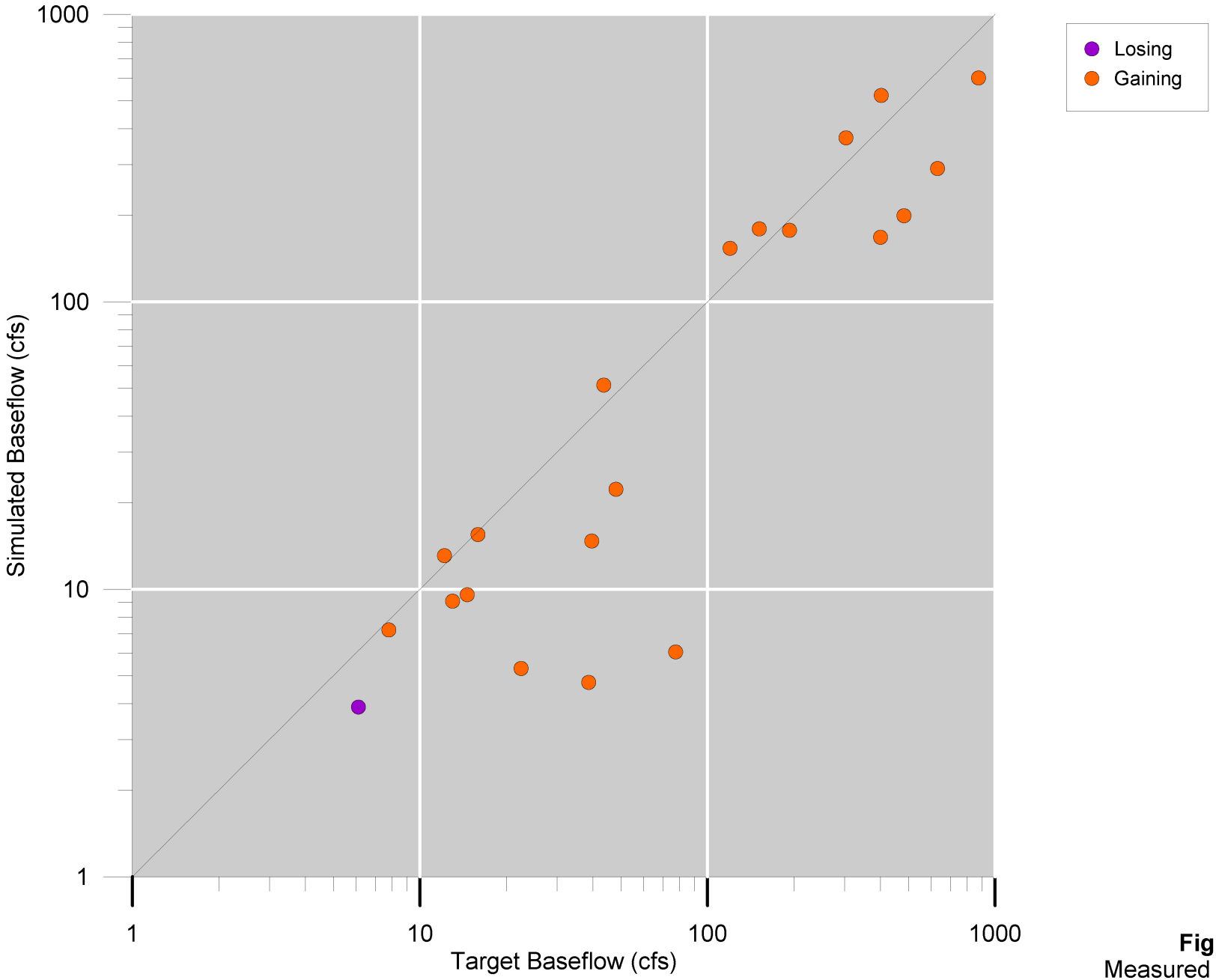


Figure 47
Measured vs. Simulated Baseflow

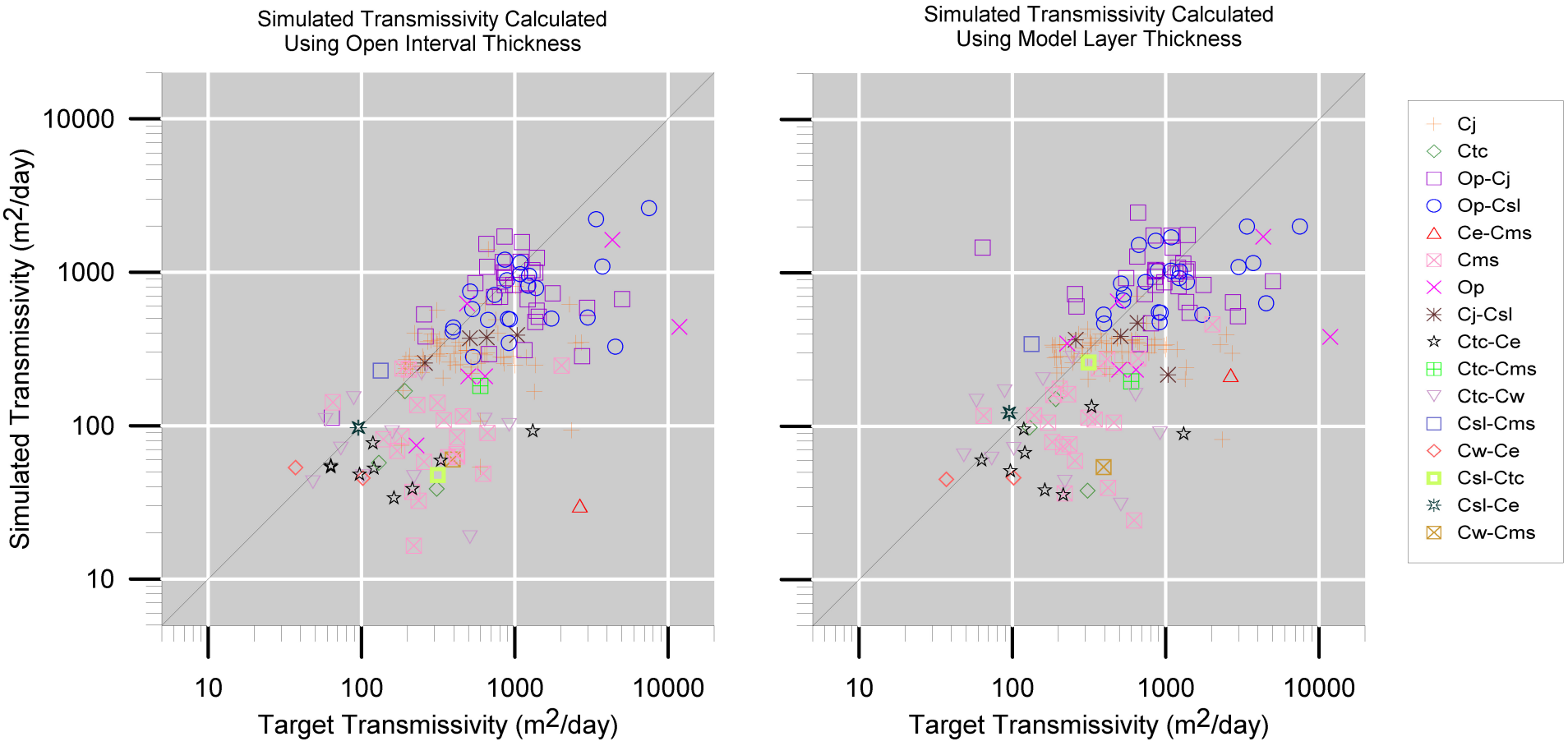
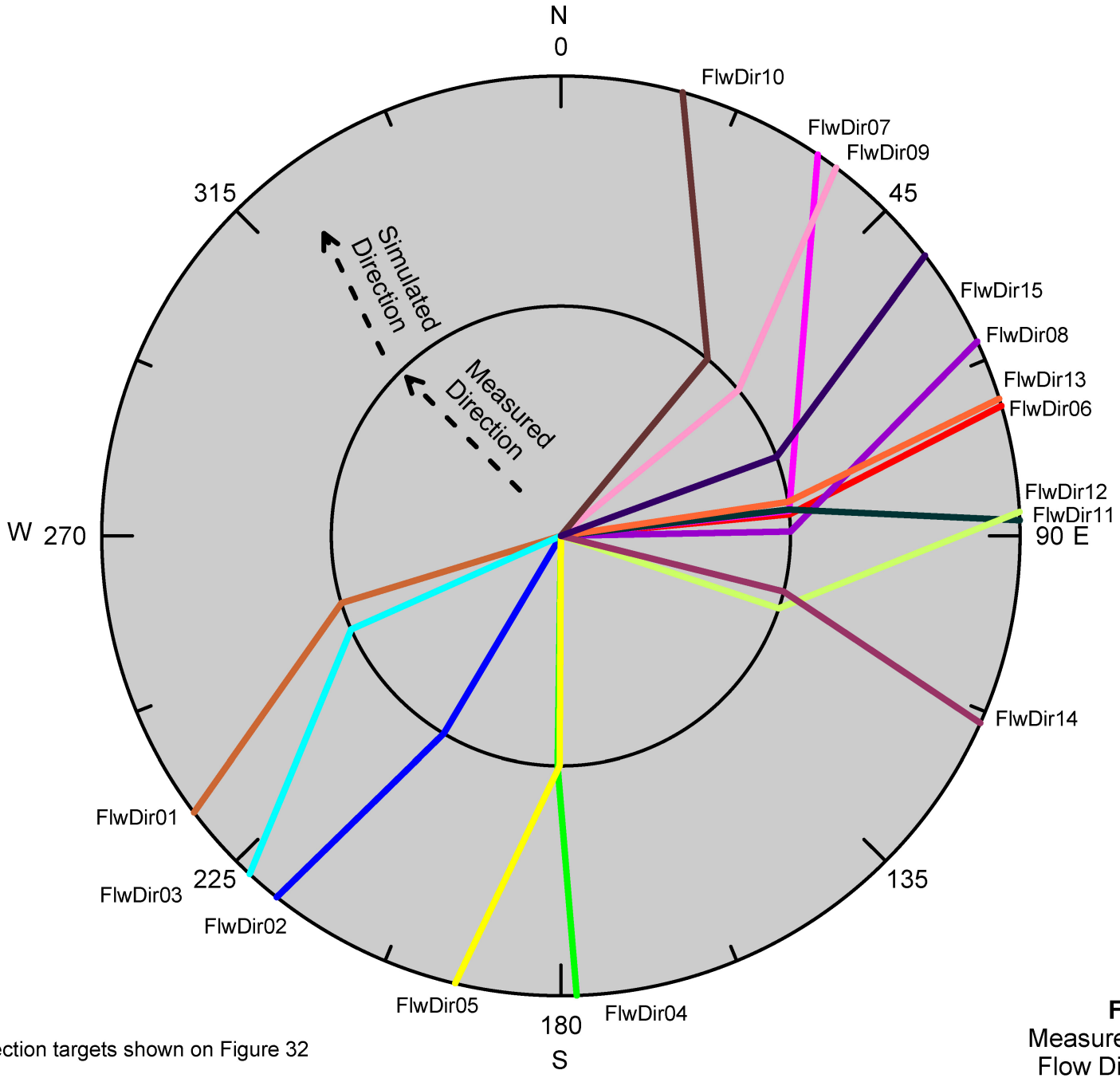


Figure 48
Measured vs. Simulated
Transmissivity Values



Note: location of flow direction targets shown on Figure 32

Figure 49
Measured vs. Simulated
Flow Direction Targets

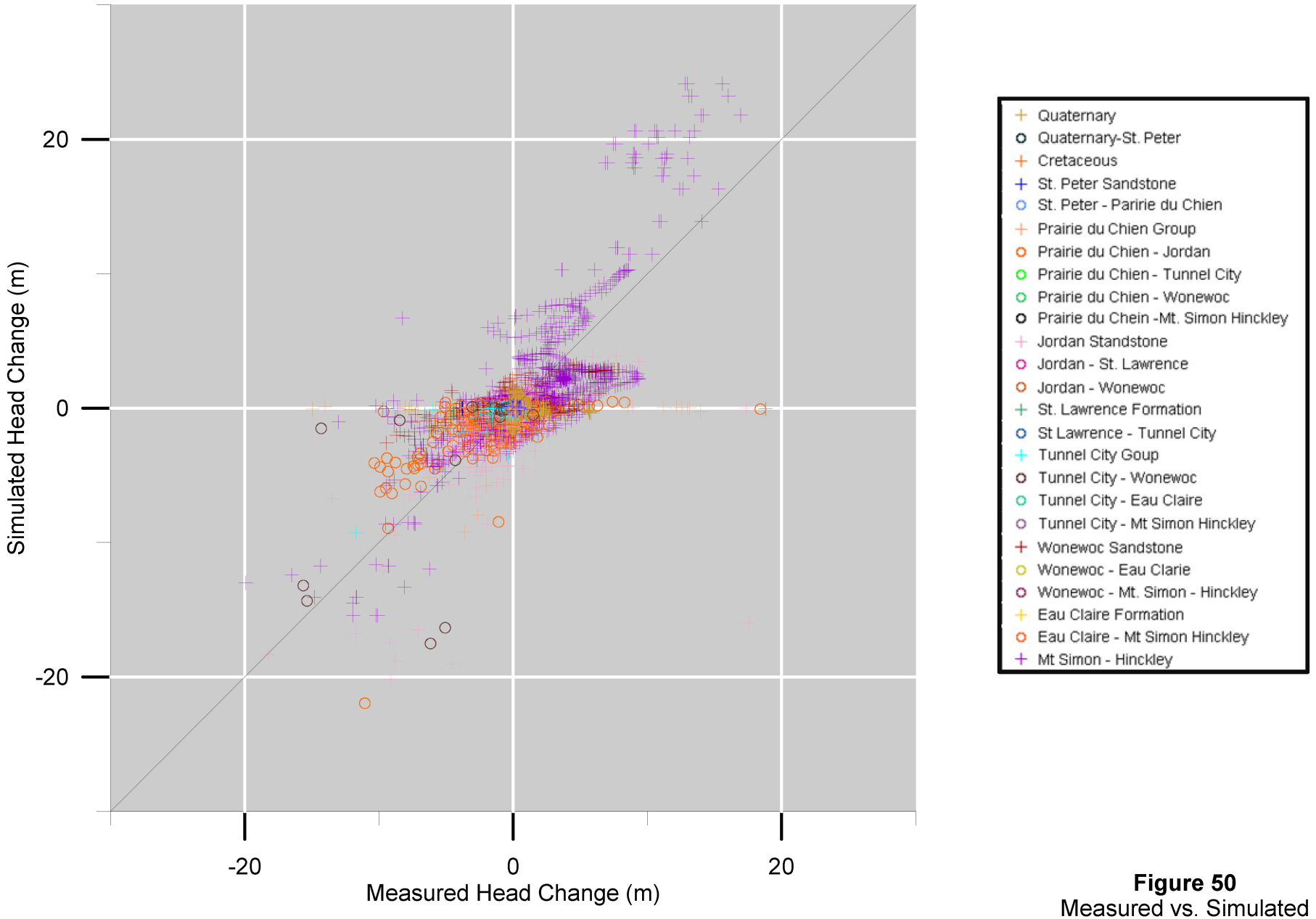


Figure 50
Measured vs. Simulated
Head Change
Transient Simulation 2003-2011

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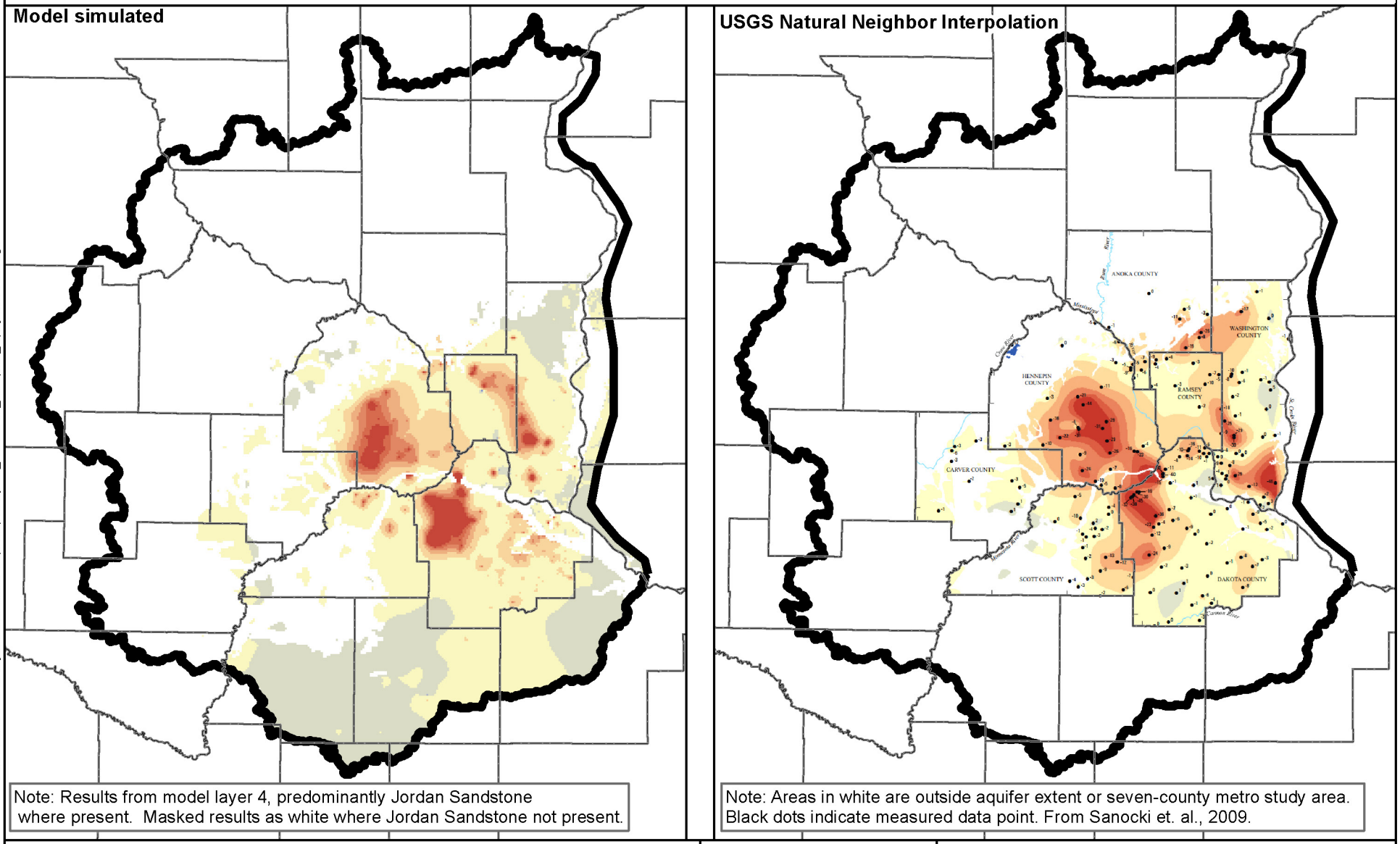

Model Boundary

County Boundary

Head change (ft)

- Less than -25
- -20.1 to -25
- -15.1 to -20
- -10.1 to -15
- -5.1 to -10
- 0 to -5
- 0 - 5
- 5.1 to 10
- 10.1 to 15
- 15.1 to 20
- 20.1 to 25
- Greater than 25

N

0 10 20

Miles

0 15 30

Kilometers

Figure 51

Model simulated head change and USGS interpolated head change between March 2008 and August 2008, Prairie du Chien-Jordan aquifer

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

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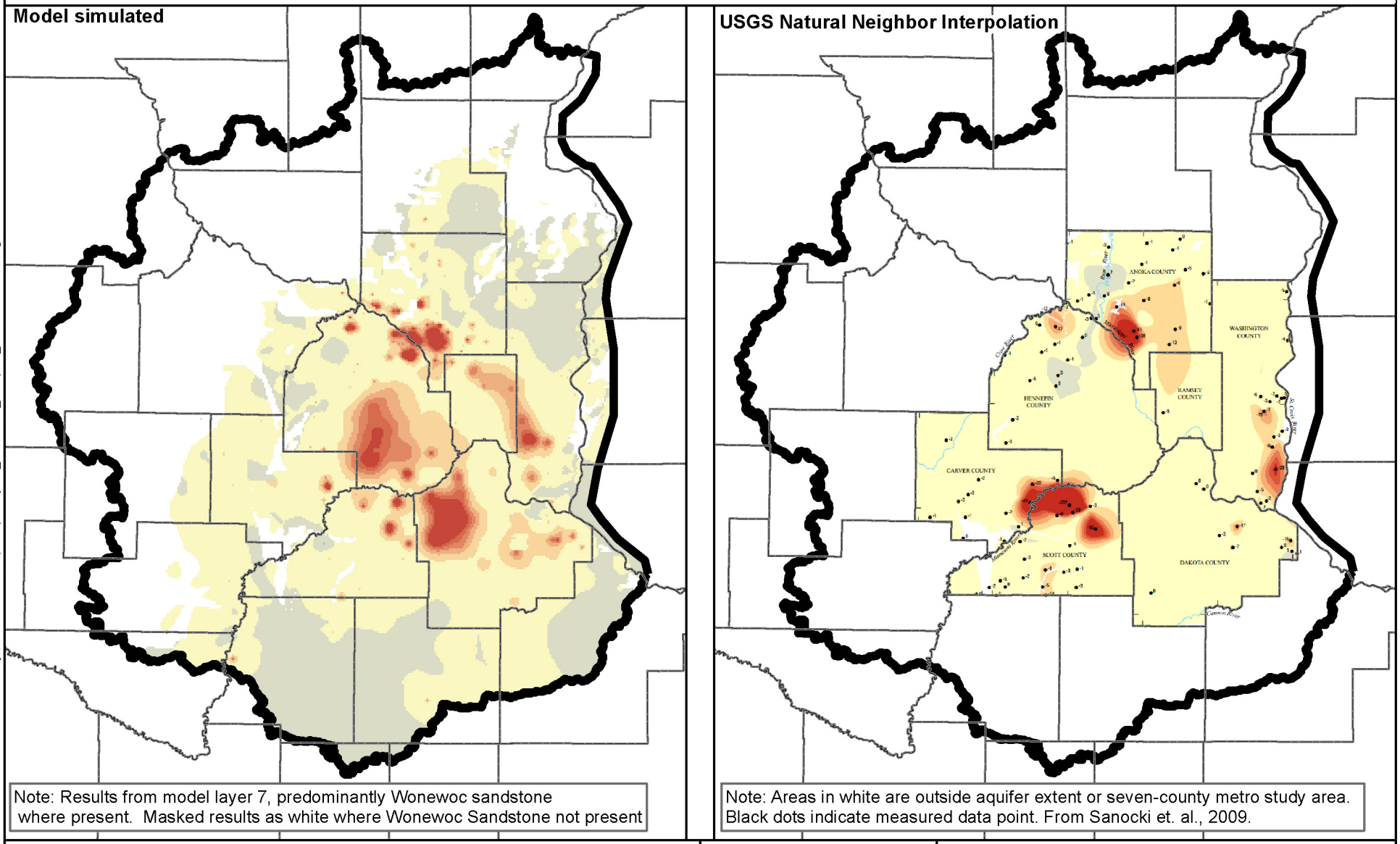


Note: Results from model layer 7, predominantly Wonewoc sandstone where present. Masked results as white where Wonewoc Sandstone not present

Note: Areas in white are outside aquifer extent or seven-county metro study area. Black dots indicate measured data point. From Sanocki et. al., 2009.

Model Boundary

County Boundary

Head change (ft)

- Less than -25
- -20.1 to -25
- -15.1 to -20
- -10.1 to -15
- -5.1 to -10
- 0 to -5
- 0 - 5
- 5.1 to 10
- 10.1 to 15
- 15.1 to 20
- 20.1 to 25
- Greater than 25

N

0 10 20
Miles

0 15 30
Kilometers

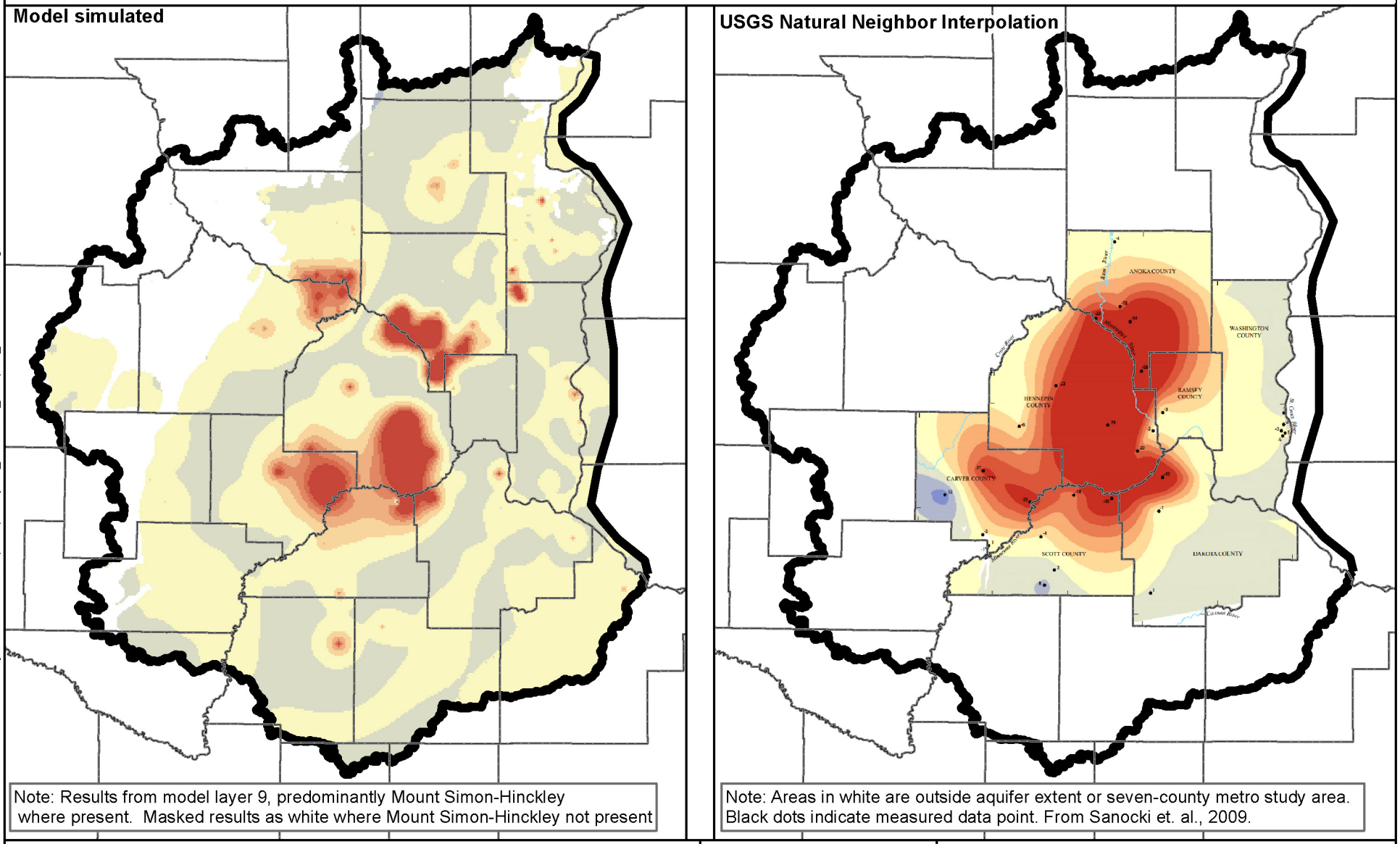
Figure 52

Model simulated head change and USGS interpolated head change between March 2008 and August 2008, Tunnel City and Wonewoc aquifer

Barr Footer: File: I:\Projects\23621\1087\Maps\ReportSyn08_Drawdown_Compare_CtcCw.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Results from model layer 9, predominantly Mount Simon-Hinckley where present. Masked results as white where Mount Simon-Hinckley not present

Note: Areas in white are outside aquifer extent or seven-county metro study area. Black dots indicate measured data point. From Sanocki et. al., 2009.

Model Boundary

County Boundary

Head change (ft)

- Less than -25
- -20.1 to -25
- -15.1 to -20
- -10.1 to -15
- -5.1 to -10
- 0 to -5
- 0 - 5
- 5.1 to 10
- 10.1 to 15
- 15.1 to 20
- 20.1 to 25
- Greater than 25

N

0 10 20

Miles

0 15 30

Kilometers

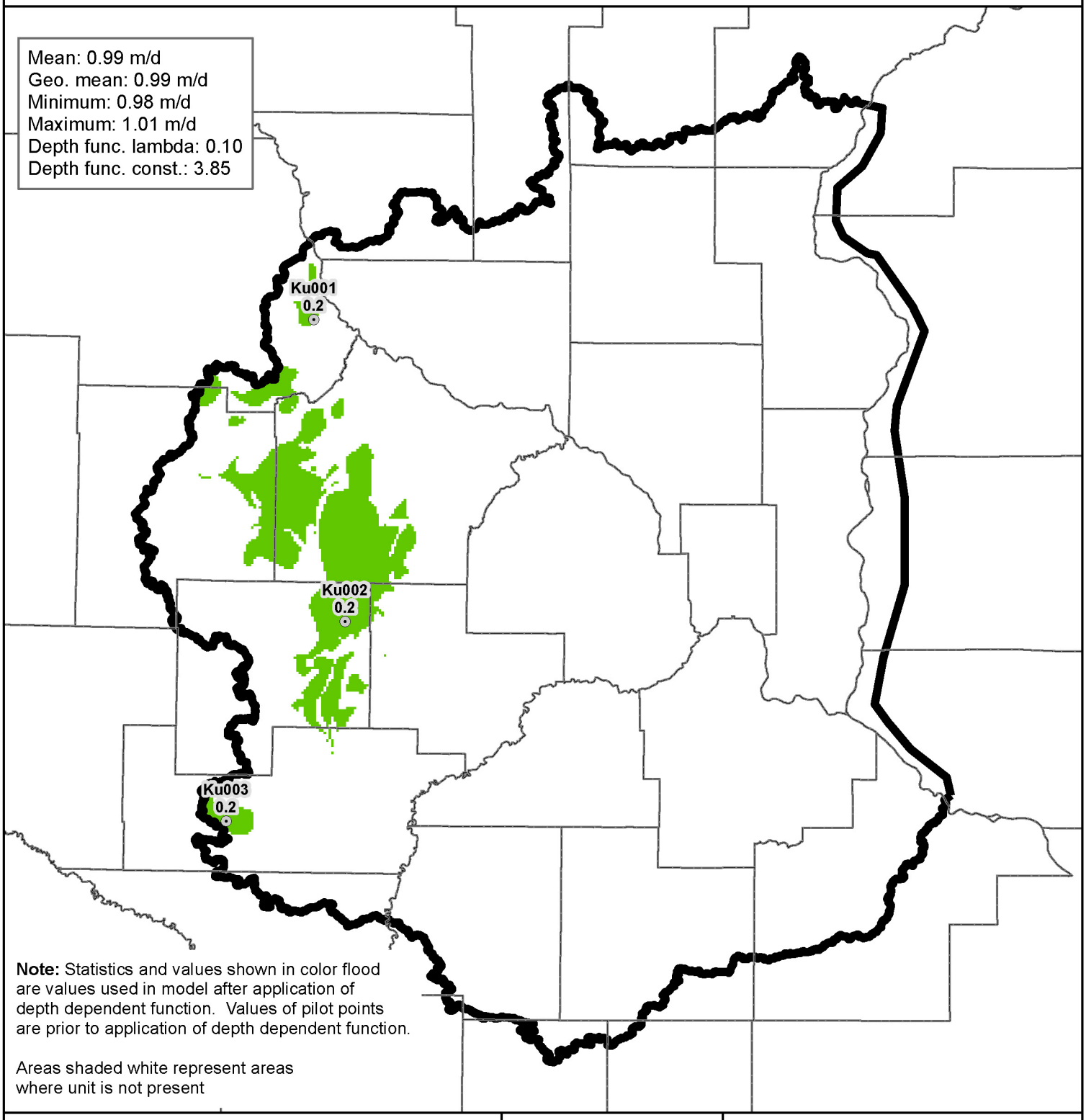
Figure 53

Model simulated head change and USGS interpolated head change between March 2008 and August 2008, Mount Simon-Hinckley aquifer

Barr Footer: File: I:\Projects\23621\1087\Maps\ReportSyn08_Drawdown_Compare_Cms.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Ku.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

0 10 20
Miles

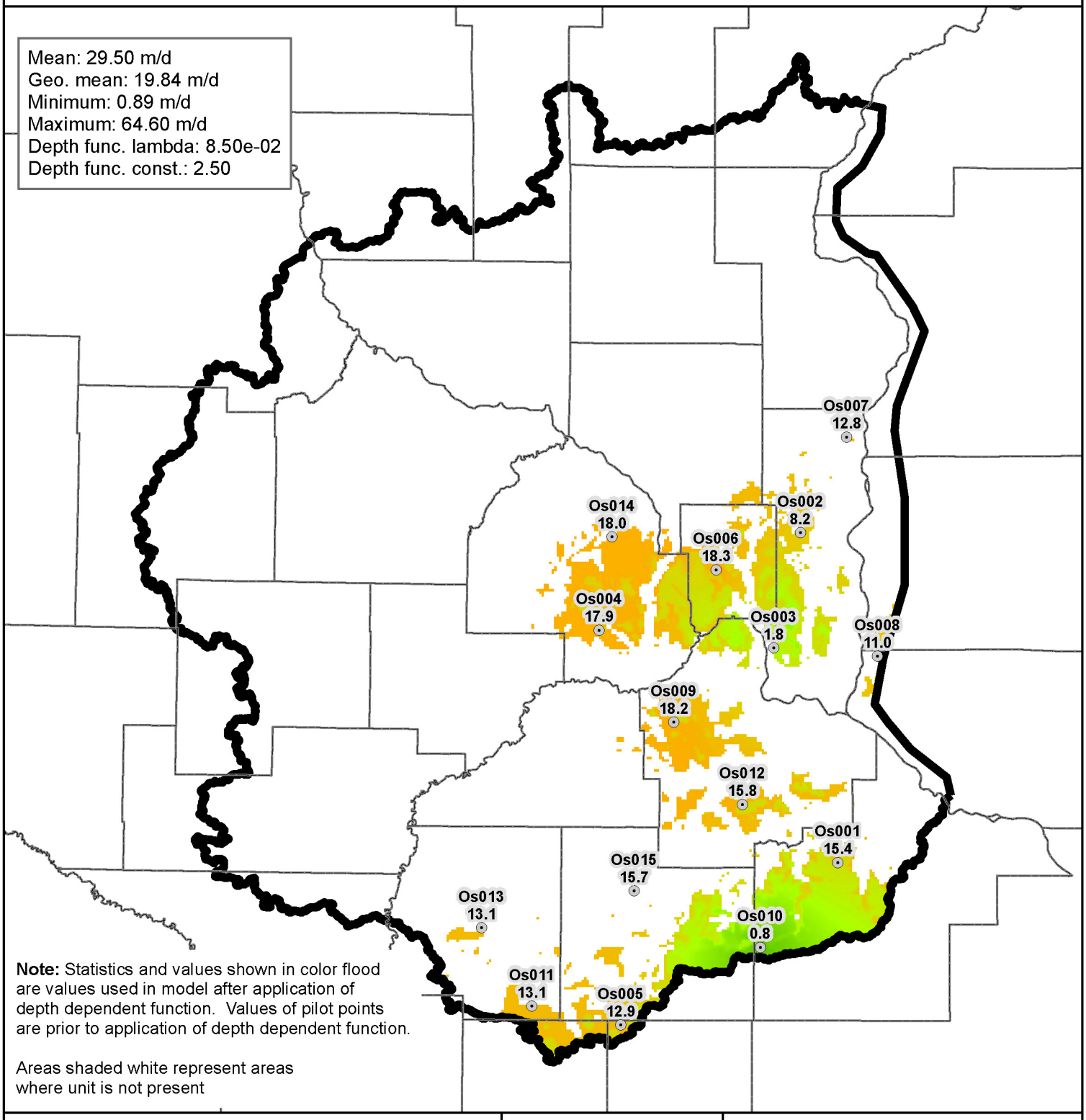
0 15 30
Kilometers

Figure 54

Horizontal Hydraulic Conductivity
Cretaceous and/or
unnamed Paleozoic

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

0 10 20
Miles

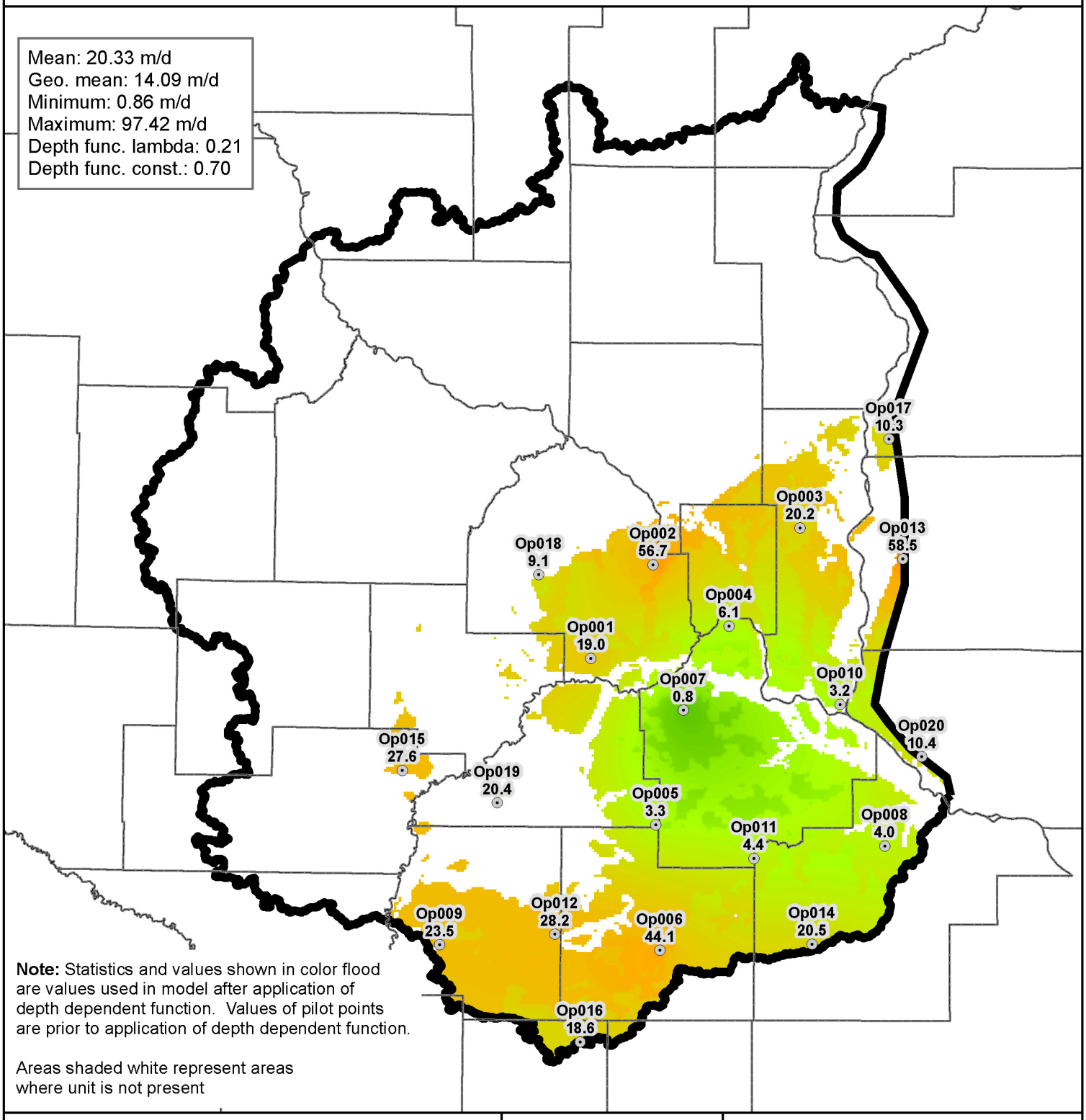
0 15 30
Kilometers

Figure 55
Horizontal Hydraulic Conductivity
St. Peter Sandstone

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Os.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Op.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

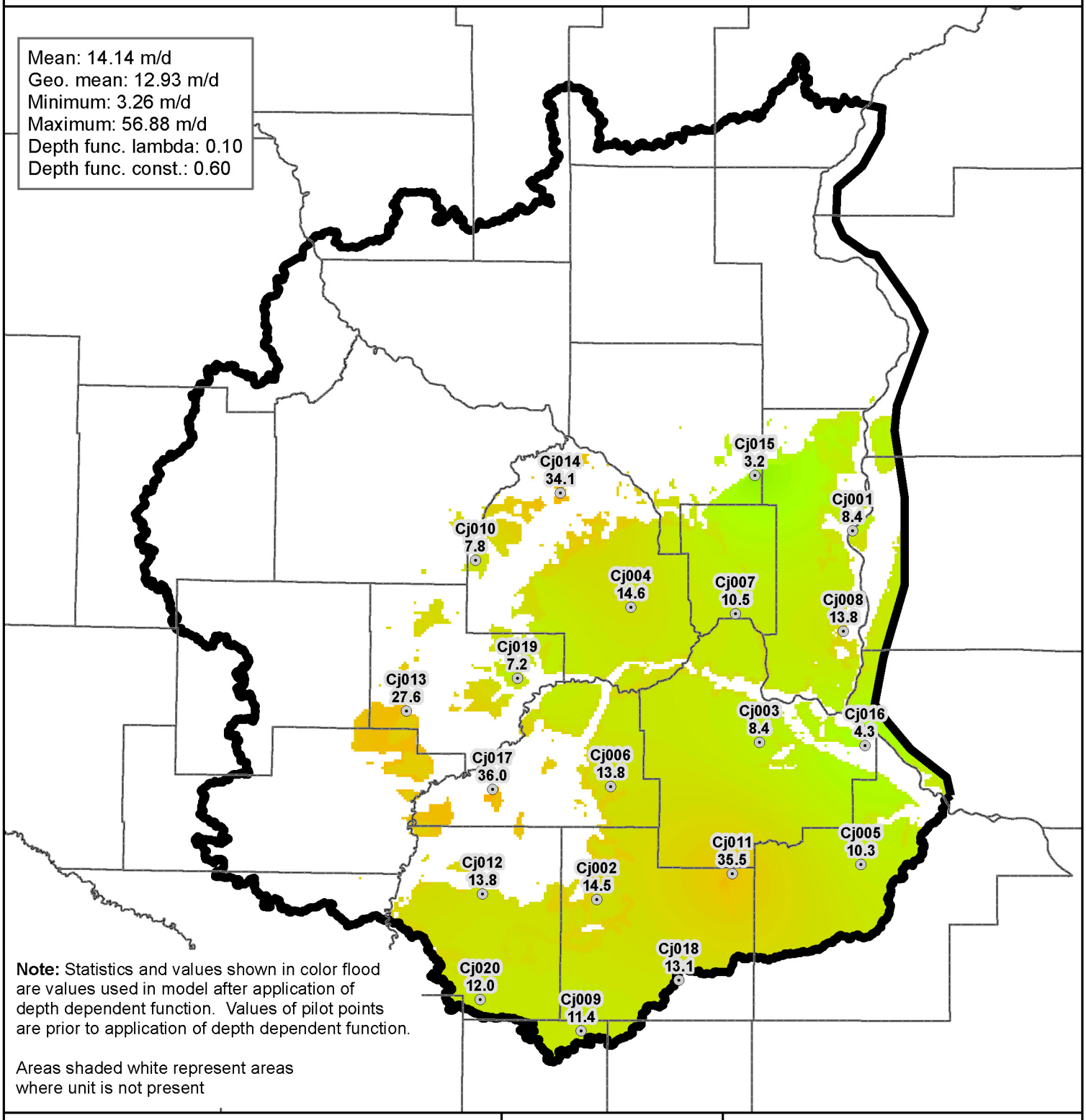
0 10 20
Miles

0 15 30
Kilometers

Figure 56
Horizontal Hydraulic Conductivity
Prairie du Chien Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Cj.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

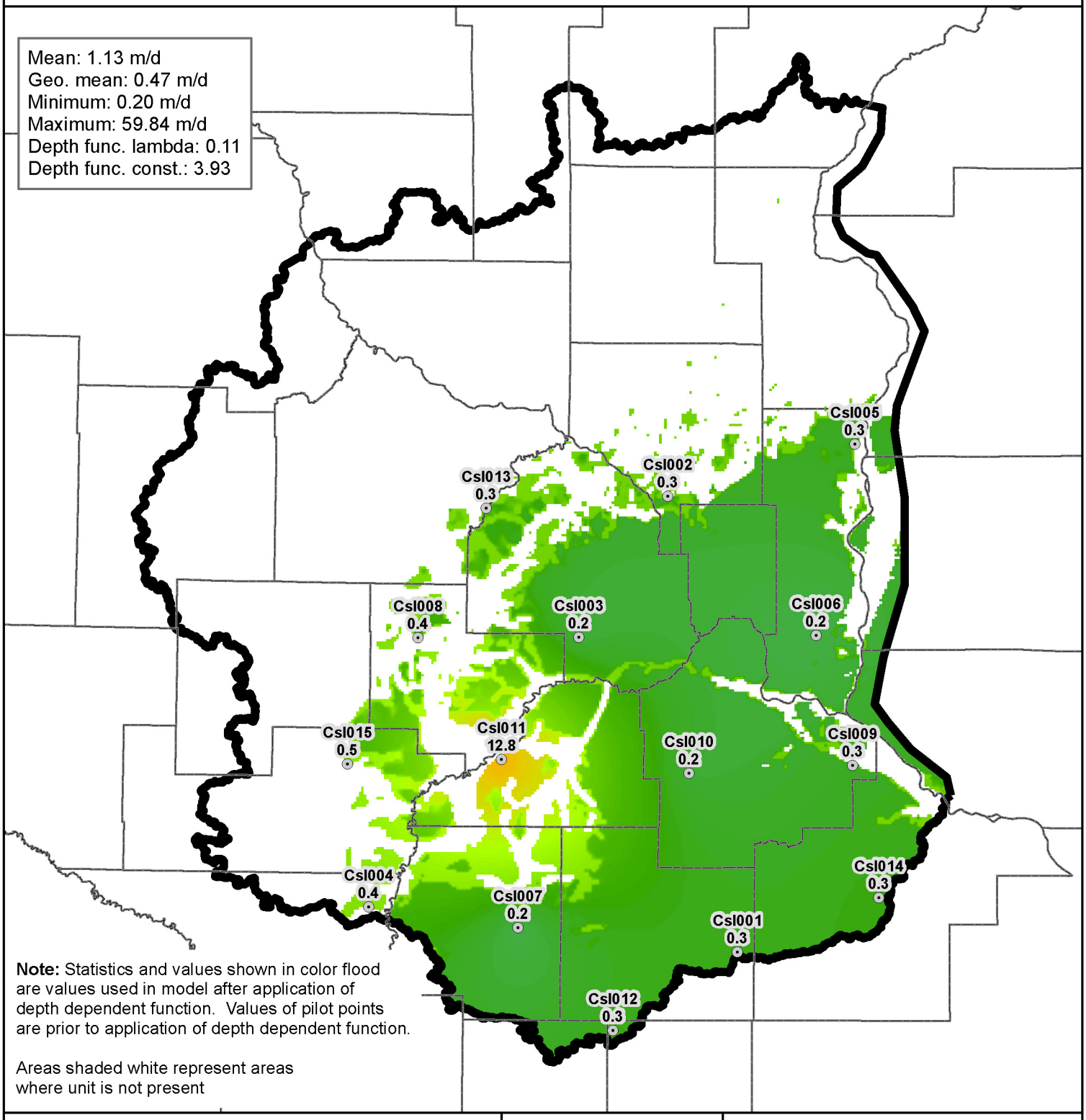
0 10 20
Miles

0 15 30
Kilometers

Figure 57
Horizontal Hydraulic Conductivity
Jordan Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Csl.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

0 10 20
Miles

0 15 30
Kilometers

Figure 58
Horizontal Hydraulic Conductivity
St. Lawrence Formation

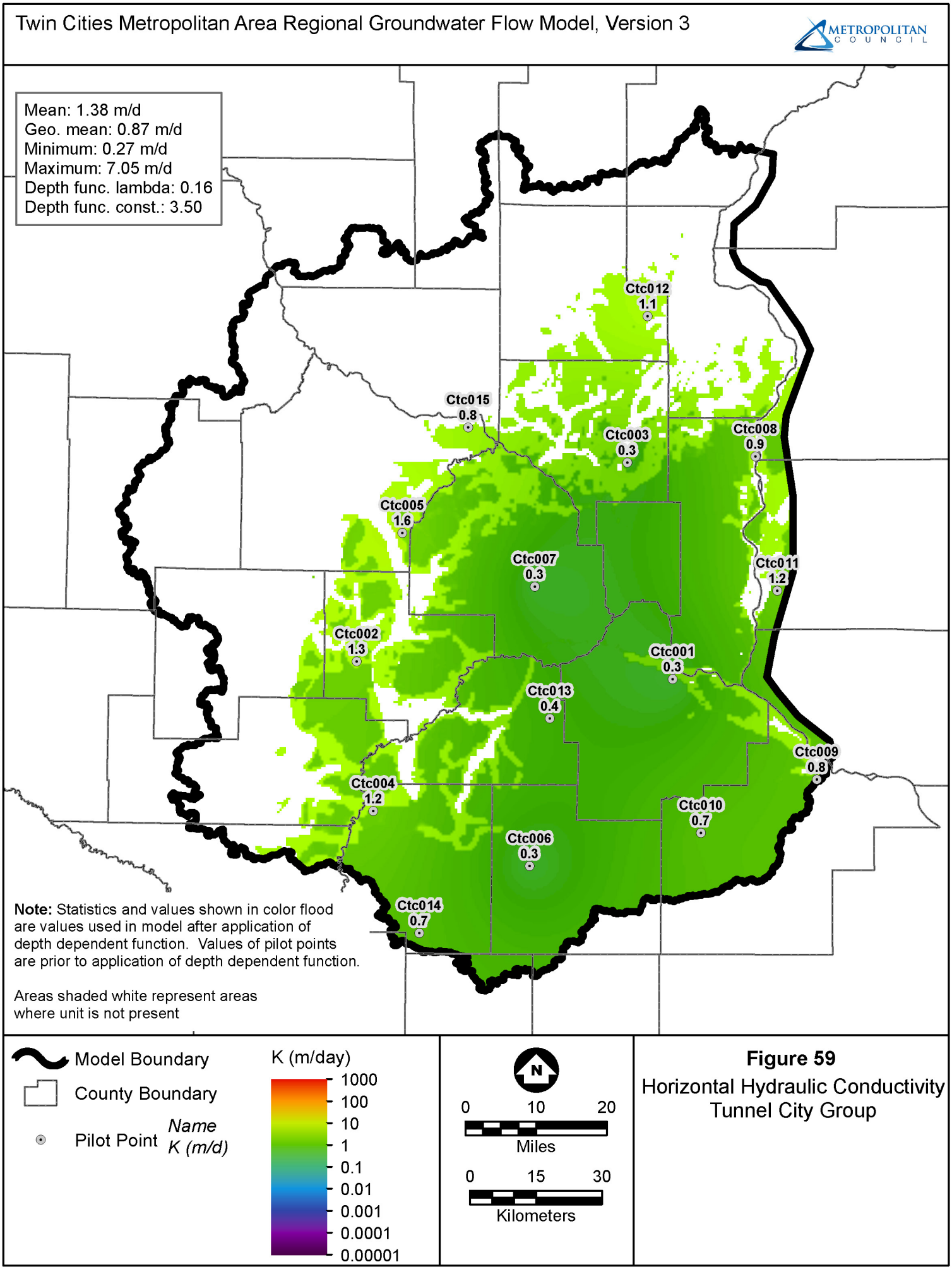
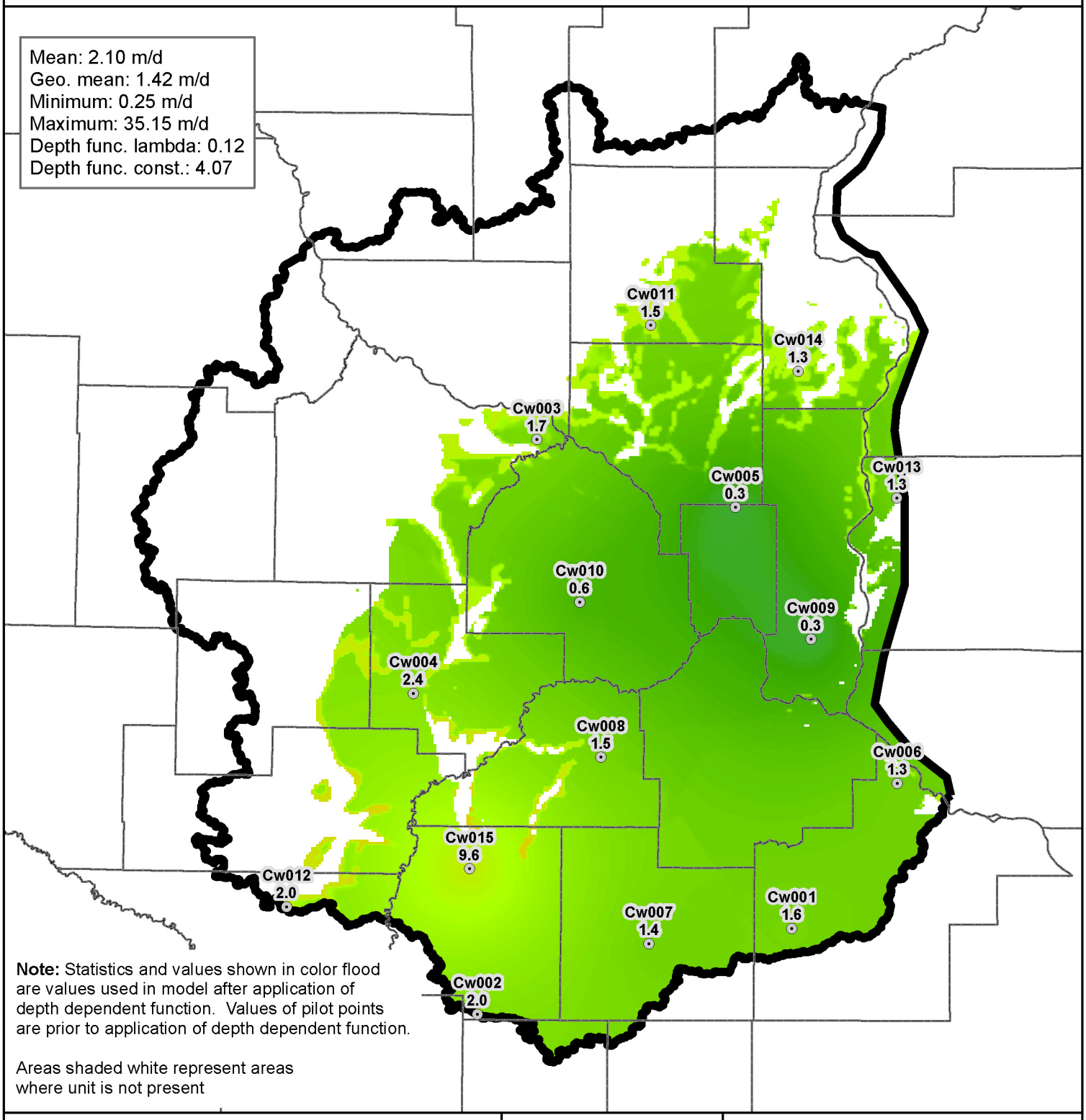


Figure 59
Horizontal Hydraulic Conductivity
Tunnel City Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Cw.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

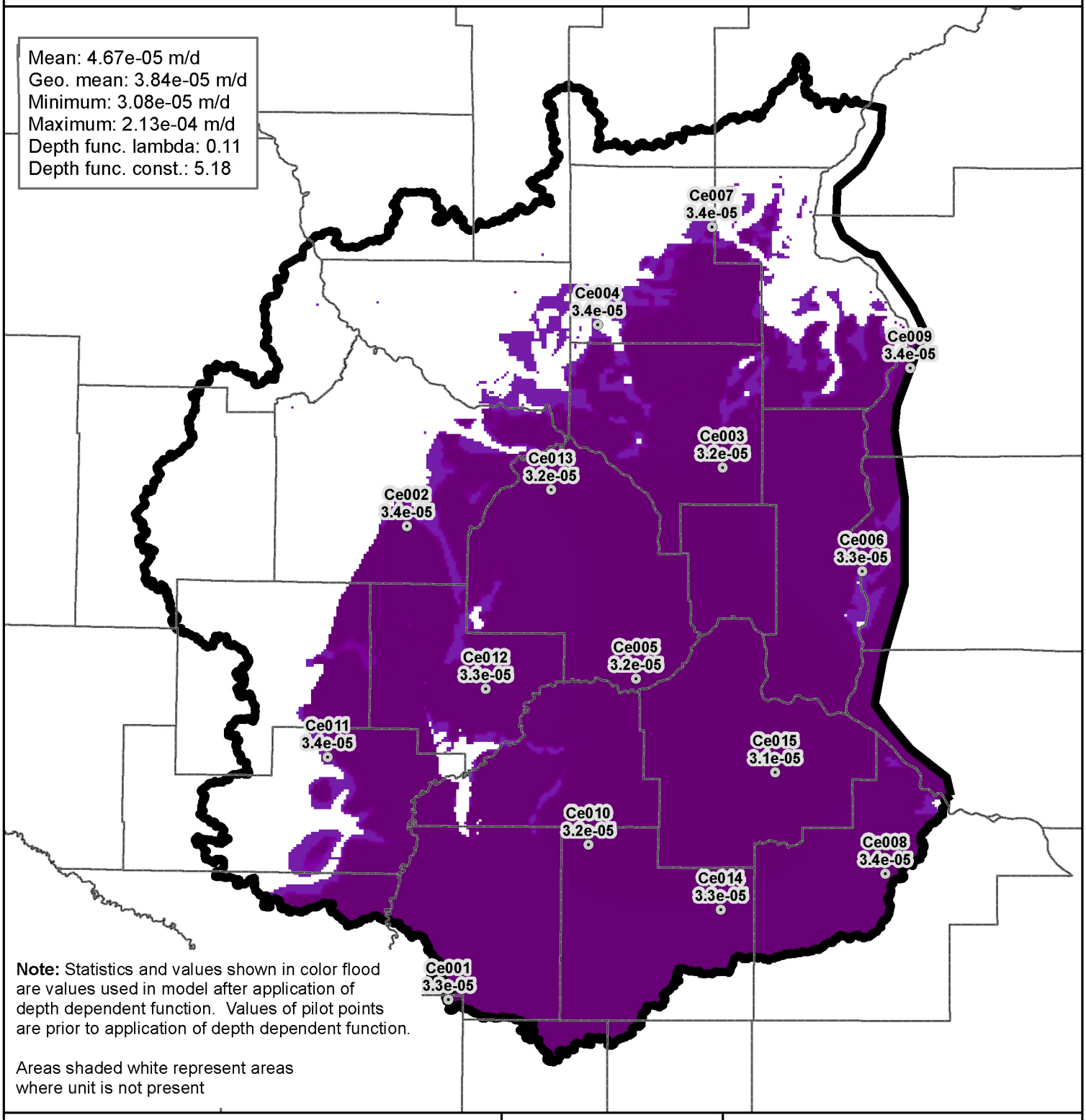
0 10 20
Miles

0 15 30
Kilometers

Figure 60
Horizontal Hydraulic Conductivity
Wonewoc Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Ce.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

0 10 20
Miles

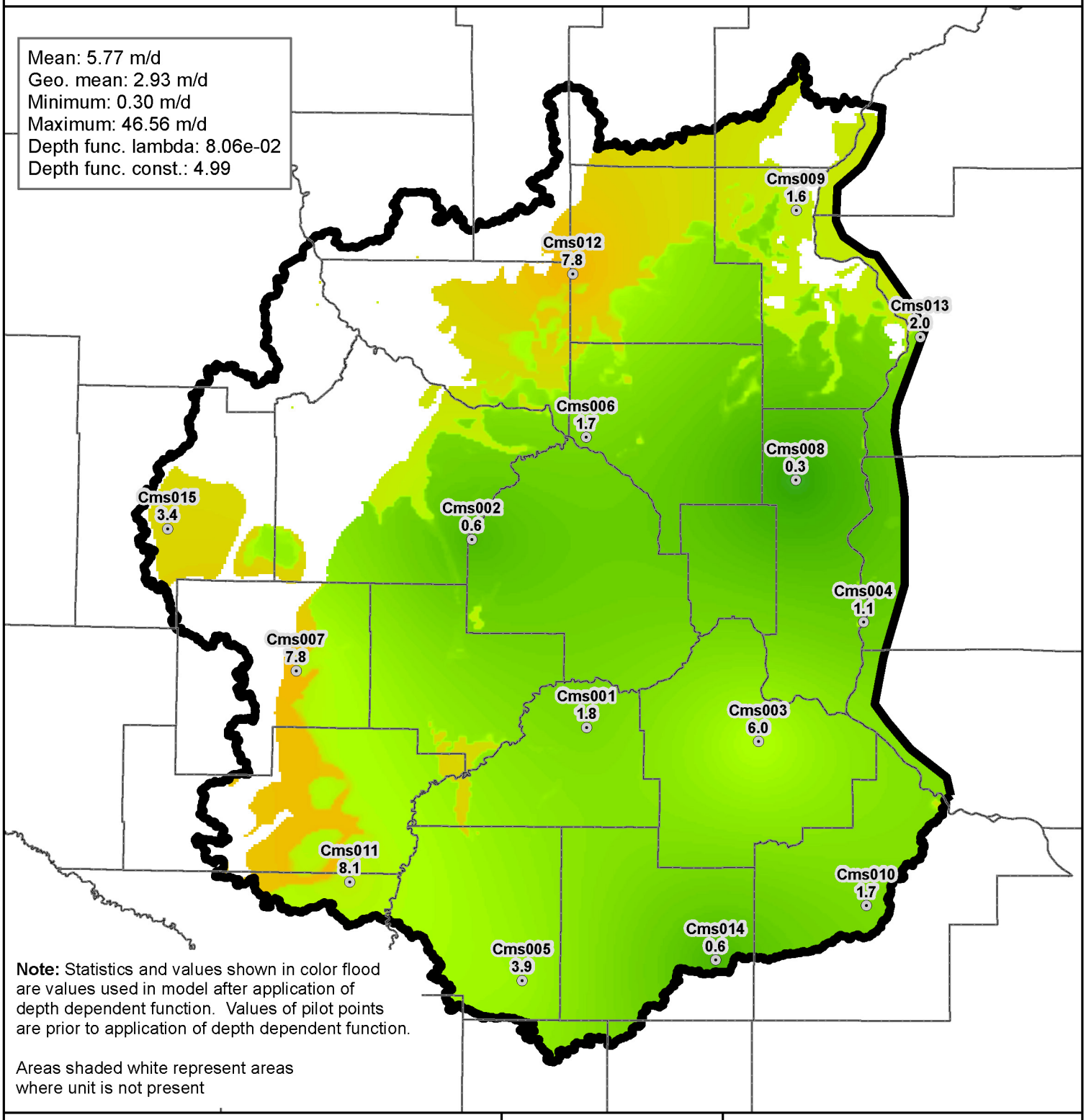
0 15 30
Kilometers

Figure 61

Horizontal Hydraulic Conductivity
Eau Claire Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Cms.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

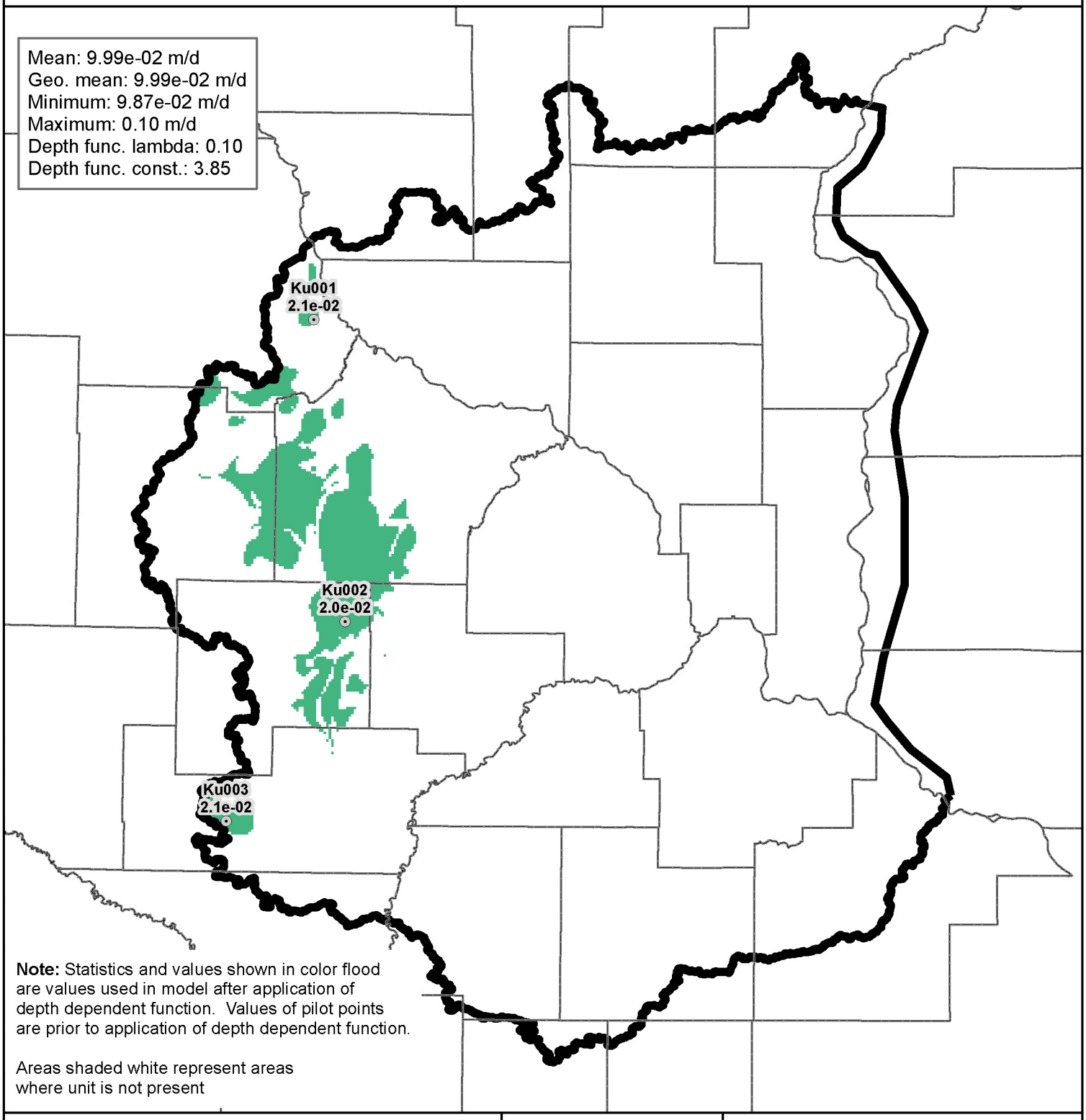
0 10 20
Miles

0 15 30
Kilometers

Figure 62
Horizontal Hydraulic Conductivity
Mount Simon and
Hinckley Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

0 10 20
Miles

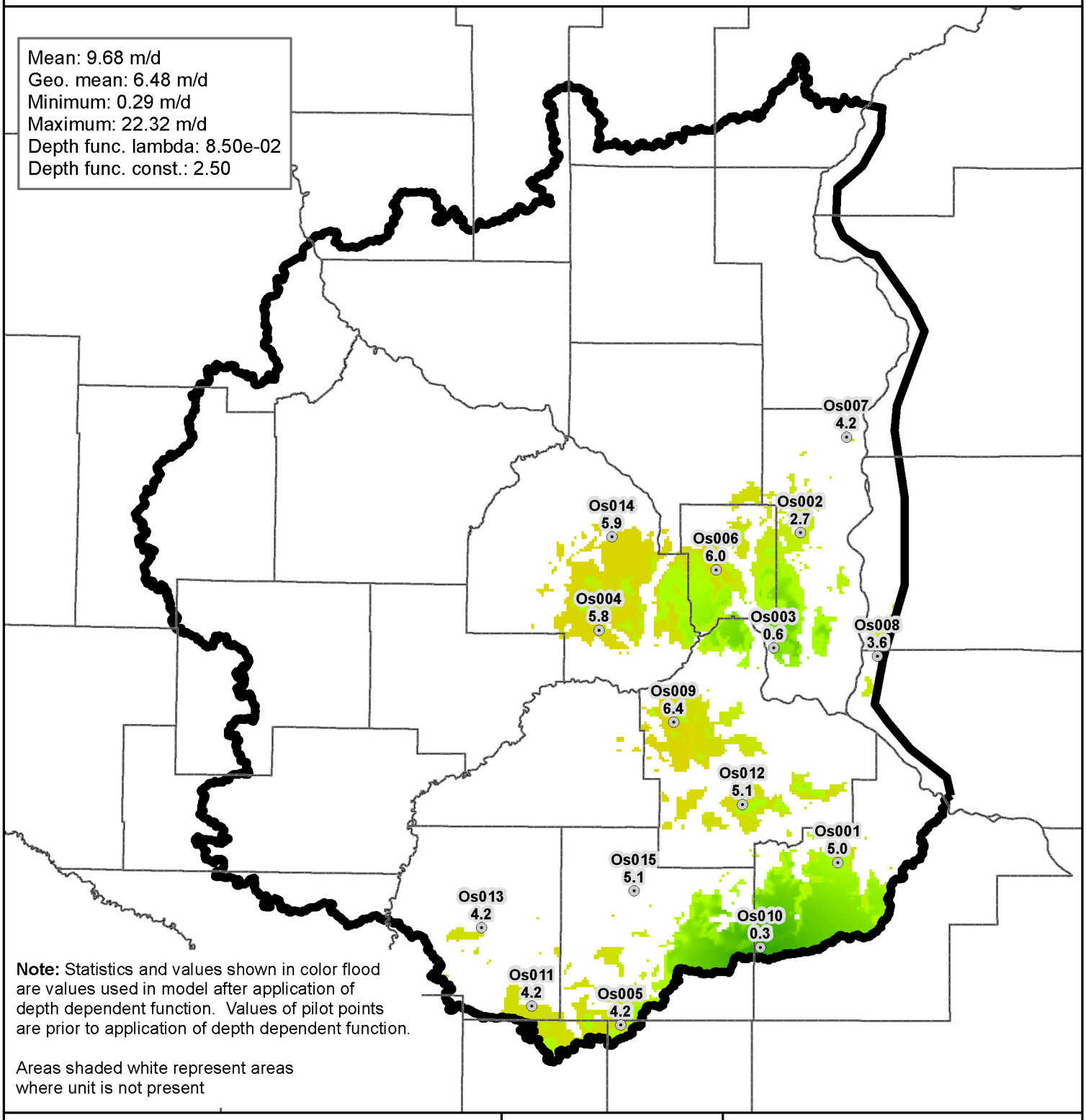
0 15 30
Kilometers

Figure 63

Vertical Hydraulic Conductivity
Cretaceous and/or
unnamed Paleozoic

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Ku.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Model Boundary

County Boundary

Pilot Point *Name K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

0 10 20
Miles

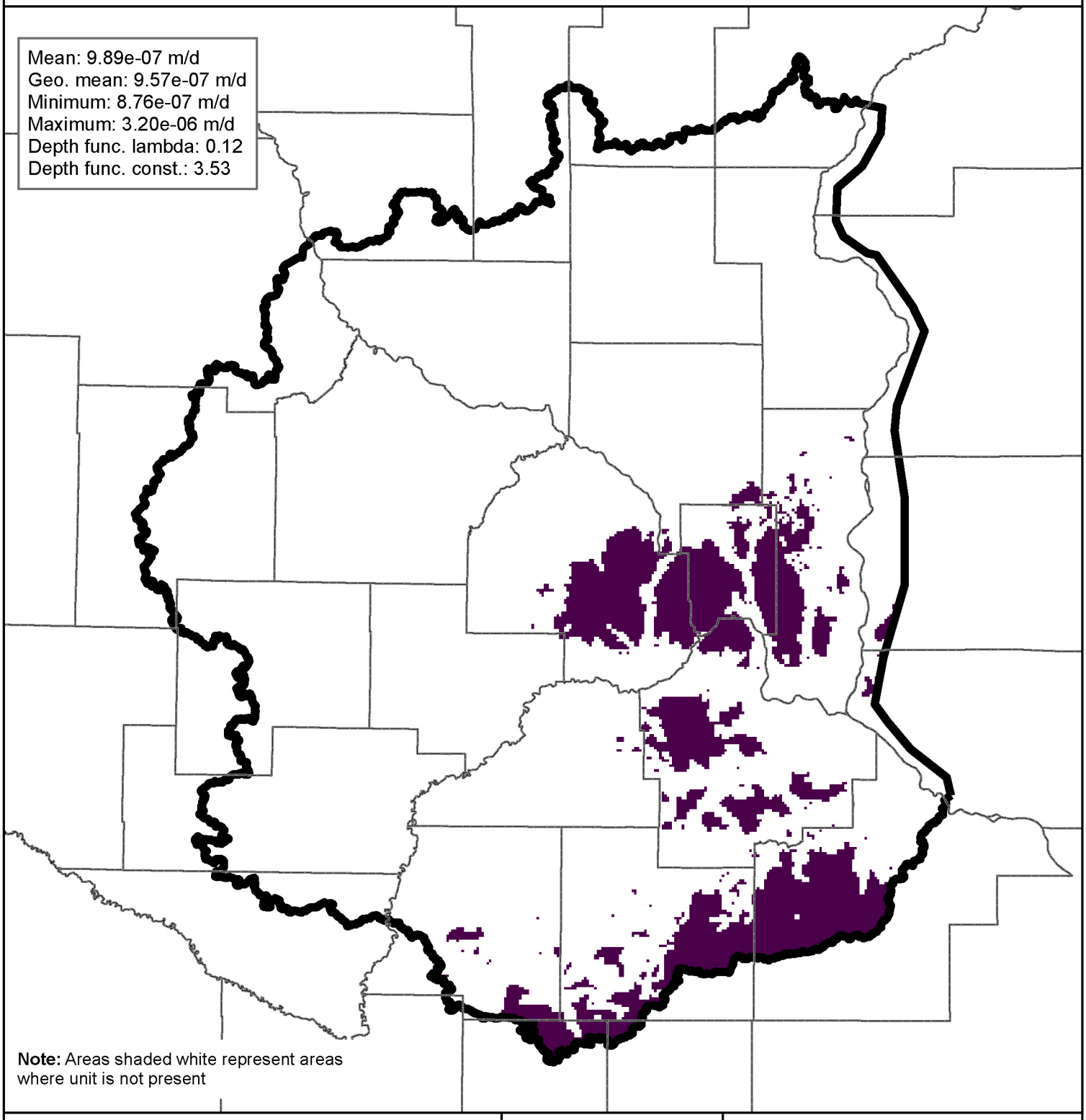
0 15 30
Kilometers

Figure 64
Vertical Hydraulic Conductivity
St. Peter Sandstone

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Os.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Os_Quasi_3D.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

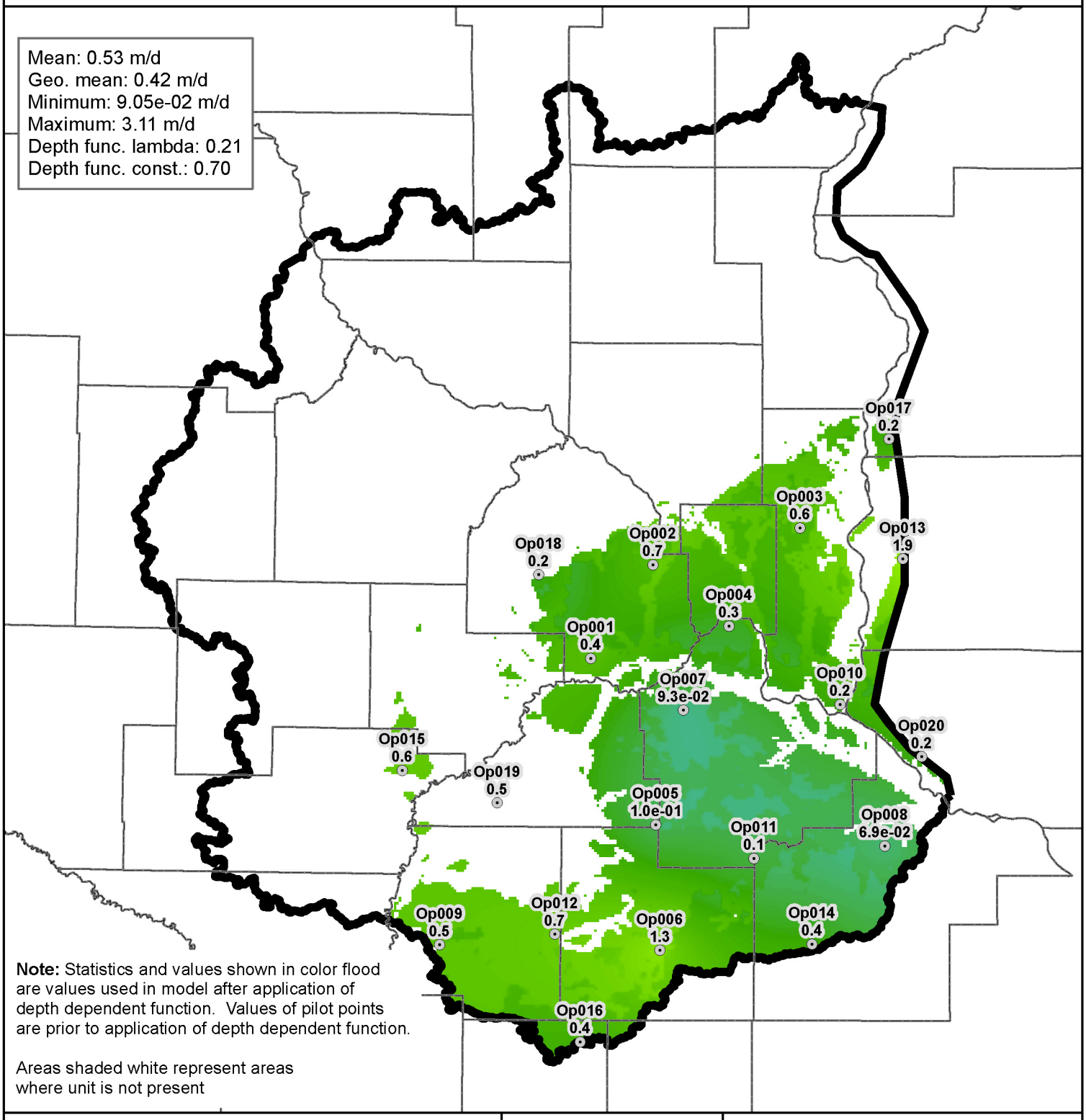
0 10 20
Miles

0 15 30
Kilometers

Figure 65
Vertical Hydraulic Conductivity
St. Peter Sandstone
Quasi-3D Confining Layer

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Op.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

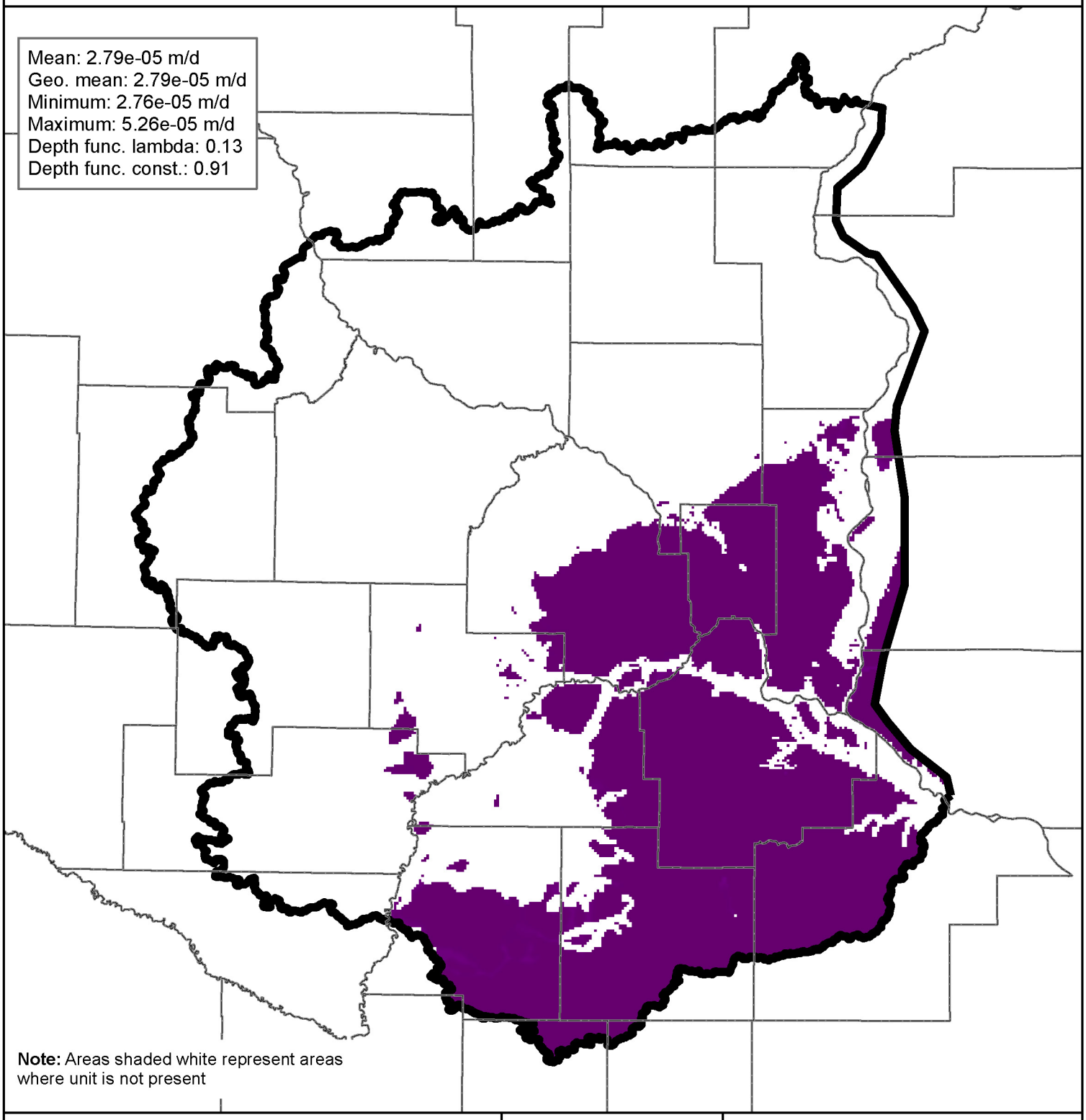
0 10 20
Miles

0 15 30
Kilometers

Figure 66
Vertical Hydraulic Conductivity
Prairie du Chein Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Op_Quasi_3D.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

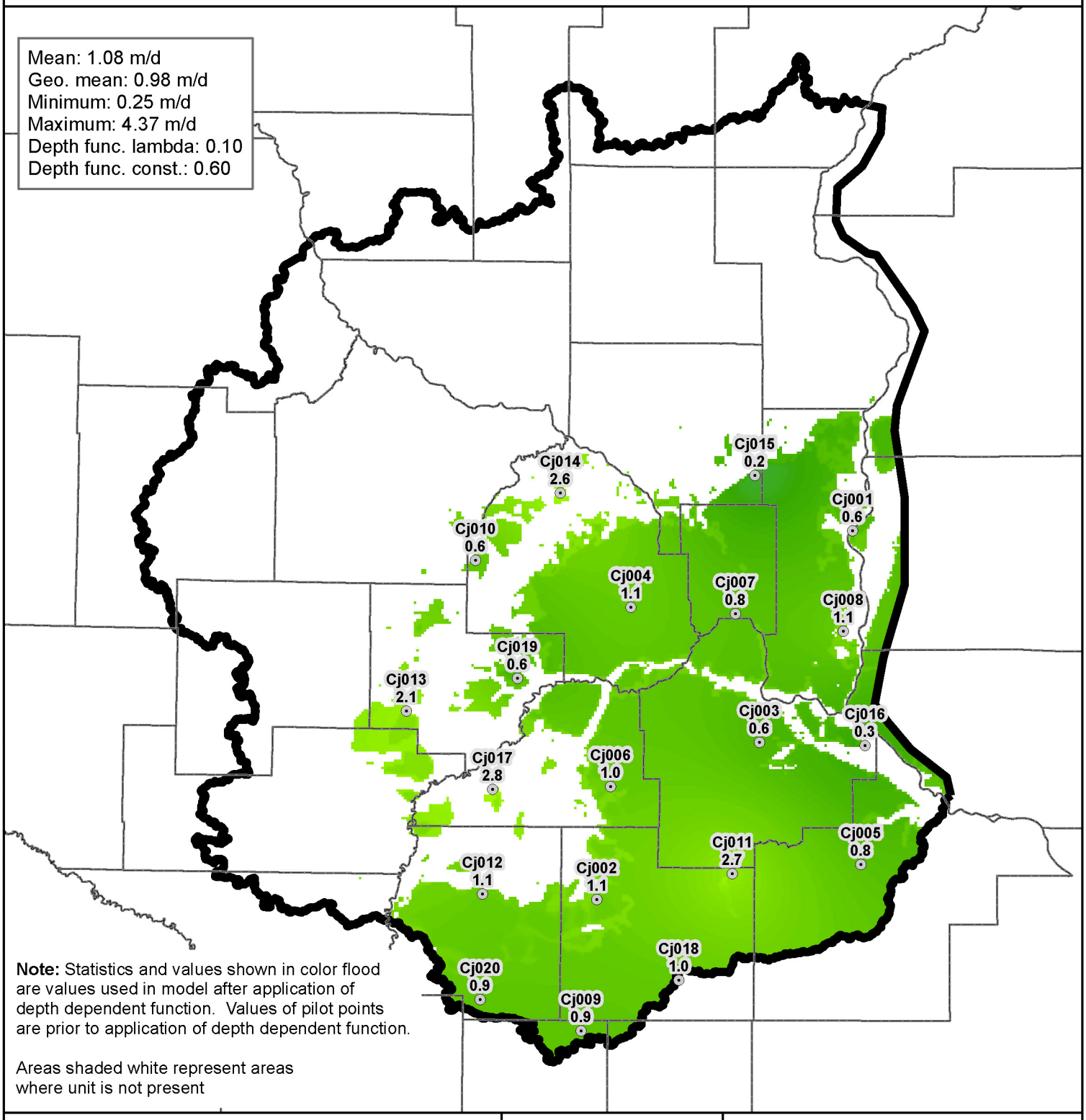
0 10 20
Miles

0 15 30
Kilometers

Figure 67
Vertical Hydraulic Conductivity
Prairie du Chien Group
Quasi-3D Confining Layer

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Cj.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

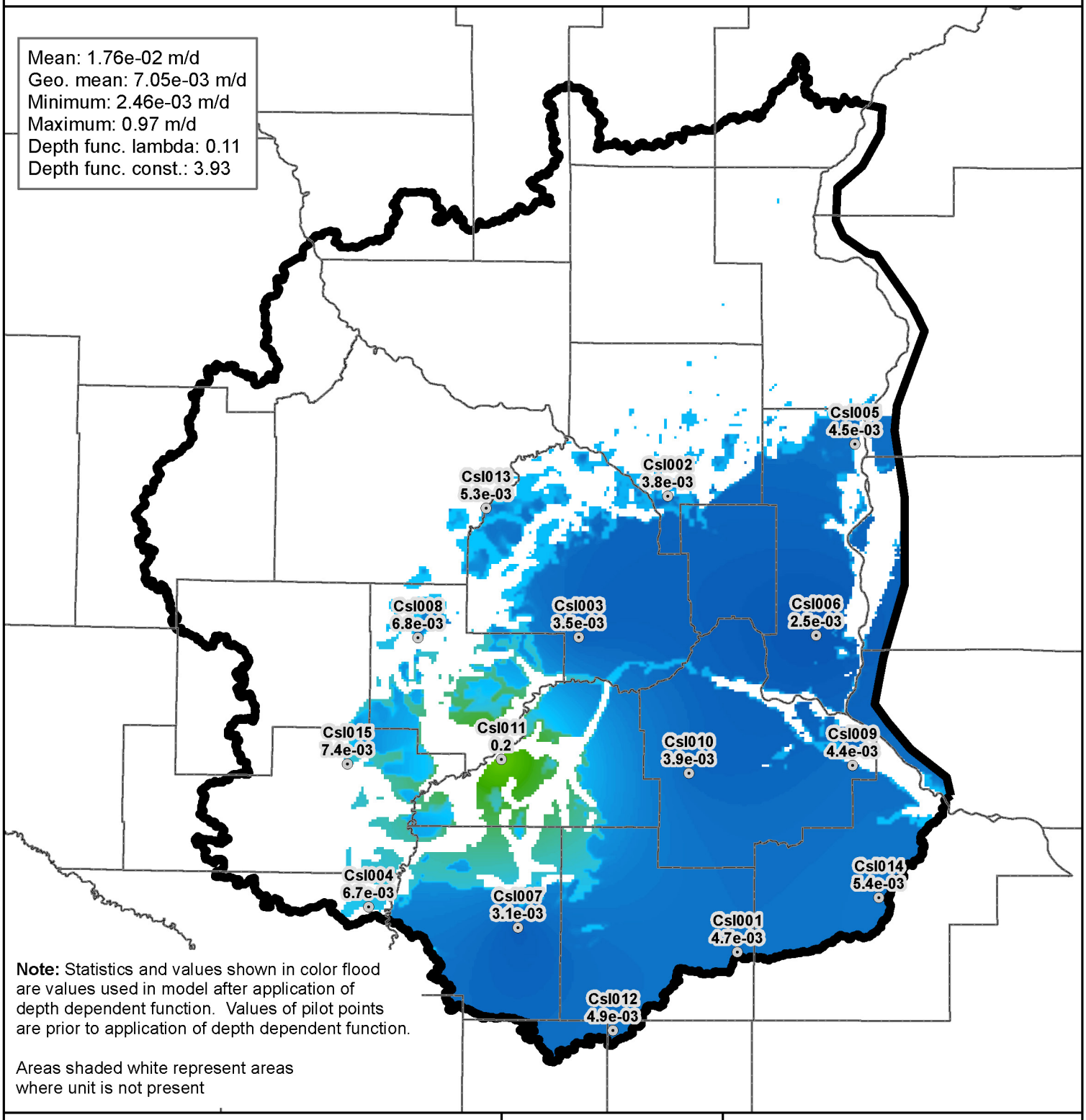
0 10 20
Miles

0 15 30
Kilometers

Figure 68
Vertical Hydraulic Conductivity
Jordan Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Csl.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

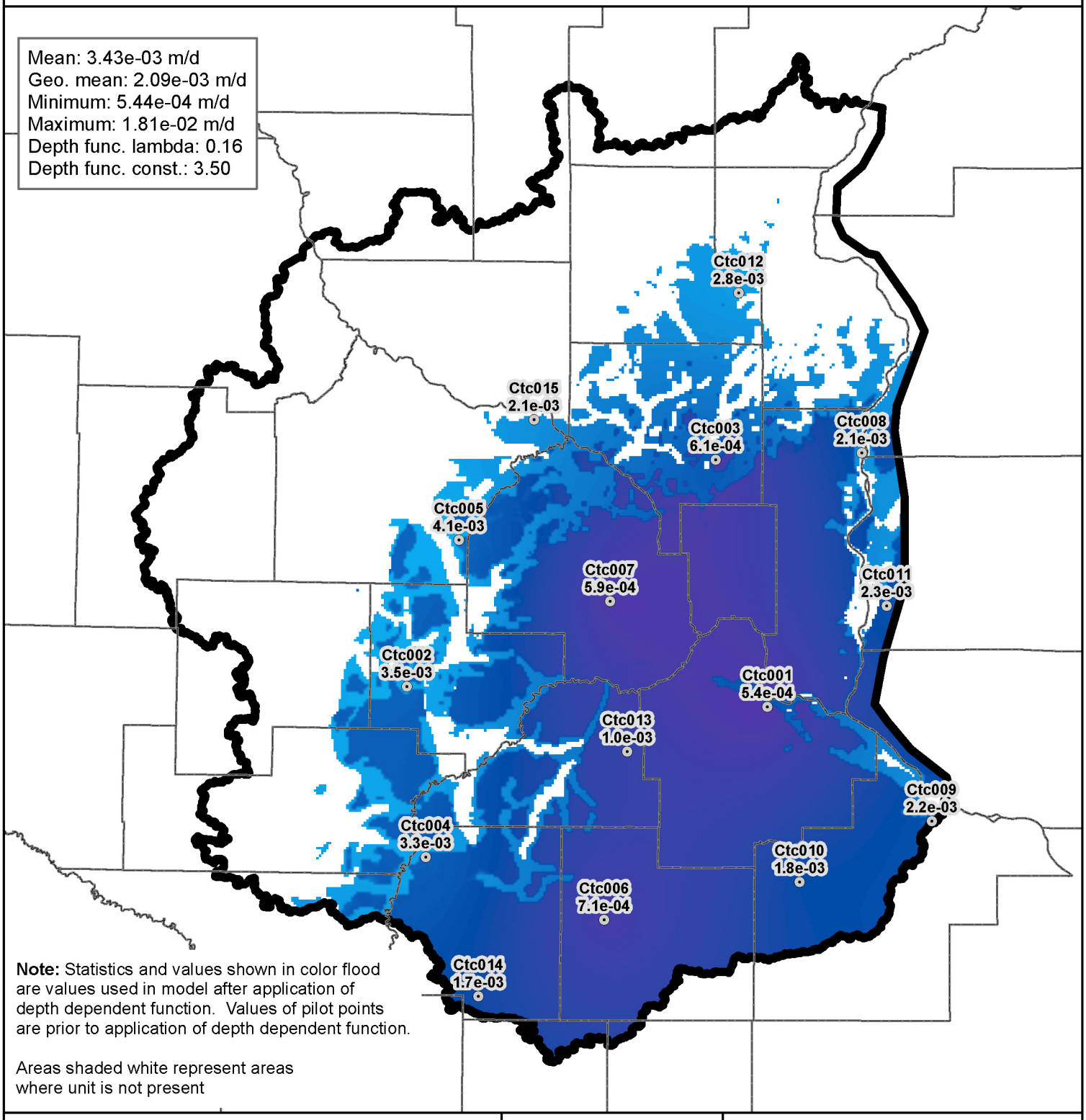
0 10 20
Miles

0 15 30
Kilometers

Figure 69
Vertical Hydraulic Conductivity
St. Lawrence Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Ctc.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

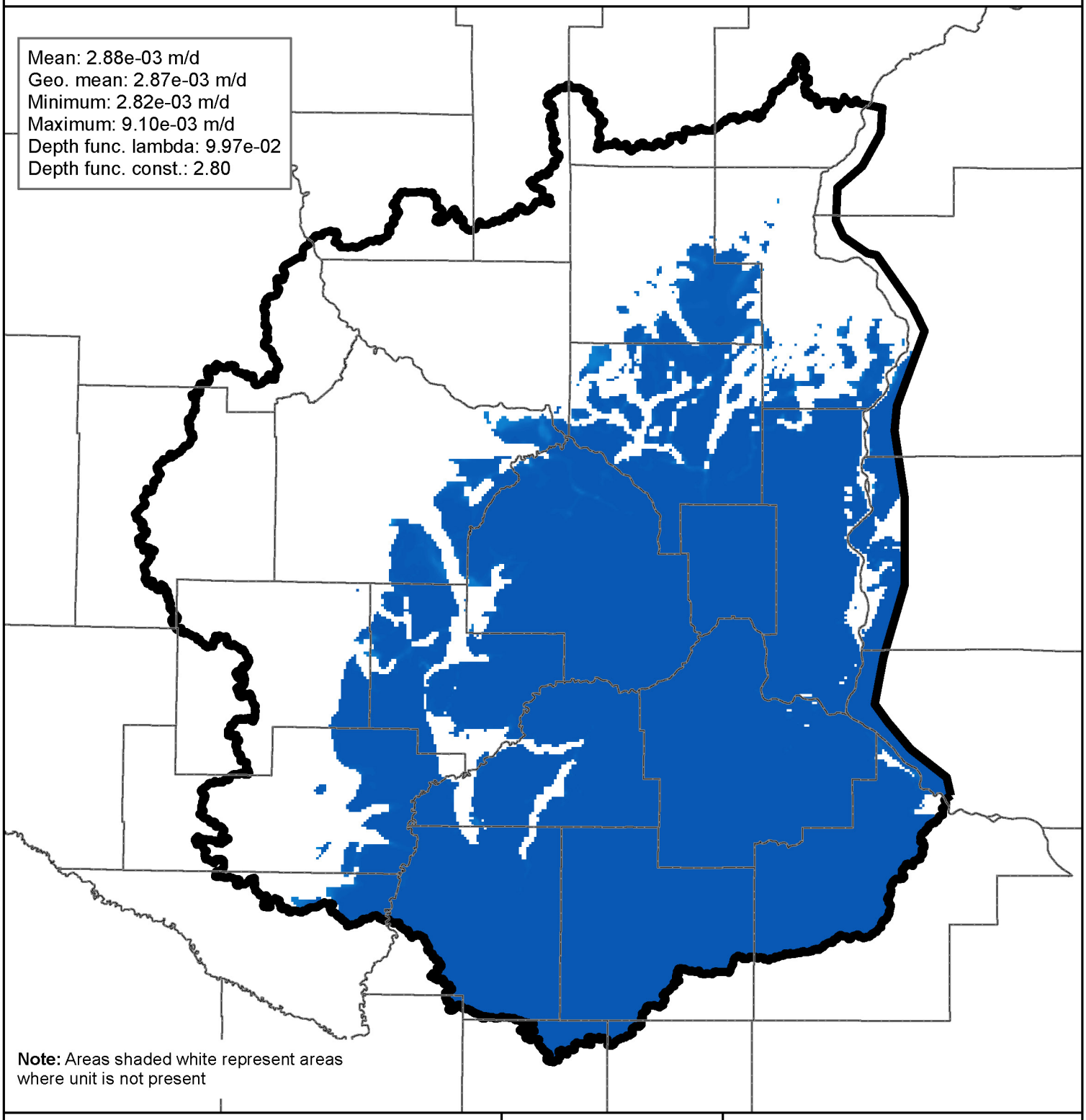
0 10 20
Miles

0 15 30
Kilometers

Figure 70
Vertical Hydraulic Conductivity
Tunnel City Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Ctc_Quasi_3D.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

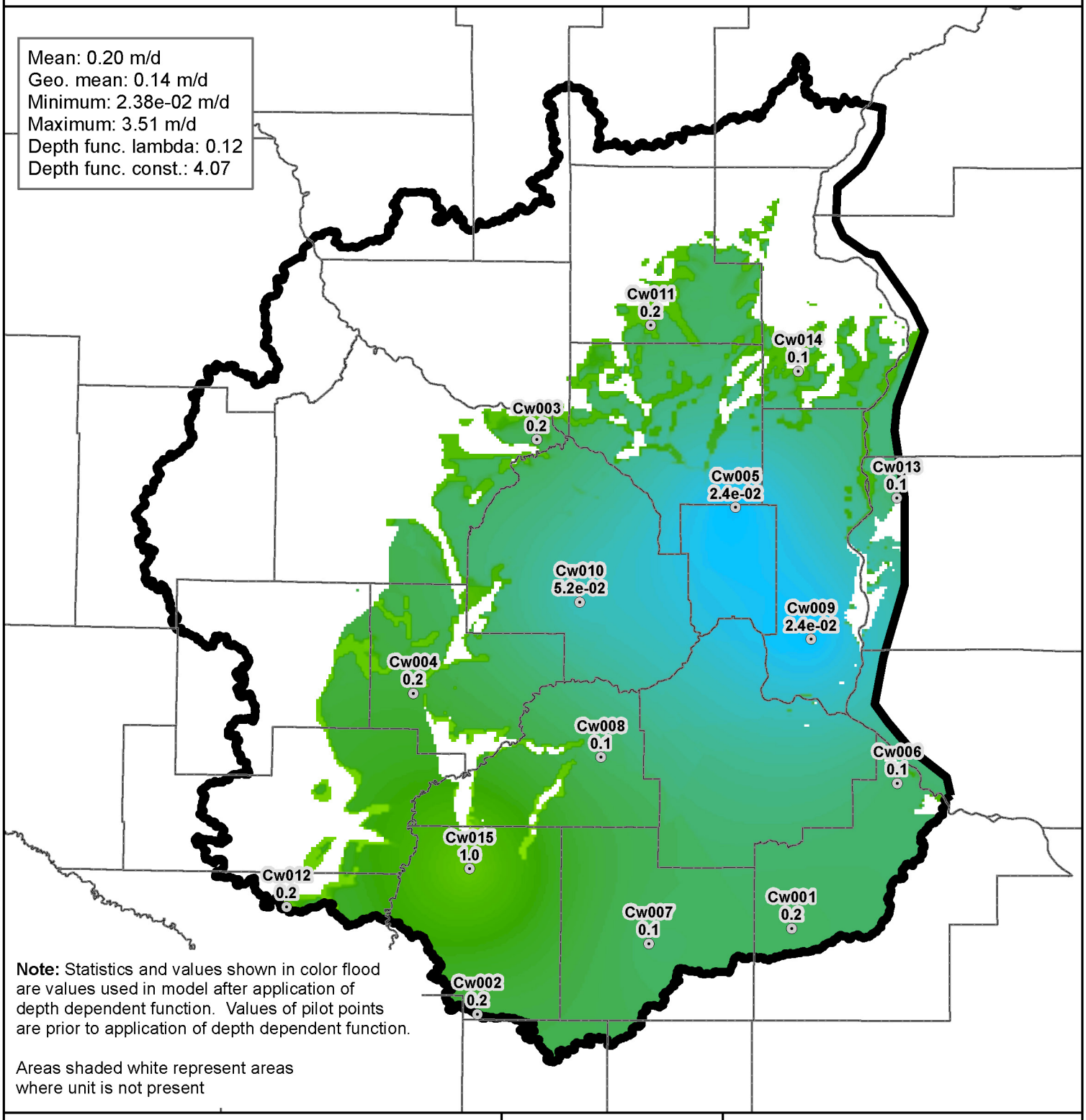
0 10 20
Miles

0 15 30
Kilometers

Figure 71
Vertical Hydraulic Conductivity
Tunnel City Group
Quasi-3D Confining Layer

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Cw.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

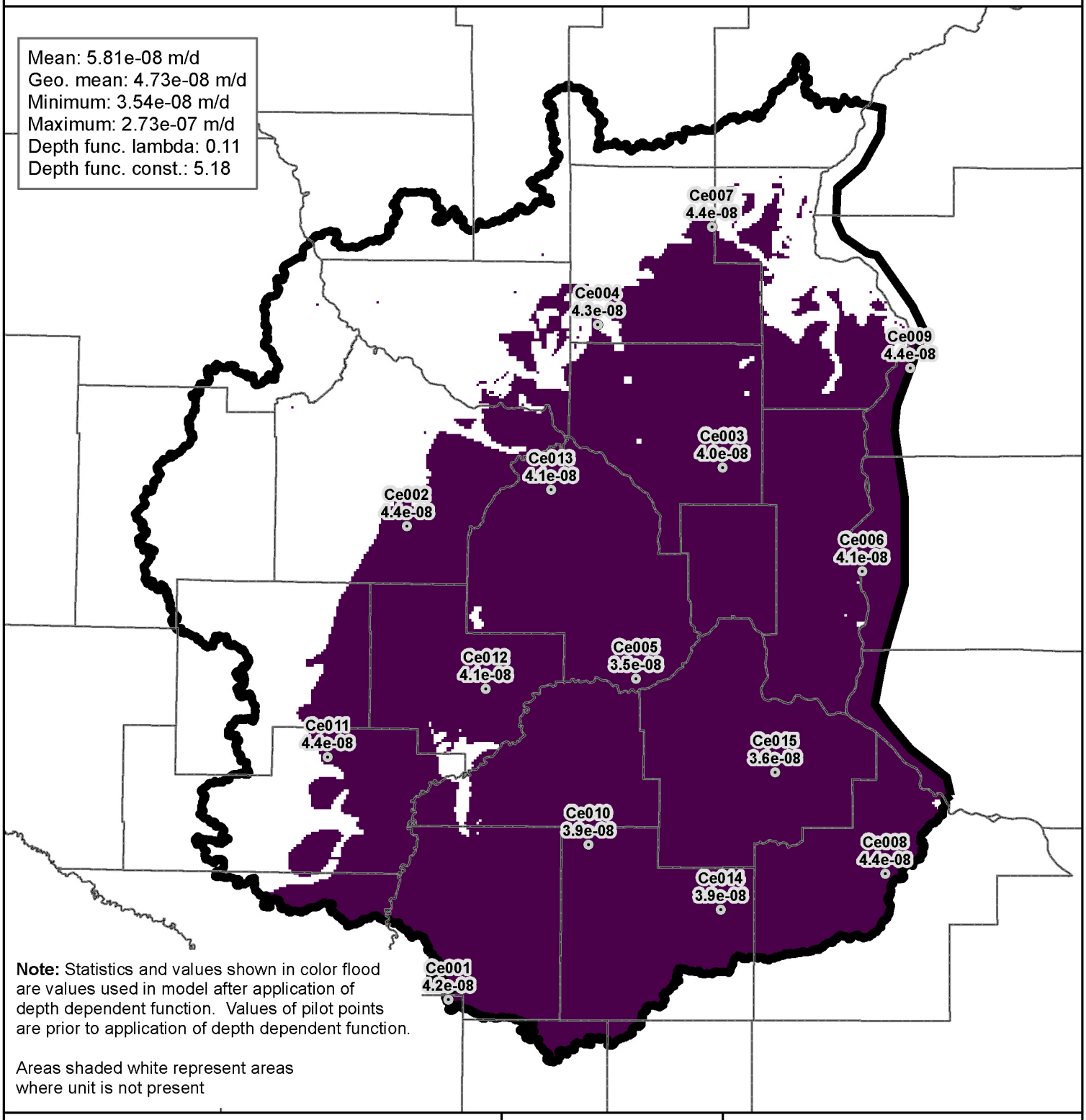
0 10 20
Miles

0 15 30
Kilometers

Figure 72
Vertical Hydraulic Conductivity
Wonewoc Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Statistics and values shown in color flood are values used in model after application of depth dependent function. Values of pilot points are prior to application of depth dependent function.

Areas shaded white represent areas where unit is not present

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Ce.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

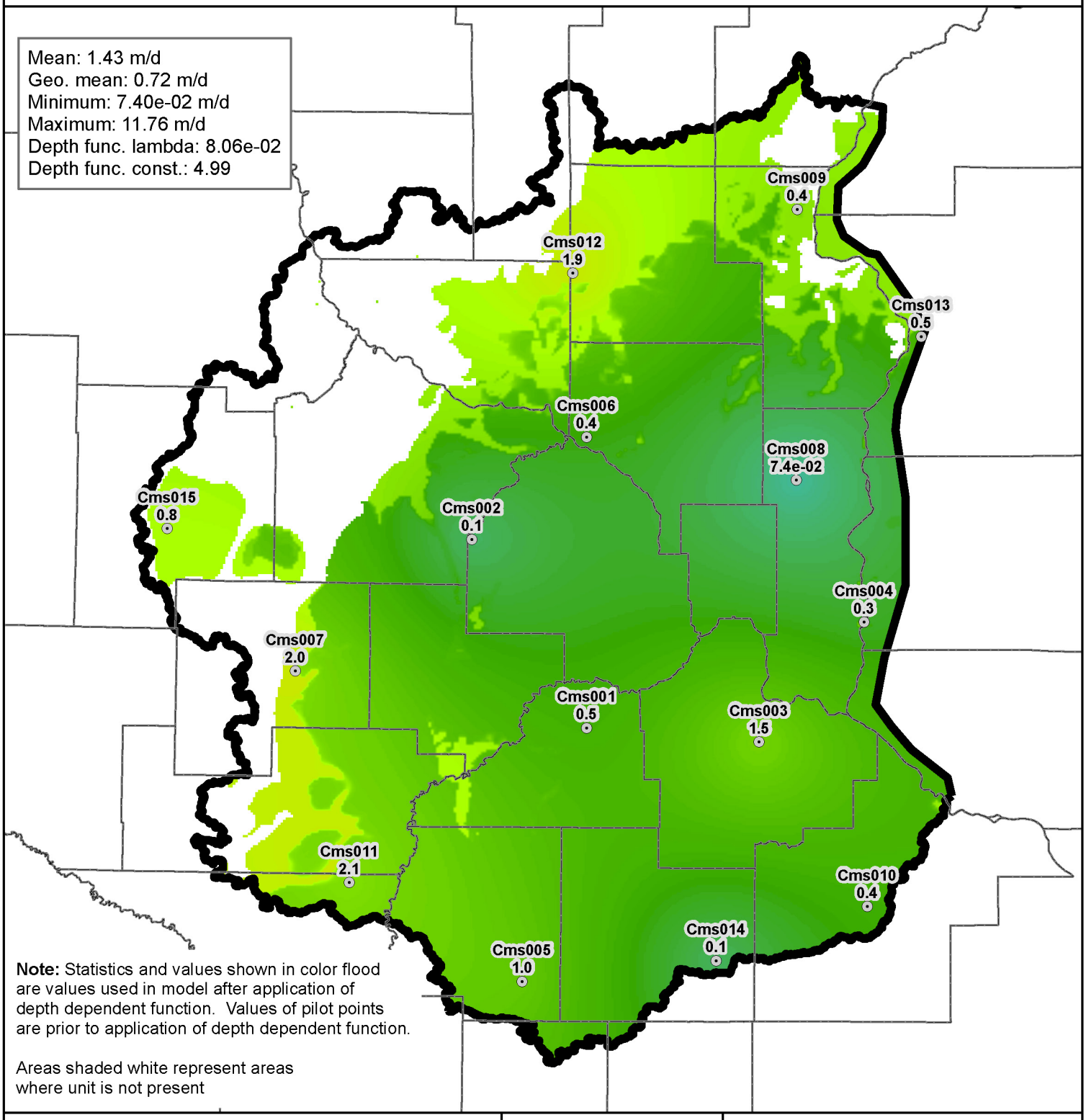
N

0 10 20
Miles

0 15 30
Kilometers

Figure 73
Vertical Hydraulic Conductivity
Eau Claire Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Cms.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *K (m/d)*

K (m/day)
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

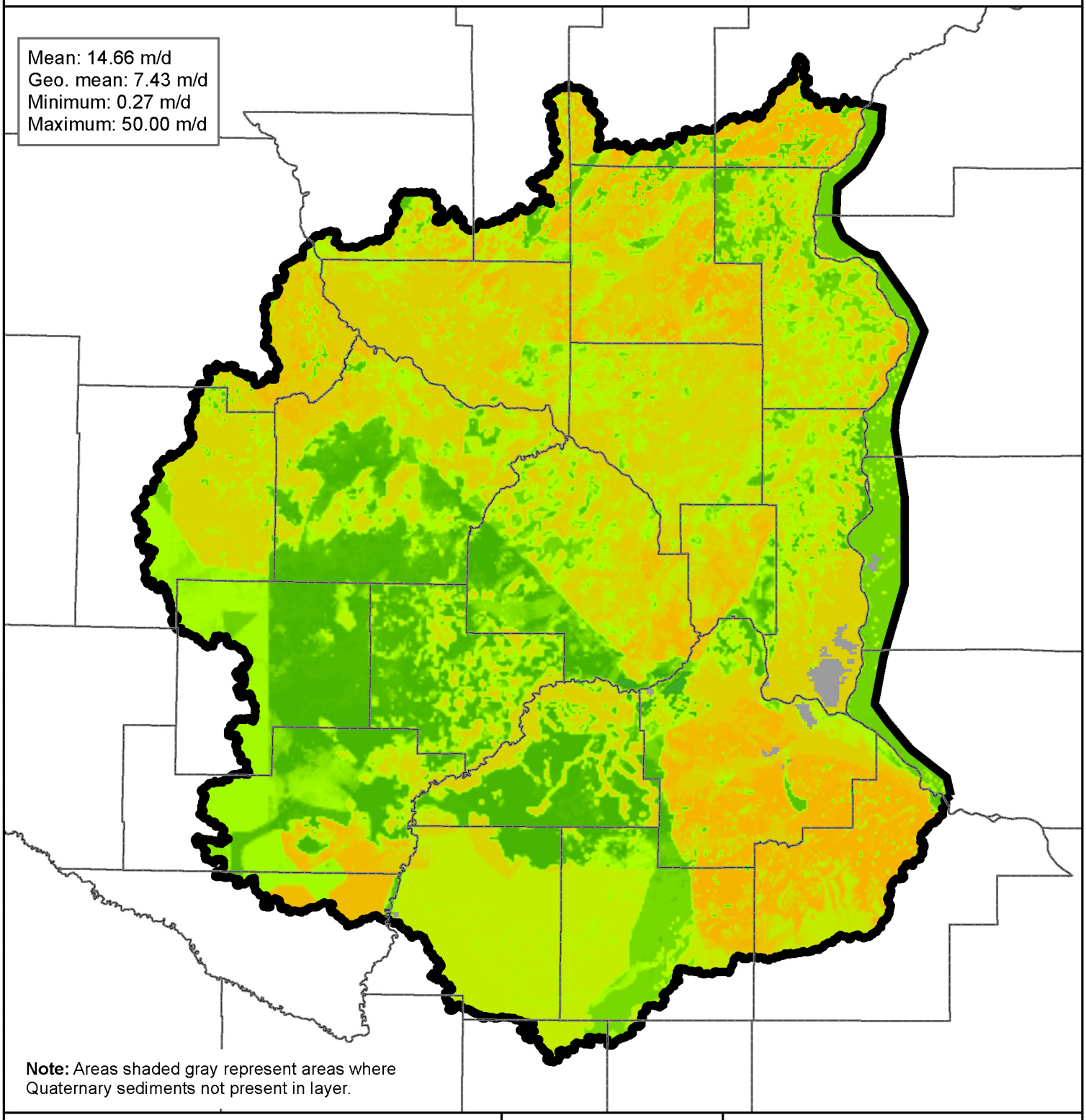
0 10 20
Miles

0 15 30
Kilometers

Figure 74
Vertical Hydraulic Conductivity
Mt. Simon and
Hinckley Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer1.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

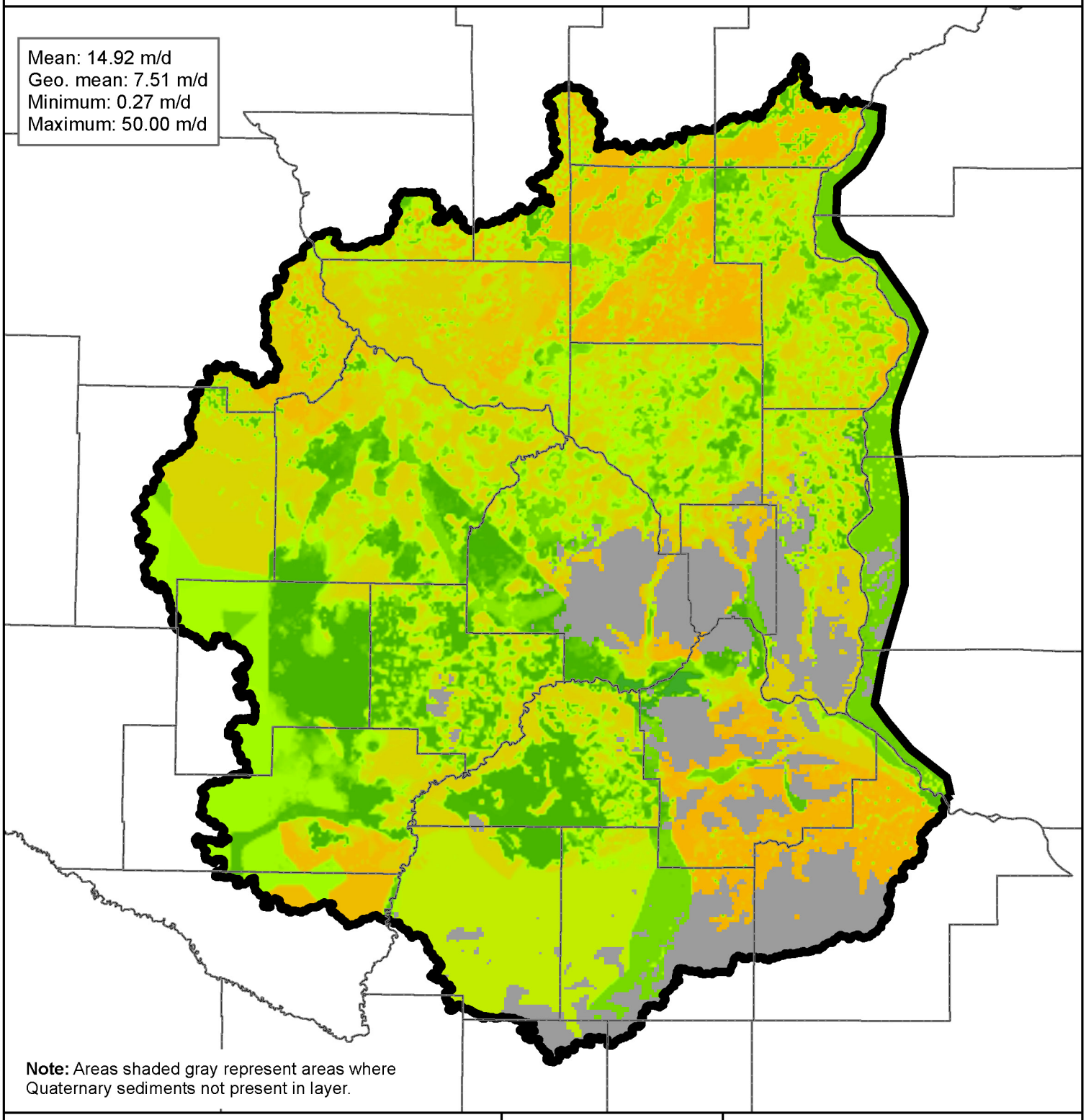
0 10 20
Miles

0 15 30
Kilometers

Figure 75
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 1

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer2.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

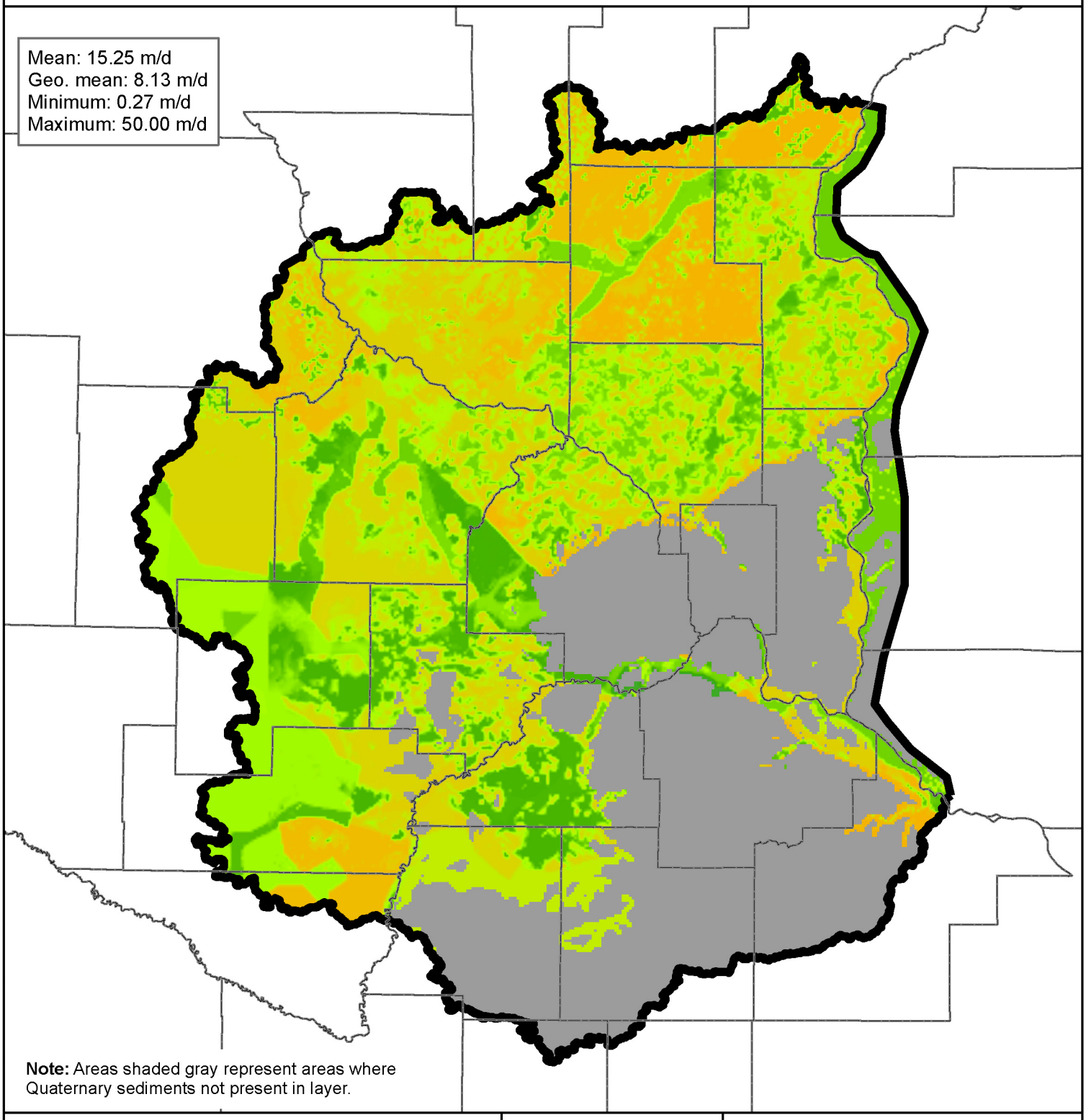
0 10 20
Miles

0 15 30
Kilometers

Figure 76
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 2

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer3.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

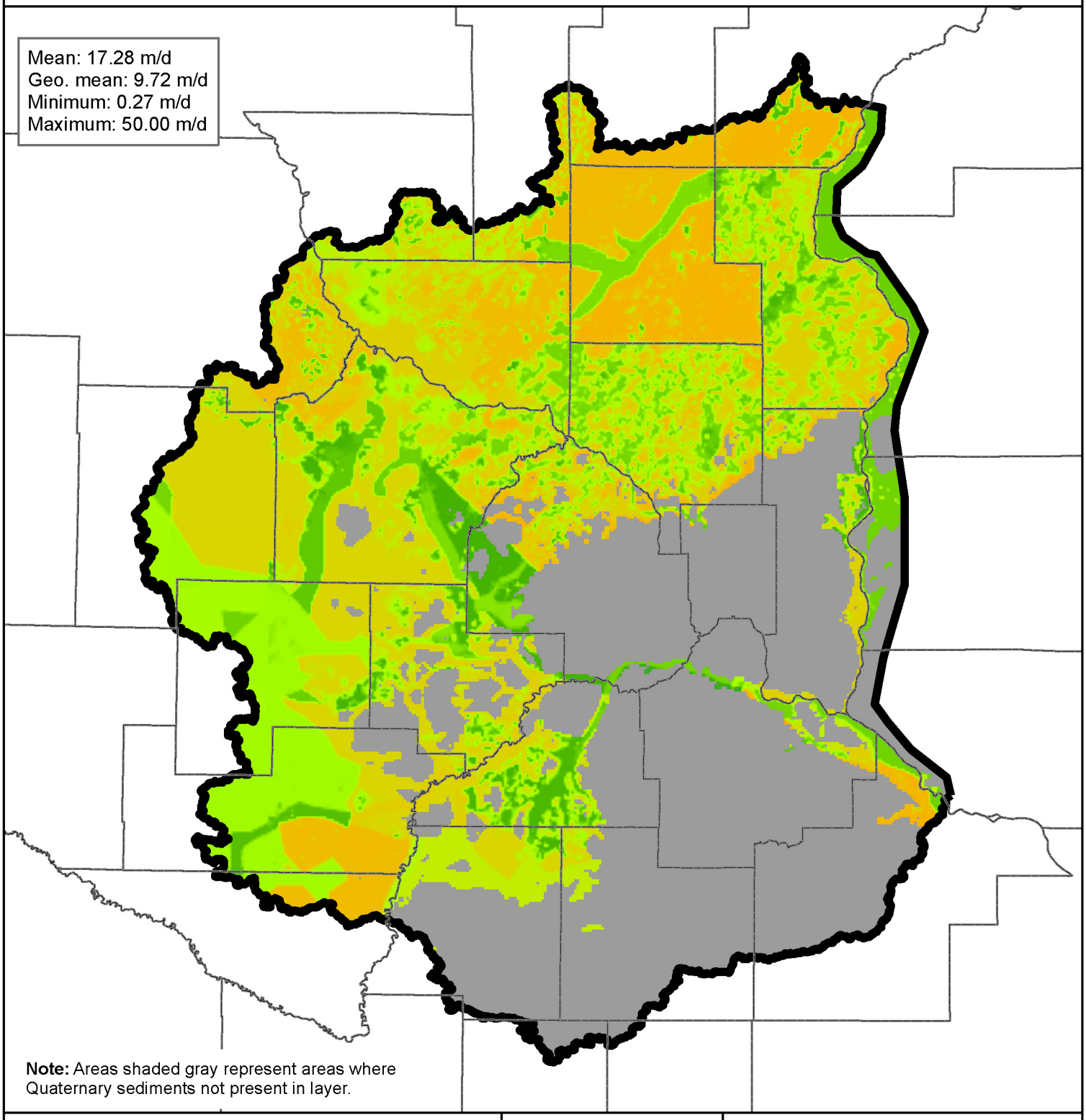
0 10 20
Miles

0 15 30
Kilometers

Figure 77
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 3

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer4.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

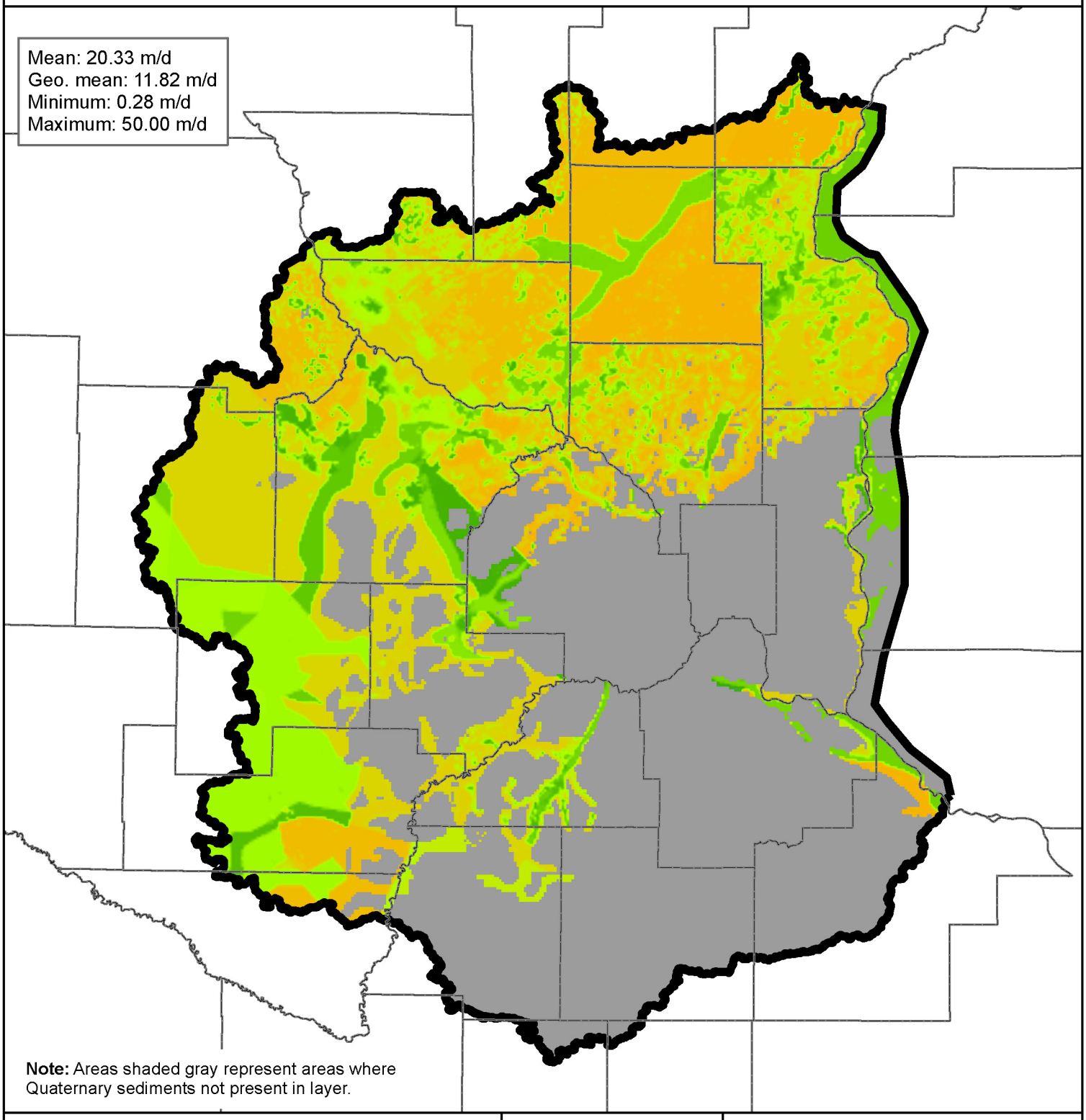
0 10 20
Miles

0 15 30
Kilometers

Figure 78
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 4

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer5.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

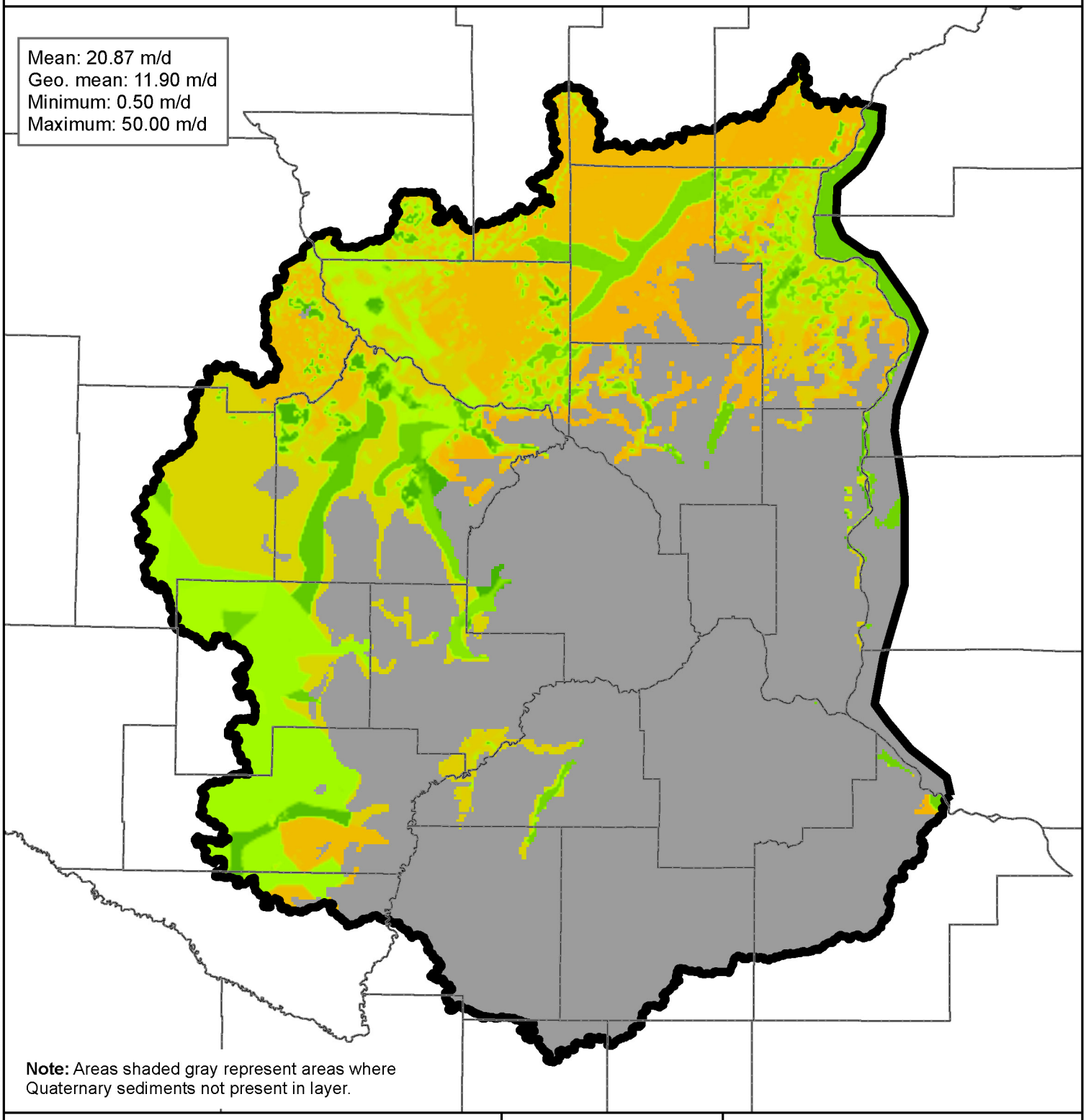
0 10 20
Miles

0 15 30
Kilometers

Figure 79
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 5

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer6.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

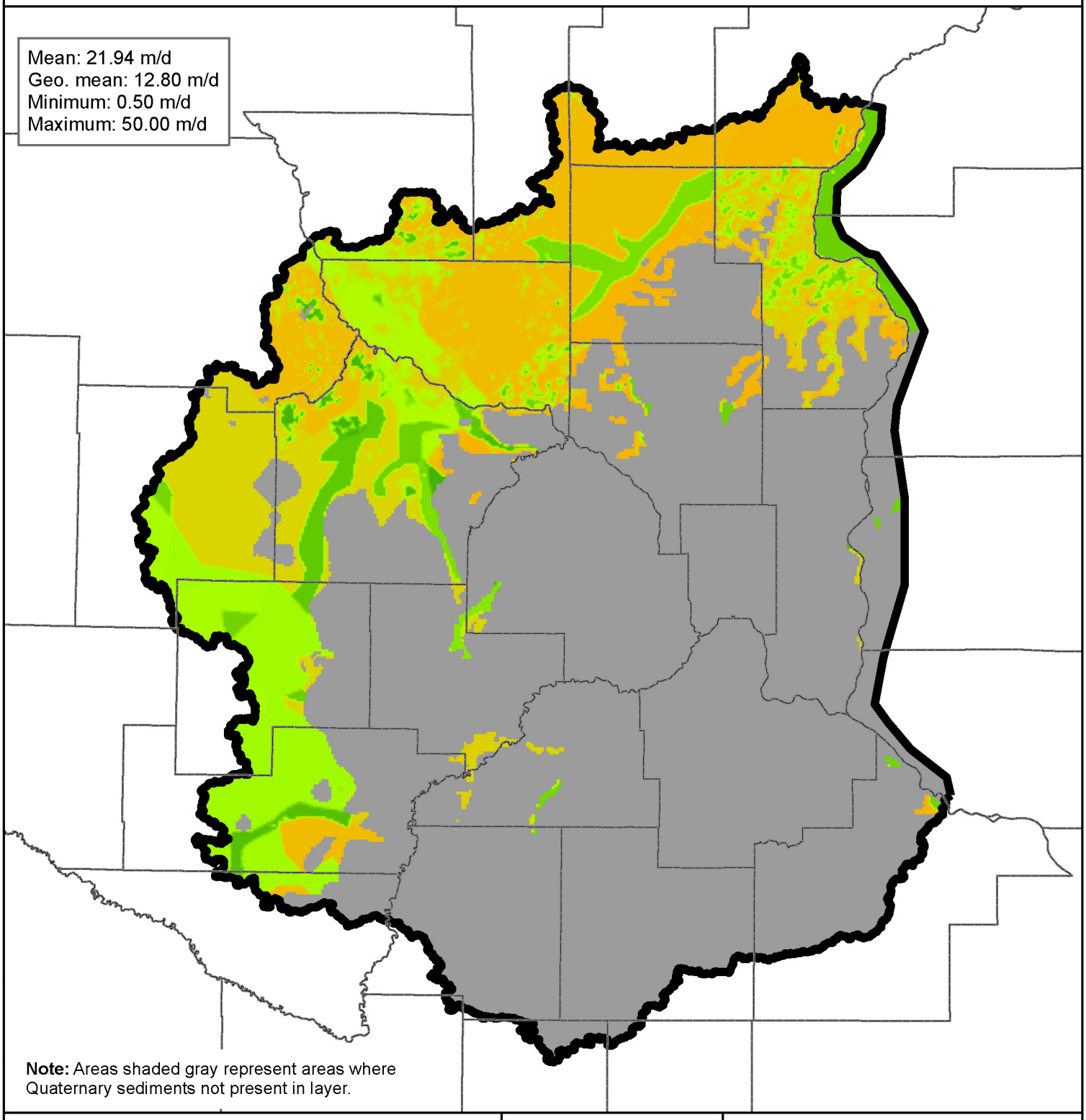
0 10 20
Miles

0 15 30
Kilometers

Figure 80
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 6

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer7.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

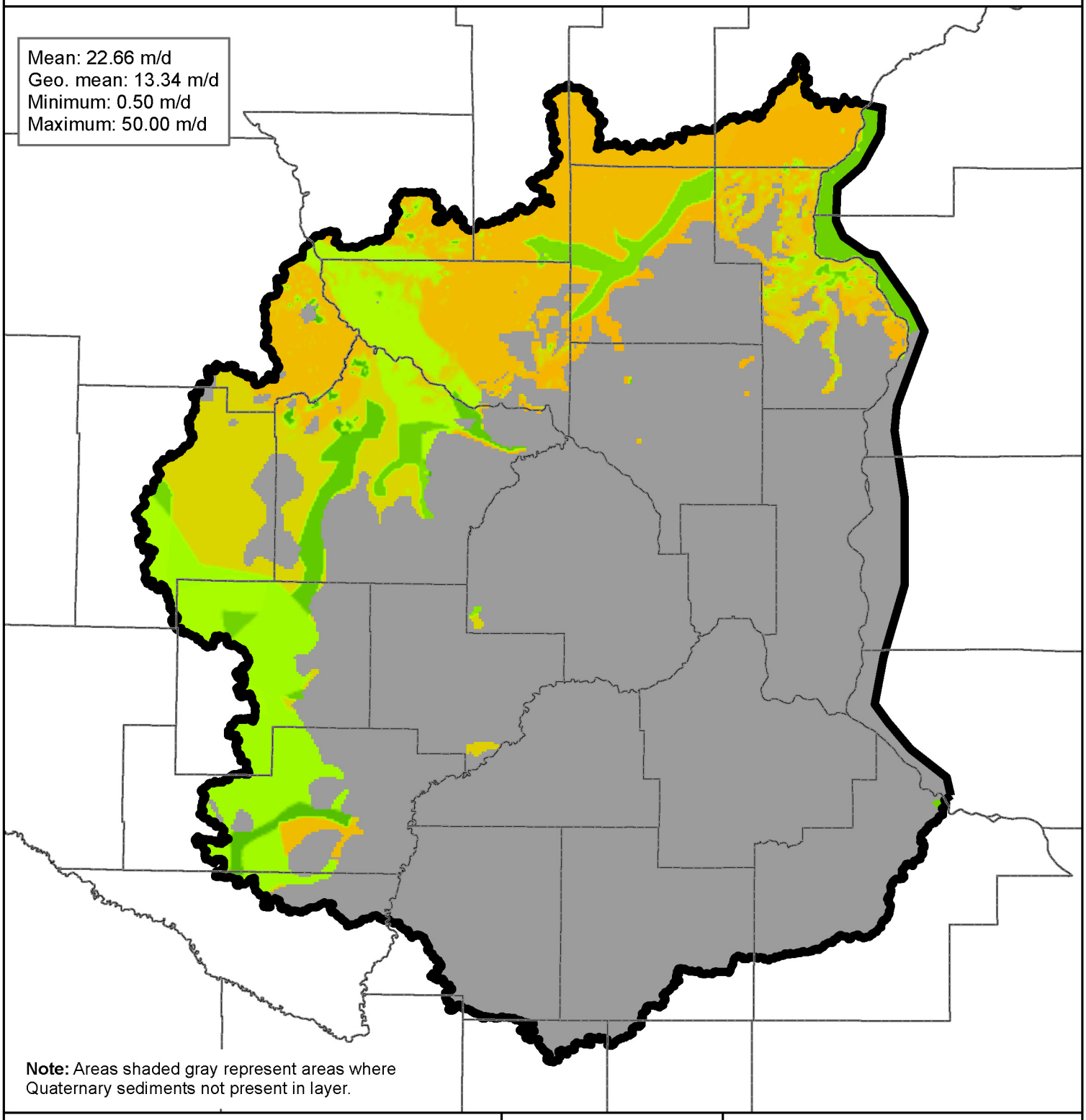
0 10 20
Miles

0 15 30
Kilometers

Figure 81
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 7

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer8.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

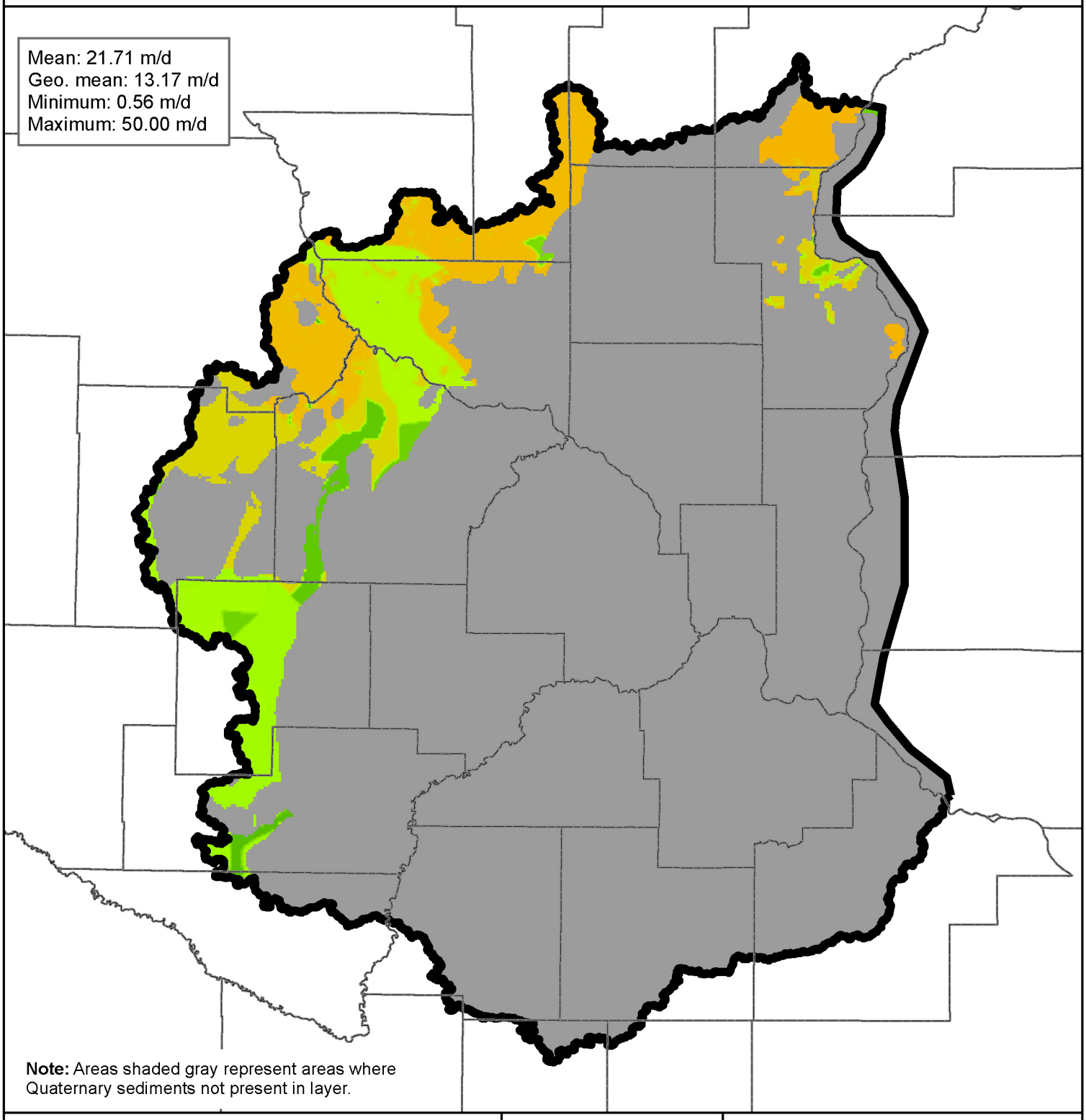
0 10 20
Miles

0 15 30
Kilometers

Figure 82
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 8

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Layer9.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

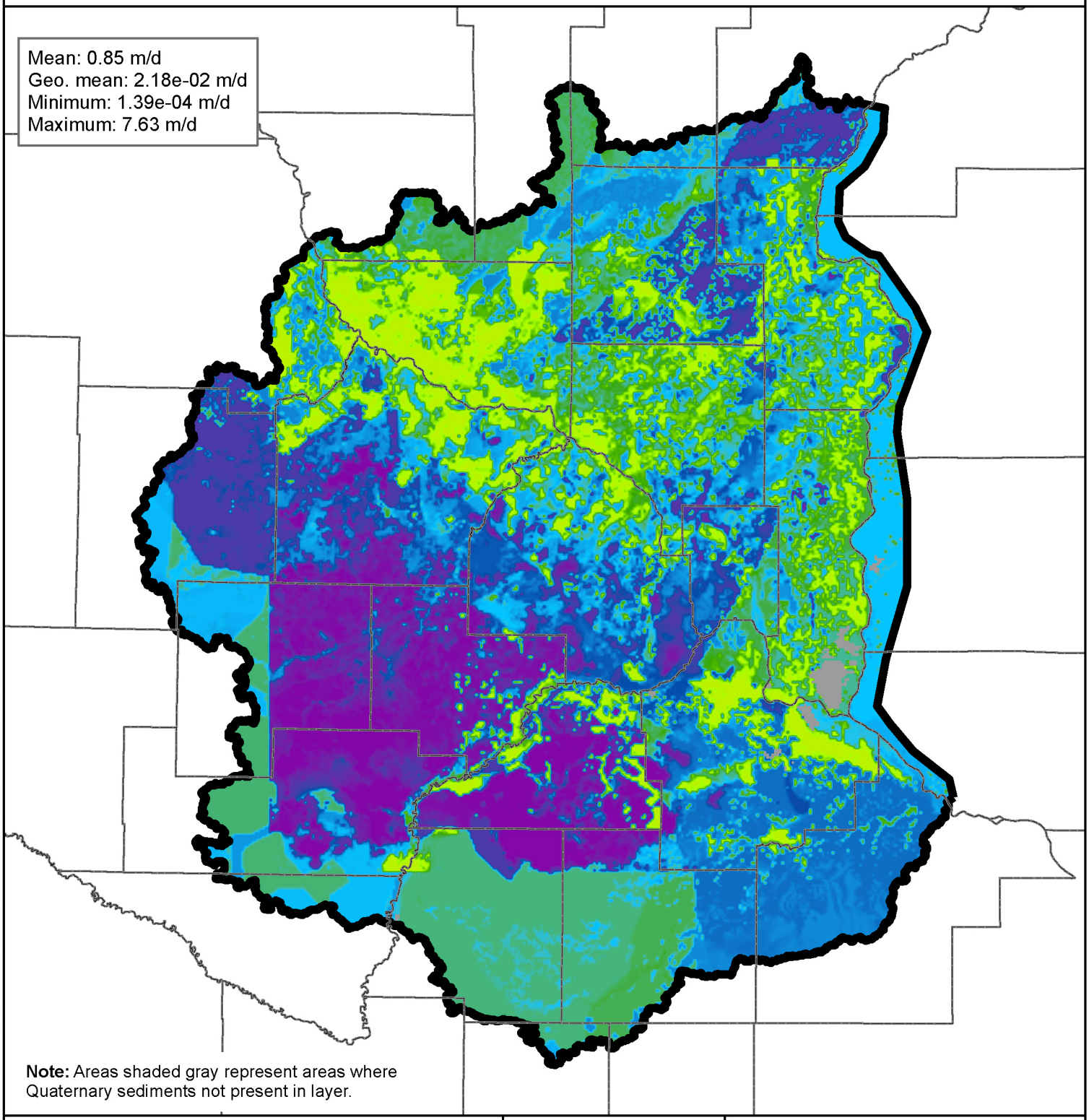
0 10 20
Miles

0 15 30
Kilometers

Figure 83
Horizontal Hydraulic Conductivity
Quaternary Sediments
Model Layer 9

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL

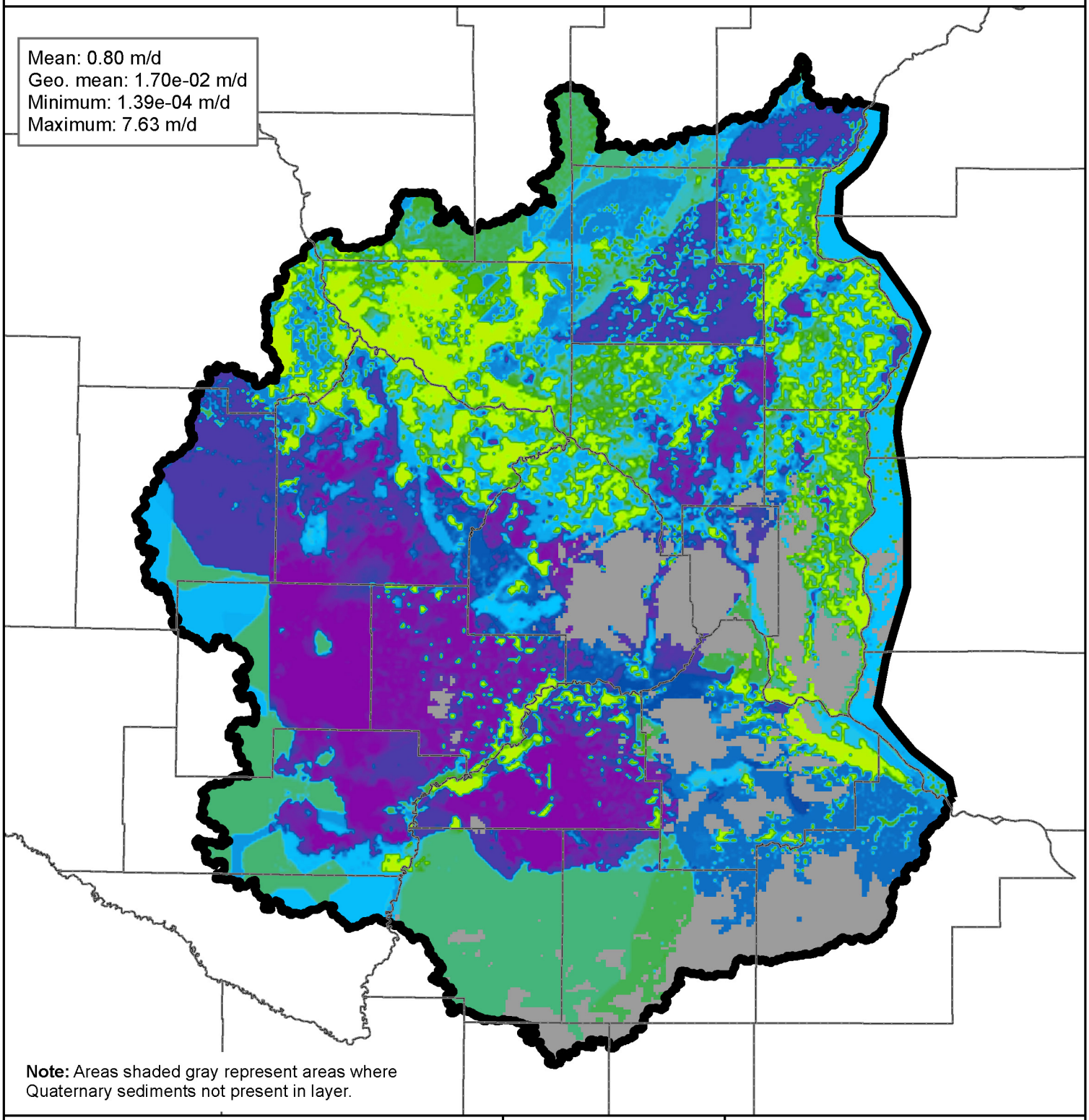


Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer1.mxd User: egc

Figure 84
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 1

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer2.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

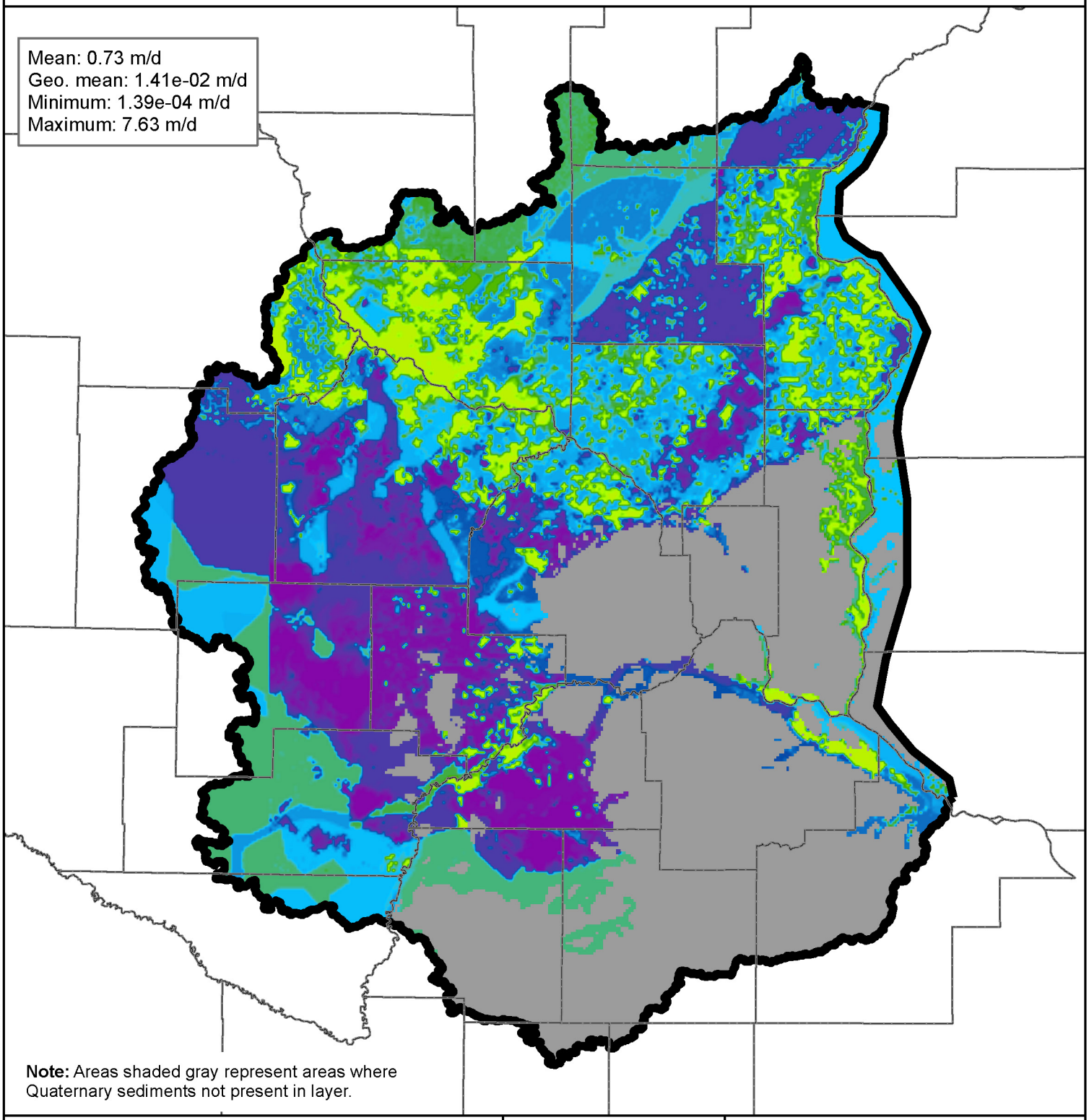
0 10 20
Miles

0 15 30
Kilometers

Figure 85
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 2

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer3.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

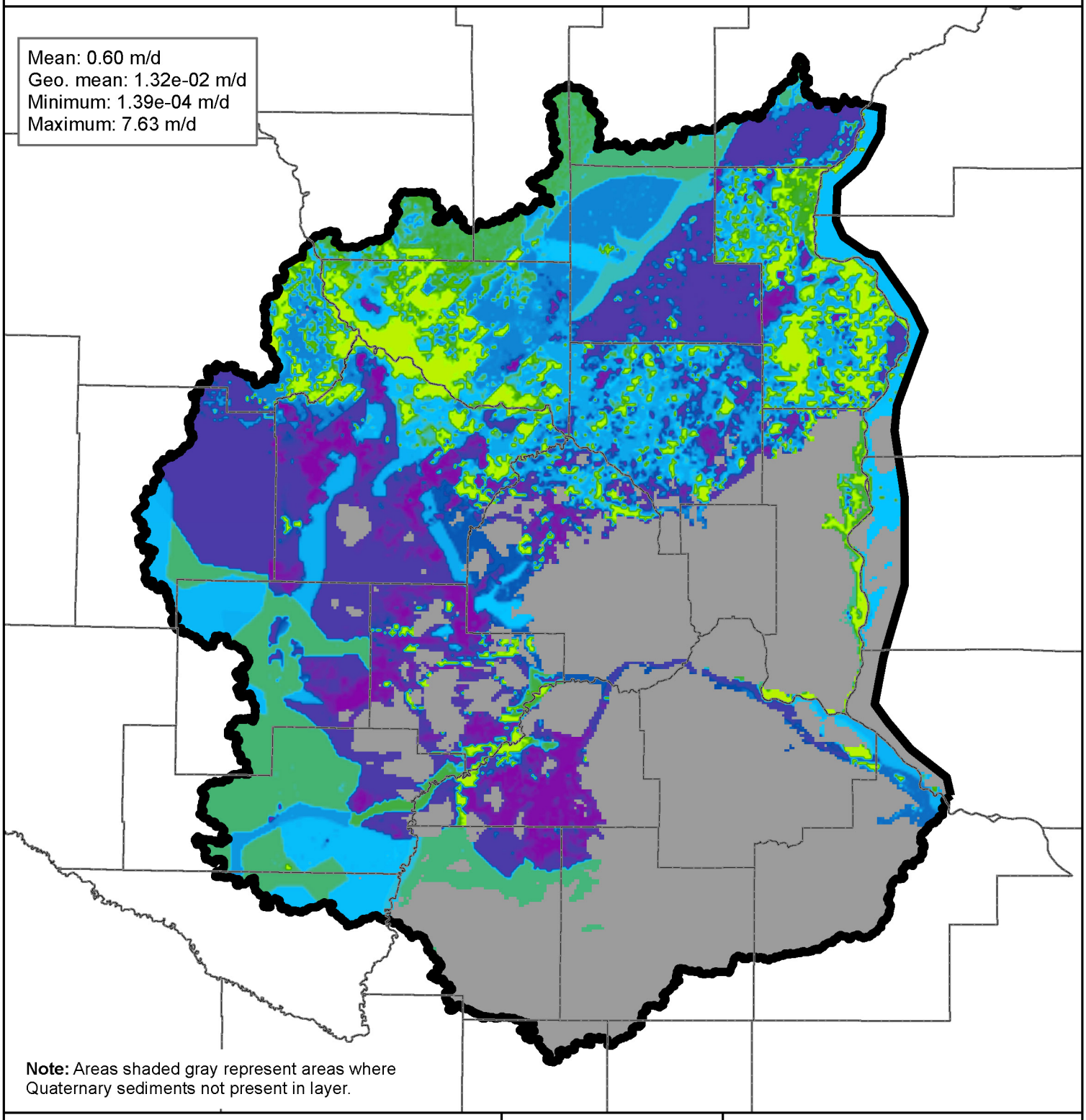
0 10 20
Miles

0 15 30
Kilometers

Figure 86
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 3

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer4.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

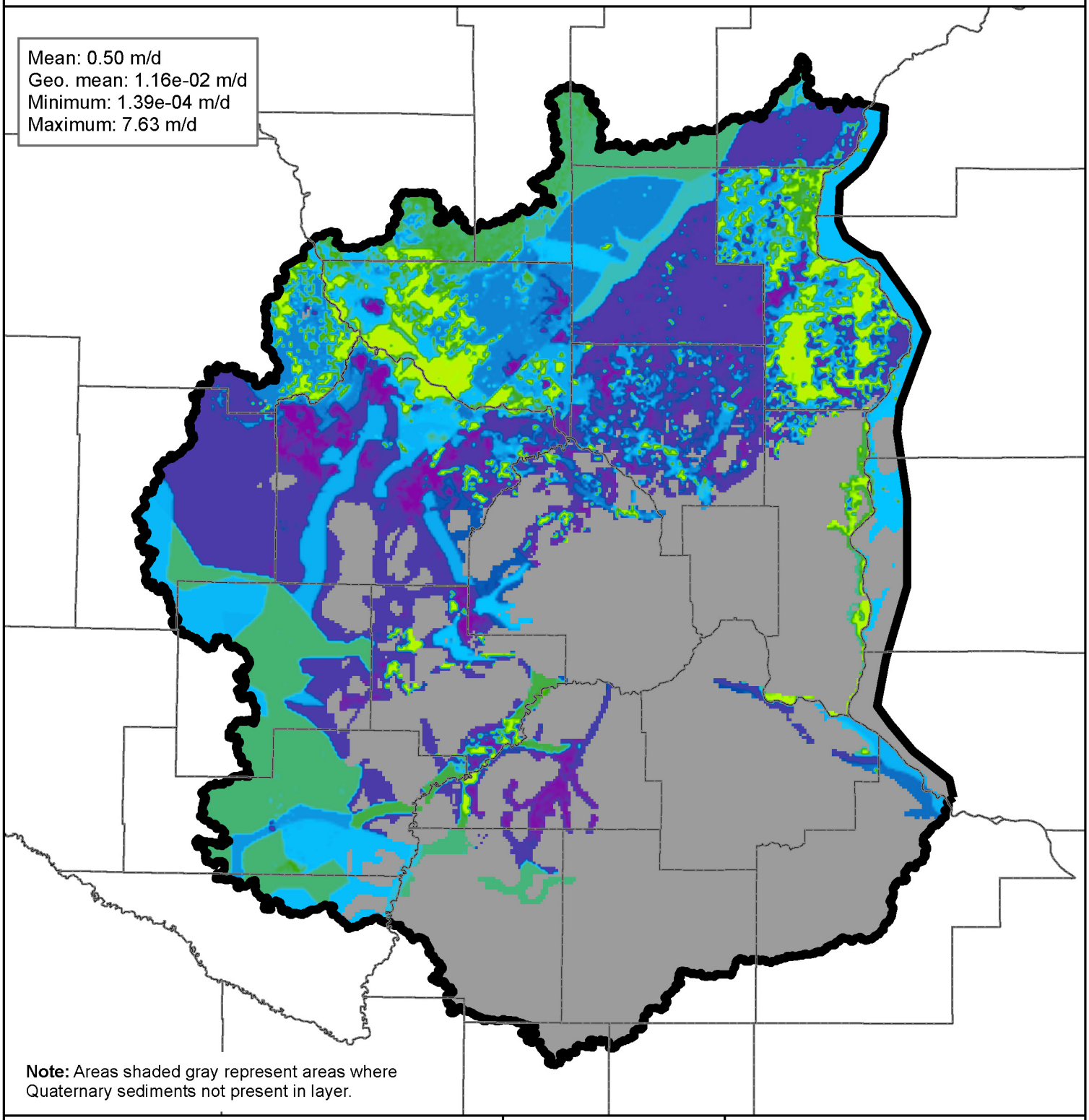
0 10 20
Miles

0 15 30
Kilometers

Figure 87
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 4

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer5.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

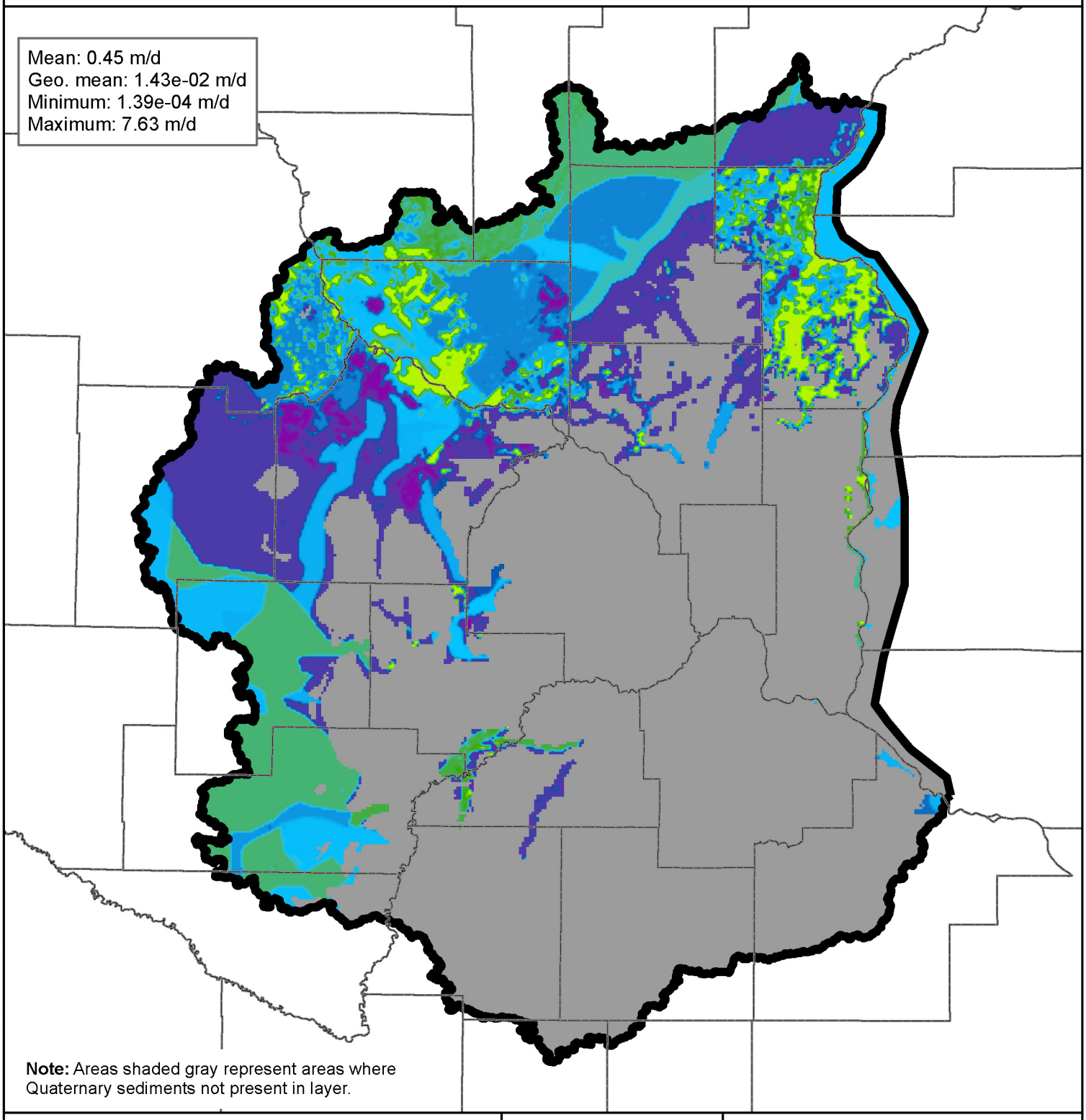
0 10 20
Miles

0 15 30
Kilometers

Figure 88
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 5

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer6.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

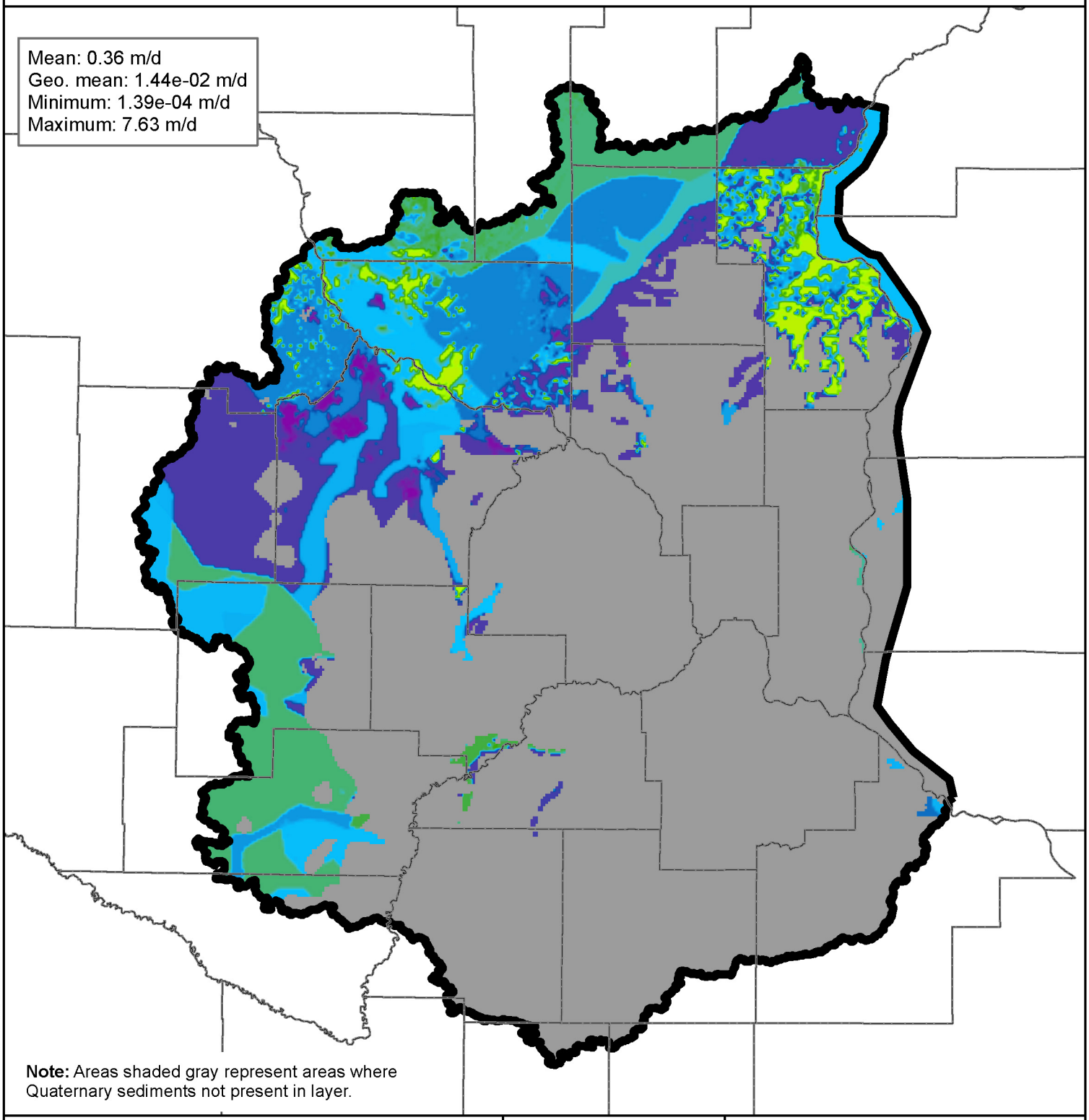
0 10 20
Miles

0 15 30
Kilometers

Figure 89
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 6

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer7.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

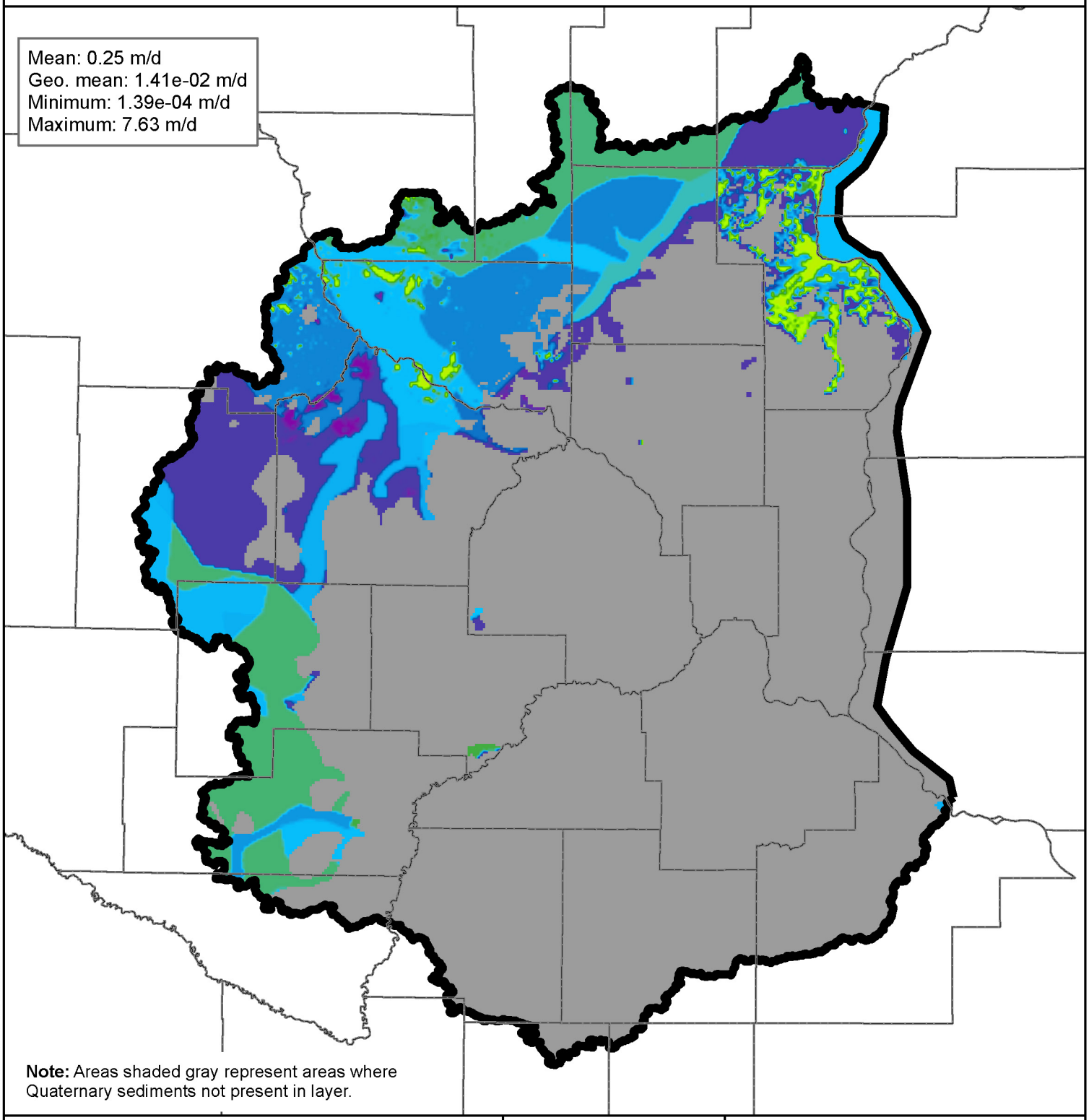
0 10 20
Miles

0 15 30
Kilometers

Figure 90
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 7

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer8.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

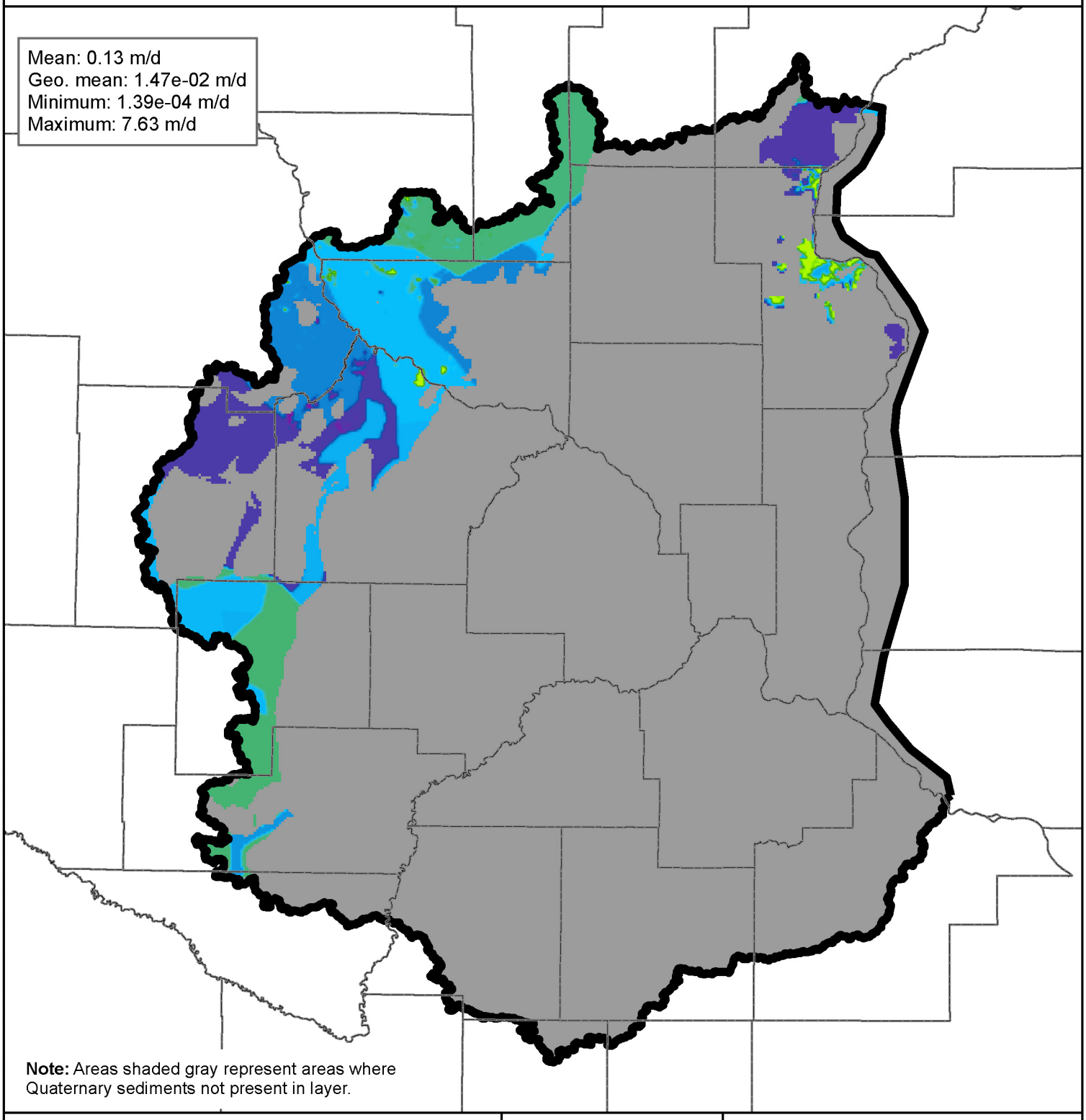
0 10 20
Miles

0 15 30
Kilometers

Figure 91
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 8

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKz_Quat_Layer9.mxd User: egc

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

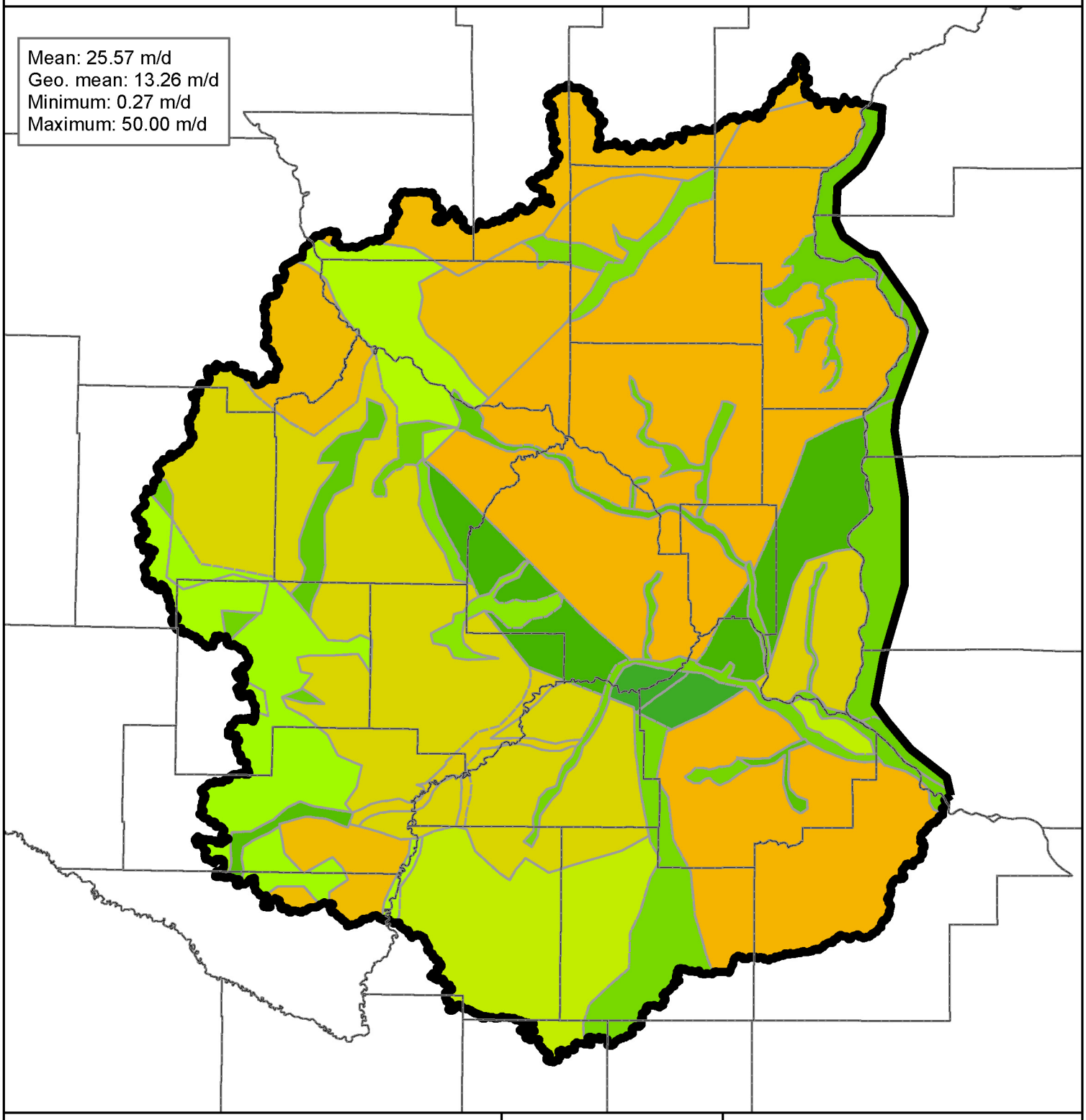
0 10 20
Miles

0 15 30
Kilometers

Figure 92
Vertical Hydraulic Conductivity
Quaternary Sediments
Model Layer 9

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportKx_Quat_Unknown.mxd User: egc

Model Boundary

County Boundary

Unknown Quaternary Zone Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

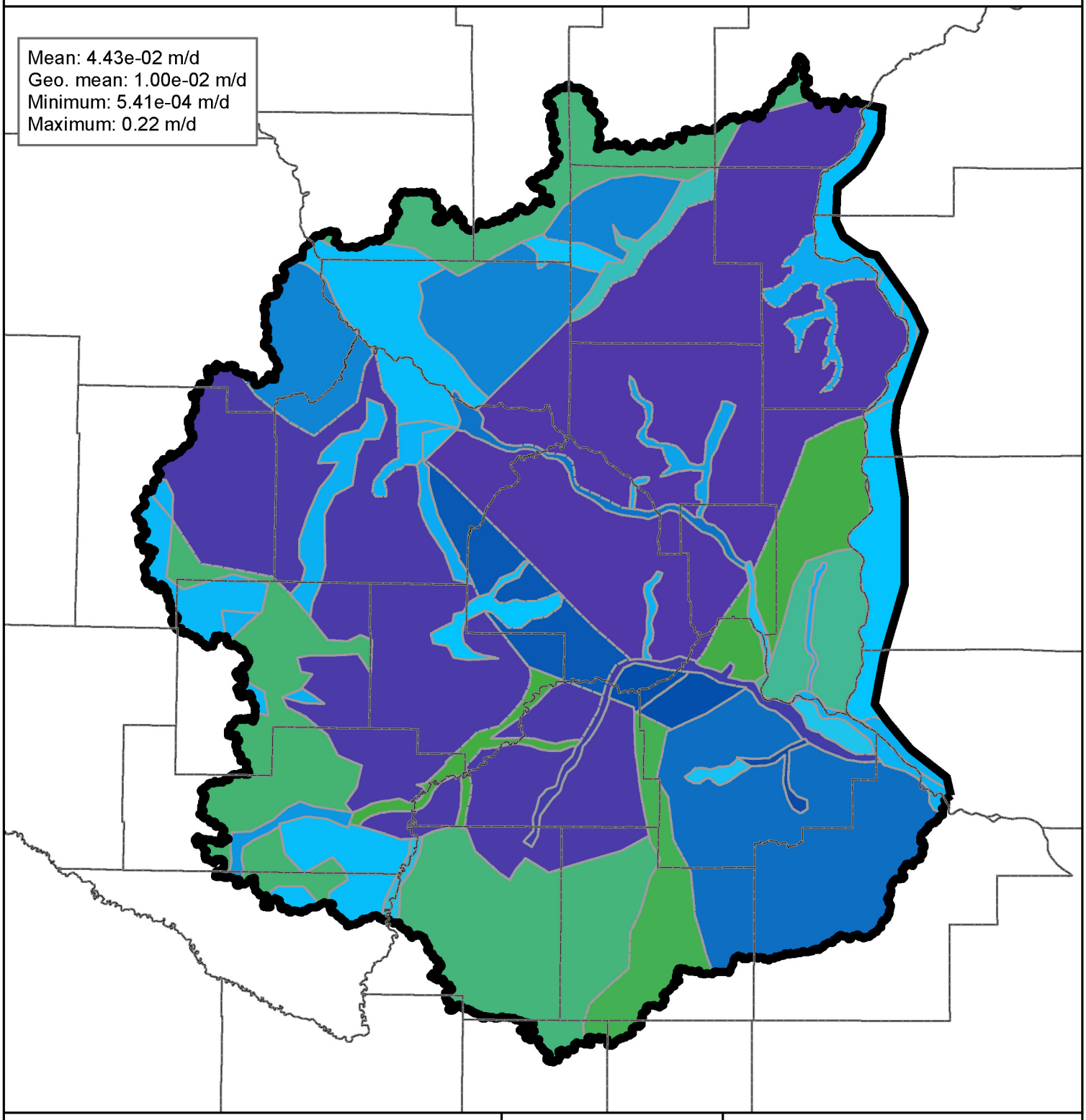
0 10 20
Miles

0 15 30
Kilometers

Figure 93
Horizontal Hydraulic Conductivity
Quaternary Zones
Filling Unknown Materials

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Kz_Quat_Unknown.mxd User: egc

Model Boundary

County Boundary

Unknown Quaternary Zone Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

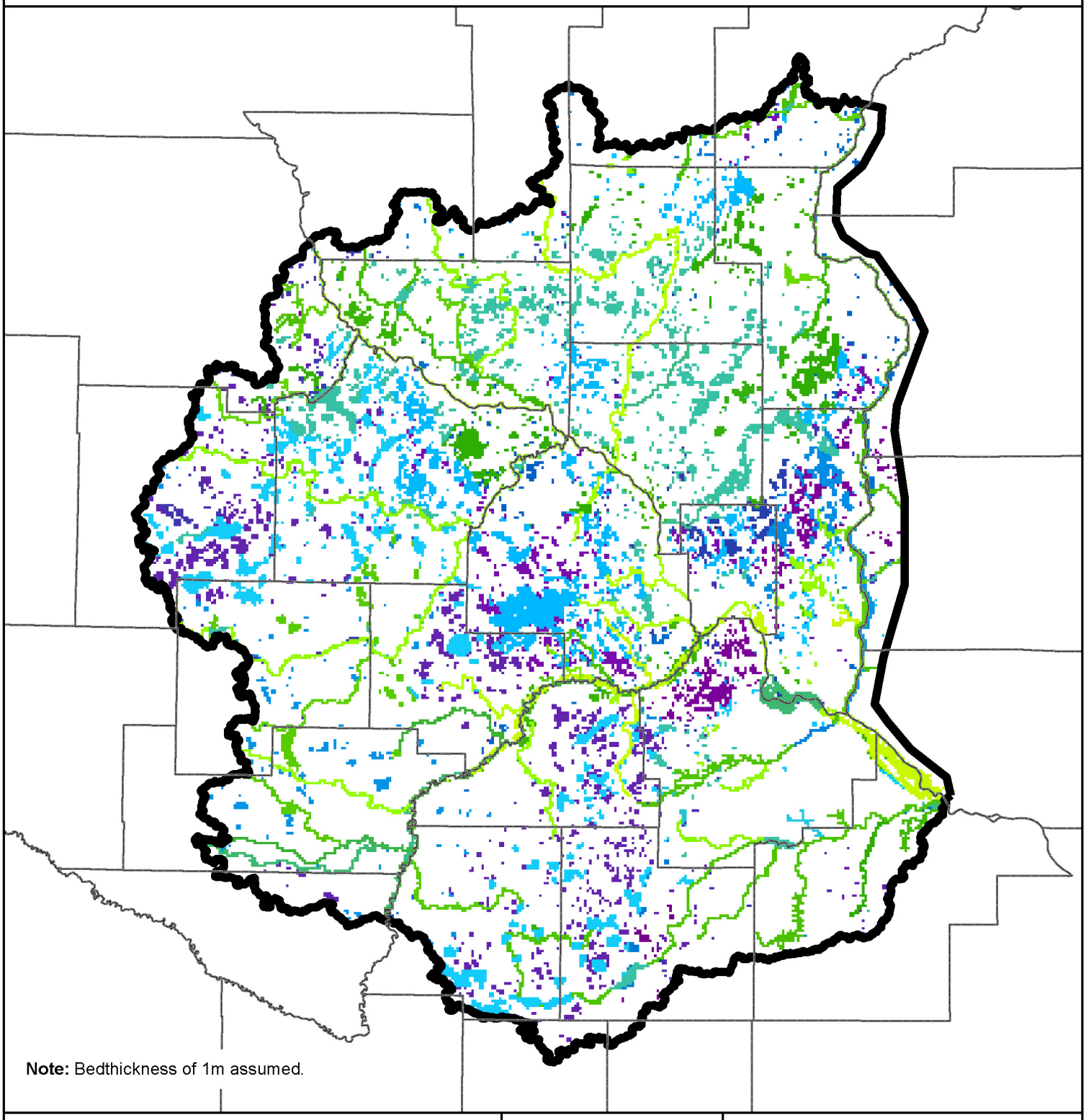
0 10 20
Miles

0 15 30
Kilometers

Figure 94
Vertical Hydraulic Conductivity
Quaternary Zones
Filling Unknown Materials

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Note: Bedthickness of 1m assumed.

Model Boundary

County Boundary

K (m/day)

1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001

N

0 10 20
Miles

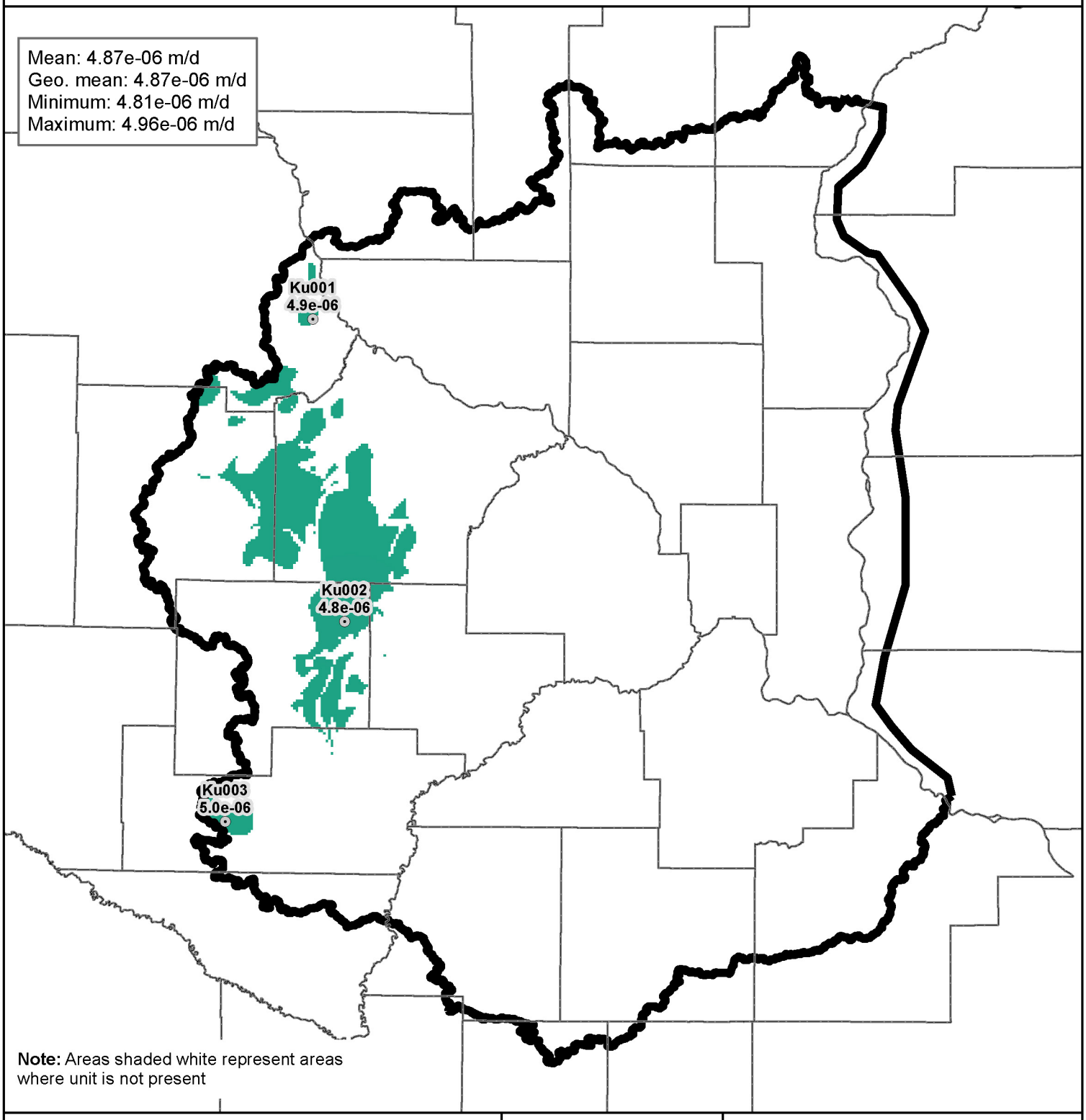
0 15 30
Kilometers

Figure 95
River Bed Conductance
Expressed as Kz

Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\River_Conductance_as_raster.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Ku.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

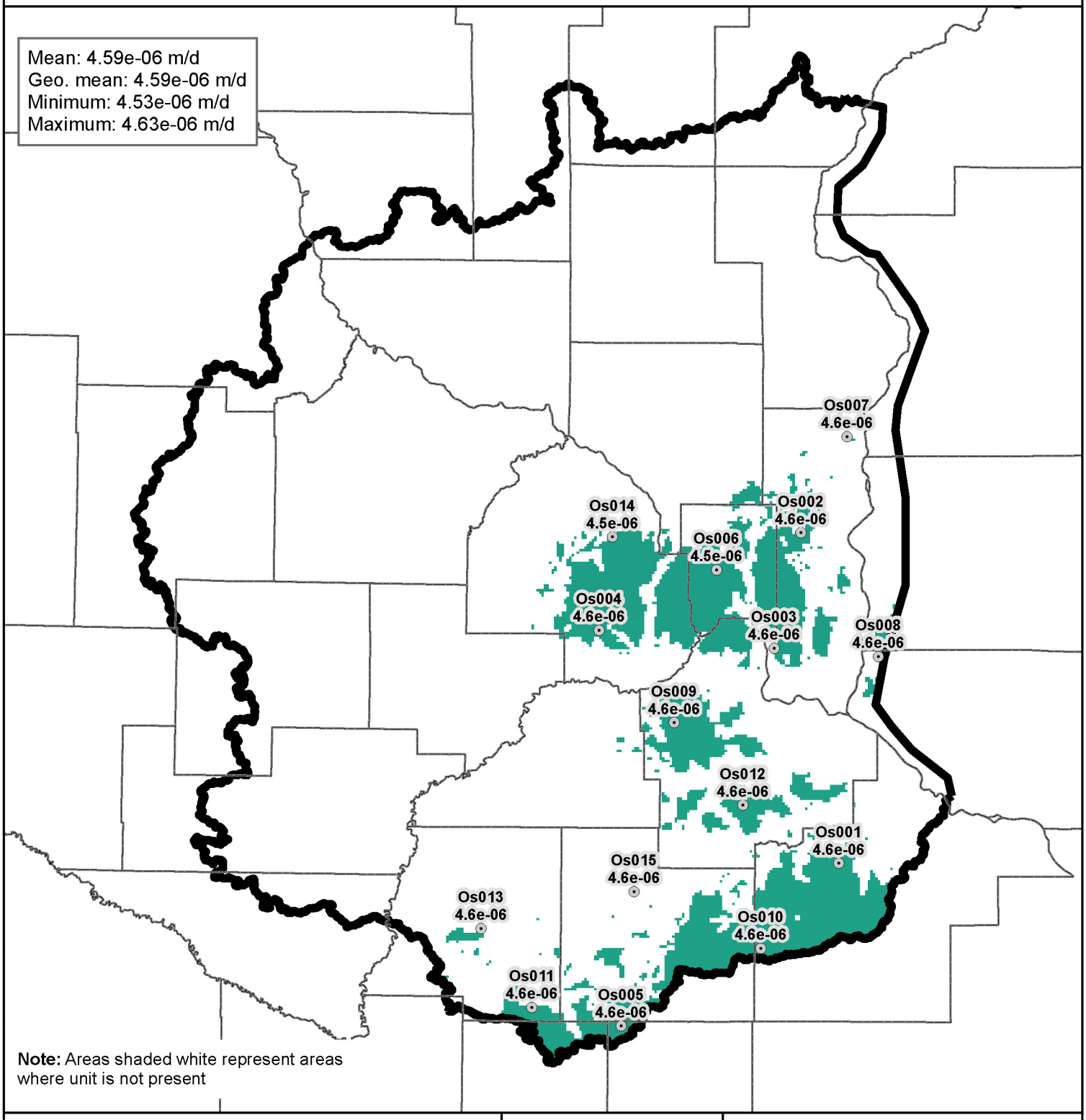
N

0 10 20
Miles

0 15 30
Kilometers

Figure 96
Specific Storage
Cretaceous and/or
unnamed Paleozoic

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Os.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

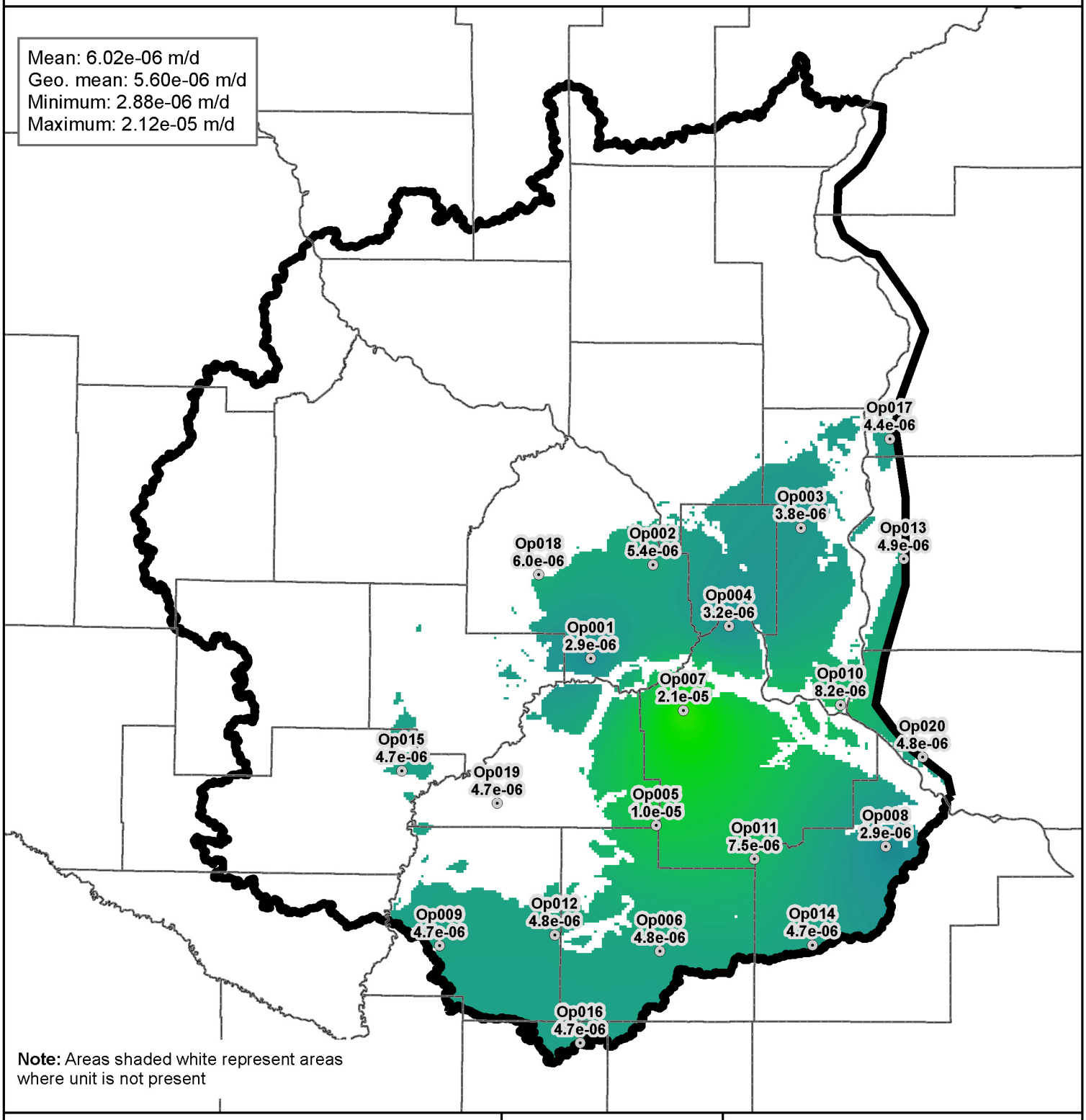
0 10 20
Miles

0 15 30
Kilometers

Figure 97
Specific Storage
St. Peter Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Ss_Op.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

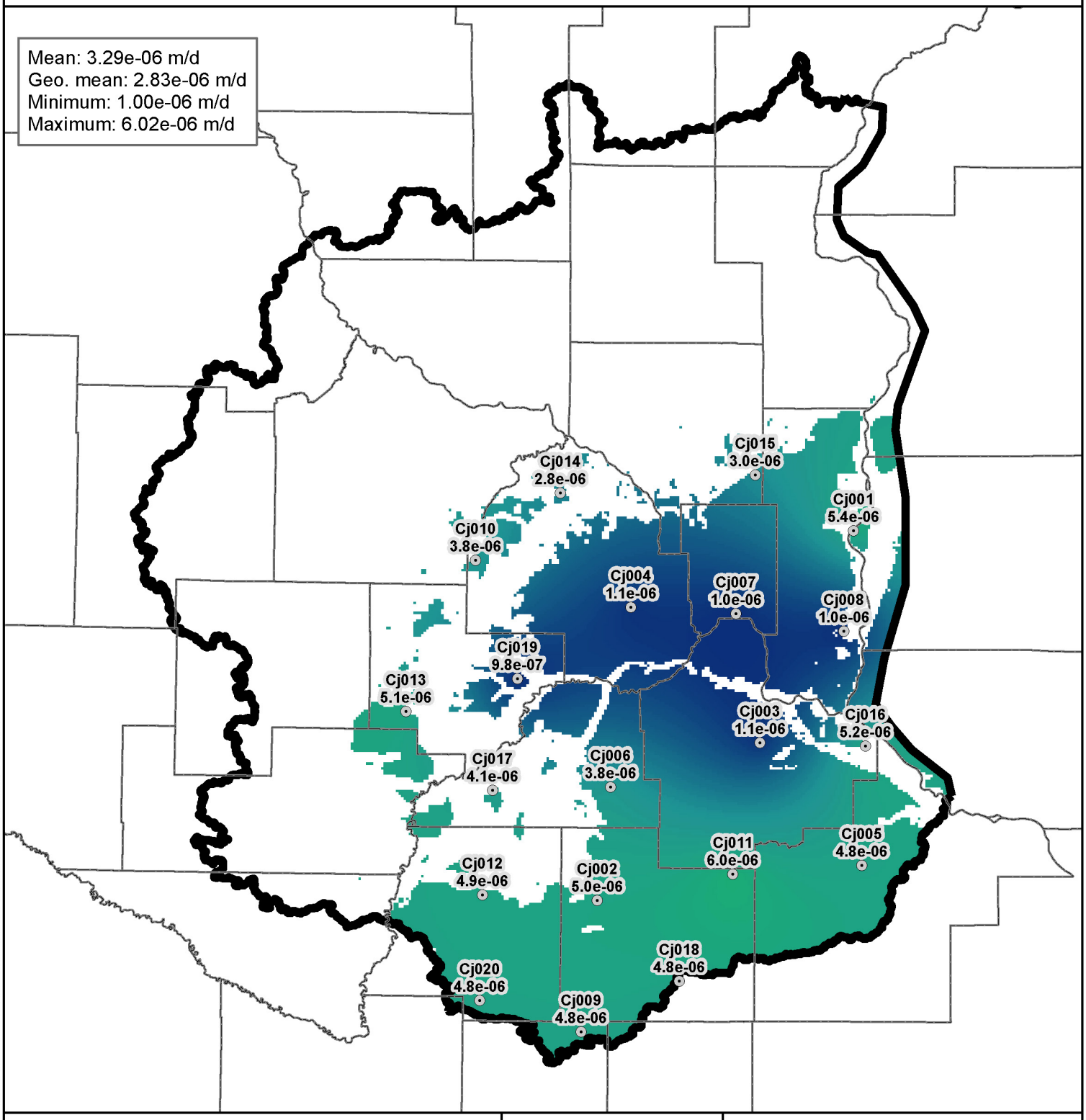
N

0 10 20
Miles

0 15 30
Kilometers

Figure 98
Specific Storage
Prairie du Chien Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

0 10 20
Miles

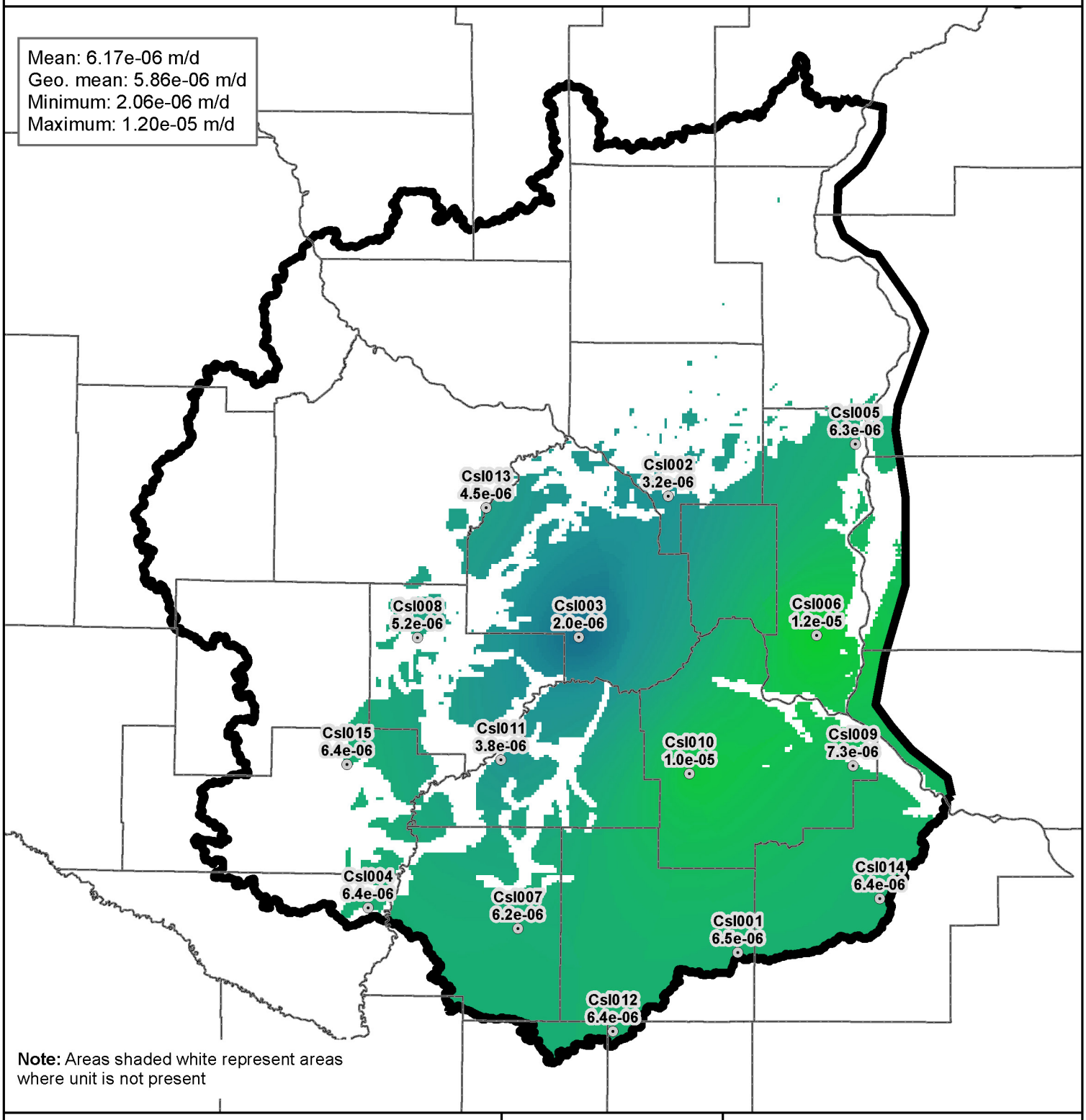
0 15 30
Kilometers

Figure 99
Specific Storage
Jordan Sandstone

Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Cj.mxd User: egc

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Csl.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

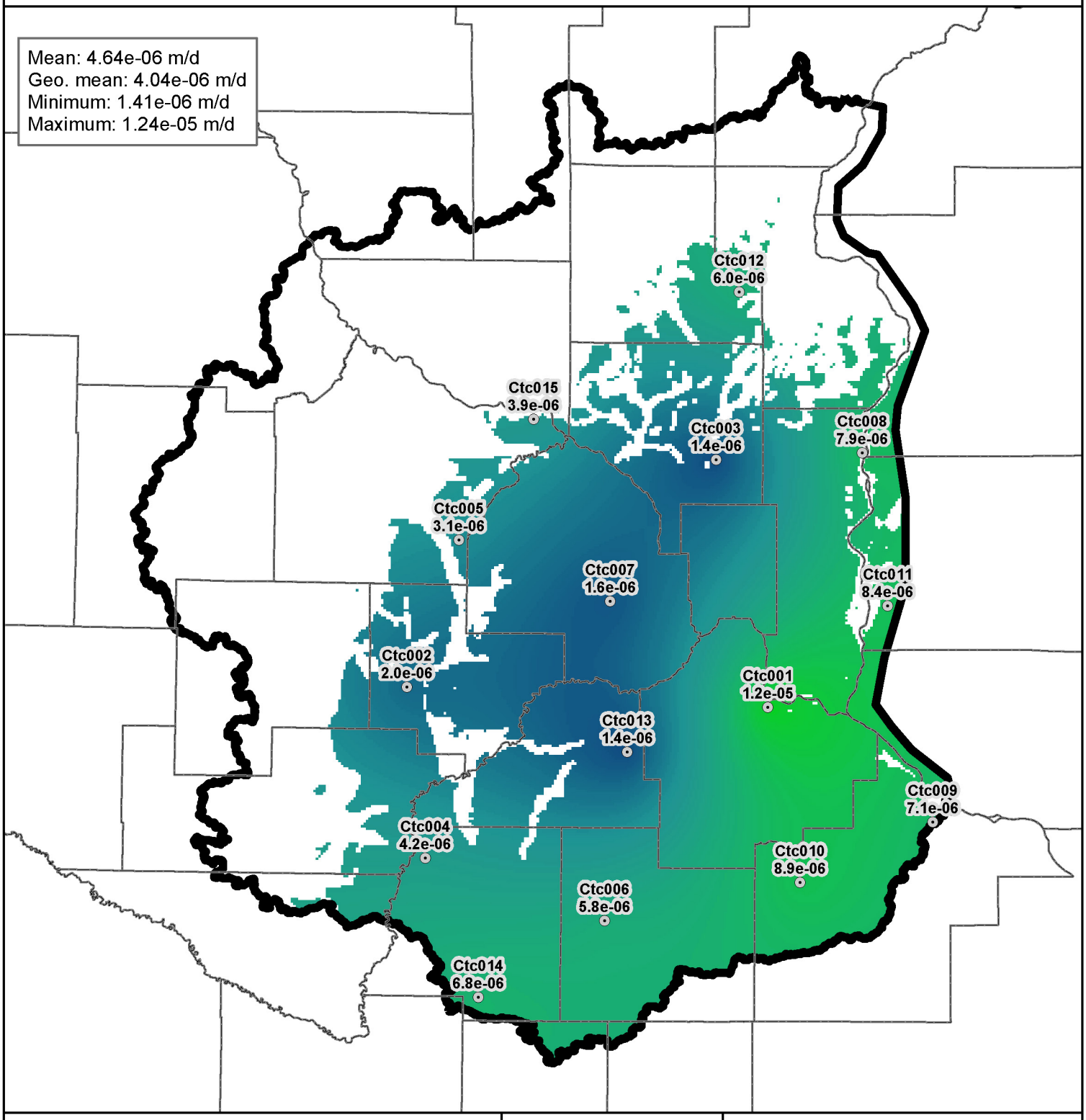
N

0 10 20
Miles

0 15 30
Kilometers

Figure 100
Specific Storage
St. Lawrence Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Ctc.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

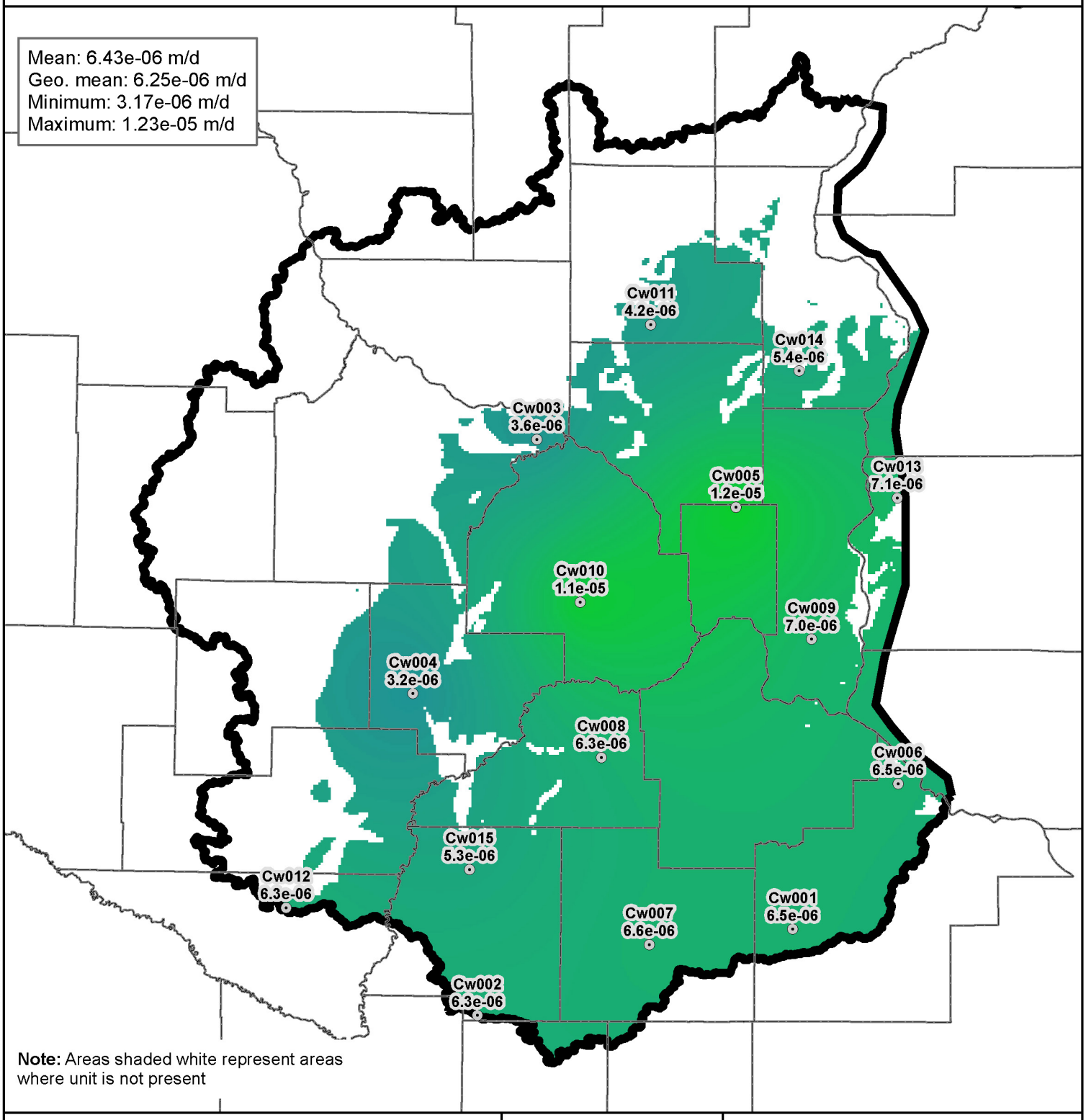
0 10 20
Miles

0 15 30
Kilometers

Figure 101
Specific Storage
Tunnel City Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Cw.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

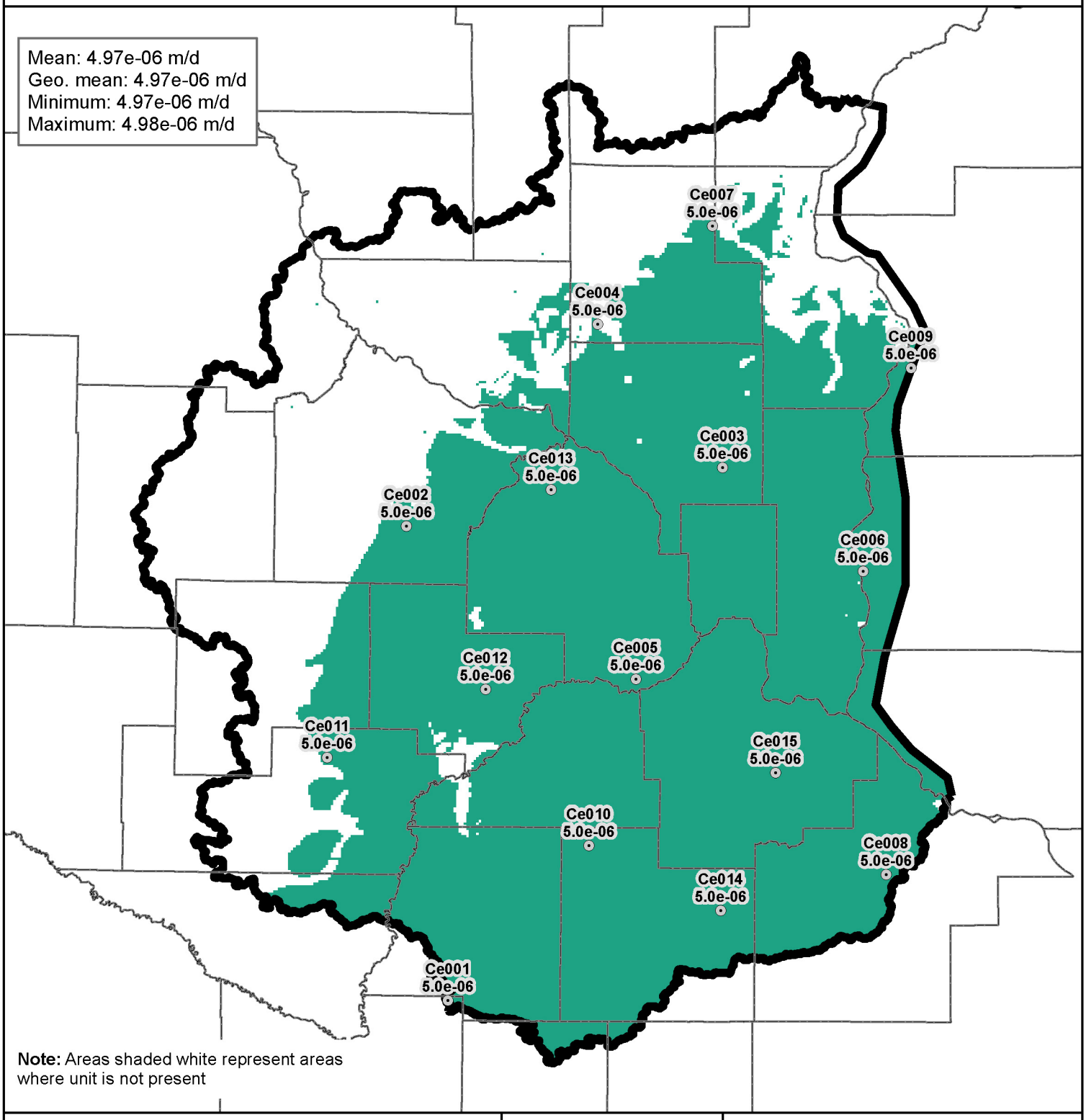
0 10 20
Miles

0 15 30
Kilometers

Figure 102
Specific Storage
Wonewoc Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Ce.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

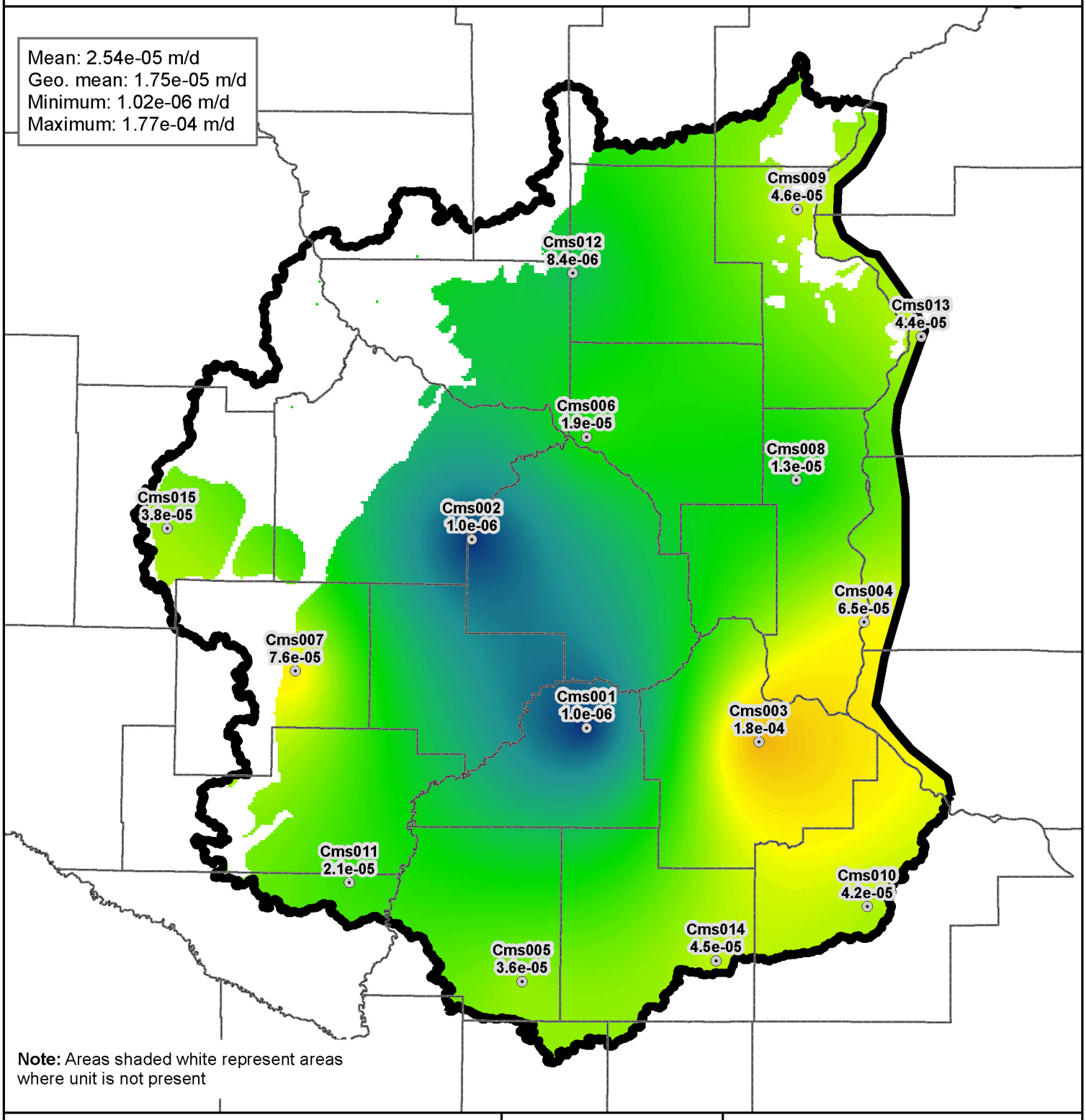
N

0 10 20
Miles

0 15 30
Kilometers

Figure 103
Specific Storage
Eau Clairie Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Cms.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Ss (1/m)*

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

0 10 20
Miles

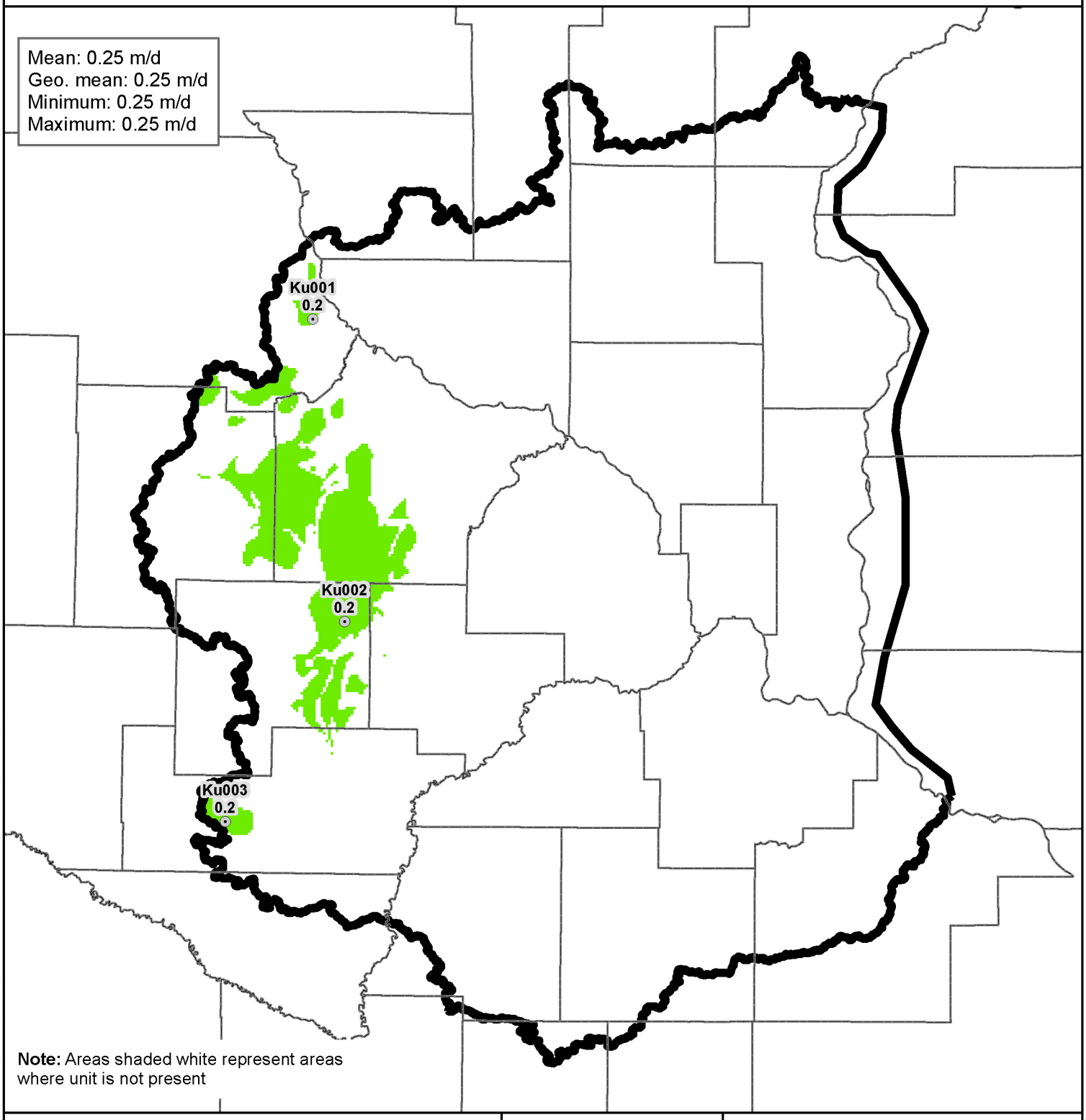
0 15 30
Kilometers

Figure 104

Specific Storage
Mount Simon &
Hinckley Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSy_Ku.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Sy (%)*

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

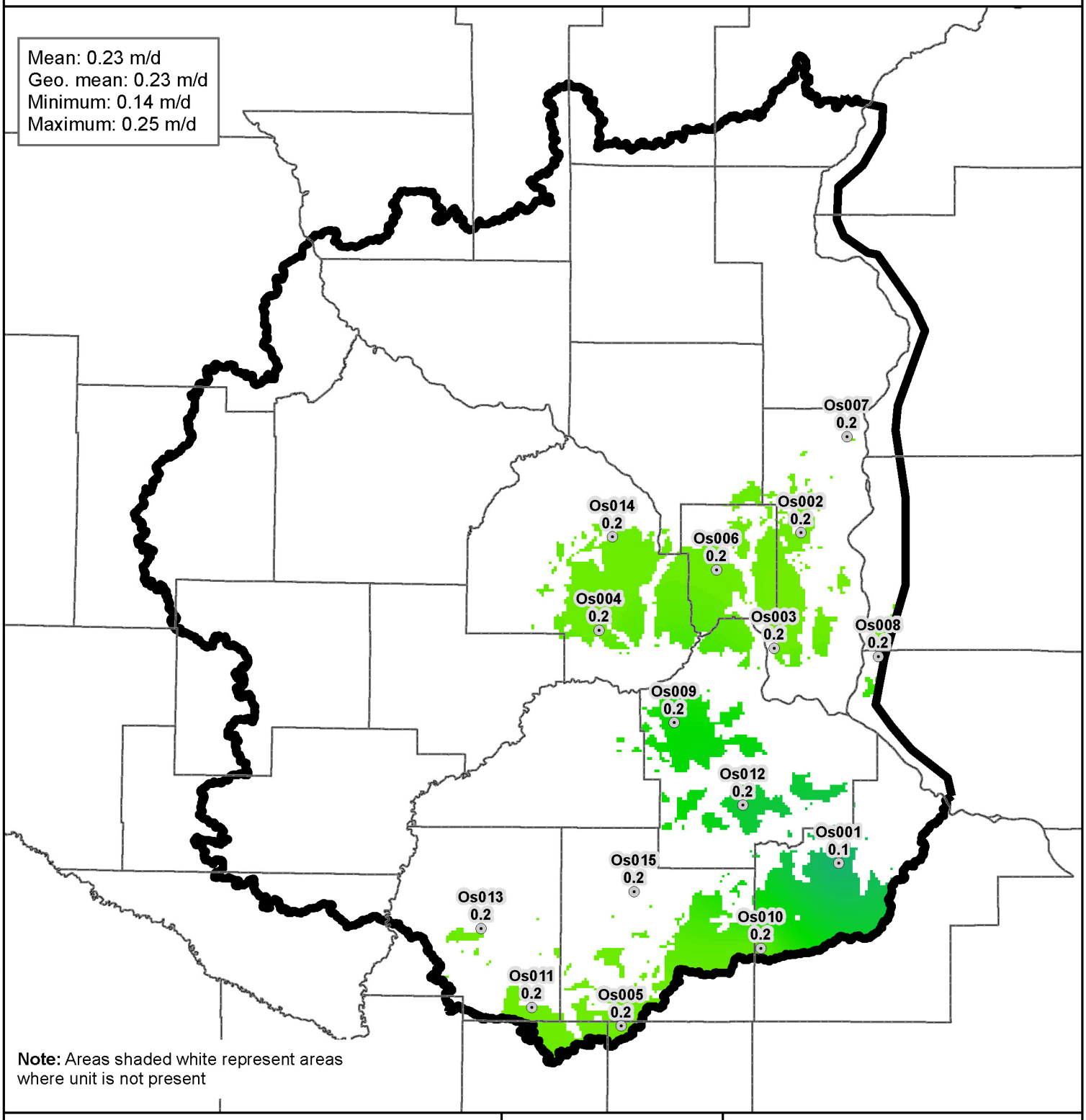
0 10 20
Miles

0 15 30
Kilometers

Figure 105
Specific Yield
Cretaceous and/or
Unnamed Paleozoic

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Os.mxd User: egc

Model Boundary

County Boundary

Pilot Point

Name
Sy (%)

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

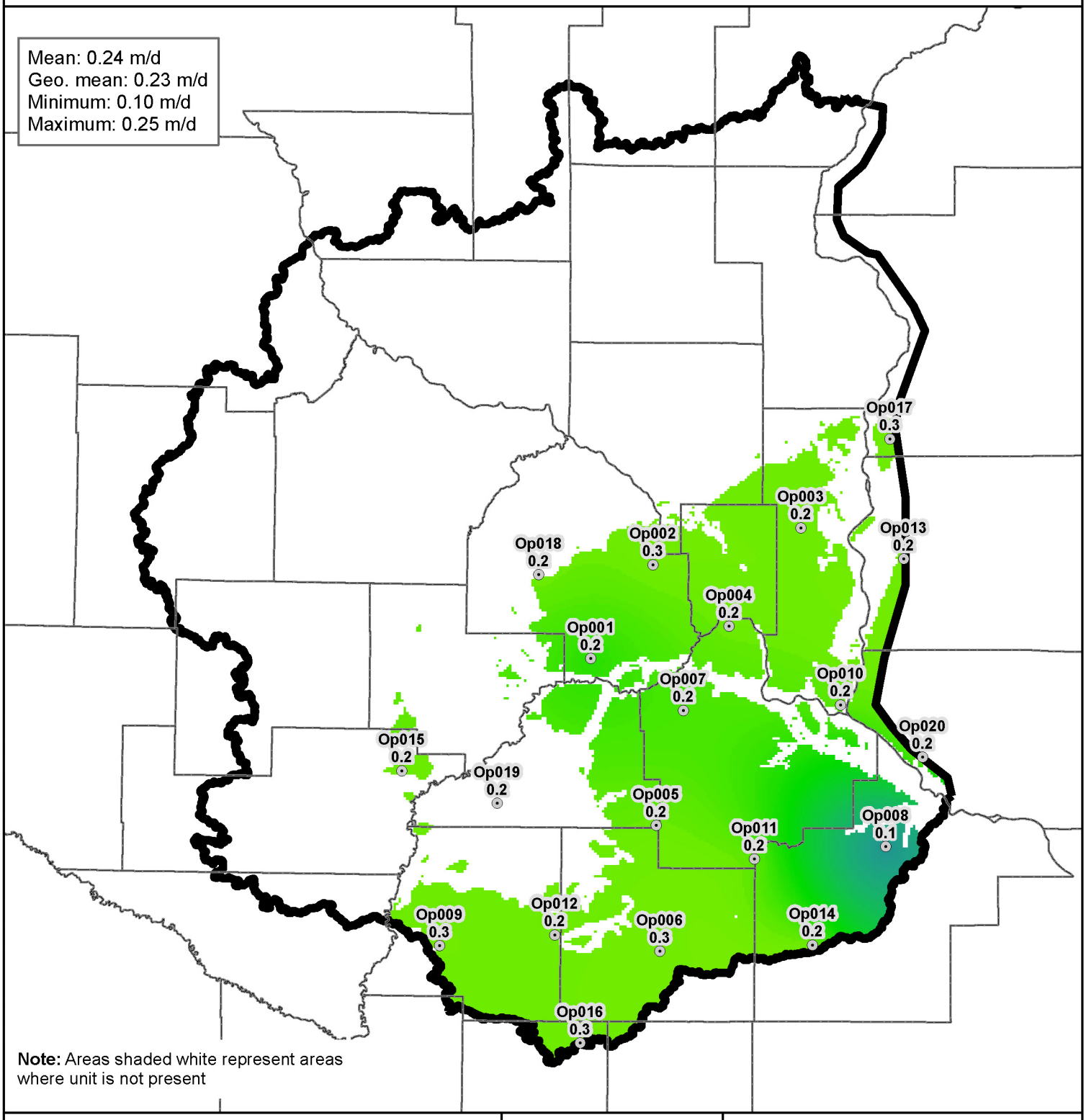
0 10 20
Miles

0 15 30
Kilometers

Figure 106
Specific Yield
St. Peter Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Op.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Sy (%)*

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

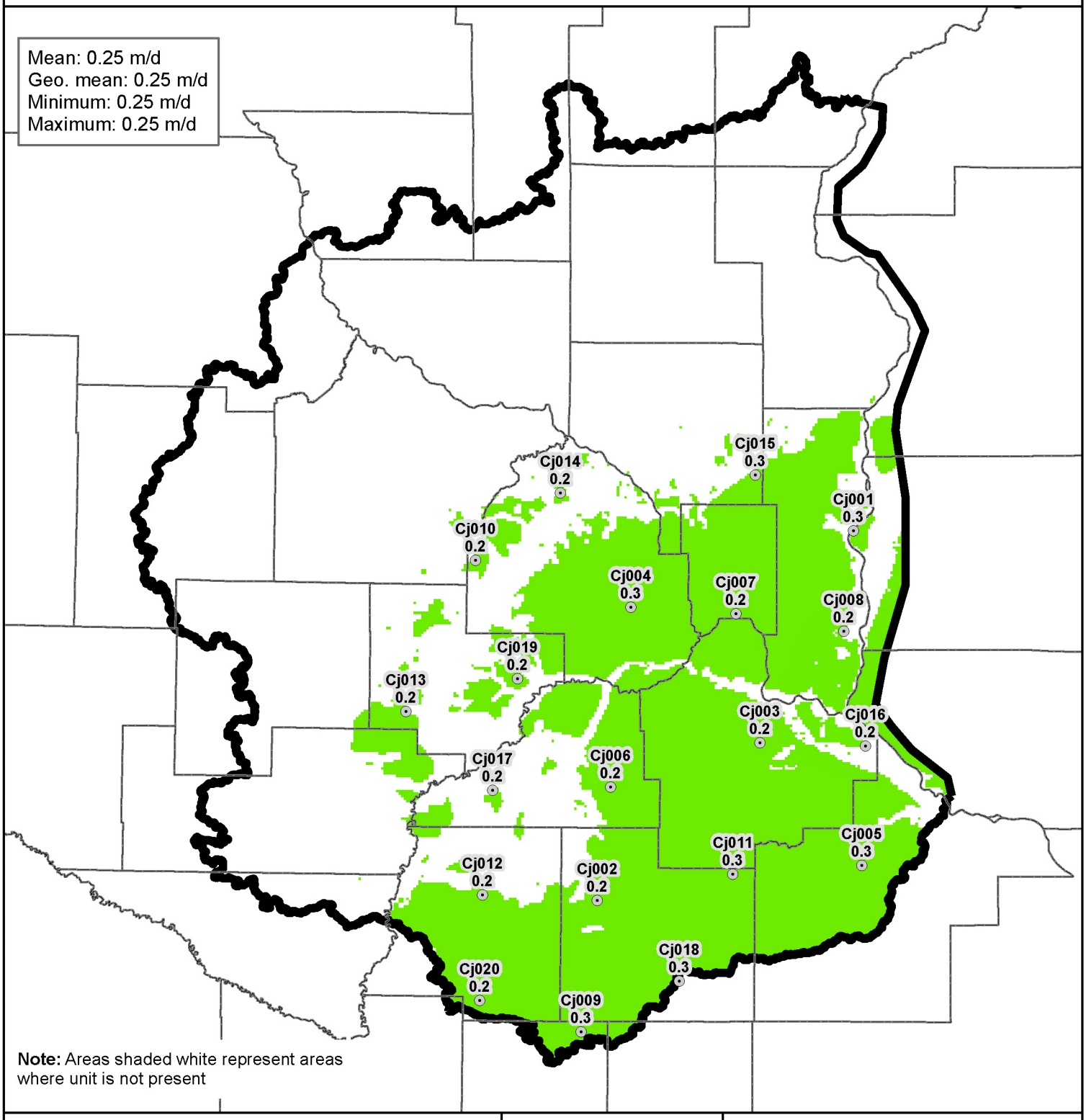
0 10 20
Miles

0 15 30
Kilometers

Figure 107
Specific Yield
Prairie du Chien Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Cj.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Sy (%)*

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

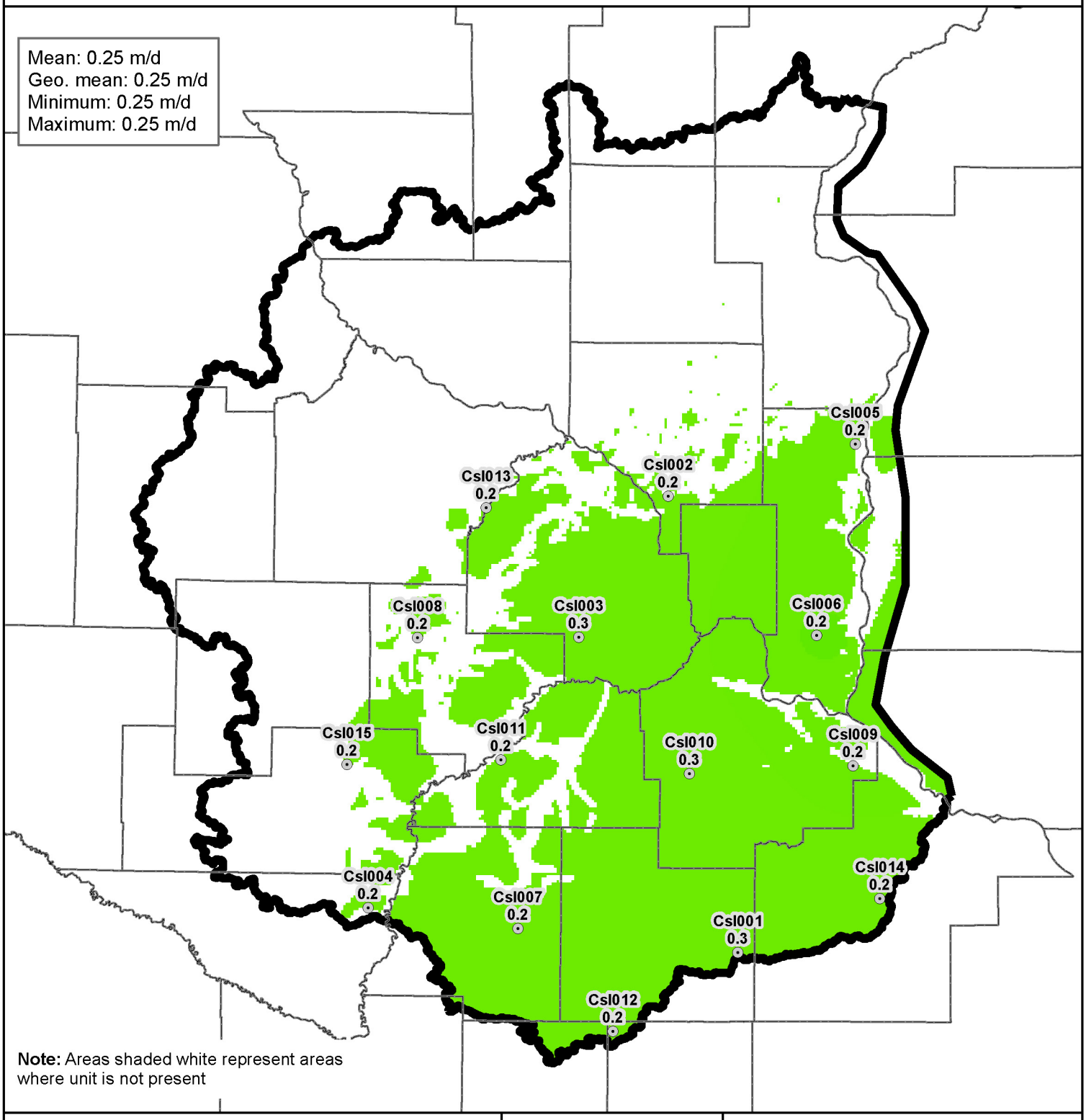
0 10 20
Miles

0 15 30
Kilometers

Figure 108
Specific Yield
Jordan Sandstone

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Csl.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Sy (%)*

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

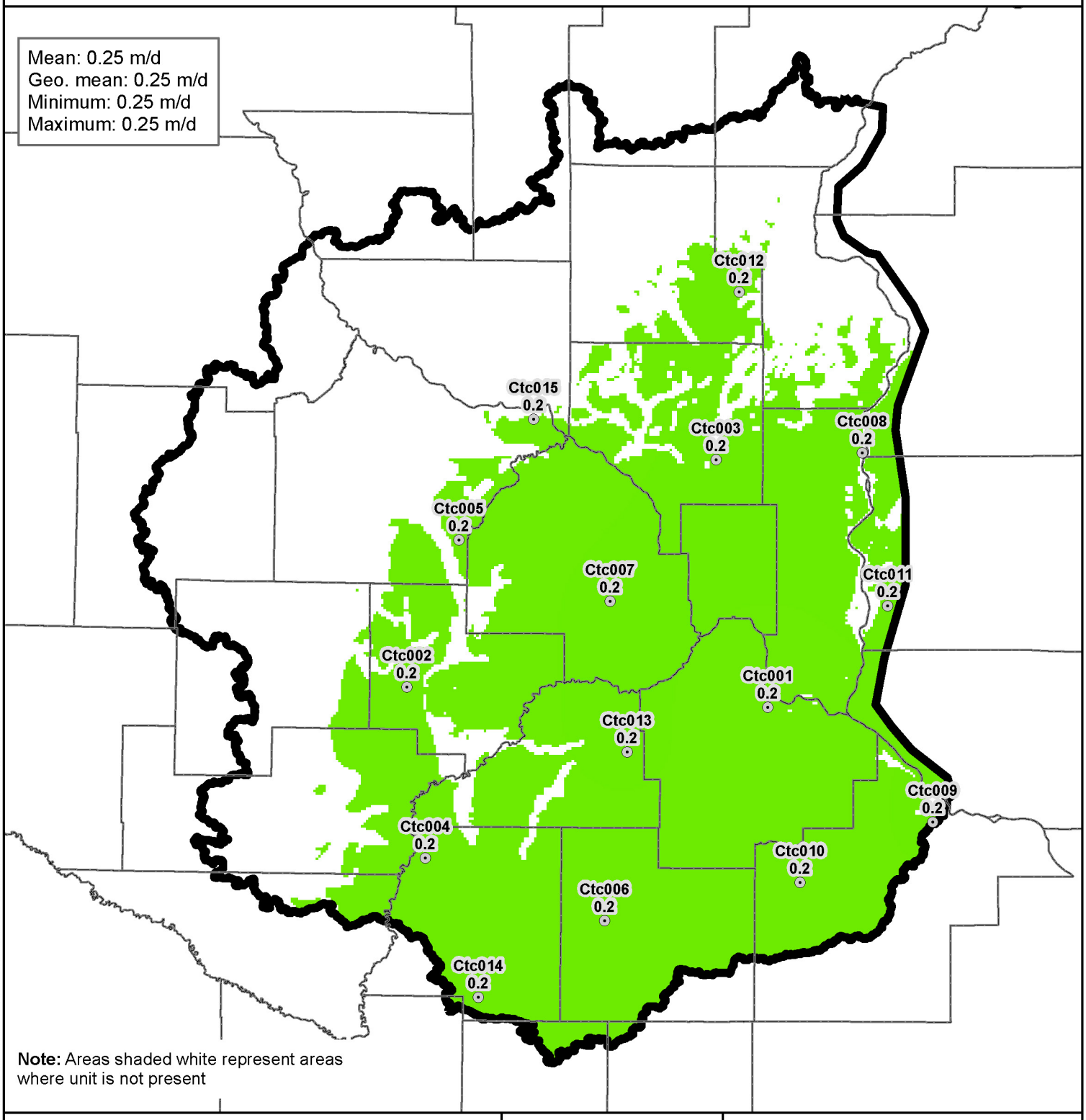
0 10 20
Miles

0 15 30
Kilometers

Figure 109
Specific Yield
St. Lawrence Formation

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Ctc.mxd User: egc

Model Boundary

County Boundary

Pilot Point *Name* *Sy (%)*

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

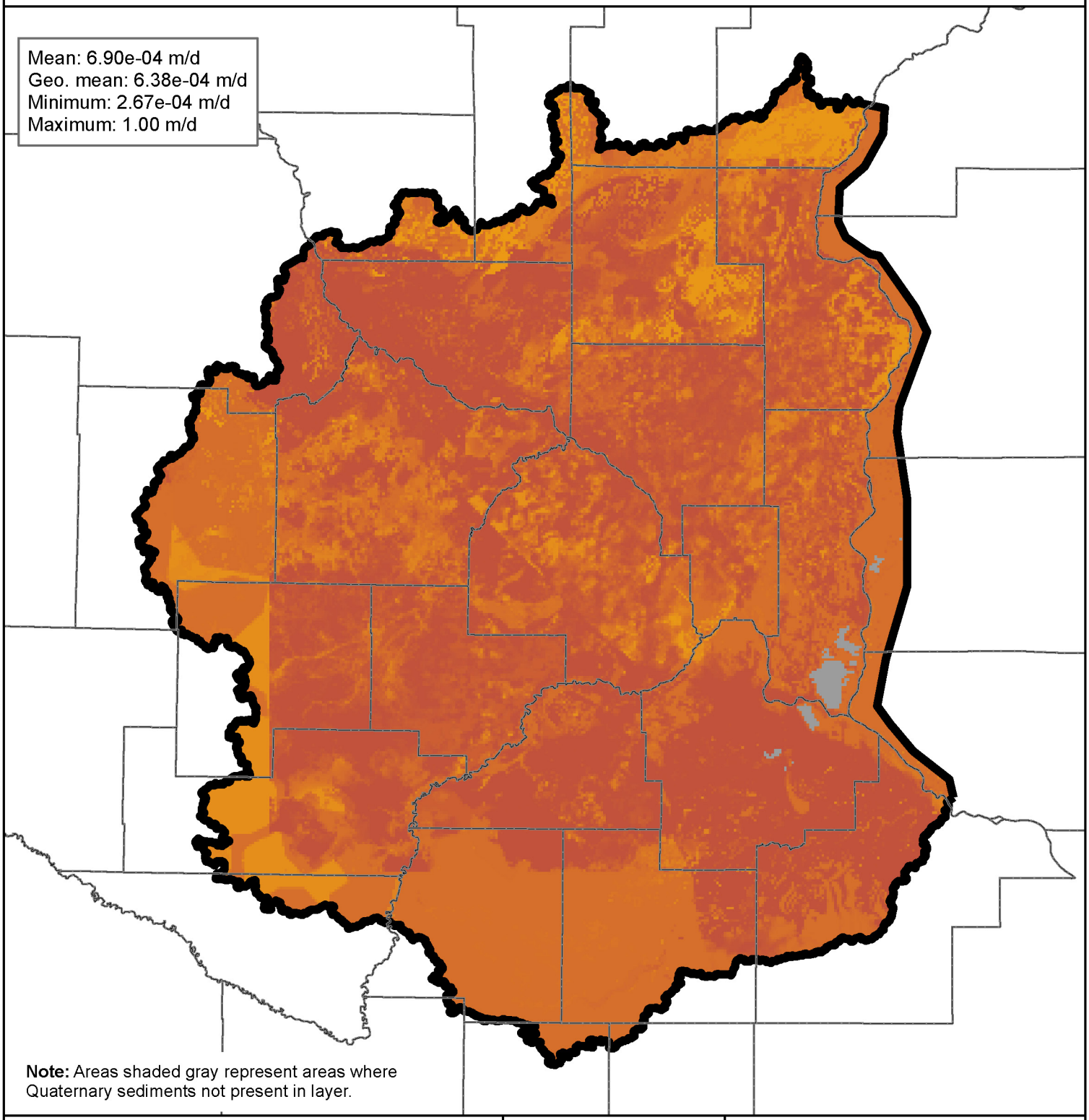
0 10 20
Miles

0 15 30
Kilometers

Figure 110
Specific Yield
Tunnel City Group

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer1.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03

1.5e-04

3.0e-05

5.0e-06

1.0e-06

N

0 10 20

Miles

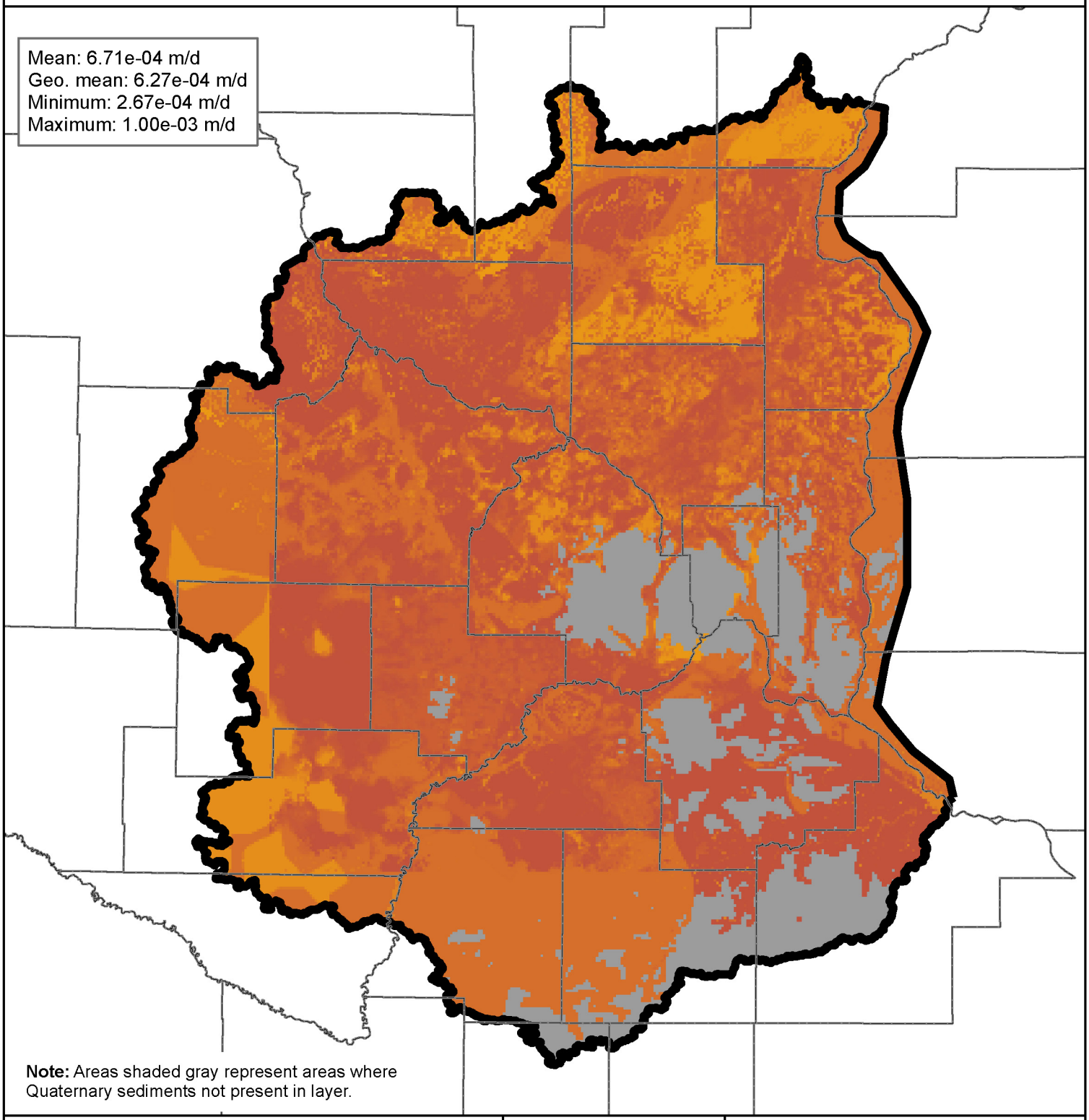
0 15 30

Kilometers

Figure 111
Specific Storage
Quaternary Sediments
Model Layer 1

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer2.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

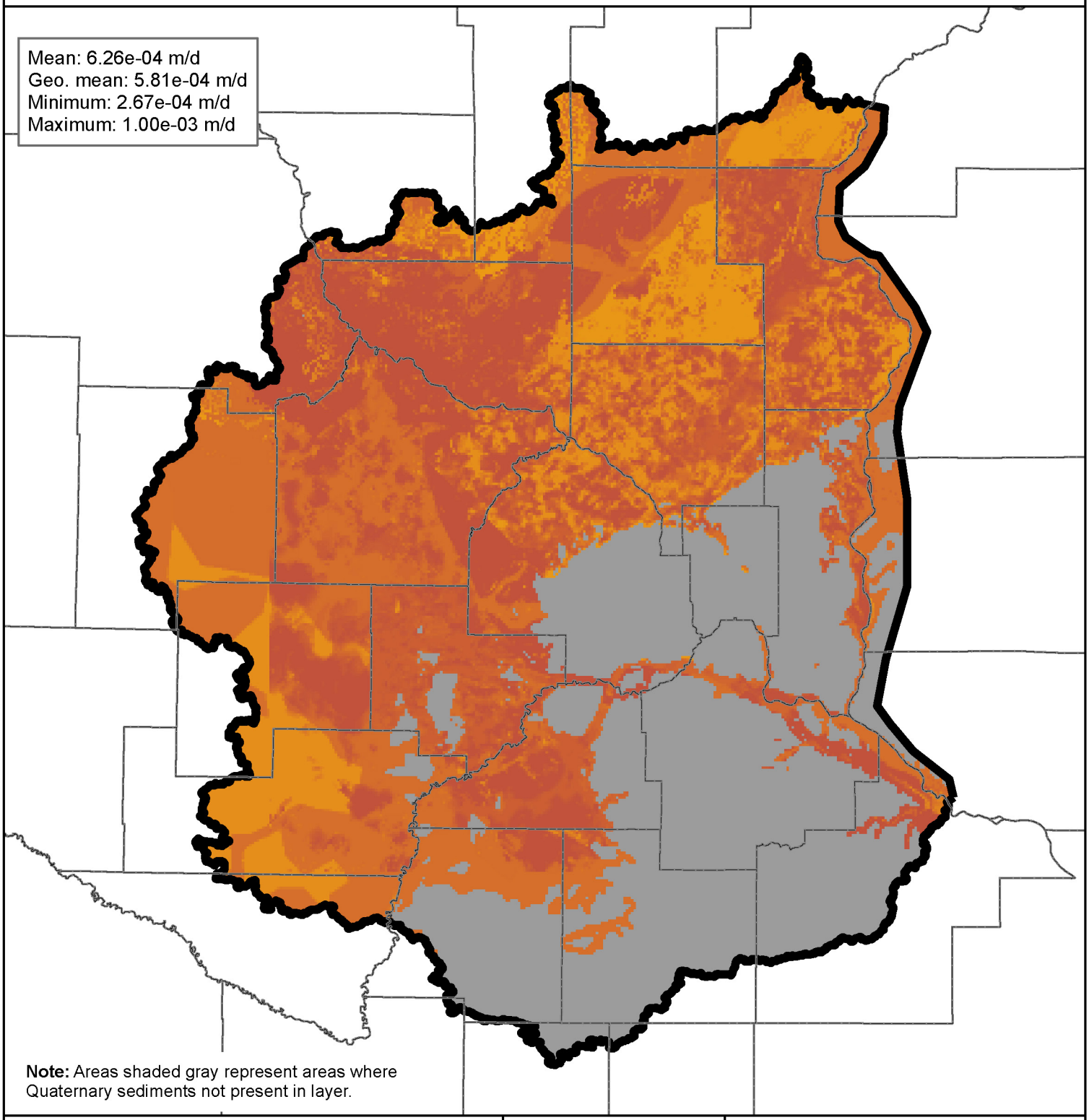
0 10 20
Miles

0 15 30
Kilometers

Figure 112
Specific Storage
Quaternary Sediments
Model Layer 2

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer3.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03

1.5e-04

3.0e-05

5.0e-06

1.0e-06

N

0 10 20

Miles

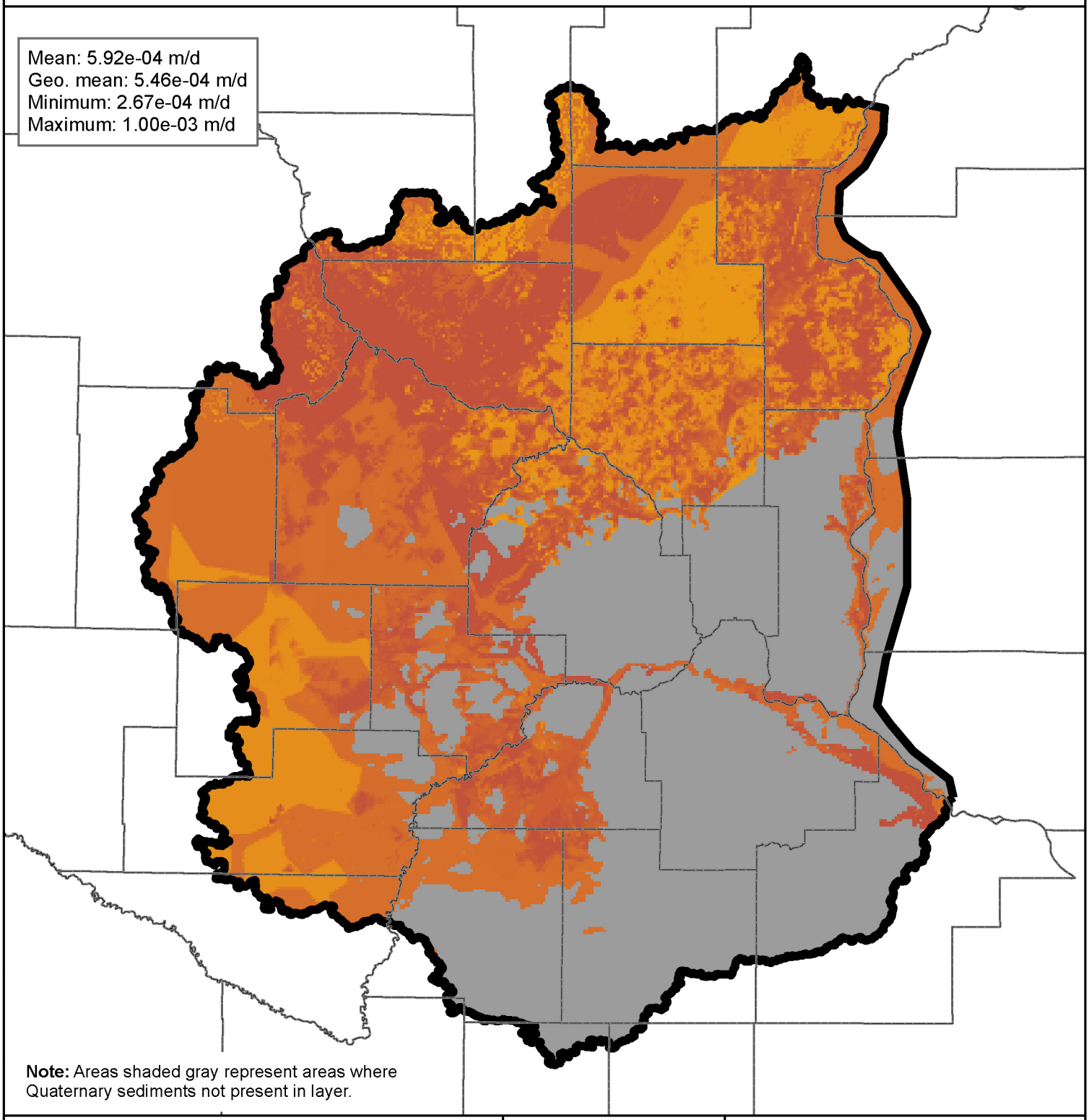
0 15 30

Kilometers

Figure 113
Specific Storage
Quaternary Sediments
Model Layer 3

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer4.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

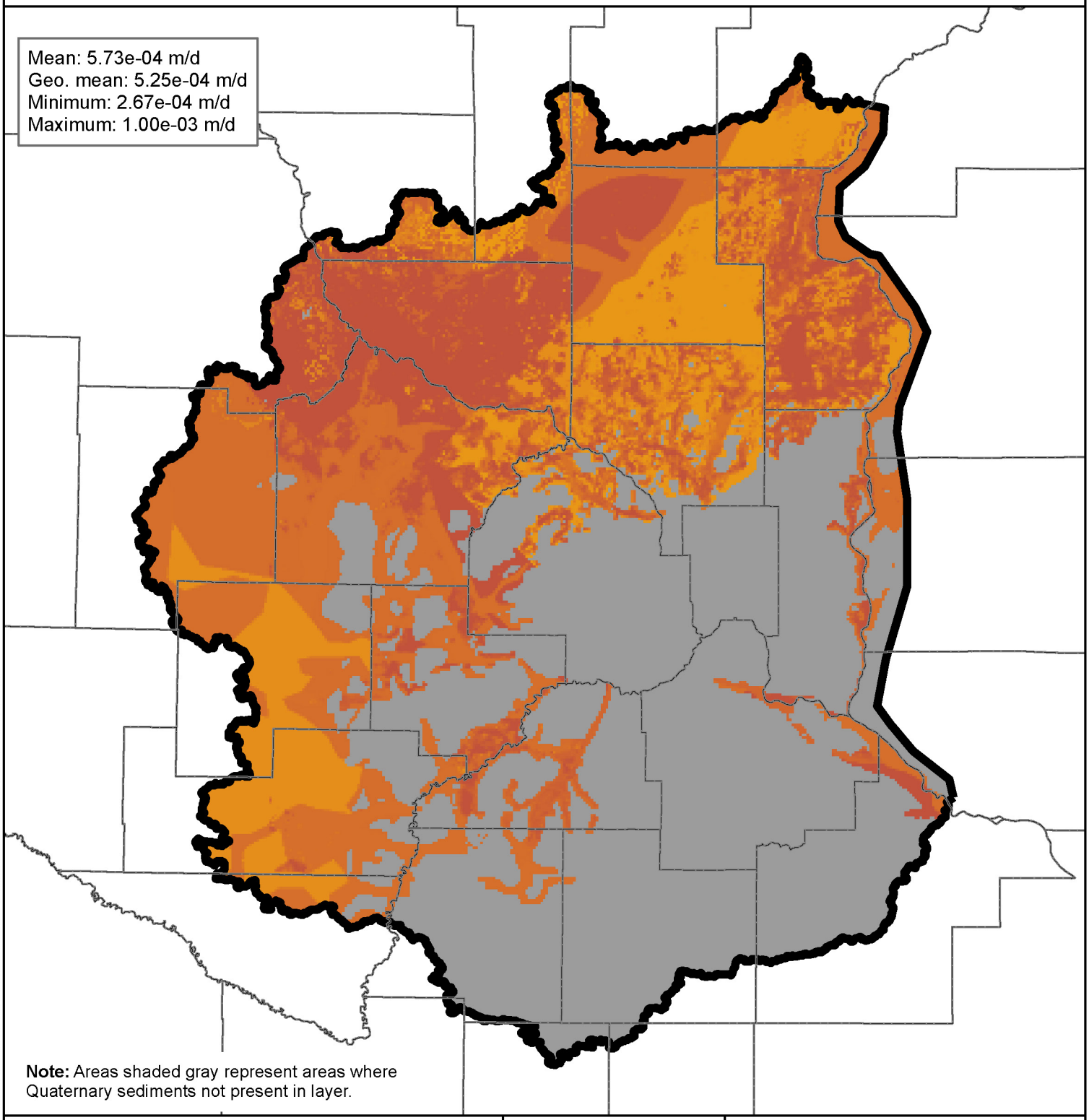
0 10 20
Miles

0 15 30
Kilometers

Figure 114
Specific Storage
Quaternary Sediments
Model Layer 4

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer5.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03

1.5e-04

3.0e-05

5.0e-06

1.0e-06

N

0 10 20

Miles

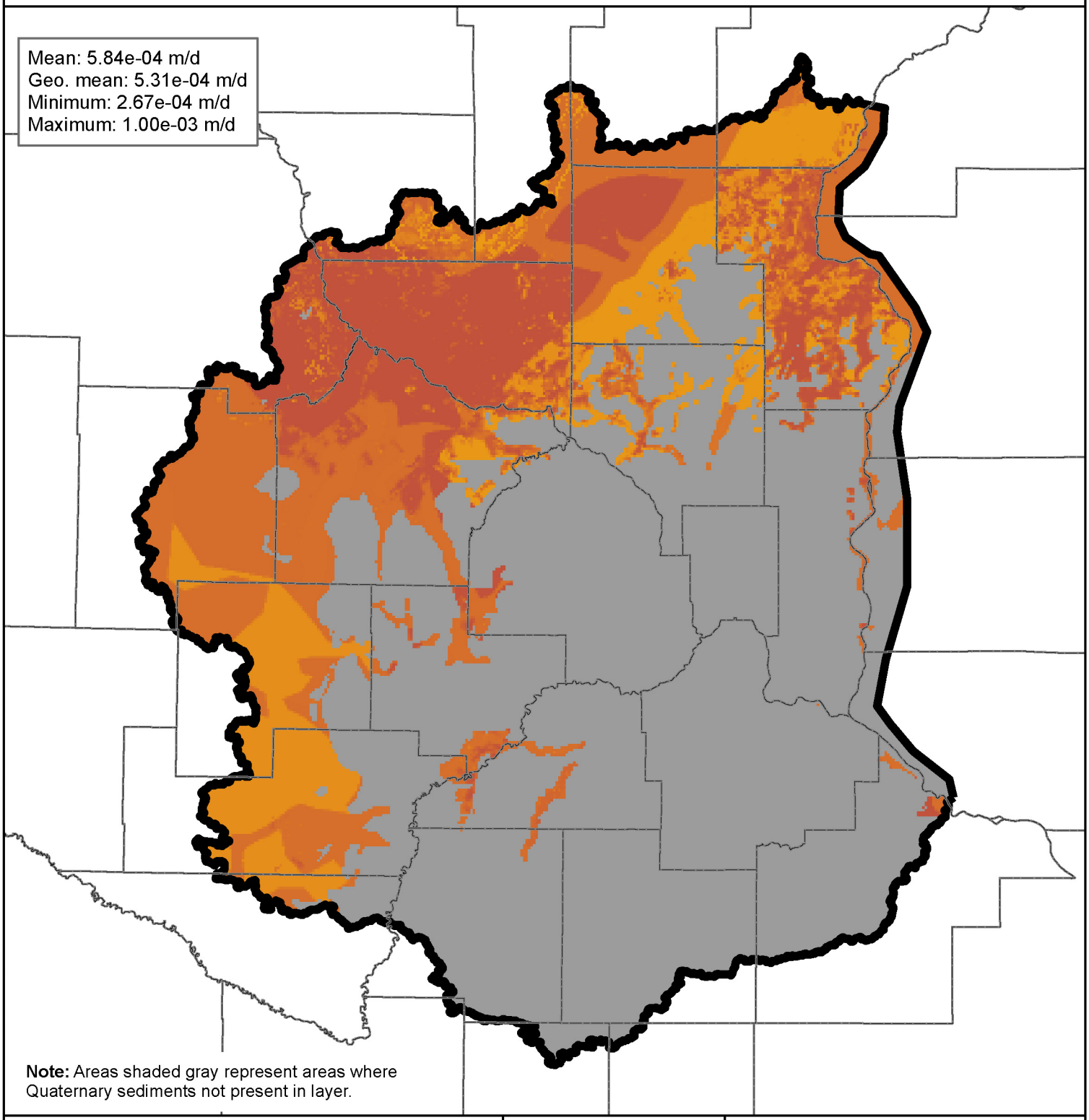
0 15 30

Kilometers

Figure 115
Specific Storage
Quaternary Sediments
Model Layer 5

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer6.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03

1.5e-04

3.0e-05

5.0e-06

1.0e-06

N

0 10 20

Miles

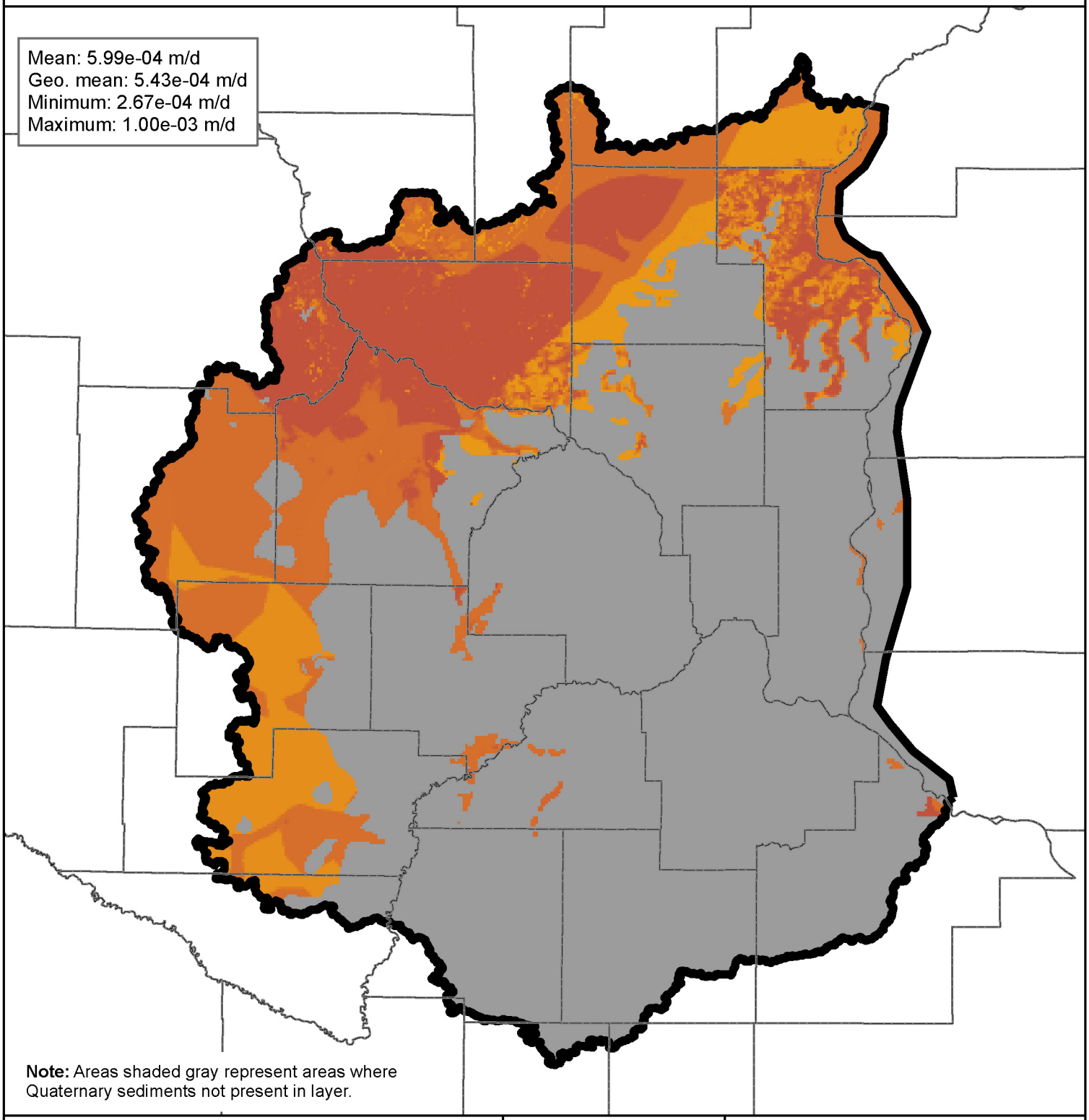
0 15 30

Kilometers

Figure 116
Specific Storage
Quaternary Sediments
Model Layer 6

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Ss_Quat_Layer7.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03
1.5e-04
3.0e-05
5.0e-06
1.0e-06

N

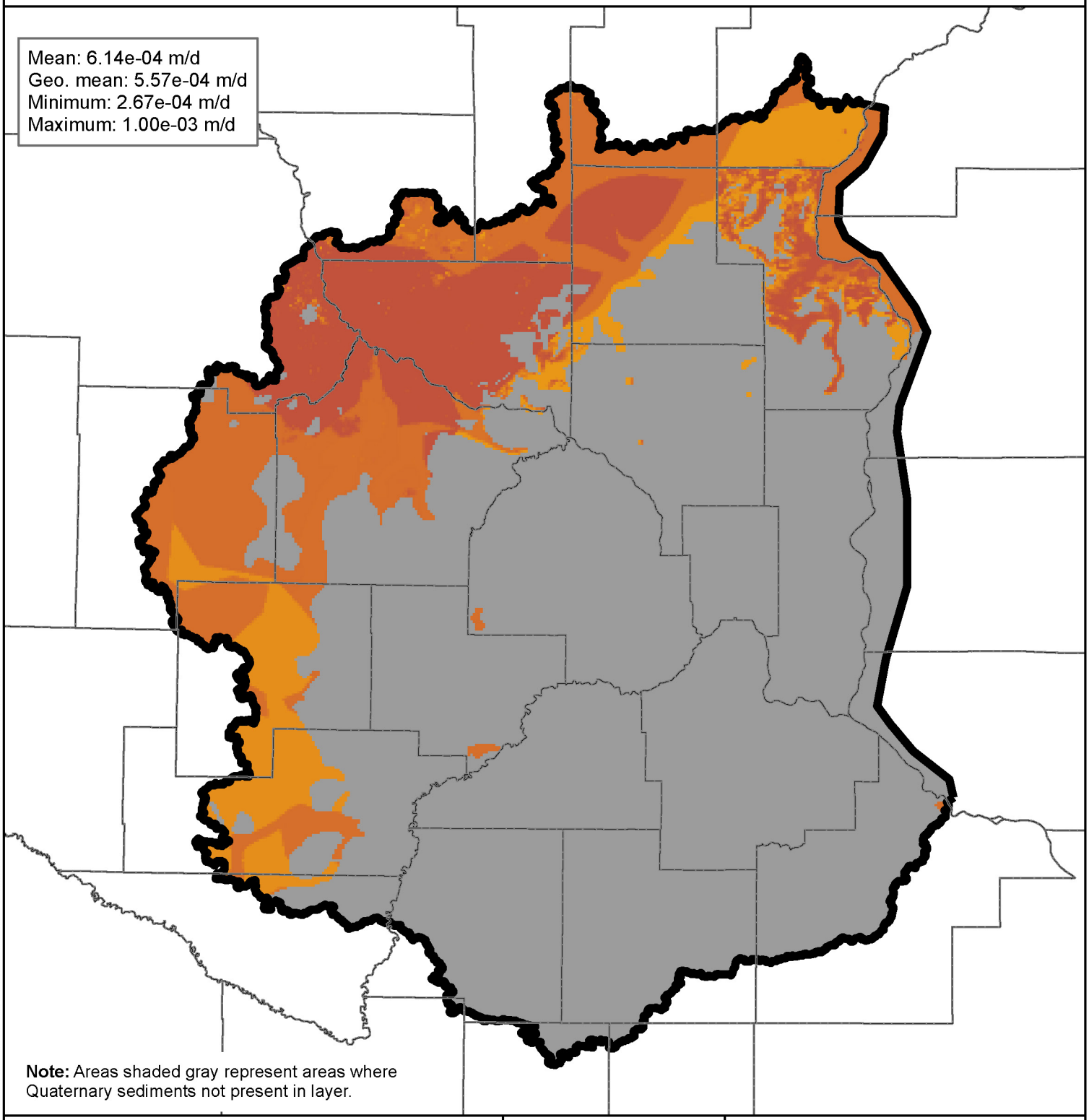
0 10 20
Miles

0 15 30
Kilometers

Figure 117
Specific Storage
Quaternary Sediments
Model Layer 7

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer8.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03

1.5e-04

3.0e-05

5.0e-06

1.0e-06

N

0 10 20

Miles

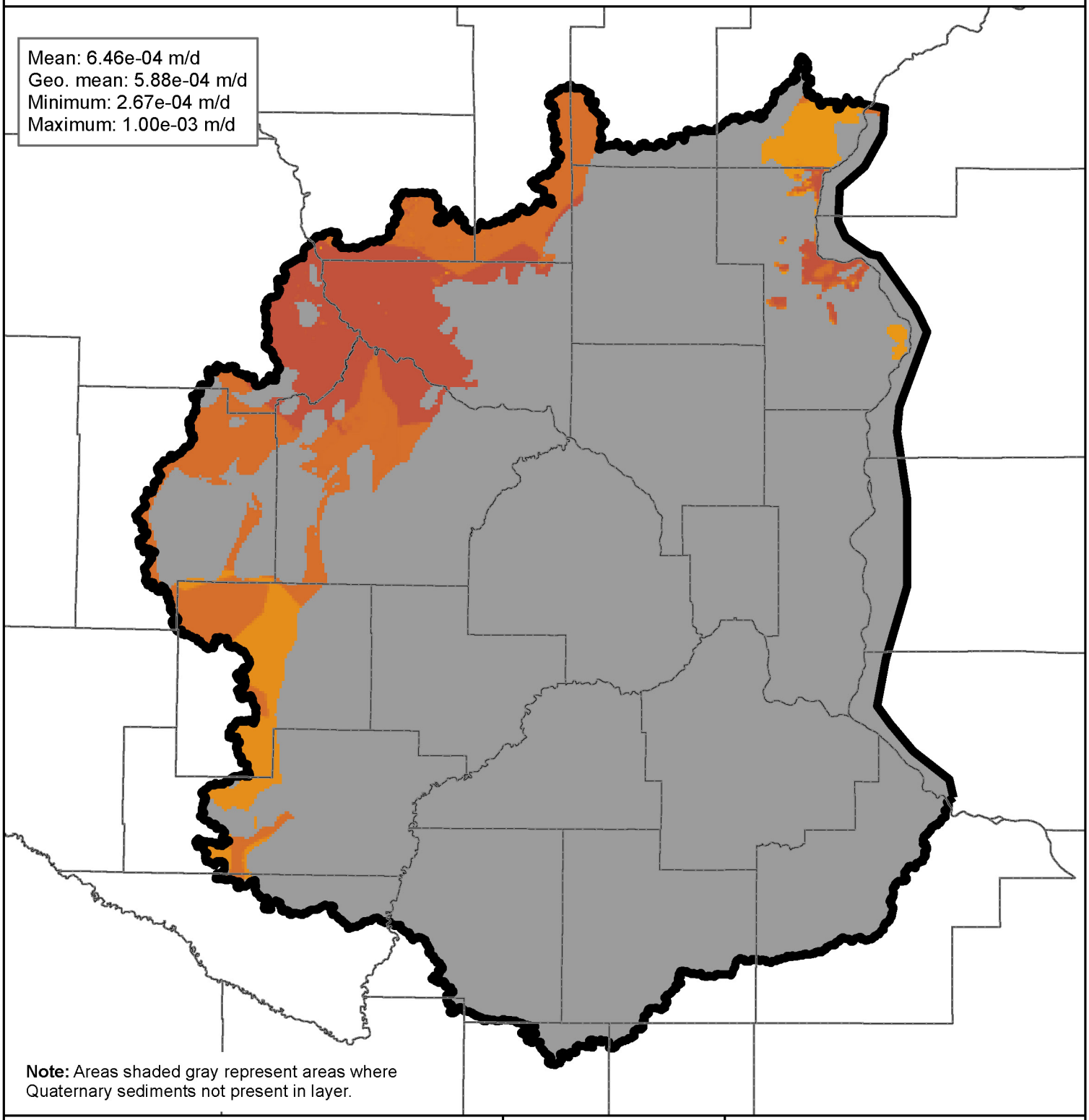
0 15 30

Kilometers

Figure 118
Specific Storage
Quaternary Sediments
Model Layer 8

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSs_Quat_Layer9.mxd User: egc

Model Boundary

County Boundary

Ss (1/m)

1.0e-03

1.5e-04

3.0e-05

5.0e-06

1.0e-06

N

0 10 20

Miles

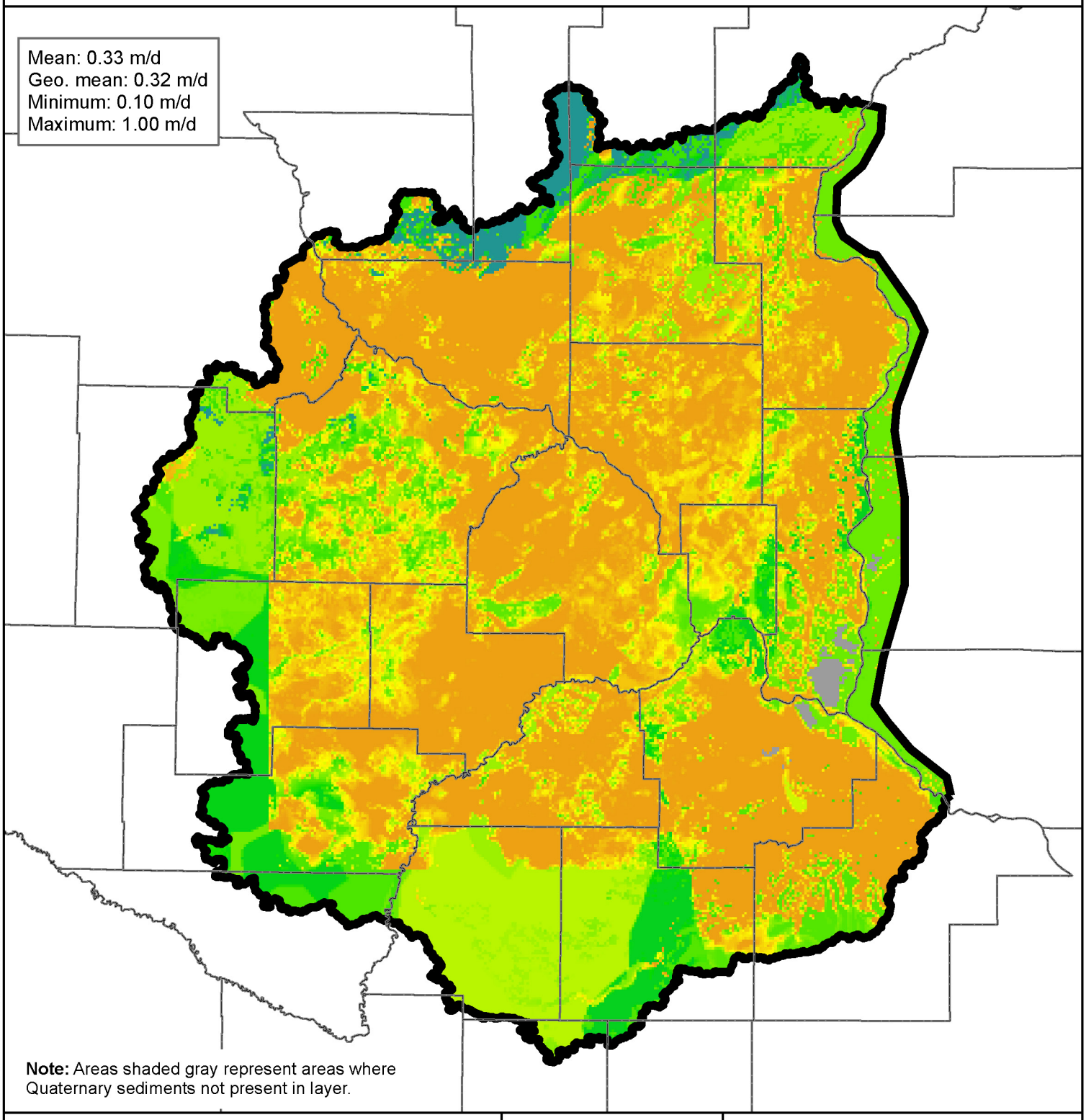
0 15 30

Kilometers

Figure 119
Specific Storage
Quaternary Sediments
Model Layer 9

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Quat_Layer1.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

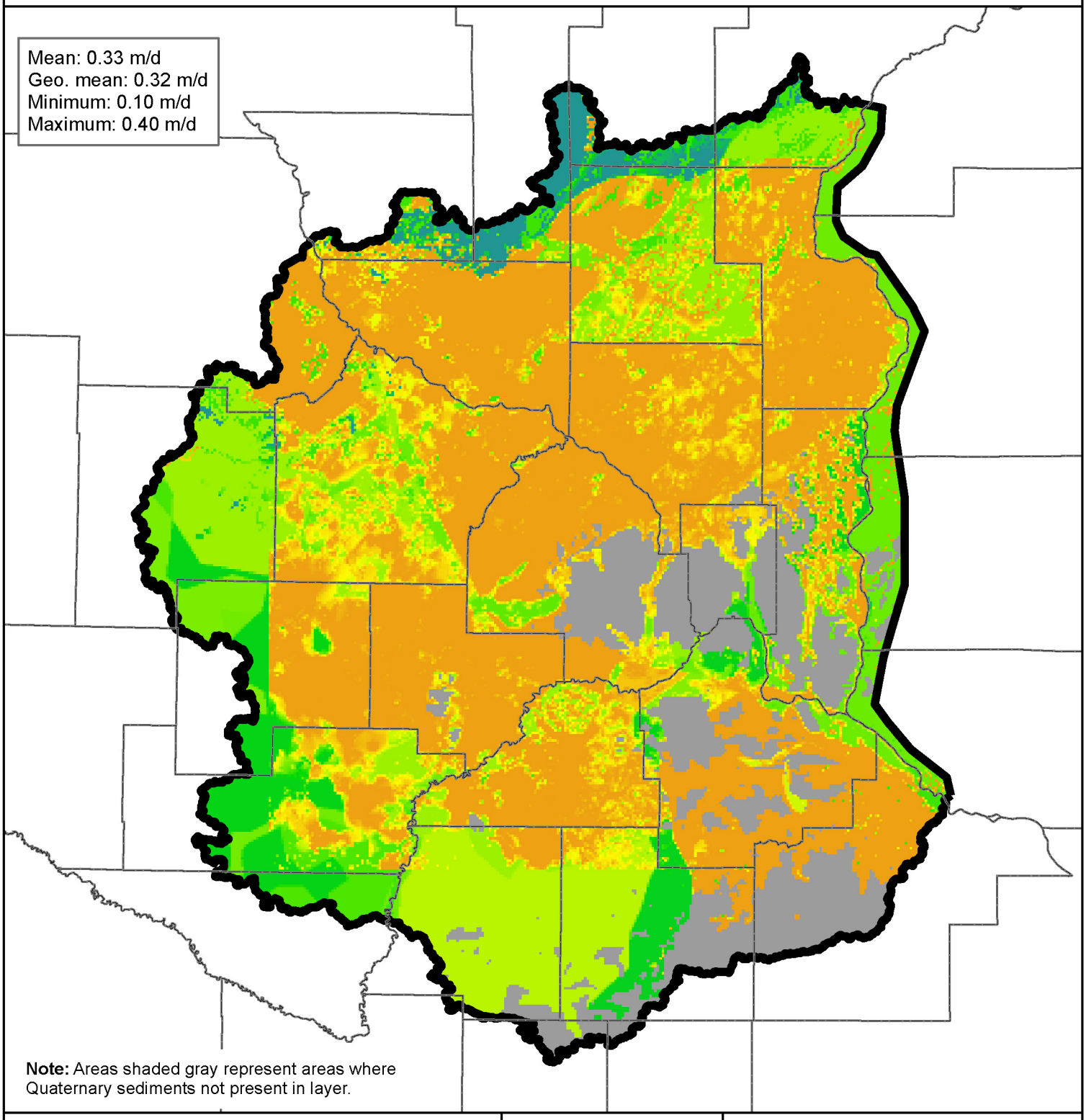
0 10 20
Miles

0 15 30
Kilometers

Figure 120
Specific Yield
Quaternary Sediments
Model Layer 1

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSy_Quat_Layer2.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

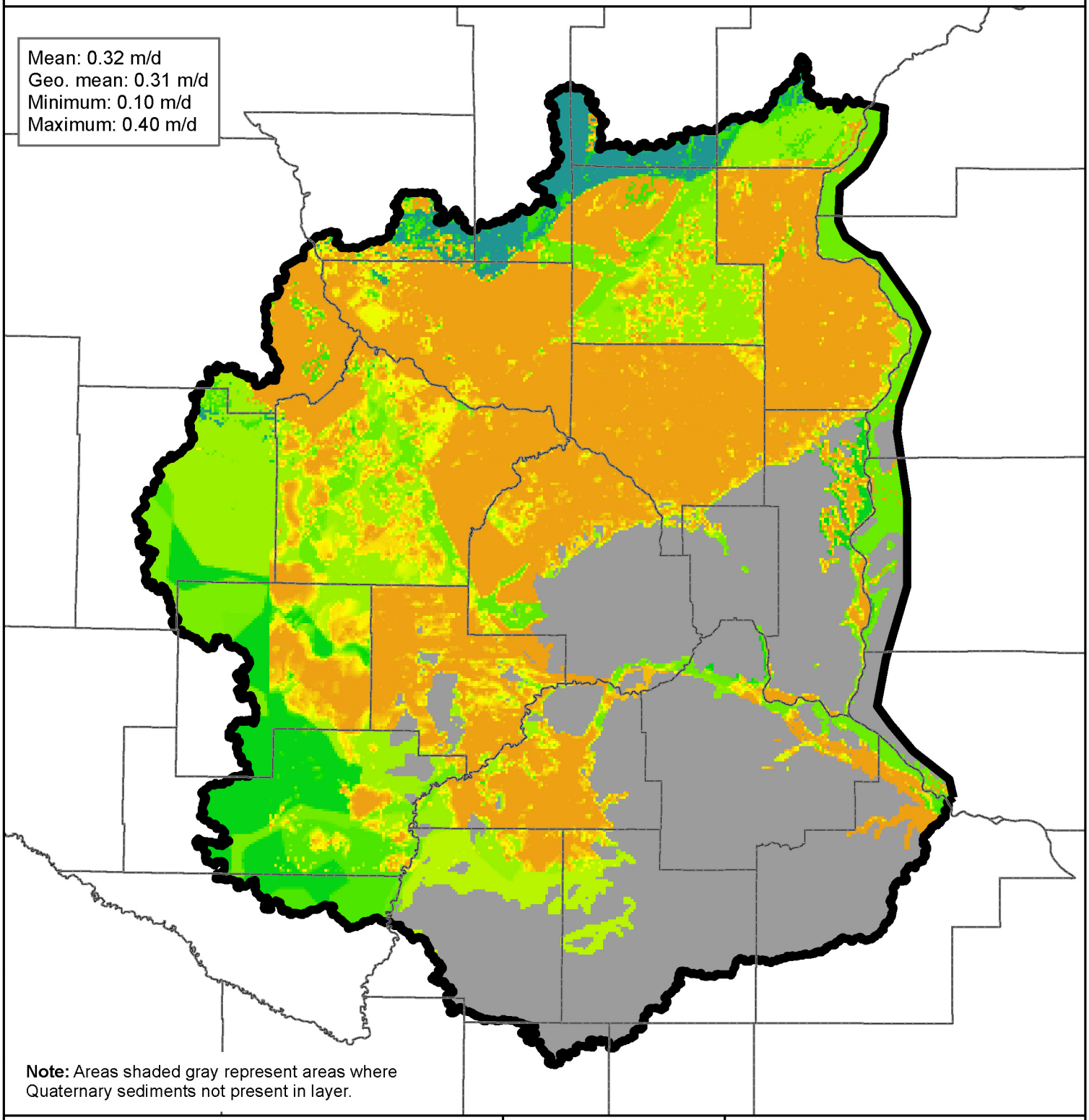
0 10 20
Miles

0 15 30
Kilometers

Figure 121
Specific Yield
Quaternary Sediments
Model Layer 2

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSy_Quat_Layer3.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

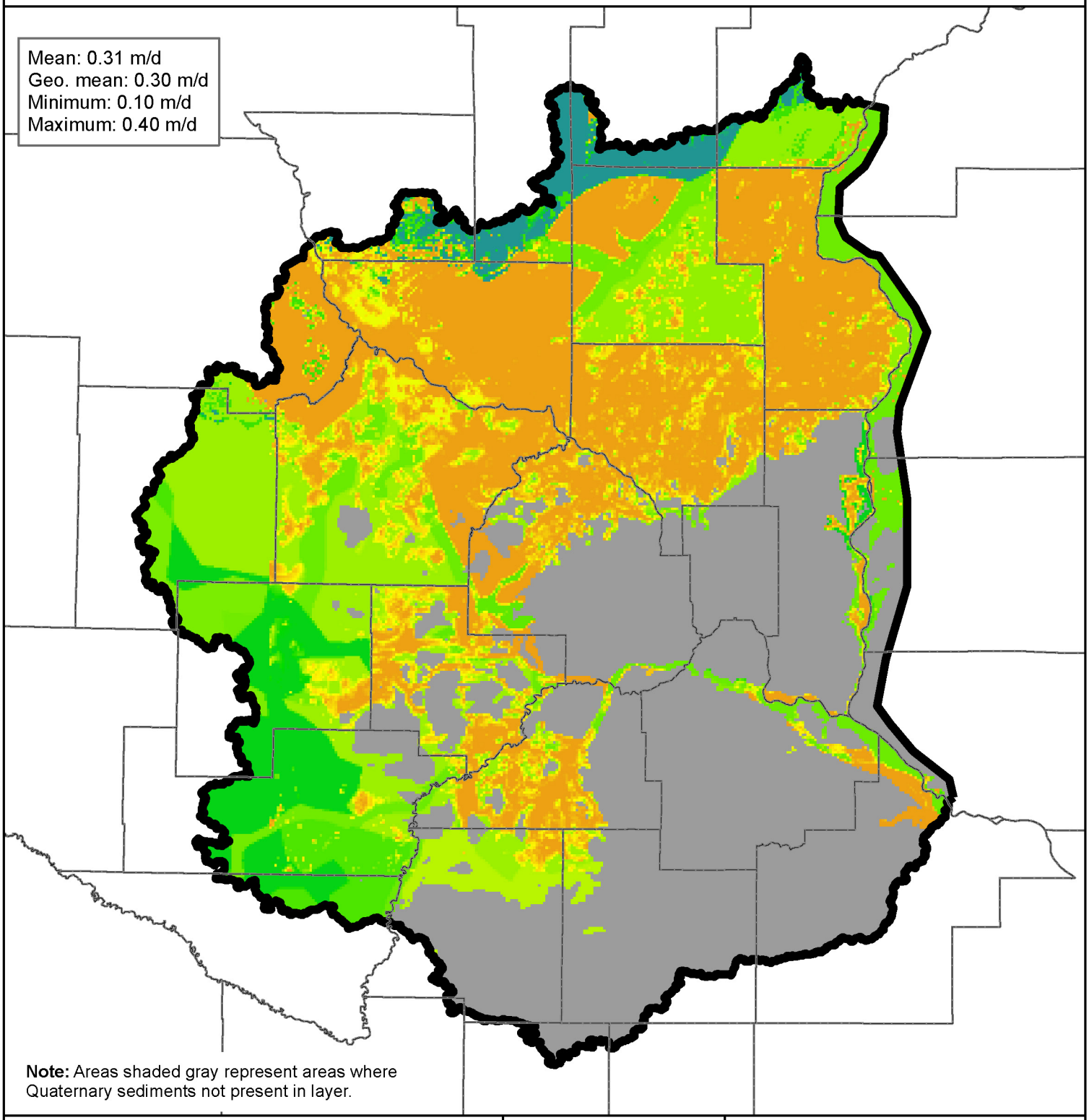
0 10 20
Miles

0 15 30
Kilometers

Figure 122
Specific Yield
Quaternary Sediments
Model Layer 3

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Quat_Layer4.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

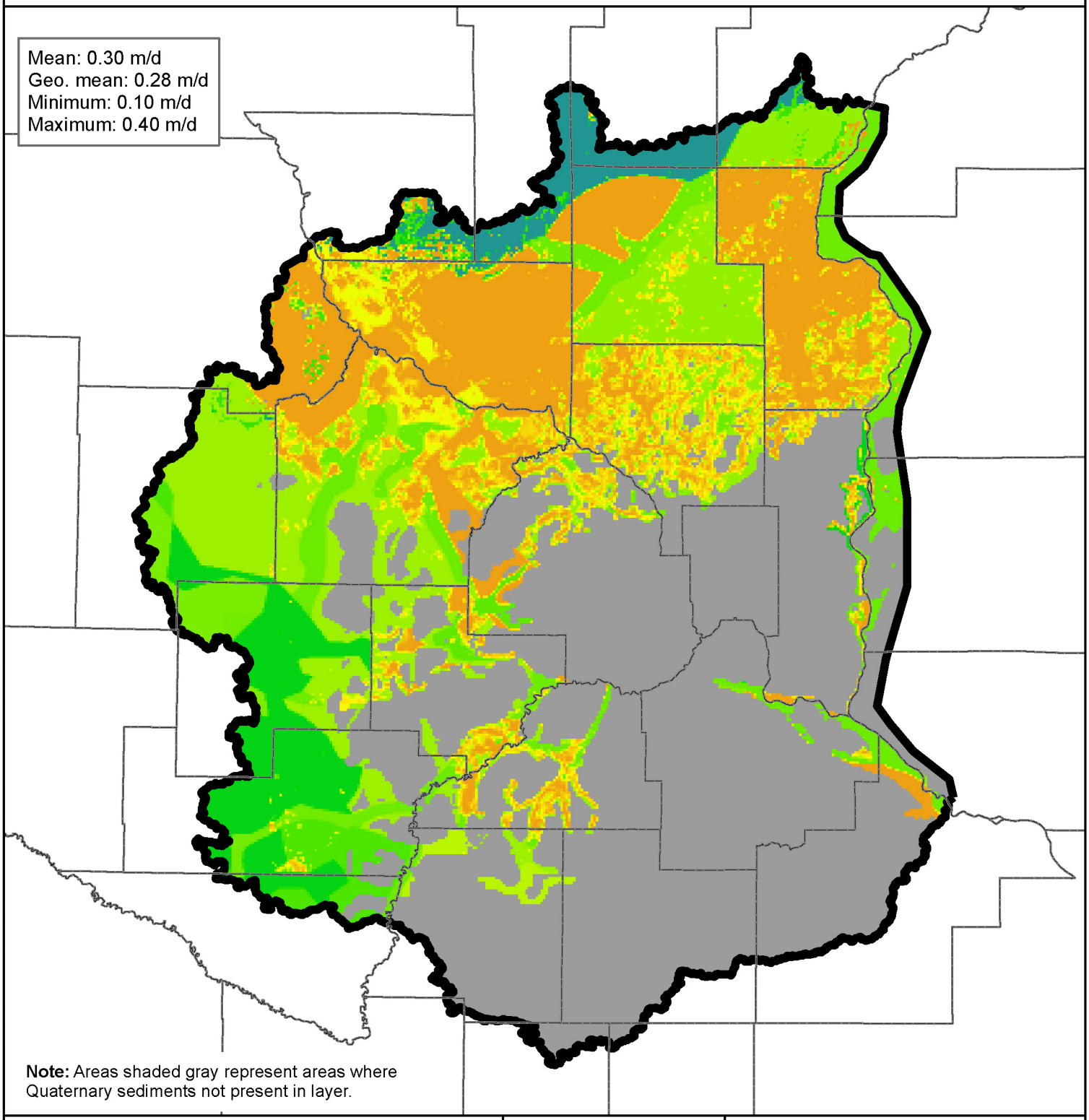
0 10 20
Miles

0 15 30
Kilometers

Figure 123
Specific Yield
Quaternary Sediments
Model Layer 4

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Quat_Layer5.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

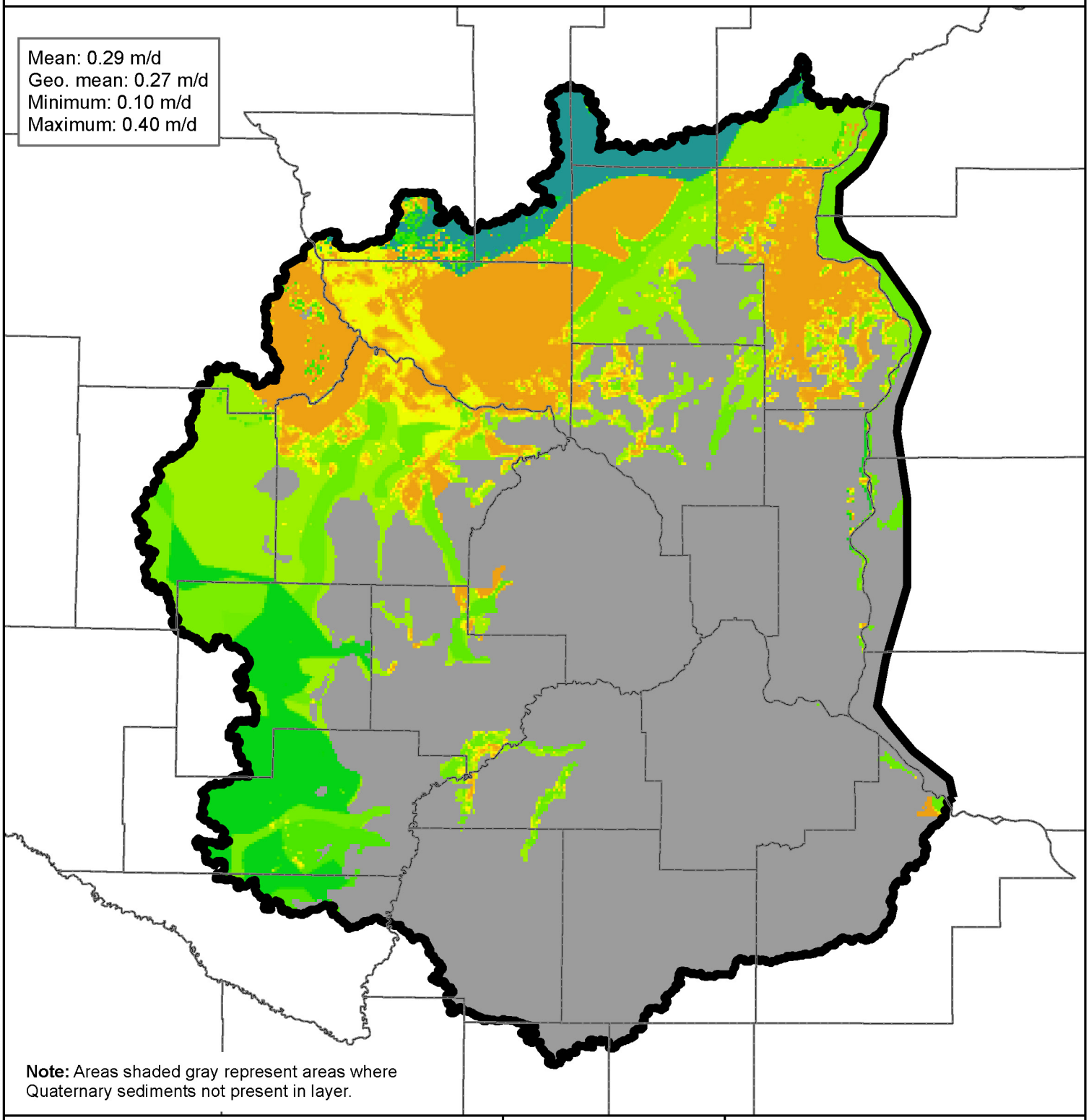
0 10 20
Miles

0 15 30
Kilometers

Figure 124
Specific Yield
Quaternary Sediments
Model Layer 5

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSy_Quat_Layer6.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

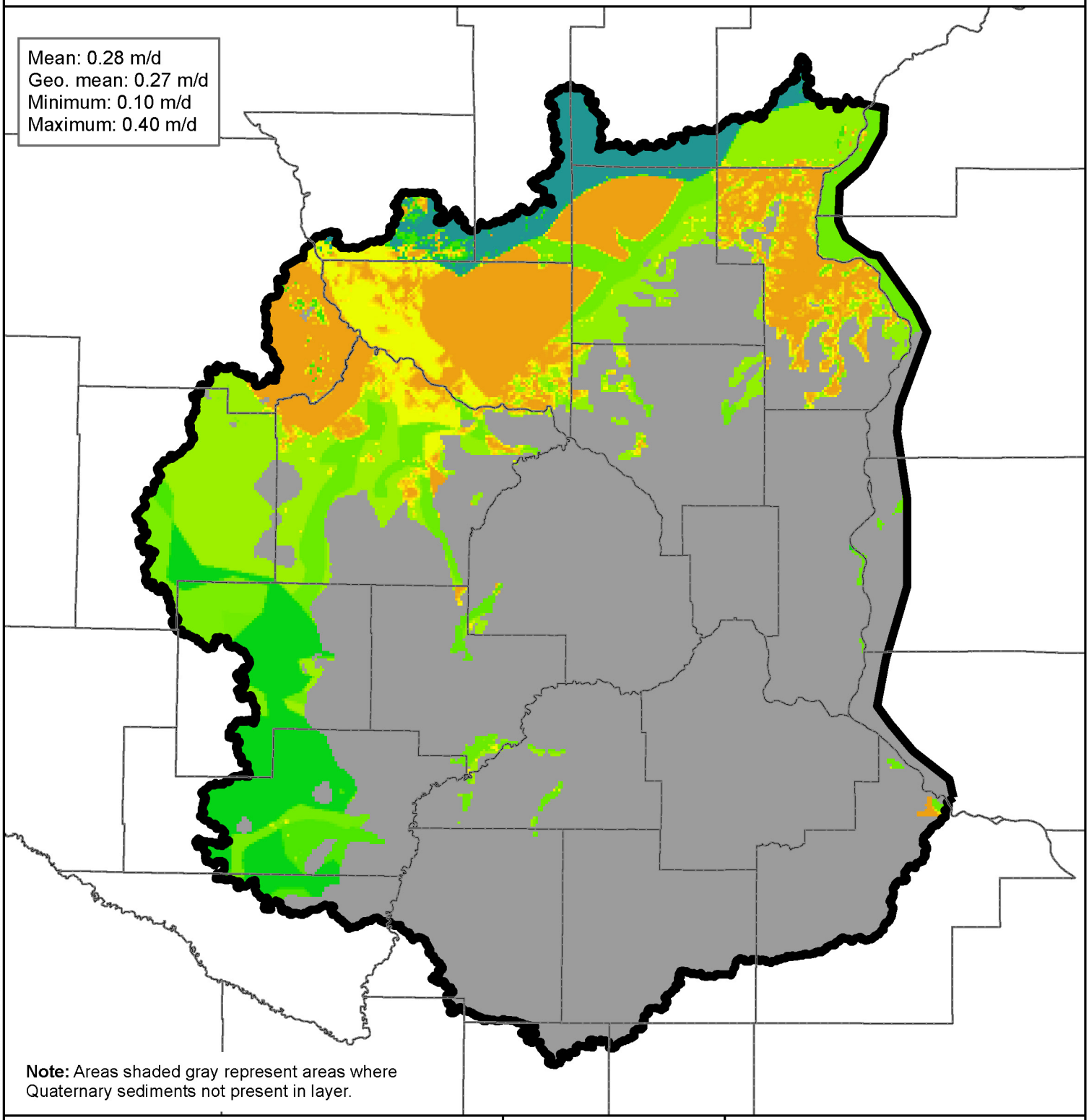
0 10 20
Miles

0 15 30
Kilometers

Figure 125
Specific Yield
Quaternary Sediments
Model Layer 6

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\Report\Sy_Quat_Layer7.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

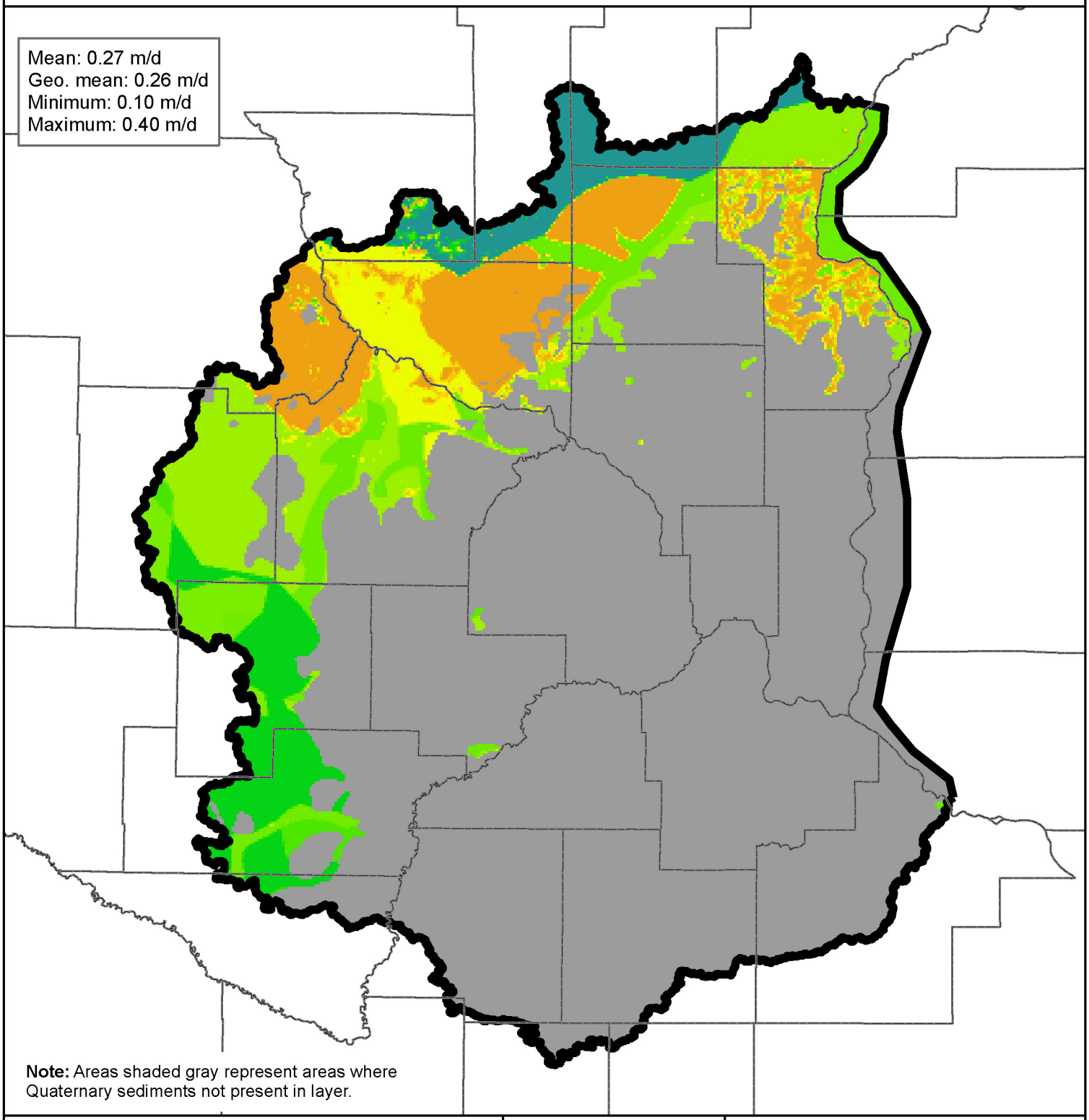
0 10 20
Miles

0 15 30
Kilometers

Figure 126
Specific Yield
Quaternary Sediments
Model Layer 7

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSy_Quat_Layer8.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

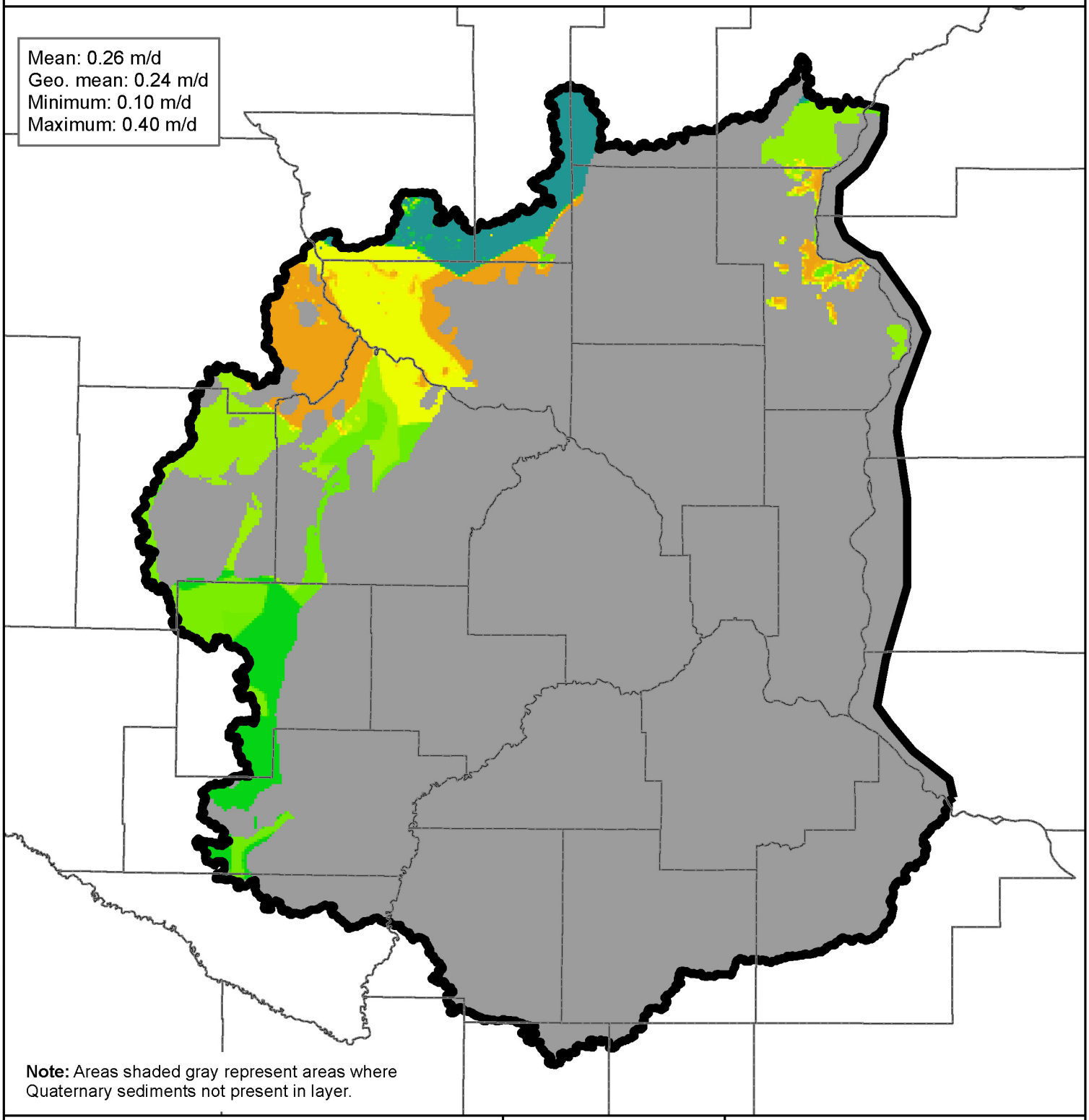
0 10 20
Miles

0 15 30
Kilometers

Figure 127
Specific Yield
Quaternary Sediments
Model Layer 8

Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

METROPOLITAN COUNCIL



Barr Footer: File: I:\Projects\23\62\1087\Maps\ReportSy_Quat_Layer9.mxd User: egc

Model Boundary

County Boundary

Sy (%)

0.5
0.4
0.3
0.2
0.1
0.01

N

0 10 20
Miles

0 15 30
Kilometers

Figure 128
Specific Yield
Quaternary Sediments
Model Layer 9

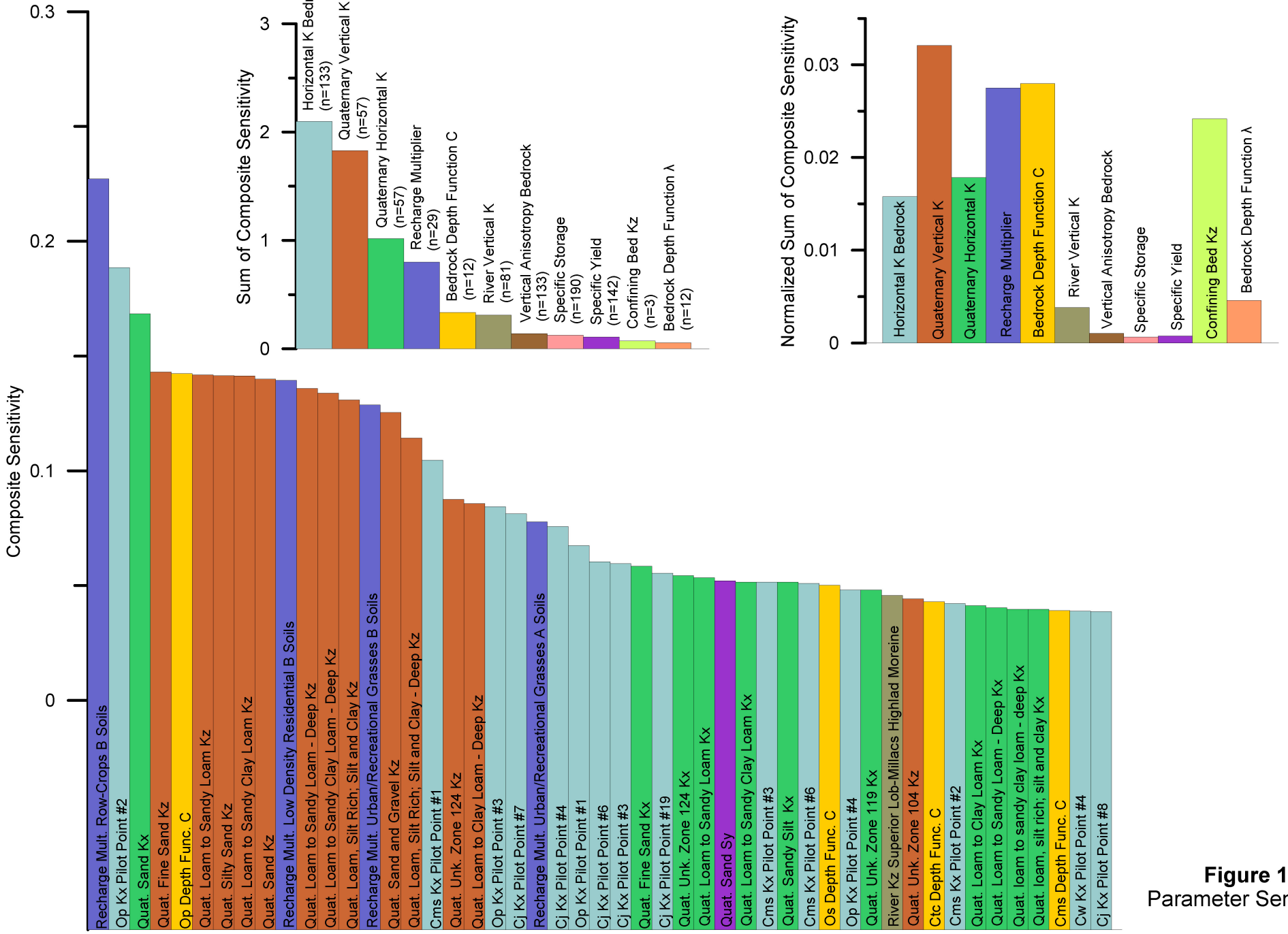


Figure 129
Parameter Sensitivities

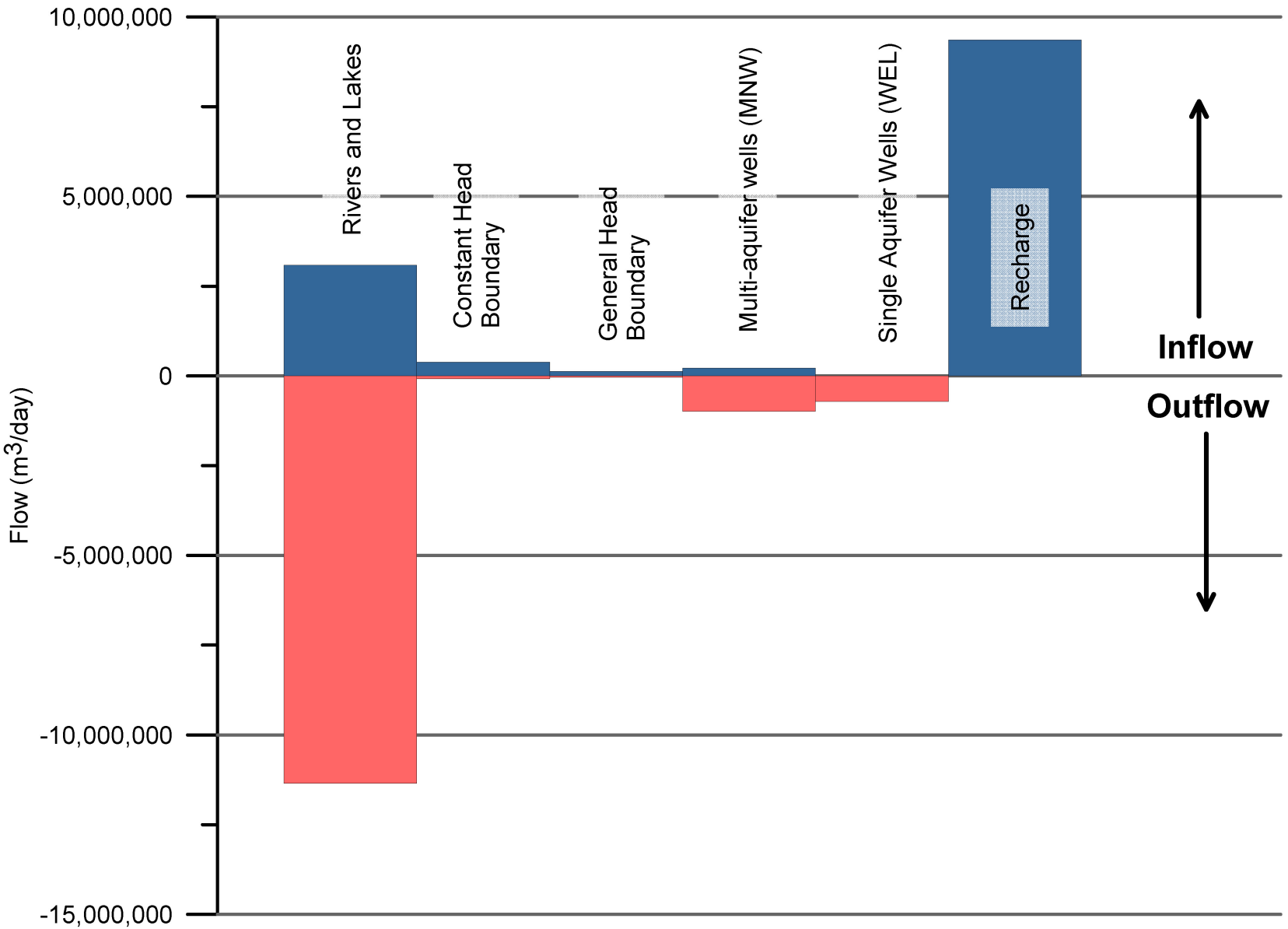
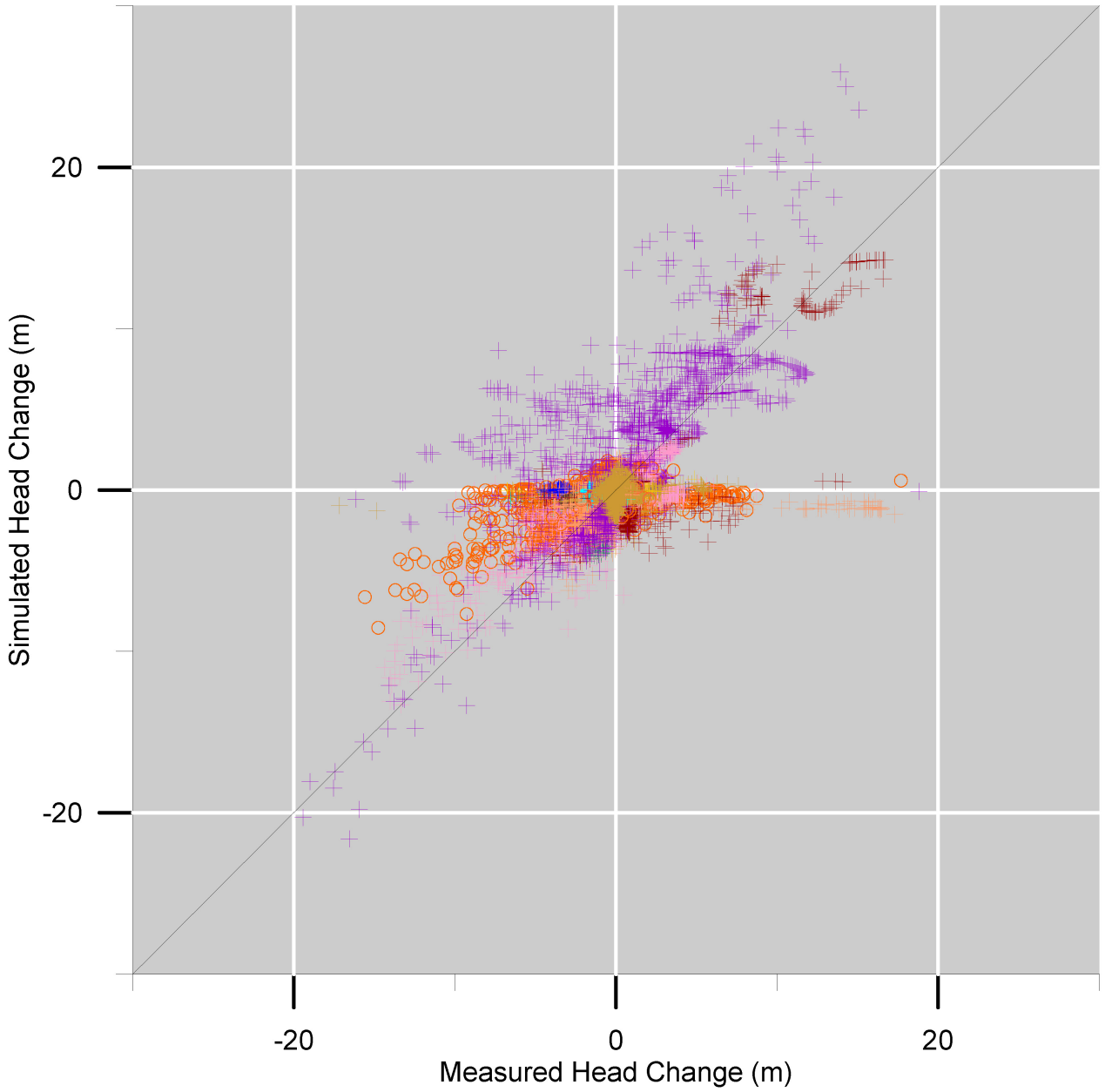
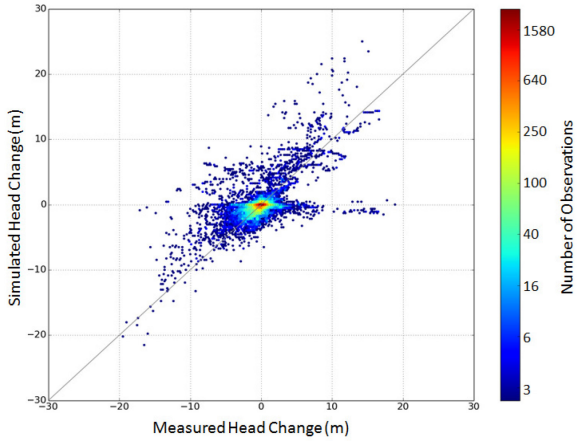


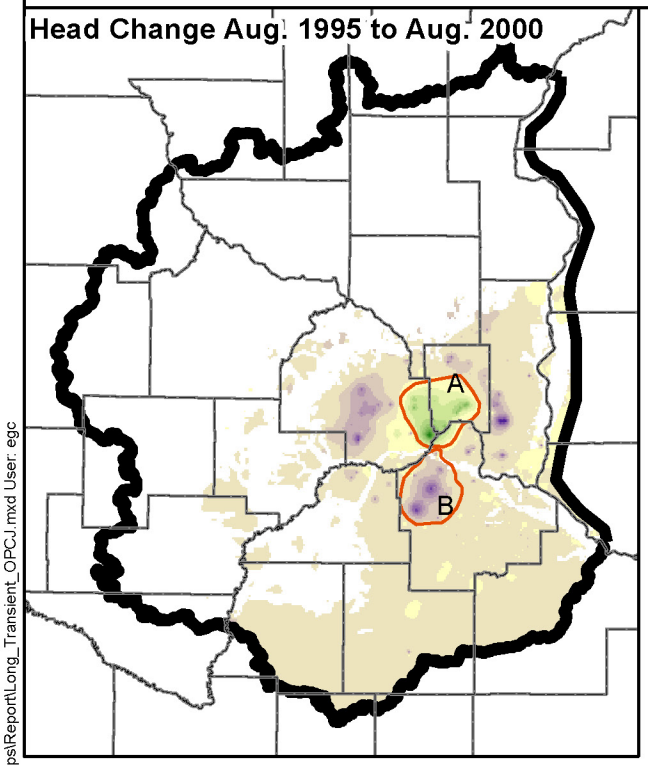
Figure 130
Model Mass Balance

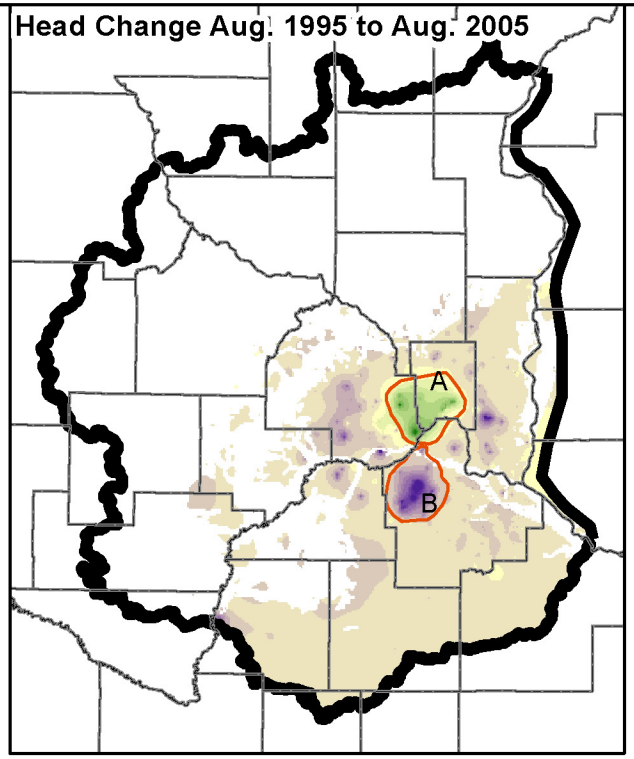


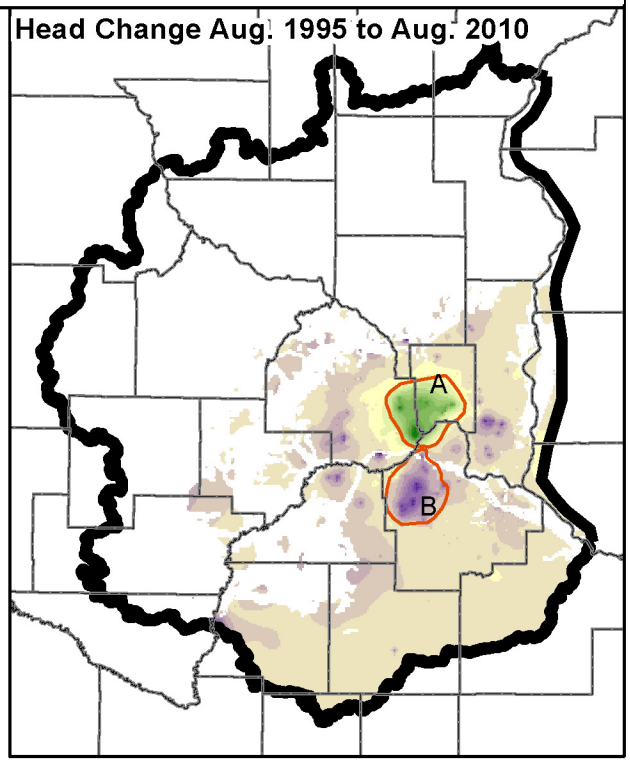


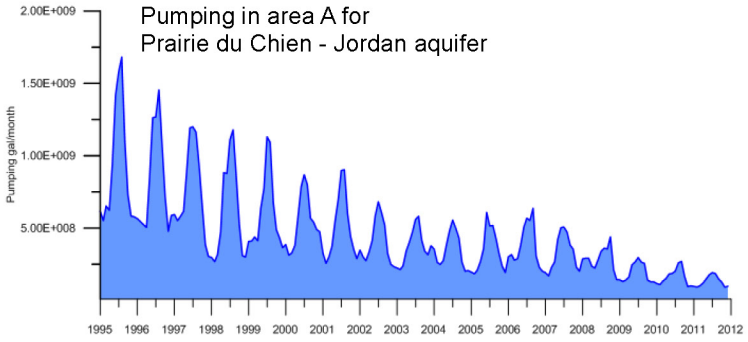
Quaternary
Quaternary-St. Peter
Cretaceous
St. Peter Sandstone
St. Peter - Paririe du Chien
Prairie du Chien Group
Prairie du Chien - Jordan
Prairie du Chien - Tunnel City
Prairie du Chien - Wonewoc
Prairie du Chein -Mt. Simon Hinckley
Jordan Standstone
Jordan - St. Lawrence
Jordan - Wonewoc
St. Lawrence Formation
St Lawrence - Tunnel City
Tunnel City Goup
Tunnel City - Wonewoc
Tunnel City - Eau Claire
Tunnel City - Mt Simon Hinckley
Wonewoc Sandstone
Wonewoc - Eau Clarie
Wonewoc - Mt. Simon - Hinckley
Eau Claire Formation
Eau Claire - Mt Simon Hinckley
Mt Simon - Hinckley

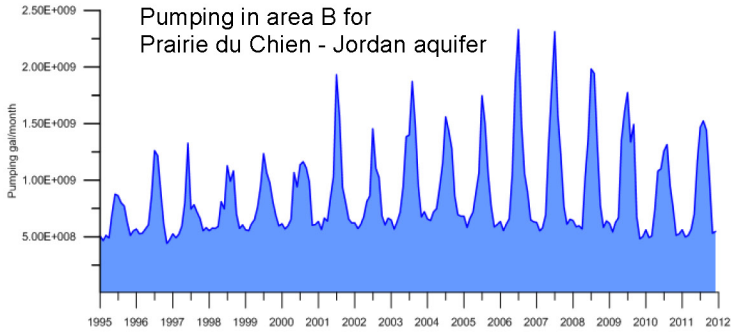
Figure 131
Measured vs. Simulated
Head Change
Long Transient Simulation 1995-2011











Model Boundary

County Boundary

Note: Model layer 4, Jordan aquifer shown

Head Change (ft)

<-50	-14.9 to -10	20.1 to 25
-49.9 to -45	-9.9 to -5	25.1 to 30
-44.9 to -40	-4.9 to 0	30.1 to 35
-39.9 to -35	0.1 to 5	35.1 to 40
-34.9 to -25	5.1 to 10	40.1 to 45
-24.9 to -20	10.1 to 15	45.1 to 50
-19.9 to -15	15.1 to 20	> 50

N

0 10 20

Miles

0 15 30

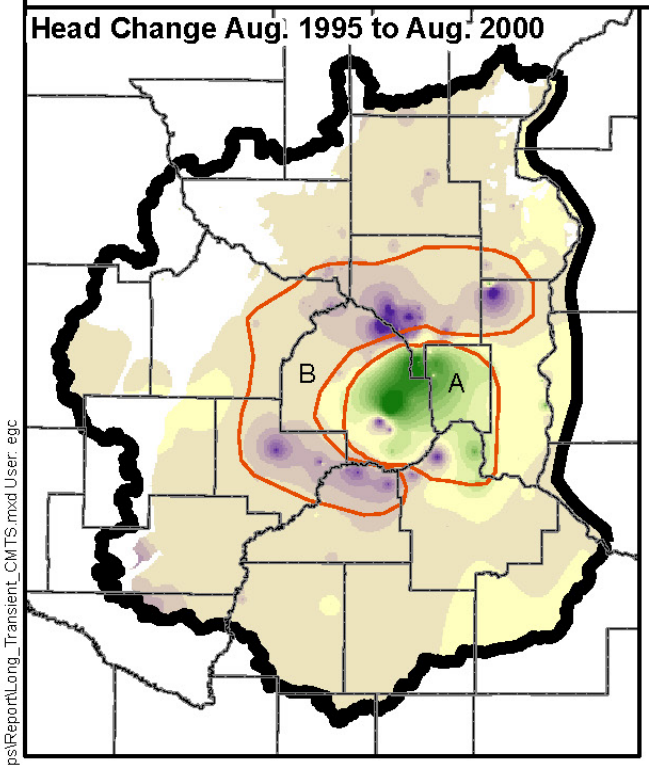
Kilometers

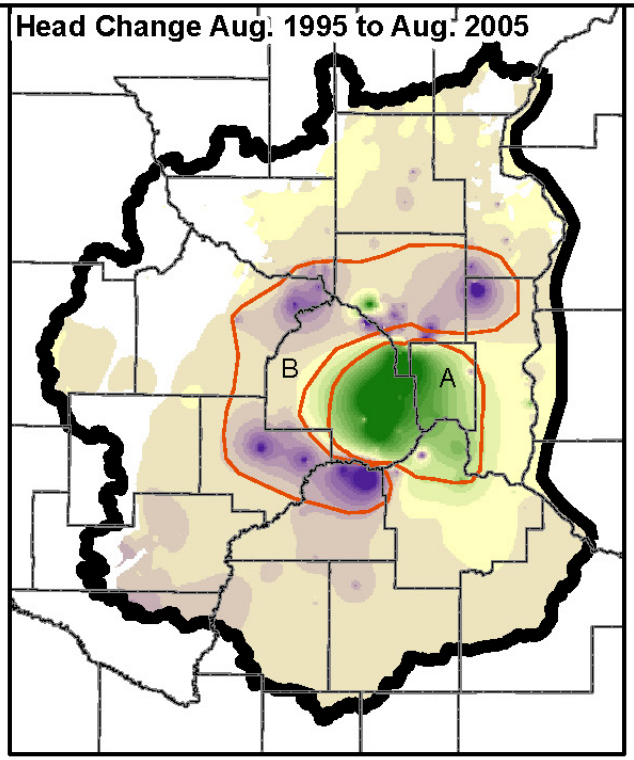
Figure 132

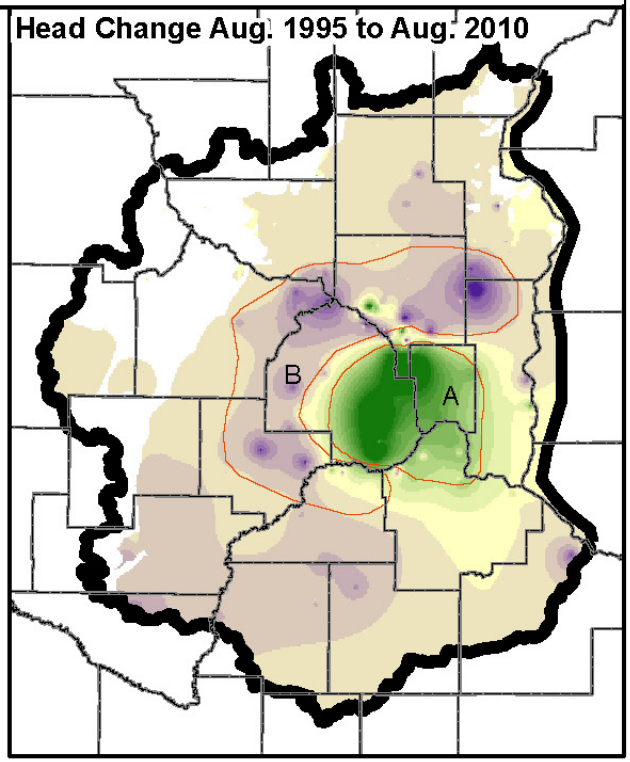
Model simulated head change
Prairie du Chien - Jordan aquifer
August1995 to August 2000,
August 1995 to August 2005,
and August 1995 to August 2010

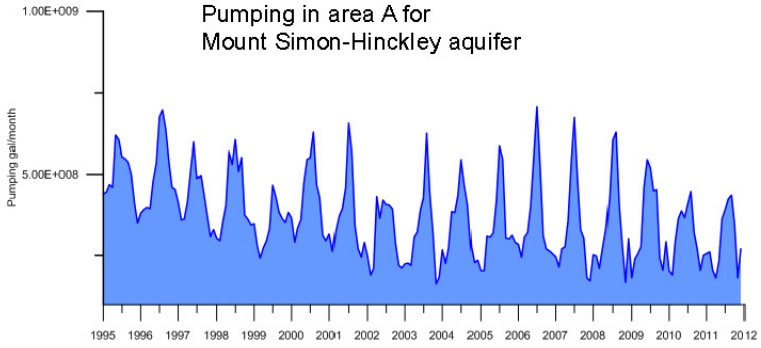
Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3

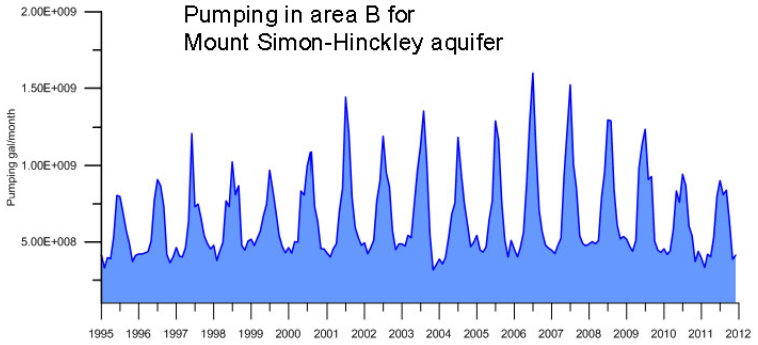
METROPOLITAN COUNCIL











Model Boundary

County Boundary

Head Change (ft)

< -50	-14.9 to -10	20.1 to 25
-49.9 to -45	-9.9 to -5	25.1 to 30
-44.9 to -40	-4.9 to 0	30.1 to 35
-39.9 to -35	0.1 to 5	35.1 to 40
-34.9 to -25	5.1 to 10	40.1 to 45
-24.9 to -20	10.1 to 15	45.1 to 50
-19.9 to -15	15.1 to 20	> 50

N

0 10 20

Miles

0 15 30

Kilometers

Figure 133

Model simulated head change
Mt. Simon Hinckely aquifer
August 1995 to August 2000,
August 1995 to August 2005,
and August 1995 to August 2010

Barr Footer: File: I:\Projects\23\62\11087\Maps\Report\Long_Transient_CMTS.mxd User: egc